REPORT OF

THE ARMY SCIENTIFIC ADVISORY PANEL

AD HOC GROUP

FOR

PRODUCT IMPROVEMENT

SEPTEMBER 1974

BACKGROUND

The United States Army depends heavily upon the product improvement process as a means of achieving the proper state of readiness with respect to Army material. For example, the January 1974 Five Year Defense Plan calls for $249.8 million in fiscal year 1973, $199 million in fiscal year 1974 and $277 million in fiscal year 1975 in procurement funds alone. This important process in generally driven by the three broad classes of requirements.

I Those needed to correct significant deficiencies in existing material.

II Those needed to:

1) Cause the Army to be compliant with public laws

2) Allow for extension of service life

3) Improve the cost effectiveness of a system

4) Effect low priority minor modifications

III Those needed to improve operational capability.

Examples of each class are attached in Appendix I.

In April of 1973 an Ad Hoc Panel of the Army Scientific Advisory Panel was assembled to study the product improvement process. This Panel was requested to:

(1) Study the product improvement process, report observations and conclusions and propose recommendations that would help to improve the process.

(2) Develop a rationale and method for a continuing involvement on the part of the Army Scientific Advisory Panel in the product improvement process.

A statement of the specific goals of the Ad Hoc Panel may be found in the ASAP Terms of Reference detailed in Appendix II. The panel memebers and consultants involved in the deliberations which resulted in this report are listed in Appenidx III.

The study was to be completed in approximately on year. The basis for the data and findings was a series of briefings provided by the many Army agencies listed in Appendix IV. The specific projects that were reviewed are also included in Appendix IV. These reviews provided much of the information that lead to the observations and conclusions of the Study. Notes, minutes and briefings presented by the agencies are filed with the ASAP.

The Panel is very grateful for the cooperation and forbearance of these agencies and their people. These agencies represented a good cross section of people and organizations involved in product improvement.

ASAP Ad Hoc Group on Product Improvement
Summary of Conclusions and Recommendations

1. The report defines three classes of product improvements.

a. Class I - Those needed to correct deficiencies in existing materiel.

b. Class II - Those needed for the Army to comply with public laws, allow for extension of service life, improve cost effectiveness and effect low priority modifications.

c. Class III - Those needed to improve operational capability.

2. Class I (Deficiency Correcting) - Conclusions and Recommendations.

a. Conclusions.

(1) Traditional failure analysis and "quick fix" approaches are used.

(2) Over emphasis on safety could impair operational capability.

(3) Lack of failure definitions cause friction between developer and user.

(4) The ASAP can be helpful in this class.

(5) Unforeseen deficiencies are inevitable, but are treated operationally and on a funding basis as if they are not expected.

b. Recommendations.

(1) Support increased approval delegation to USAMC.

(2) Use statistical analysis of failures.

(3) Develop techniques to assure all available and necessary Army resources can be applied to problem.

(4) Original developer should be used as opposed to maintenance engineering elements on these problems.

(5) Develop failure criteria related to operational objectives, examine effect of safety fixes on operational capability, train user in philosophy of systems as well as technology and involve him earlier in development cycle.

(6) Technical disciplines available on ASAP should be used on a selective basis.

(7) Continuing ASAP panel should review difficult Class I product improvements. Panel should serve as mechanism for ASAP involvement.

(8) Expect unforeseen deficiencies. Charge AMC with job of expedited correction of deficiencies and necessary planning.

3. Class II (Extended Life) - Conclusions and Recommendations.

a. Conclusions.

(1) Lack of higher headquarters guidance to commodity commands results in rejection of PIPs and wasted manhours.

(2) Equipment Improvement Recommendations result in few product improvement proposals.

(3) Reliability enhancement through product improvement is a fact of life for newly deployed technically complex equipment.

(4) Application of the "design to unit production cost" concept may increase dollars spent to improve reliability, availability and unatainability of new systems.

(5) Class II programs could benefit by using ASAP expertise in RAM and general systems analysis.

b. Recommendations.

(1) DA should provide technical and funding guidance.

(2) Study usefulness of Equipment Improvement Recommendation System.

(3) Augment TAERS/TAMMS/Sample Data Collection information with engineering information. Involve materiel design people in the design of the data system.

(4) Incorporate reliability growth modeling and estimates in product improvement proposals as a program cost estimating tool.

(5) Do not apply the design to unit production cost method to the degree that system growth is inhibited.

(6) ASAP panel should study some projects in this class with emphasis on systems to which the design to cost concept has been applied.

4. Class III (Improved Operational Capability) - Conclusions and Recommendations.

a. Conclusions.

(1) Class III product improvement programs are small in number but are high dollar consumers.

(2) AMC does not have an element designated to identify, represent and involve the user (including commands other than TRADOC) in the product improvement process.

(3) Commercial "off-the-shelf" developments and technology should be employed to a greater extent.

(4) Funding distinctions and definitions should be clarified with respect to this class.

(5) ASAP can be of greatest assistance in this category.

b. Recommendations.

(1) ASAP continuing panel on product improvement should assign first priority to this category.

(2) AMC should develop and implement a line user oriented organization with a significant role in the control and management of project funds to perform a function similar to a marketing element in industry.

(3) Place emphasis on trade-offs between new starts and product improvements.

(4) Class III product improvements should fit into a long range plan to achieve improved capabilities with materiel systems.

(5) The DA Comptroller should assist in clarifying funding distinctions and definitions.

(6) Reliability growth methods should be applied in this category.

(7) Exercise caution in the use of the "design to unit production cost" concept.

5. Most significant recommendations.

a. Support increased delegation of HQAMC and commodity commands.

b. Increased capability should be part of long range plans for systems. Deficiencies should be expected with new systems and planned for. Statistical analysis of failures should be applied. DA guidance should be provided to permit better prioritization of PIP's in the Extended Life Class.

c. AMC should develop a user oriented organizational element to communicate with TRADOC, major commands and other identified users to perform a marketing function.

SUMMARY

The product improvement process by definition should involve an activity which starts with an item that exists and proceeds to an item that should be more useful to a user. The efficiency and ultimate results of such a process should then be primarily related to the following:

1) The proper definition of the need and the priority, and the generation of a requirement that accurately describes the need and the priority.

2) The proper description of the item to be improved and the state of this item.

3) The proper description of the end item and the desired state of this item.

4) The proper definition of the desired improvement and the nature of the desired improvement.

5) The state of the technology base from which the improvement must be derived.

6) The ability of a developing/acquisition organization to understand 1., 2., 3., 4., and 5.

7) The ability of a development/acquisition organization to develop/ acquire and effect the desired improvement and during the process measure progress.

8) The ability of an organization to communicate its need for proper resource commitment.

9) The proper definition of the user, and the ability of an organization to gain acceptance on the part of the user.

10) The efficiency of the total mechanism by which the requirement is generated, ultimately fulfilled, and executed.

11) The proper line and staff management structure to operate the total mechanism.

12) Proper delegation of authority within the proper line and staff management structure.

The Ad Hoc panel attempted to apply the above criteria to the Army's product improvement processes. As a first step it was necessary to understand the three broad classes of product improvements and redefine these classes in terms that were convenient. The definitions and characteristics that resulted were the following:

Class I -- Those needed to correct significant deficiencies in existing material

(a) Description and characteristics. The need originates with the user after deployment. Product improvement proposals in this category concern significant unforeseen operational and safety problems. Problems of this nature disclosed before deployment are corrected with engineering change orders during the development process. Procurement and Operating (OMA) funds are used in this category. This category represents 3% of total PIPs and 1% of total dollars in the FY 75 AMC product improvement submission. OCRDA is not significantly involved in this category.

Class II -- Those needed to:

1) Cause the Army to be compliant with public laws

2) Allow for extension of service life

3) Improve the cost effectiveness of a system

4) Effect low priority minor modifications

(a) Description and characteristics. These PIPs include modifications necessary for compliance with public laws, extended life, cost effectiveness, RAM, improvement (RAM/RISE program), non-urgent safety modifications and low priority minor modifications. These PIPs represent those that are conceived after deployment and in the case of RAM/RISE and extended life are primarily intended to improve cost effectiveness and low life cycle costs. Procurement and OMA funds are used in this category. In the AMC FY75 PIP submission, this category represents the largest number of total PIPs (78%) and about 49% of the total program cost. Independent R&D on the part of the Aerospace and Defense industry is a significant contributor in this category. This activity on the part of industry is a natural result of profits generally being a direct function of volume and life of a production line. OCRDA, because of interest in 1) the technical and systems trade-offs associated with obtaining new systems or upgrading old systems, and 2) the need for technical input, is more concerned with this category than with deficiency correction. Implementation of PIPs in this category is not generally mandatory to the performance of a mission. A decision to disapprove such a PIP will not seriously degrade operational capability and may be tolerable.

Class III -- Those needed to improve operations capability.

(a) Description and characteristics. The need arises from the competitive acts of a potential aggressor. The requirement for the improved

operational capability originates in the force development community as a result of threat analysis, doctrinal development and intelligence. These requirements may be satisfied by new development, use of commercial items or product improvement of existing items. The requirement must be formally established through use of a Required Operational Capabiltiy (ROC) document. Engineering is funded with R&D funds. OCRDA is heavily involved in this category. In the FY 75 PIP submission, these PIPs constituted 19% of the total PIPs and approximately 50% of total product improvement dollars Independent Research and Development on the part of the Aerospace and Defense industry is also a significant contributor in this category.

The panel observed that the criteria enumerated above seemed to be most nearly satisfied for product improvements falling within Class I. It was felt however that in Class I, improvement must be achieved with respect to criteria 1, 6, 7, 9, and 12 with the prime attention being paid to 1 and 12.

*1) The proper definition of the need and the priority and the generation of a requirement that accurately describes the need and the priority.

6) The ability of a developing/acquisition organization to understand 1, 2, 3, 4 and 5.

7) The ability of a developing/acquisition organization to develop/acquire and effect the desired improvement, and during the process, measure progress.

9) The proper definition of the user and the ability of an organization to gain acceptance on the part of the user.

*12) Proper delegation of authority within the proper line of staff management structure.

The Ad Hoc Group on Product Improvement recognizes that in spite of the excellent design and development engineering done by the Army and its vendors, certain deficiency corrective and life improvement activities must be expected. Time and test funding contraints simply make it impossible and impractical to fully "shake down" newly developed end items. This fact is particularly relevant in view of the accelerated requirements to field materiel in some realistic time. Thus, effective administrative processes in funding to pursue corrective action later in the programs as a result of the disclosure of field discrepancies must be in place. This should be a normal method of operations since it is not possible to cover all failure modes in an evaluation program of finite dollars and duration.

It was further evident from the nature of Class I product improvements that the Army Scientific Advisory Panel could serve as a source of specific expertise in attempting to solve specific problems. It would be prudent however to employ this expertise only on an exception basis. The continuing ASAP panel on PI should be intimately aware of this class and at least include a PI program in this class in its deliberations. The criteria for selection of a program should be need, priority and a product improvement to which ASAP's technological expertise can be helpful.

With regard to Class II product improvements there is an opportunity for improvement with respect to all criteria. Emphasis should be placed upon 1, 4, 7, 9, 10, 11, and 12. Special emphasis however should be placed on 1, 4, 7, 10, and 11.

*1) The proper definition of the need and the priority and the generation of a requirement that accurately describes the need and the priority.

*4) The proper definition of the desired improvement and the nature of the desired improvement.

*7) The ability of development/acquisition organization to develop/acquire and effect the desired improvement, and during the process, measure progress.

9) The proper definition of the user and the ability of an organization to gain acceptance on the part of the user.

*10) The efficiency of the total mechanism by which the requirement is generated, ultimately fulfilled, and executed.

*11) The proper line and staff management structure to operate the total mechanism.

12) Proper delegation of authority within the proper line and staff management structure.

Class II product improvements can also benefit from ASAP involvement especially where systems analysis expertise is required. This is true since this category is heavily involved with improvements involving maintainability, availability, and reliability disciplines. There are members of the ASAP possessing the proper expertise. Certainly the continuing panel on product improvement should include a sample of programs in this category and at least one member of the panel who should be skilled in RAM and general systems analysis disciplines.

The Class III product improvements involving Improved Operational Capability suffer from a lack of adequate attention to criteria 1, 3, 4, 5, 8, 9, 10, 11, and 12. The areas which are cirtical however are 1, 9, 10 and 11.

*1) The proper definition of the need and the priority and the generation of a requirement that accurately describes the need and the priority.

3) The proper description of the end item and the desired state of this item.

4) The proper definition of the desired improvement and the nature of the desired improvement.

5) The state of the technology base from which the improvement must be derived.

8) The ability of an organization to communicate its need for proper resource commitment.

*9) The proper definition of the user and the ability of an organization to gain acceptance on the part of the user.

*10) The efficiency of the total mechanism by which the requirement is generated, ultimately fulfilled, and executed.

*11) The proper line and staff management structure to operate the total mechanism.

12) Proper delegation of authority within the proper line and staff management structure.

In fact no line organization could be found within MAC that is responsible to define and represent the user on a continuing interactive basis in the development process. Staff organizations abound and the vacuum with respect to user definition and representation during the product improvement process becomes filled by the development/acquisition organization interspersed with a large quantity of staff advisors. Since this process is very clearly related to the new materiel acquisition process it would not be surprising to find that similar problems exist with that process.

To ameliorate this situation the Army must develop a means to include with its organization a line function whose responsibilities include:

1) Translation of the broad requirements developed by TRADOC and the force develop to user terms that the developer/acquisition can understand.

2) Definition of who is the user.

3) Definition of the improved product that will be accepted and used by the user.

4) Joint with the developer/acquisitioner - the development of a useful and saleable improved product. This responsibility must include a significant role in the control and management of project funds.

5) Selling of the improved product to the user.

6) Interpretation and iteration of the user's desires on a real time basis with the developer's/acquisitioner's problem and limitations throughout the product improvement process.

7) The communication and translation of real time user requirements to TRADOC and the Force Developer.

8) The iteration of requirements with TRADOC and the Force Developer.

9) The representation of the user in trade-offs related to the satisfaction of requirements by new or product improved materiel.

With this type of line operation involved in the process it should be possible to increase delegation of authority and reduce the time to get something meaningful to the user. It should also therefore be possible to reduce the number and size of the various staff functions involved in the product improvement process.

The new materiel acquisition programs are now under the guidance of the "design to unit production cost" principles. While these principles may possess significant advantages, the panel is concerned that overenthusiasm in the application of these principles will lead to "spot" design, i.e., designs having insufficient base structure to allow for prudent growth through reasonable product improvement processes. Overapplication of DTUPC could lead to an extremely expensive future Class II and Class III product improvement program or little opportunity to employ the Class III process at all.

The Army appears to have became more effective in trade-off decisions between new development and Class III product improvement. However, decisions to employ product improvement seem to be reactive rather than being the result of a planned approach.

The Army Scientific Advisory Panel is and should obviously be involved in Class III type product improvements. A continuing panel of the ASAP should follow and provide technical advice on product improvements required to enhance operational capability. The ASAP can be especially helpful in providing recommendations regarding the degree to which developing technology will allow continued product improvement to meet operational requirements. This information is necessary to conduct a valid trade-off on a timely basis between new development and product improvement.

OBSERVATIONS, CONCLUSIONS, AND RECOMMENDATIONS

The group has arrived at the following observations, conclusions, and recommendations with respect to product improvements.

A. Class I -- Product Improvement Programs

Observations

1. This category represents 3% of total PIPs and 1% of total dollars in the FY 75 AMC product improvement submission. Problems addressed in this category concern significant unforseen operational and safety problems.

2. Deficiencies involving safety are discovered and dealt with quickly and efficiently. Operational deficiencies do not seem to carry the priority associated with safety.

3. In the case of safety, the definition of failure is evident. In those cases involving operational capability, there is a lack of a clear definition of failure. In many cases, operational deficiencies are recognized at an early date but the process of correction is slow.

4. The panel has noted the 14 Sep 73 letter from DCSLOG to Cdr, USAMC delegating authority to accomplish deficiency correcting projects. The impact of the letter on expediting correction of these deficiencies cannot be evaluated at this time since the recommended delegations have not been fully implemented.

5. In the past there appears to have been little interest concerning Class I product improvement programs on the part of the ASAP. There has also been no formal mechanism for the ASAP to participated in these programs.

6. It is impossible by any practical means to totally eliminate the phenomenon of unforeseen deficiencies that arise after development and fielding.

Conclusions:

1. The panel feels that continued emphasis and quick response to safety defiiencies are warranted. It appears however that traditional failure analysis and the "quick fix" are the chief methods employed. Insufficient scientific discipline is applied to problem analysis. The emphasis is on statistical analysis as opposed to a disciplined search for causative factors.

2. Safety is the driving factor in this category and, if allowed to become an obsession, could impair operational capability.

3. In this category the need for product improvement is tied directly to a failure definition. Lack of a clear definition of what constitutes failure often caused friction between the developer and the user with a consequent slow processing of PI's affecting operational capability.

4. The ASAP can be helpful with Class I PI's.

5. The phenomenon of inevitable unforeseen deficiencies does not seem to be recognized; i.e., they are treated operationally and on a funding basis as if they are not expected.

Recommendations:

1. Enforce the spirit of the DCSLOG letter to Cdr, USAMC, i.e. increased delegation, in view of:

a) The urgency of these proposals

b) The relatively small percentage of total product improvement dollars involved. Delegation should be encouraged to as low a level as possible, e.g., commodity command or project manager level.

2. Traditional failure analysis, although good, must be reinforced by a scientifically correct search for causative factors. We strongly recommend such reinforcement. This can be achieved by involving the commodity command R&D people more directly in the analysis. Statistical analysis is necessary in the approach to problem solution but it is not sufficient. It is also best to employ a critical mass of various technological disciplines. For a complex problem the necessary critical mass of disciplines will generally not be found in one subordinate command. We therefore recommend that a complete inventory be developed of the rare technical talent and tacilities available in AMC and see how these talents can be more optimally applied to product improvement in Class I.

3. A successful method used by industry is to form ad hoc failure analysis boards where a multi-disciplinary approach is required. There is a need for such boards. Failures normally ascribed to design errors are often caused by poor production practices, improperly characterized service conditions, unexpected operator usage, and improper maintenance. The panel feels strongly that, in general, the approach to failure analysis does not effectively exploit the aggregate of resources available to the Army.

4. For out-of-production items, OMA funds are utilized to fund PIPs. The engineering "fixes" therefore appear to be performed mainly by maintenance engineering elements. The panel feels that more emphasis should be placed on the use of the original developer in the solving of these problems.

5. More failure criteria must be developed. These criteria must relate to operational objectives. Unless compelling reasons are evident, safety fixes should be examined for the effect produced on operational

capability. It would also be very helpful to the user to receive in-depth education and training in the philosophy of the system as well as the technology employed, and to involve him earlier in the development cycle.

6. It is recommended that the specific technical disciplines embodied in the ASAP be made available to help in this type of PI. In this category, however, involvement should be on a selective basis. A letter should be prepared to USAMC, the commodity commands, DCSLOG, ACSFOR, and TRADOC indicating that ASAP expertise is available to augment existing capabilities and consulting talent.

7. The continuing ASAP panel on product improvement should be assigned to review key difficult Class I product improvements, especially those involving extreme problems after fielding. This panel should also serve as the formal mechanism for ASAP involvement in this PI class.

8. Expect unforeseen deficiencies and within broad delegation guidelines charge AMC with the job of planning for and correcting these on an expedited basis.

B. Class II - Product Improvement Programs

Observations:

1. In the AMC FY 75 proposed program, this category represents the largest number of total PIP's (78%) and about 49% of the total program cost. Implementation of PIPs in this category is not mandatory to perform a mission.

2. This category of product improvements a very slow process. Furthermore, the method of prioritizing PIPs is not clear. Motivation to improve cost effectiveness and reduce life cycle costs connected with Army materiel is impeded by the slow process and lack of delegation except when there is a high level attention such as in the RAM/RISE program. No DA technical and budget guidance is provided AMC for preparation of the product improvement program. At one command, only two of approximately 2,000 Equipment Improvement Recommendations (EIR) in one year were translated into product improvements and perhaps a similar situation exists at other commands. (It is recognized that EIR's generate low order improvements to materiel such as maintenance actions and publications changes.)

3. Data bases used by AMC in this category vary according to command, adequacy, type, and system design, and the quality of personnel collecting the data. The data is primarily logistics based and does not contain technical information needed to support PIPs. To overcome this, USAAVSCOM has found it necessary to field data teams in certain instances to provide the necessary information.

4. The ASAP appears to have had little formal interest in the past in Class II product improvements. The projects in this category are generally funded by PEMA funds. Installation of kits and engineering of modifications to out-of-production equipment is funded by the OMA appropriation (P7).

Conclusions:

1. The commodity commands are the most important source of expertise in their various commodities. Commodity commands develop PIPs based on data concerning system operation and guidance from various sources. However, these PIPs are not normally solicited by higher headquarters. Therefore, higher headquarters reviews these proposals in light of policy and funding guidance not available to the commands. Consequently, proposals are rejected at HQAMC and HQDA after a time consuming process of preparation and review. Manhours expended in reviewing PIPs submitted by the commands could be significantly reduced if guidelines for PIP preparation to include total dollar thresholds were provided and used at all levels (e.g., Five Year Defense Plan funding levels should be a baseline for dollar value of PIP proposals).

2. Considering the vast numbers of Equipment Improvement Recommendations submitted at one command and the few acturally implemented as PIP's in this category either

a) The majority of the field inputs are not useful or valid, or

b) The command is unable to properly evaluate input from the field, or

c) An artificial choke on the system has been applied, or

d) The system that generates the data is inefficient.

3. Reliability growth has been recognized by AMC as a measure of the success of development programs and is being currently implemented in several major programs. Reliability growth modeling can provide a significant input to estimates of product improvement cost and field reliability at various times in the life of a give materiel item.

Product improvement in terms of reliability enhancement is a fact of life for newly fielded equipment with high technical content. It is an evolutionary process of reliabilty growth which can be reasonably well predicted.

4. The "design to unit production cost" concept inherently affects the ultimate number and total cost of product improvements to achieve extended life, to increase cost effectiveness, or to reduce life cycle cost since system design RAM features are traded off to achieve unit production cost goals. Application of the DTUPC concept without sufficient priority attached to system growth potential may significantly increase dollars spent on product improvement over the life cycle of a system.

5. Class II programs could benefit significantly by using ASAP expertise in RAM and general systems anslysis.

Recommendations:

1. DA guidance is necessary to permit the decentralization necessary DA to speed the submission and approval or disapproval process for PIPs. Procedures need to be devised which will provide commodity commands with general technical and funding level guidance before preparation of proposals. Then, as long as the proposals were in accordance with the guidance and funding thresholds, the proposals would be approved and the commands could proceed to engineer, procure and install the modification. Resources would then be provided in accordance with budget procedures similar to new materiel acquisition procedures. The Commodity Command and AMC would disapprove proposals not included within the funding thresholds or if sufficiently urgent, would forward them as unfinanced requirements.

2. The data collection process concerning reliability, maintainability, and availability is of great significance in this category. The panel feels that TAERS/TAMMS Sample Data Collection information must be augmented with engineering information to really get the job done. The best result is likely to be obtained if people involved in the design of materiel help develop the data collection systems. In general, this has not been the case.

3. PIPs should incorporate reliability growth estimates and reliability growth modeling should be used as a program cost estimating tool. This would provide for better cost/effectiveness estimates and program cost control. A paper is attached by Dr. Reethoff of the panel in Appendix V.

4. The Army must not apply DTUPC method of contracting to the degree that it seriously inhibits future growth potential of newly developed systems. Considering that in the case of the XM-1 tank this method has relegated growth potential to 17th priority, the likelihood of over-application of design-to-cost is not trivial. It is recommended that those employing this method be careful to apply the principles within the spirit of the guidance as opposed to the letter of the procedure. OCRDA should most certainly be consulted on trade-offs associated with potential technological growth vs. low unit product cost.

5. The continuing ASAP panel on product improvement should select several projects in this class and provide specific recommendations involving RAM that could help the process become more useful and efficient. Programs employing the DTUPC method should be prime candidates for study.

C. Class III -- Product Improvement Programs

Observations:

1. In the AMC FY 75 proposed program, this category constituted 19% of the total PIPs and approximately 50% of the total product improvement dollars.

2. The panel has not found a "line" organization that has the responsibility to sell to the user on a continuing basis items developed for the user. There also is no organization that keeps the user involved in such a manner that he will contribute significantly to what is developed and there-by enthusiastically accept the item. "Line" here implies funding authority and line responsibility for guiding and selling the materiel concept so that it will be useful and accepted.

3. Intense activity has traditionally existed in regard to new system development and product improvement. Recently the Army has, at least in two areas (tactical vehicles and commercial construction equipment) tried to use procurement of commercial equipment as another means of fulfilling requirement.

4. The decision to employ product improvement to obtain an improved operational capability vs. the use of new approaches seems to be the result of a reactive phenomenon as opposed to a planned approach.

5. Since R&D funds are employed in this category, semantic difficulties exist with what does or does not constitute proper R&D or PEMA funded effort. This is a factor which introduces confusion into the PI process and interferes with efforts to obtain the proper resource commitment.

6. The Class III product improvements enjoy a more normal attention on the part of the ASAP. This is expected since they either involve the exploitation of new technology or involve significant trade-off studies concerning decisions to employ product improvement or new development.

7. Items developed in this category ultimately became candidates for Class I and Class II PI expenditures.

Conclusions:

1. In the FY 75 AMC Product Improvement Estimate, Class III product improvement programs account for the greatest share of PI costs even though the number of projects is significantly less in number.

2. AMC does not have one of the significant line elements in its management structure that is required to have an efficient PI program. It is the element required to identify represent, and involve the user during the PI process. It also sells the improved product to the user. Problems created by this serious omission may also occur in Class I and Class II product improvements but are most serious in Class III progams. Staff and other line elements of the Army purport to serve this role. They cannot properly do this. They perform a valuable staff role. The definition and rationale for the needed line organization is described in Appendix VI.

3. It seems very sensible to the panel to employ commercial off the shelf developments and technology to a greater extent.

4. Clarification of funding distinctions and definitions would be helpful with respect to product improvements aimed at improved operational capability.

5. This category involves the exploitation of advanced technology to achieve improved operational capability. The ASAP can be of the greatest assistance in these types of product improvements.

6. The Class I and Class II programs that will ultimately be required will be more efficient and less costly if reliability growth methods are applied during the Class III process and the exercise of DTUPC is done with a caution similar to that previously recommended for new items of materiel.

Recommendations:

1. The ASAP continuing panel on product improvement should assign first priority to the Improved Operational Capability category. The programs chosen should involve a significant degree of advance technology and ideally the PIPs should cut across commodity lines. The ASAP panel could be most helpful with such PIPs.

2. AMC should develop and implement a line user oriented organization as described in the paper in Appendix VI. Its function should be the following:

a) Translation of the broad requirements developed by TRADOC and the force developer to real time user terms that the developer/acquisitioner can understand.

b) Definition of who is the user.

c) Definition of the improved product that will be accepted and used by the user.

d) Joint with the develop/acquisitioner - the development of a useful and saleable improved product. This responsibility must include a significant role in the control and management of project funds.

e) Selling of the improved product to the user.

f) Interpretation and iteration of the user's desires on a real time basis with the developer's/acquisitioner's problems and limitations throughout the product improvement process.

g) The conveyance and translation of real time user requirements to TRADOC and the Force Developer.

h) The iteration of requirements with TRADOC and the Force Developer.

i) The representation of the user in trade-offs related to the satisfaction of requirements by new or product improved materiel.

Programs having an Army Program Manager should include this new line organization reporting directly to the Army Program manager. For programs not sufficiently large to warrant an Army Program Manager this line organization should report at the commodity level in AMC equivalent to that enjoyed by the development/acquisition manager.

This recommendation is consistent with the requirements expressed in Appendix VI.

3. Place more emphasis on the careful development of trade-offs between new starts and product improvement. The Scout Task Force output should be used as a good example of the process of making a trade-off between a new start and a product improvement. Continue the search for commercial off the shelf items that fulfill operational requirements both at system and subsystem level.

4. Class III product improvements should fit into a long range plan designed to achieve improved operational capability. This long range plan should be driven by long range needs as expressed by TRADOC and the force developers. PIPs involving improved operational capability should fit into a planned series of PIPs designed to push an item of materiel to a competitive limit consistent with requirements and projections regarding advances in the state of the art. The detailed design of this plan must be the joint responsibility of the AMC line user representative organization previous cited, his counterpart developer/acquisitoner, and TRADOC.

5. The DA Comptroller should work out a set of funding distinctions and definitions to help in the removal of semantic difficulties. The panel notes recent DCSLOG guidance (14 Sep 73 letter to Cdr, USAMC) setting up guidelines for the various categories of product improvements

(increased capability, in-production and out-of-production systems, deficiency correcting projects). The panel also notes guidance contained in House Appropriations Committee Report 96-662 dated 26 Nov 73. Steps should be taken to insure that appropriate guidance is included in the revision of AR 700-35, Product Improvement of Army Materiel.

6. Apply reliability growth methods and modeling to improve materiel in this category. Take measures to assure that product improvements are well designed. Exercise caution in the use of DTUPC.

This report is the result of the exposure of the first ASAP ad hoc panel to the broad properties of the Army's product improvement program. The terms of reference for the panel were management oriented with the desire that guidelines should be developed for a continuing PI panel. There was no in-depth review of any specific PI program. This would not have been consistent with the terms of reference of the study. The panel attempted to develop a framework for more detailed individual PIP review by the succeeding panel. Detailed review of at least one critical Class I program, one important Class II program and two Class III programs would represent a practical and useful contribution on the part of the ASAP in any year. It is further recommended that in the case of Class III programs, the machanism for threat assessment and integration into long range planning be further studied.

The recommendations in many cases are considered to be significant provided the data assembled in the limited number of visits was representative. Army personnel who provided the data were most helpful and cooperative. For this the panel was very grateful.

Some of the management recommendations are pointed and strong, especially those concerned with involvement and representation of the user in the development process. It is felt by the panel that this emphasis is justified. Action in this area could do much to improve the product improvement process and the development/acquisition of Army materiel in general.

APPENDIX I

Deficiency Correction	CH-47C Helicopter
Extended Life	M110 Self-propelled Howitzer
	M107, Field Artillery Gun
Improved Operational Capability	M60A1 Tank

PRODUCT IMPROVEMENT PROPOSAL
For the use of this form, see AR 700-35; the proponent agency is Office of the Deputy Chief of Staff for Logistics.

1. SUBMITTED BY: US Army Aviation Systems Command (AMSAV-EEP)	2. DATE	3. PROPOSAL NO. 1-75-01-703
4. END ITEM(S) TO BE IMPROVED CH-47C Helicopter Item is in/out of production	5. UNIT COST $2.026	6. LIN (SB 700-20) K 30449
7. MAJOR COMPONENT TO BE IMPROVED T55-L-11A Engine	8. UNIT COST $147,850	9. FSN 2840-428-6382

10. TYPE CLASSIFICATION: (S) LP-U, LP-T, STD. A, STD. B, OTHER (Explain)
a. END ITEM(S) X
b. COMPONENT

11. FOLLOW-ON ITEM None F.Y. OF FIRST PROD

12. DESCRIPTION OF IMPROVEMENT:

SEE ATTACHED

13. ESSENTIALITY OF IMPROVEMENT

SEE ATTACHED

14. PRIORITY: ☐ URGENT ☒ URGENT W/LIM. ☐ NORMAL

15. TYPE OF IMPROVEMENT:
a. ☐ CORRECTS DEFICIENCIES KNOWN PRIOR TO PRODUCTION
b. ☐ CORRECTS DEFICIENCIES FOUND DURING PRODUCTION
c. ☒ CORRECTS DEFICIENCIES FOUND AFTER PRODUCTION
d. ☐ INCREASES QMR/SDR SPECIFICATIONS
e. ☐ NO CHANGE IN QMR/SDR, IMPROVES/REDUCES (______)

DA Form 3701-R, 1 Mar 71

16. Improved End Item Unit Cost $147,850. MOD KIT UNIT COST $5,185.

17. COST DATA BY FISCAL PROGRAM	RDTE	PEMA PRINCIPAL	PEMA SECONDARY	STOCK FUND	OMA	TOTAL
a. Engineering, Test & Eval						
b. Prototypes ( )						
c. End Item Production + or -						
d. Modification Kits		2.976				2.976
e. Application of Kits						
f. Repair Parts Stockage						
g. Other Support Costs					.005	.005
Total		2.976			.005	2.981

18. COST DATA BY FISCAL YEAR	CURRENT FY 74	BUDGET FY 75	FY 76	FY 77	FY	FY	TOTAL
a. RDTE							
b. PEMA Principal Item	DO NOT HAVE IT [illegible]	.996	.996	.358			2.976
c. PEMA Secondary Item							
d. Stock Fund							
e. O&MA	.005						.005
Total	.631	.996	.996	.358			2.981
19. Qty of improved end items to be proc.							
20. a. Modification Kits (Qty)	96	192	192	69			.549
b. Installed at Depot or Mfg Plant		185	185	179			549
c. Installed below Depot Level							

21. REMARKS Replace turbine - No install req -

PREPARED BY

TYPED NAME, GRADE, AND TITLE	OFFICE SYMBOL	TELEPHONE NO
HARRY WOOLVERTON, GS-13, Aero Engr	AMSAV-EEP	5356

RECOMMEND APPROVAL

TYPED NAME OF CONFIGURATION MANAGER/PRODUCT IMPROVEMENT COORDINATOR	SIGNATURE

REVERSE OF DA FORM 3701-R, 1 MAR 71

Supplement to PIP No. 1-75-01-703

12. DESCRIPTION OF IMPROVEMENT:

a. Summary - The ECP number assigned to this modification is LY-GT-55-88. This project will provide for changes to improve the integrity of the Power Turbine Assembly of the T55-L-11A engine.

b. Background -

(1) Age of The End Item - The T55-L-11A engine is used in the CH-47C aircraft. There are 534 engines in the Army inventory.

(2) Nature of The Defect - The existing configuration consist of separate parts (power shaft, third wheel, stub shaft iand fourth turbine wheel) which are held together by mounting bolts and a clamping ring on the forth wheel. An inadvertent improper assembly of the clamping ring or imperfections on the mating surfaces could result in high local stress concentrations during engine operation. Even though the existing procedures serve to assure proper assembly of the parts, the precautions required indicate the need for the more efficient design.

c. Engineering Approach -

(1) Description of Change - The proposed change introduces an integral power turbine shaft system in which the third stage turbine assembly is inertia welded to the power shaft and the stub shaft. The retention of the fourth wheel is by means of a high strength locknut rather than the bolt and ring clamp which is presently used. The web area of the fourth wheel is also increased for added strength.

(2) Technical Aspects - The proposed hardware will provide the added margin to assure that there will be no failures of the fourth stage turbine wheel. It also provides for additional overspeed margins.

(3) Amount of Testing/Evaluation - The proposed hardware has completed 70 hours of forced failure testing at power turbine inlet temperatures in excess of 2100°F. The hardware has been exposed to 2000 cycles of accelerated aging and 1800 hours of development operation without incident. The welded rotor has also been subjected to torsional and thermal fatigue testing.

(4) Milestones - See the attached schedule.

d. Benefits

(1) In Quantative Terms - The existing configuration has a potential failure mode which could become more critical with part life and repeated overhaul. In the event a failure did occur it would result in total loss of the aircraft. The proposed configuration would eliminate this possible failure mode.

Supplement to PIP No. 1-75-01-703

(2) Economic Analysis - The total cost to incorporate the proposed hardware is approximately 2.8 million dollars. The hardware introduced by this proposeal (Turbine Discs and Power Shafts) are high dollar items but are normally low replacement items at depot overhaul. From the point of view of longer life hardware or lower replacement rates, this proposal is not cost effective and a cost study is not attached. The prime reason for the proposal is to eliminate a potential failure mode and assure the safety of the aircraft.

e. Milestones - See attached schedule.

f. Impact If This PIP is Disapproved - If this PIP is not approved, there will be probable failures and loss of aircraft due to the failure mode which has been identified.

13. ESSENTIALITY OF IMPROVEMENT:

This PIP is required to eliminate a possible failure mode in the fourth disc assembly. A failure of this type could result in total loss of the aircraft.

18. PRIOR YEARS FUNDING AND PROGRESS ATTAINED:.

a. Prior Year Funding Approved

Amount	Fiscal Program	Fiscal Year
$70,000.00	FY 71 & FY 72	FY 71 & FY 72

b. The proposed hardware was evaluated under the T55-L-11 "Get Well" Program. It was taken through development and a 150 hour Benchmark Test under this program. During the CY 72 Product Improvement Program it was qualified in a 150-hour MQT test.

Supplement to PIP No. 1-75-01-703

CH-47/T55

______________ (Date)

MILESTONE CHART

Contract Award for FECP Submittal	X (3rd Qtr, FY 73)
Engineering Analytical Design Complete	____ (___ months) Complete
Prototype Fabrication Complete	____ (___ months) Complete
Testing Complete	____ (___ months; ___ bench & ___ Eng Test).
FECP Preparation Complete	____ (___ month)
FECP Submittal Complete	X (___ Qtr, FY___)
FECP Approval	X (3rd Qtr, FY 73)
Contract Award for Modification Kits, MWO, etc.	X (1st Qtr, FY 74)
Modification Kit Leadtime	9 months
MWO/Kit Trial Installation N/A	X (N/A Qtr, FY ___)
Modification Kit Delivery	X (1st Qtr, FY 75 @ 30 per mth)
MWO Issued N/A	X (N/A Qtr, FY ___)
Modification Kit Installation - Start	X (1st Qtr, FY 75)
Modification Kit Installation - Complete	X (2nd Qtr, FY 77)
Technical Publication Changes Issued	X (3rd Qtr, FY 74)
SSE/SGE Available	X (3rd Qtr, FY 74)
Trainers Modified, Training Aids Available	X (3rd Qtr, FY 74)

PRODUCT IMPROVEMENT PROPOSAL

For the use of this form, see AR 700-35; the proponent agency is Office of the Deputy Chief of Staff for Logistics.

1. SUBMITTED BY:	2. DATE	3. PROPOSAL NO.
Gen Thomas J. Rodman Laboratory, Rock Island Arsenal, ATTN: SARRI-LA-4430 (SPA), Rock Island, IL 61201	Nov 73	1-72-05-077

4. END ITEM(S) TO BE IMPROVED	5. UNIT COST	6. LIN (SB 700-20)
Howitzer, Heavy SP M110	$191,922.00	K56981
Gun, Field Artillery, SP M107	$198,258.00	J97230
Item is out of production		

7. MAJOR COMPONENT TO BE IMPROVED	8. UNIT COST	9. FSN
Howitzer, Heavy SP, M110	$191,922.00	2350-439-6243
Gun, Field Artillery, SP M107	$198,258.00	2350-436-6635

10. TYPE CLASSIFICATION: (S) LP-U, LP-T, STD. A, STD. B, OTHER (Explain)
a. END ITEM(S) X
b. COMPONENT* X

11. FOLLOW-ON ITEM — F.Y. OF FIRST PROD
M110E2, Improved 8-Inch, SP Howitzer — 1975

12. DESCRIPTION OF IMPROVEMENT:

This Product Improvement is composed of 3 kits:

a. Kits 1 and 2 will provide for the increased safety, reliability and maintainability (RAM of the M107/M110) chassis.

b. Kit 3 provides for the extended range of the weapon through the conversion of all M107/M110 chassis to the M110E2 configuration.

13. ESSENTIALITY OF IMPROVEMENT

SEE CONTINUATION SHEET.

14. PRIORITY: ☐ URGENT ☒ URGENT W/LIM. ☐ NORMAL

15. TYPE OF IMPROVEMENT:
a. ☐ CORRECTS DEFICIENCIES KNOWN PRIOR TO PRODUCTION
b. ☐ CORRECTS DEFICIENCIES FOUND DURING PRODUCTION
c. ☐ CORRECTS DEFICIENCIES FOUND AFTER PRODUCTION
d. ☒ INCREASES QMR/SDR SPECIFICATIONS
e. ☒ NO CHANGE IN QMR/SDR, IMPROVES/REDUCES (Reliability & Maintainability)

DA Form 3701-R, 1 Mar 71

1-72-05-077D Revised

16. Improved End Item Unit Cost ________________ MOD KIT UNIT COST $ ________________

17. COST DATA BY FISCAL PROGRAM	RDTE	PEMA PRINCIPAL	PEMA SECONDARY	STOCK FUND	OMA	TOTAL
a. Engineering, Test & Eval	11.131				.246	11.577
b. Prototypes (8)					.154	.154
c. End Item Production + or -						
d. Modification Kits		37.248				37.248
e. Application of Kits				.085	4.067	4.152
f. Repair Parts Stockage				3.173		3.173
g. Other Support Costs		.313		.296	.603	1.212
Total	11.131	37.561		3.554	5.070	57.316

18. COST DATA BY FISCAL YEAR	FY 74 & PRIOR	CURRENT FY 75	BUDGET FY 76	FY 77	FY 78	FY___	FY___	FY___ & FUTURE	TOTAL
a. RDTE	10.480	.651							11.131
b. PEMA Principal Item	6.600	11.092	19.869						37.561
c. PEMA Secondary Item									
d. Stock Fund	.586	1.284	1.684						3.554
e. O&MA 738017.000	.515 (1)	.488							1.003
f. O&MA 728012.120									
g. O&MA 732207.XOX			1.361	1.486	.001				2.848
h. O&MA 721111.131									
i. O&MA ~~Program~~ 567113 1				.600	.526				1.126
j. O&MA Program 2			.013	.060	.020				.093
Total	18.181	13.515	22.927	2.146	.547				57.316
19. Qty of improved end items to be proc									
20. a. Modification Kits (Qty)									
b. Installed at Depot or Mfg Plant									
c. Installed below Depot Level									

21. REMARKS

(1) Phase I Costs. For detailed information refer to the original submission of this PIP,

(2) See 3701-R forms for each kit to obtain block 20 information.

Note all costs are expressed in FY 74 dollars.

BLOCK 12 CONTINUATION SHEET

12. Summary of Configuration Change: Four armament, twelve automotive and two safety oriented changes are proposed for the M107/M110 SPA weapons to improve their RAM/safety characteristics. In addition to RAM/safety mods, two additional items are being proposed to increase the operational capability of the weapon system. These items are a new, longer range cannon assembly, XM201, and a new direct fire reticle for the M116/M116C Telescopes to compensate for the change in muzzle velocity for direct fire missions.

a. Background:

(1) The design age of the M107/M110 SPA Weapons is approximately ten years.

(2) Compared to other field artillery pieces, the Army's Heavy SPA family has historically demonstrated a relatively lower durability index for several mission critical components. This results in a correspondingly lower availability index for the weapons for extended combat mission usage. The maintenance burden associated with lower durability/reliability of both armament and automotive components has been an object of considerable concern by the user.

b. Engineering Approach:

(1) Description of Configuration Change: Sixteen high failure rate components and two potentially dangerous components will be redesigned to reduce the effects of firing shock loads, rough terrain travel and operator abuse or provide safety features to prevent operator abuse/mishandling or provide environmental protection. The XM201 extended range cannon assembly and an associated change to the direct fire telescope reticle will be added to fulfill a user requirement for extended range capability. The attached individual Product Improvement Proposal (DA Forms 3701-R and continuation sheets) present individual modifications. Note that the trailing idler arm and hub assembly improvement has been changed in concept since the last submission.

(2) Technical Aspects:

(a) Change/Improvement in strength/materials: Each of the twenty proposals are addressed separately in the attachments to this overall proposal.

(b) Change/Improvement in Operating Characteristics: A significant reduction in frequency of mission abortion due to operational failure is expected. Some modifications will result in a significant reduction of down time required to repair a given failure. Two modifications will result in improved system safety, and two modifications will result in increased operational capability.

(c) Disadvantages: One proposed modification will result in an 18% reduction in cruising range. However, the resultant range will be greater

BLOCK 12 CONTINUATION SHEET (2 of 3)

than the original requirement of 300 miles and a significant increase in reliability of the flexible fuel cell bladder over the present rigid, welded fuel cell is expected.

(3) Testing:

(a) Amount and Results of Fabrication Testing to date: No appreciable amount of individual testing to date except on the XM201 Cannon. It has been tested several thousand rounds through feasibility, AD and ED and DT II phases.

(b) Amount of testing recommended: RAM and safety changes have been installed on four weapons and will be tested during the M110E2 DT II/OT II tests. The cannon and reticle will be tested according to the M110E2 Coordinated Test Plan.

(4) Estimated changes to Tech Data Package:

(a) 282 New drawings.

(b) 215 Drawings changed.

(c) 11 New Specs.

(d) 290 SQAPs.

(5) Recommended Milestones:

(a) Receipt of Funding: 4 QTR FY 72.

(b) Finish Design & Development: 1 QTR FY 73

(c) Initial Prototype Procurement: 1 QTR FY 73

(d) Prototype Installation: 1 QTR FY 74

(e) Begin Testing of Prototype by TECOM: 1 QTR FY 74

(f) Evaluation of Test: 3 QTR FY 74.

(g) Acceptance of PIP: 3 QTR FY 74.

(h) Tech Data Package Completed: 4 QTR FY 74.

(i) Begin Mfg of Kits: 3-4 QTR FY 75

(j) Begin Retrofit: 1 QTR FY 76.

(k) End Retrofit: 2 QTR FY 78

BLOCK 12 CONTINUATION SHEET (3 of 3)

d. Benefits:

(1) Cost effective for two or more years of field use.

(2) Safety: Two PIPs are safety oriented. The Gun Tube Retraction Valve will be modified to provide greater operator safety. The driver's hatch cover latch will also be redesigned to prevent accidental closing.

(3) Mission/System/Part Reliability: A significant decrease in critical component failure is expected, thereby substantially increasing reliability.

(4) A significant increase in range capability will be achieved upon installation of the XM201 Cannon.

e. Impact of Project Disapproval: Revert to reliability characteristics as they exist to date. The user will be faced with perpetuation of the present maintenance burden. Increase in range capability will not be realized unless the XM201 Cannon is installed on the M110 SPHs. Increase in long range projectile lethality will not be realized unless the XM201 Cannon is installed on the M107 SPGs. The capability of meeting the foreign 8-Inch Howitzer threat will not be attained.

M60A1 Tank (PI)
PIP 1-72-5-053C

PRODUCT IMPROVEMENT PROPOSAL
For the use of this form, see AR 705-33; the proponent agency is Office of the Deputy Chief of Staff for Logistics.

1. SUBMITTED BY: Project Manager, M60 Tanks	2. DATE: Feb 72	3. PROPOSAL NO.: 1-72-5-053C
4. END ITEM(S) TO BE IMPROVED: Tank, Combat, FT, 105MM Gun, M60/M60A1 1/ (Item is in/out of production)	5. UNIT COST: $261,321 / 163,200 1/	6. LIN (SB 700-20): V13100 1/
7. MAJOR COMPONENT TO BE IMPROVED: 2/	8. UNIT COST: 2/	9. FSN: 2/

10. TYPE CLASSIFICATION: (S) LP-U, LP-T, STD A, STD B, OTHER (Explain)
a. END ITEM(S) 1/
b. COMPONENT N/A

11. FOLLOW-ON ITEM M60A1E3 F.Y. OF FIRST PROD FY 1975

12. DESCRIPTION OF IMPROVEMENT:

a. Summary: The basic premise for the M60A1 Tank Product Improvement Program is the fact that the M60 Series Tanks will remain active as the main battle tank of the US Army for the next 10-15 years. As such, there is a need to improve the basic tank performance and combat effectiveness to keep pace with technological advances of other nations.

(Cont'd on attached sheet)

13. ESSENTIALITY OF IMPROVEMENT

a. Statement of Problem: Except for IR fire control and the add-on stabilization system which will be introduced into new M60A1 Tank production in CY72, the combat effectiveness of the M60/M60A1 Tank fleet has remained status quo since initial production in 1960. The current M60/M60A1 Tank is based on an evolutionary process from the M48 Series Tanks.

(Cont'd on attached sheet)

14. PRIORITY: [ ] URGENT [X] URGENT W/LEI. [ ] NORMAL.

15. TYPE OF IMPROVEMENT:
a. [ ] CORRECTS DEFICIENCIES KNOWN PRIOR TO PRODUCTION
b. [ ] CORRECTS DEFICIENCIES FOUND DURING PRODUCTION
c. [X] CORRECTS DEFICIENCIES FOUND AFTER PRODUCTION
d. [X] INCREASES QMR/SDR SPECIFICATIONS
e. [X] NO CHANGE IN QMR/SDR, IMPROVES/ (Basic tank performance and combat effectiveness; Materiel Need (CD) is in process)

DA Form 5761-R, 1 Mar 71

STAN R. SHERIDAN
Colonel Armor
Project Manager, M60 Tanks

16. Improved End Item Unit Cost	$328,282 3a/	MOD KIT UNIT COST	$93,990 3b/

17. COST DATA BY FISCAL PROGRAM	RDTE	PEMA PRINCIPAL	PEMA SECONDARY	STOCK FUND	OMA	TOTAL
a. Engineering, Test & Eval	10.600	18.229				28.829
b. Prototypes ( )	6.197	2.139				8.336
c. End Item Production + or -		110.747				110.747
d. Modification Kits		432.526				432.626
e. Application of Kits		31.337				31.387
f. Repair Parts Stockage				89.005		89.005
g. Other Support Costs	1.157	3.250			.150	4.557
Total	17.954	648.928		89.005	.150	756.037

18. COST DATA BY FISCAL YEAR	CURRENT FY 73	BUDGET FY 74	FY 75	FY 76	FY 77	FY 78	TOTAL
a. RDTE	~~2.900~~ 4.9	1.5 .400	6.4				8.300
b. PEMA Principal Item	11.179	15.255	32.017	35.287	74.860	74.860	244.058
c. PEMA Secondary Item							
d. Stock Fund	.605	✓ 2.012	4.743	5.178	10.767	10.767	34.072
e. O&MA	.042	✓ .036	.048				.126
Total	19.726	17.703	36.808	41.065	85.627	85.627	286.556
19. Qty of improved end items to be proc.			180	360	360	360	1.260
20. a. Modification Kits (Qty)			6		540	540	1.086
b. Installed at Depot or Mfg Plant			6		540	540	1.086
c. Installed below Depot Level							

21. REMARKS $ in Millions All costs are in FY72 constant dollars except as noted.

1/ Blocks 4, 5, 6 & 10

VEHICLE	UNIT COST	LIN	TC
M60	$163.200	V13100	Std B
M60A1	261.321	V13100	Std A

(Note: Unit cost of M60 is the average production cost. M60A1 unit cost is FY 72 program cost, w/o product improvement projected to a quantity of 360 tanks).

BLOCK 13 CONTINUATION SHEET (1 of 2)

13a. Statement of the problem and urgency: Recent testing has created high level concern over the RAM characteristics of the M107/M110 Weapons System. Also, USACDC-MA has expressed concern over the high Maintenance Burden for the M107 Weapon. The following components have been selected in a coordinated effort by ARMCOM, TACOM, TRADOC, and the US Army Maintenance Board as being those that, if improved, would most significantly improve the RAM characteristics and operator safety of the M107/M110 Weapons.

(1) Auxiliary Drive Magnetic Clutch
(2) Traversing Mechanism
(3) Elevation Mechanism
(4) Loader-Rammer
(5) Hatch Cover Hold-Open Latch
(6) Gun Tube Retraction Valve
(7) Spade Control Valve & Lever
(8) Idler Arm and Hub Assy
(9) Low Coolant Warning
(10) Intercom Box Protection Step
(11) Throttle Control Yield Link
(12) Deck Stiffener
(13) Hydraulic Tube Guard
(14) Master Relay (quick disconnect)
(15) Voltage Regulator
(16) Fuel System Air Purge
(17) Fuel Cell
(18) Gun Tube Travel Lock
(19) XM201 Cannon
(20) Direct Fire Reticle

The first 18 line items are proposed to be installed in depot from FY 76 through FY 78. The XM201 Cannon and the new MIL Scale Reticle for the M116/M116C Telescopes are proposed to be installed via MWO method over the time period of FY 76 through FY 78.

b. Related Activity: Since the M107/M110 Weapons are the current Heavy Artillery Weapons assigned to Division/Corps/Army and will be for several years yet, it behooves the Army to increase the Reliability through cost effective PIPs to the extent that the marginal cost of the PIP equals the marginal return or savings in Maintenance Burden.

The M107/M110 Chassis will also be utilized for the M110E2, 8-Inch Improved SPH. It is expected that problems presently associated with the system components will be perpetuated if they are not corrected/improved prior to retrofit of the XM201 Cannon.

c. New Item Prospects: With the exception of the M110E2, which calls for installation of the XM201 Cannon on the M107/M110 Chassis, no new development of 8-Inch SPHs are funded at present. No other new requirements documents exist. It is generally considered that a 10-15 year time period will elapse between inception and fielding of a major new weapons system. NOTE: When the XM201 Cannon is retrofitted on the M107/M110 Weapons, the direct fire reticle in the M116/M116C Telescope must be changed to compensate for the change in muzzle velocity.

BLOCK 13 CONTINUATION SHEET (2 of 2)

d. EIR/EPRs pertaining to this problem: 170 EIRs, 182 EPRs and one accident report, as well as a significant number of unofficial failure reports are on file related to the M107/M110 components selected as candidates for Product Improvement.

NOTE: The first 16 line items shown above under paragraph 13a. comprise Kit I.
The Fuel Cell and Travel Lock comprise Kit II.
The XM201 Cannon and Reticle comprise Kit III.

Block 12 - Description of Improvement (Cont'd)

b. Background: The basic M60A1 PI Program was recommended for approval by the October 1969 SOMRB and approved by the Chief of Staff, Army, in Jan 70. As originally approved, the program comprised a series of improvements planned for release on an incremental basis beginning in 1971 and ending in 1975. In Nov 71, DA approved a program reorientation to develop and produce the last five product improvements on an integrated weapon systems basis.

c. Engineering Approach:

(1) Description of Configuration Change:

A description of each improvement is provided in each individual PIP. The total summation of all fire power improvements results in a significant increase in fire control accuracy, performance and improved first round hit probability. The mobility improvements increase battlefield agility, cross country performance and manueverability. Together, the fire power and mobility improvements increase survivability in today's combat environment and improve overall combat effectiveness for the M60/M60A1 Tank weapons system.

(2) Technical Aspects:

A conservative low-risk development program is being pursued to assure proper integration into the end item tank. All items are being designed to permit installation in the existing tank envelope without major modification to hull and turret castings. All improvements will be capable of being installed during depot overhaul or at a higher level of maintenance where feasible. Typical changes consist of welding mounting brackets to the hull and turret, installing new electical cables and hydraulic tubing, and bolt on application of sub-system components.

(3) Amount of Fabrication, Test & Evaluation:

Initial components will be subjected to laboratory reliability, qualification, life and environmental test requirements of MIL-STD-810B. Next, three tanks will be assembled: one for Engineering Design Tests, one for math model and systems analysis, and one for logistics support, maintenance evaluation and publications. Three additional tanks will be assembled for Contractor Engineering Tests (CET) to include 4,000 miles of operation each, with live firing exercises to be conducted at Ft. Knox. Finally, eight tanks will be assembled for Engineering Test/Expanded Service Test (ET/EST). Two tanks will be subject to ET at Aberdeen Proving Ground, one at Yuma Proving Ground for ET and five at Ft. Knox for EST. Prior to issue to troops, an additional seven (7) tanks, from the production line, will be subjected to Initial Production Testing (IPT) by USATECOM.

(4) Change to Technical Data Package (TDP):

The change in performance characteristics are significant enough to warrant a change in Tank Model Designator and creation of a new TDP. Upon completion of ET/EST the PI tank will Type Classified "A" and given a new designator. The current assigned experimental designator is M60A1E3. Three (3) complete new TDP's will be generated: one for new tank production, one for retrofit of fielded M60A1 Tanks, and one for retrofit of fielded M60 Tanks.

(5) Milestones:

Laboratory reliability, qualification and life test are currently in process. CET is scheduled to begin in Dec 72, and ET/EST will be completed in Feb 74. Type Classification "LP" is planned for Jun 74 and first production deliveries will begin in Dec 75. IPT will be completed in Jul 76 and the improved tank configuration will be Type Classified Standard "A" in Sep 76.

d. Economic Analysis/Cost Effectiveness:

Economic analysis/cost effectiveness study is not applicable since this PIP has been previously approved by DA and, therefore, such an analysis would not be useful and/or not result in increased decision effectiveness. The DA decision was primarily based upon combat effectiveness improvements including such factors as reliability, availability and maintainability.

e. Impact of Disapproval:

The product improvements described herein are currently funded programs and are in various stages of development. The improvements are within the current "state-of-the-art" and are attainable in the immediate future. Based on the fact that a new main battle tank cannot be developed and produced in sufficient quantity to replace the M60/M60A1 Tank fleet in less than 15-20 years, disapproval of the M60A1 PI Program will result in maintaining an out-moded weapons systems for the same timeframe.

Block 13 - Essentiality of Improvement (Cont'd)

b. Related Activity: None

c. Follow-On Item: A new main battle tank program is being planned.

Block 21 - Remarks (Cont'd)

2/ Blocks 7, 8, and 9. The individual components comprising the M60A1 Tank (PI) are addressed in the individual sub-proposals attached. The CSWS mount has been deleted from the program by msg DAFD-SDF 231746Z Mar 72.

3/ Block 16

a. The Improved End Item Unit Cost is as follows:

Basic Tank, w/o improvements	$261,321
T1 Air Cleaner	598
RISE Engine	992
Alternator/Regulator	4,658
Tube-Over-Bar Suspension	7,795
LASER Rangefinder	18,622
Solid State Computer	21,601
Add-On Stabilization	12,695
TOTAL	$328,282

b. Mod Kit Unit Cost is expressed in FY 72 dollars.

T1 Air Cleaner	$ 2,240
RISE Engine	11,100
Alternator/Regulator	5,053
Tube-Over-Bar Suspension	15,440
LASER Rangefinder	24,008
Solid State Computer	23,789
Add-On Stabilization	12,354
TOTAL	$ 93,990

4/ Blocks 17 and 18

The total dollar requirement for product improvement of the M60A1 Tank is $756.037 million (See Block 17 total) and includes all costs from initiation to completion. The dollar requirement for the period FY 73 thru FY 78 is $286.556 Million (See Block 18). These totals include costs as recorded in the sub-proposal and repeated here below.

		FY 70 thru 87 TOTAL Block 17	FY 73 thru 78 TOTAL Block 18
1-72-5-053C-1			
-2	TLAC	11.449	8.538
-3	RISE Engine	71.152	16.222
-4	ALT/REG	35.877	12.446
-5	TOB Suspension	102.514	30.143
-6	LRF	170.703	58.754
-7	S/S Comp	171.447	59.143
-8	AOS	88.288	59.972
	(Sub-Total)	($651.430)	($245.218)

M60A1 Tank (PI)
PIP 1-72-5-053C

Support Cost Elements	Approp.	Block 17 (Cont'd)	Block 18 (Cont'd)
ET/Expanded ST	RDT&E	.800	.800
Systems Engineering	PEMA	13.030	4.720
Acceptance Testing	PEMA	1.000	1.000
Publications (Tank)	PEMA	.620	.620
Army Stock Fund	ASF	89.005	34.072
Training (Tank)	OMA	.105	.126
(Sub-Total)		($104.605)	($41.338)
GRAND TOTAL		$756.035	$286.590 (Millions)

The costs above do not include costs for new turret trainers.

5/ Blocks 19 and 20

These quantities represent the number of complete production and retrofit product improved M60A1 Tanks.

APPENDIX II

Terms of Reference

TERMS OF REFERENCE

1. Name: ASAP Ad Hoc Group on Product Improvement.

2. Statement of the Problem: To review, describe and assess potential and proposed product improvements of Army materiel system.

3. Considerations:

a. The key to coping with threats facing the Army is to find ways to improve its utilization of modern technology for ground warfare. There are three ways of acquiring a new capability. These are new development, a commercial "off-the-self" acquisition or product improvement of existing systems.

b. Product improvement provides a means by which better performance and extended life can be obtained from a system without investing in new development starts. A viable product improvement program includes an assessment of the effect of a proposed improvement on force effectiveness. It includes an analysis of the improvement in terms of the projected threat for the period during which the improvement would be applied and used. Finally, a proposal to product improve a system must be weighed against development efforts and the capability to procure commercial equipment or foreign systems to assure that the means to provide a capability is cost-effective and timely.

4. Terms of Reference: In its study of the problem, the Ad Hoc Group should:

a. Provide a mechanism for presentation of ASAP materiel system improvement recommendations to Army management.

b. Review product improvement management for the purpose of expediting the identification, selection, approval and funding process.

c. Review the relationship of threat analysis and planning documents to decisions regarding product improvement, i.e., assuring that materiel system improvement is justified in terms of the forecasted threat.

d. Develop criteria for selection of proposed materiel system improvements for annual review by the ASAP Group on Product Improvement.

e. Develop a framework for review of PIP proposals.

f. Analyze selected examples of proposed and on-going product improvements as a means of developing specific recommendations for improved execution of PI programs.

g. This Ad Hoc Group will operate on a continuing basis. Members will serve for a period of one year.

h. The Ad Hoc Group will report findings in the month of September in order to be of greatest value for R&D programing decisions and in formulation of the yearly Product Improvement Program submission by Army Materiel Command.

APPENDIX III

List of Members

DEPARTMENT OF THE ARMY
ARMY SCIENTIFIC ADVISORY PANEL
Washington, D. C. 20310

Members
AD HOC GROUP
on
PRODUCT IMPROVEMENT

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Chicago, Illinois 60680
(Area Code 312 996-3000)

APPENDIX III

APPENDIX IV

List of Briefings, Agencies and Projects Reviewed

Briefings Concerning Product Improvement Management

11-12 July 1973	Orientation, Pentagon
Threat Analysis	Mr. D. Holstein Army Intelligence Threat Analysis Detachment
Force Development Process	LTC W. Hayes, OACSFOR
Product Improvement Conceptual Framework	Mr. W. S. Michel, ODCSLOG
Product Improvement Management	COL C. Clement, HQ, USAMC LTC George T. Neu, USAAVSCOM
13-14 August 1973	Orientation, Pentagon
Funding Cycle	Mr. W. S. Michel, ODCSLOG, DA
New Materiel Acquisition Policies	MG George Sammet, Jr., DCRD, DA
Orientation, US Army Training & Doctrine Command	Mr. J. Harris MAJ A. Houltry
Orientation, US Army Concepts Analysis Agency	LTC R. Robinson, USACAA
Discussion	MG J. Guthrie, USAMC
12 October 1973	DCSLOG, USAREUR
Data Systems	COL G. Armstrong, Chief, AMC Logistics Assistance Office
Aviation	LTC Calloway, ODCSLOG, USAREUR
Communications-Electronics	LTC Goode, ODCSLOG, USAREUR
Combat and Tactical Vehicles	Mr. E. Kreischer, ODCSLOG, USAREUR
Missiles	MAJ R. Goode, ODCSLOG, USAREUR
Discussion	MG J. Klingenhagen, DCSLOG, USAREUR

<u>8 November 1973</u>	<u>USA Aviation Systems Command</u>
Discussion with Commander	MG Frank A. Hinrichs
AVSCOM Command Briefing	MAJ Michael D. Raley, Assistant SGS
Review of History of Product Improvement for the CH-47 (CHINOOK)	Mr. Charles W. Caesar, Chief, CH-47 Branch, Dir for Maintenance
T63 Engine Compressor Problems (OH 58 Helicopter)	Mr. William Hearst, Chief, Power Plants Branch, Dir for Maintenance
Management of the Product Improvement Program	COL John C. Geary, Director of RD&E
Data Base for Product Improvement	Mr. Edward J. Hollman, Director of Product Assurance Mr. Lou Bishop, Chief, Systems Performance Analysis Division
Configuration Control Board Process	Mr. W. Morrissey, Chief, Status Accounting Management, Director for R&D

<u>9 November 1973</u>	<u>USA Armaments Command</u>
Discussion with Commander	MG John C. Raaen
Review of XM 204 Howitzer Program	Mr. G. J. Melow
Review of M110E2 Self Propelled Howitzer Product Improvement	Mr. Stan Smith
Discussion	COL McHugh COL Sherman Mr. H. Benson

<u>12-13 December 1973</u>	<u>USA Tank-Automotive Command</u>
Mechanized Infantry Combat Vehicle	COL J. F. McCluskey, Project Manager, MICV
XM-1, Main Battle Tank	MAJ James A. Logan, PM Office, XM-1
History of the Armored Personnel Carrier Program	Mr. Clarence A. Olsen, Systems Development Division, Directorate for Research, Development, and Engineering

Discussions, General	MG J. E. Pieklik, Commanding General Dr. E. N. Petrick, Chief Scientist COL Stan R. Sheridan, Project Manager, M60 Tank Series Dr. W. F. Banks, Deputy Director for Research, Development, Engineering Mr. J. Williams, Office of Director for Research, Development, Engineering
Discussion, Product Improvement Management	Mr. L. Jakobitus, Chief, Reliability and Maintainability Division, Directorate for Product Assurance CPT E. T. Smith, System Development Division, Directorate for Research, Development and Engineering

APPENDIX V

"RELIABILITY GROWTH AND ITS RELATION TO THE PRODUCT IMPROVEMENT PROCESS"

by

Dr. Gerhard Reethof
Consultant

RELIABILITY GROWTH AND ITS RELATION TO THE PRODUCT IMPROVEMENT PROCESS

By Dr. Gerhard Reethof, Consultant

Introduction

The United States Army has recognized that quantitative reliability objectives for today's complex equipment can be specified in contracts with demonstration of achievement required in an operational environment. The industrial or military developer of the Army's equipment by applying good design practices, relying on past successful approaches and by extensive development test programs will deliver equipment of sometimes terms of the reliability objectives.

In either case, the experienced developer recognizes that he has to undergo a deficiency correction process, a learning phase during this development test process.

Why then, the developer is often asked, could he not design today's complex, highly-stressed machines "right the first time". First of all, let us recognize that the reputable developer does indeed attempt to design a reliable end item by using past successful design practices and using modern design techniques within the timing and cost constraints imposed. In many instances, and let us face this fact, the analytical techniques are simply not available or uneconomic in terms of either calander time required or man hours needed or both. Therefore, the designer is forced to make best estimates of performance factors, stresses in highly stressed parts, thus reliability, etc.

During development tests, these best estimates are, wherever possible, verified to provide reasonable assurance of meeting requirements. Therefore, a degree of uncertainty exists as a device enters early production and first fielding that all possible failure modes have a sufficiently low probability of failure (or high mean time between failure). On a somewhat pessimistic note, we may visualize the device as having a built-in distribution (in the probabilistic sense) of failure probabilities for various failure modes. The product improvement process by deficiency corrections and long life improvement is therefore the sum total of the "Find and Fix" programs which we, unfortunately, encounter during the development test and operational use phase.

Therefore, the process of reliability growth is the inexorable process of encountering these lurking low probability failure modes, the identification of needed corrective action, the redesign process, the testing of the redesign to assure that the problem has indeed been solved and that no <u>new</u> problems (low probability failure modes) have been introduced, and then finally, the incorporating of the "fix" into production items and via retrofit kits into already fielded equipment. Let us recognize that Reliability Growth occurs <u>only</u>

after the fielded items have been retrofited. We can deduce logically that maximum reliability growth on an accumulated experience basis for a population of like devices can only be attained by the rapid response of the engineering organization to the first incidence of failure of a particular failure mode by fault diagnosis, redesign, development and retrofit. Ideally, this growth can be thought of as being maximized if the particular model were taken out of service whenever a failure occurs (without waiting for second, third, etc. incidences to assure that the fault was not an oft called "isolated case").

In terms of calendar time reliability growth, the process can be maximized by using as many units as possible at a maximum rate of usage and at the most severe test conditions so that the failure mode identification rate is maximized. In each case of new failure mode incidence, a corrective action process is instituted.

Managerial Control Aspects of Reliability Growth

The considerations discussed in the introduction have given impetus, in recent years, to the study of the reliability growth processes in development programs. The aerospace field, particularly jet engines, hydro-mechanical systems and auxiliary power systems, has provided an extensive and reliable data base for these investigations.

Several important strengthened program management prospects can be identified. Some of these opportunities relate to the long range planning of cost, timing and resource allocation to proposed development programs; others relate to the short term monitoring of the effectiveness of program management in relation to both reliability and reliability growth goals, yet others relate to the redirection of resources as program exigencies develop in the development cycle.

In this sense, we recognize that the engineering managers of the various Commands of the Army are constantly faced with the making of decisions on the relative levels of manpower, equipment and facility resources that should be allocated to the various phases of their development programs in order to optimize results for particular investments or to meet a particular critical goal.

For example, in the program planning phases an estimate of initial reliability and reliability growth rates of various subsystems will be shown to provide opportunities to optimize test facility requirements and utilization for a particular number of development units in a program, as well as assembly facilities and, of course, engineering resources to respond to the rate of appearance of new failure modes. The relationships of calendar time and test time to reliability growth can be estimated for various size programs. A host of other managerial questions can be studied with such "Models" of the development process.

During the actual program execution phases, as updated and corrected Reliability Growth model can become a most valuable aid in program monitoring and resource redirection to assure the meeting of time-phased reliability goals.

For in and out of production items, an updated and corrected reliability growth picture can be effectively used to estimate deficiency correction engineering, test and retrofit resource requirements.

Characteristics of Reliability Growth

These opportunities of Reliability Growth Characteristics utilization have been recognized by the aerospace industries since the early 1960's, and more recently, by the United States Army Material Command. Dr. L. H. Crow of the Army Material Systems Analysis Agency has provided a fine summary in Interim Note No. 16, June 1972, followed by the Reliability Growth Symposium sponsored by AMSA on 26 and 27 September, 1972 at Aberdeen Proving Ground. AMSA Interim Report No. 22 contains the papers from the symposium.

The symposium was an outgrowth of a recommendation by the "Panel on Accelerated Development of Reliability" under the direction of Mr. Jack Hope. Appendix F of the panel's report contains some of the technical foundation and implementation of these concepts. This latter material is repeated here to provide further dissemination and opportunities for discussion.

The overall characteristics of development programs of such devices as jet engines, aircraft generators, hydromechanical systems have been studied in terms of Cumulative Failure Rate λ_c as a function of cumulative operating hours on various types of equipment.

Figure 1 is such a plot for 4 different types of systems plotted on Log-Log graph paper. The individual data points, although not shown for consistently run programs, fall remarkably close to the lines drawn. The cumulative failure rate λ_c is defined in equation 1

$$\lambda_c = \frac{\Sigma F}{\Sigma H}$$

where

Σ_F are the cumulative number of failures.

Σ_H are the corresponding cumulative number of operating or test hours.

By a "consistently run program" we mean that the severity of service in either test or field remains essentially unchanged.

The learning process is therefore given by a simple exponential relationship as given in equation 2.

$$\lambda_c = K\ (\Sigma H)^{-a} \tag{2}$$

where λ_c is the cumulative failure rate as defined in equation 1.

α is the exponent of the learning process

ΣH are the cumulative operating hours

K is a very important constant giving a hypothetical failure rate after the first hour of testing.

From Figure 1 we see that the exponent α, the slope of the lines varies from a low of 0.348 to a high of 0.596.

Of interest is the instantaneous failure rate λ_i of a particular phase (ΣH_i) in the program. λ_i is given by equation 3

$$\lambda_i = \frac{d(\Sigma F)}{d(\Sigma H)}_i \tag{3}$$

λ_i is therefore the incremental change in the number of failures per additional operating hour and can therefore be visualized as a figure of merit for a reliability improvement program.

By combining equations 2 and 3, we obtain equation 4

$$\Sigma F = K(\Sigma H)^{1-\alpha} \tag{4}$$

so that the instantaneous failure rate is given by equation 5

$$\lambda_i = (1-\alpha)\ K(\Sigma H)^{-\alpha} \tag{5}$$

and the ratio of the instantaneous to cumulative failure rates is given by equation 6

$$\frac{\lambda_i}{\lambda_c} = 1 - \alpha \tag{6}$$

Of further interest is the rate of change of the instantaneous failure rate with each additional operating hour. This relationship is given in equation 7

$$\frac{d\lambda_i}{d(\Sigma H)} = \alpha(\alpha-1)\ K(\Sigma H)^{-(\alpha + 1)} \tag{7}$$

The sensitivity of this reliability growth merit figure on the exponent α is readily apparent.

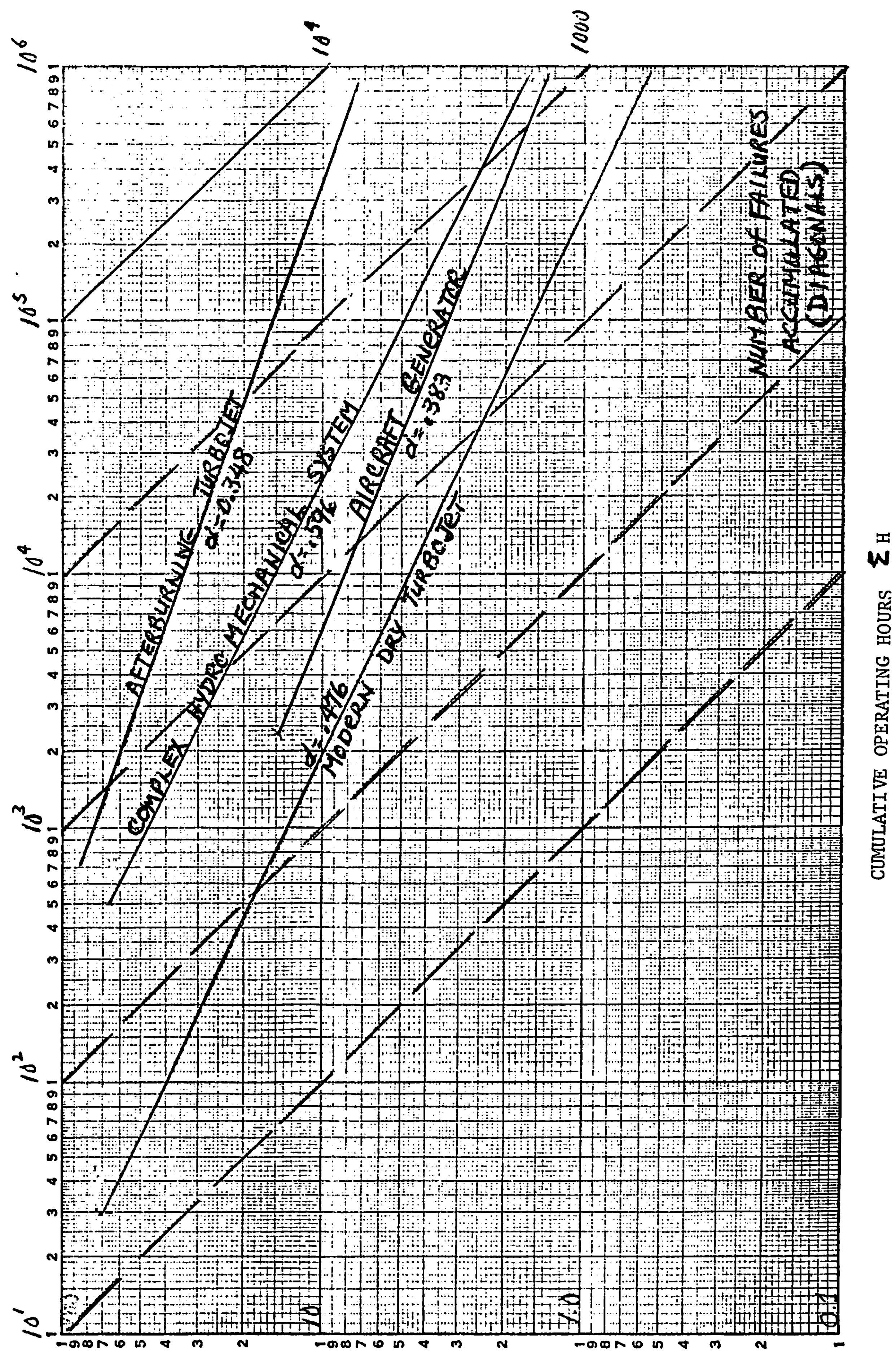


Figure 1 - Examples of Reliability Growth Experience in Mechanical Equipment

An Example

Thus consider the case of two different development programs starting with the same first hour failure rate K and having arrived at an experience level of 10 cumulative hours. Program 1 has a slope of 0.35; the other program moves more responsively and has a slope of 0.6. First of all, the cumulative failures which have been experienced for the assumption of K are given by:

$$K = 0.1 \text{ failures/hour}$$

$$\Sigma F_1 = 0.1(10^4)^{0.65} = 8.90 \approx g$$

$$\Sigma F_2 = 0.1(10^4)^{0.4} = 16.0$$

Also

$$\frac{d\lambda_i}{d(\Sigma H)_1} = 0.35(-0.65)(0.1)(10^4)^{-1.35} \approx -9.1\ (10)^{-8}$$

$$\frac{d\lambda_i}{d(\Sigma H)_2} = 0.6(-0.4)(0.1)(10^4)^{1.6} = -.96\ (10)^{-8}$$

From this little exercise it is apparent that we can expect to see considerably fewer failures for the case of the responsive program which must mean that most, if not all, of the failures are first time appearing failure modes.

The basic difference in these two programs must therefore be that for the lower exponent case we have many repeat failures relative to the second program assuming that the distribution of first time appearing failures are the same for both programs.

General Implications

The implications of these thoughts are rather interesting. Obviously in order to avoid repeat failures, the test program must be halted, and the failure must be investigated and fixed before proceeding with the testing. Thus, on a calendar time basis, far fewer test hours would vbe accumulated for the optimum reliability growth per test hour case. On the other hand, for a particular distribution of failure modes (failure mode numbers in each failure rate interval), new failure modes can only be experienced as time as accumulated. Thus the program manager is again faced with the decision between continuing to test with hardware that contains identified faults or whether to stop testing and fix the problems - but then forego the benefits of accumulating experience on the basis of calendar time. Failure can be expensive in terms of hardware usage, facilities damage and repair costs. Thus, trade-offs should be possible to establish a best course for a particular situation.

Development Program Simulation

If we indeed have some prior knowledge of the distribution of failures and the distribution of repair times, it should be possible to simulate the development program given certain test and repair facilities. Such simulations have been performed to study various alternatives in terms of cost and timing, as well as reliability levels.

An example for a jet engine test program plan simulation is next given in abbreviated form. (Credit goes to Messrs. G. W. Weber and R. S. Dorsey of General Electric's Flight Propulsion Division for the development and use of this program.)

1) Result needed: A prediction of the possible test program schedule and the factors limiting the program in either calendar time progress ot test hour accumulation.

2) The Dominant Factors in the Simulation:

   a) The number of engines available as a function of calendar time.

   b) Probability of engine failure, possible subsystems failure, as a function of accumulated test hours. The reliability improvement will be assumed to be exponential and be the result of planned corrective action. Important factors are the assumed initial reliability and the reliability growth rate expected as a result of corrective action programs.

   c) Relative severity of each test planned and the length of each test in calendar time, as well as engine hours. Each test in such a program has certain specific objectives; Therefore, the severity of the tests will vary considerably. Generally speaking, the planned length of the test will become longer as test hours are accumulated.

   d) The expected variability in engine teardown, inspection, repair times, reinstrumentation times and rebuild times is modeled by an appropriate statistical distribution which will vary somewhat with the stage in the program.

   e) Number of test cells available to permit conduct of specific tests.

   f) Number and type of engine assembly areas availible as a function of program time.

3) The system simulation is programmed using IBM's General Purpose Simulation System computer program (GPSS/360 or GPSS II), or more recent programs.

4) Probabilistic Approach: Many of the variables in the model are represented by statistical distribution; others are given by algebraic relationships. A Monte Carlo approach to sampling each distributed variable is used and the sampled values are then inserted into the model.

5) Description of Program:

a) The program simulates the actual execution of many complex test plans, in broadening failures based on the current reliability of the engines which, in turn, is based on cumulative test hours achieved per the reliability growth characteristics that have been assigned to the simulation.

b) As many activities are going on simultaneously in this simulation, the "clock" built into the GPSS/360 program is used to keep track of the various parallel happenings.

c) Engines and facilities with the appropriate capabilities are matched by decision criteria within the program.

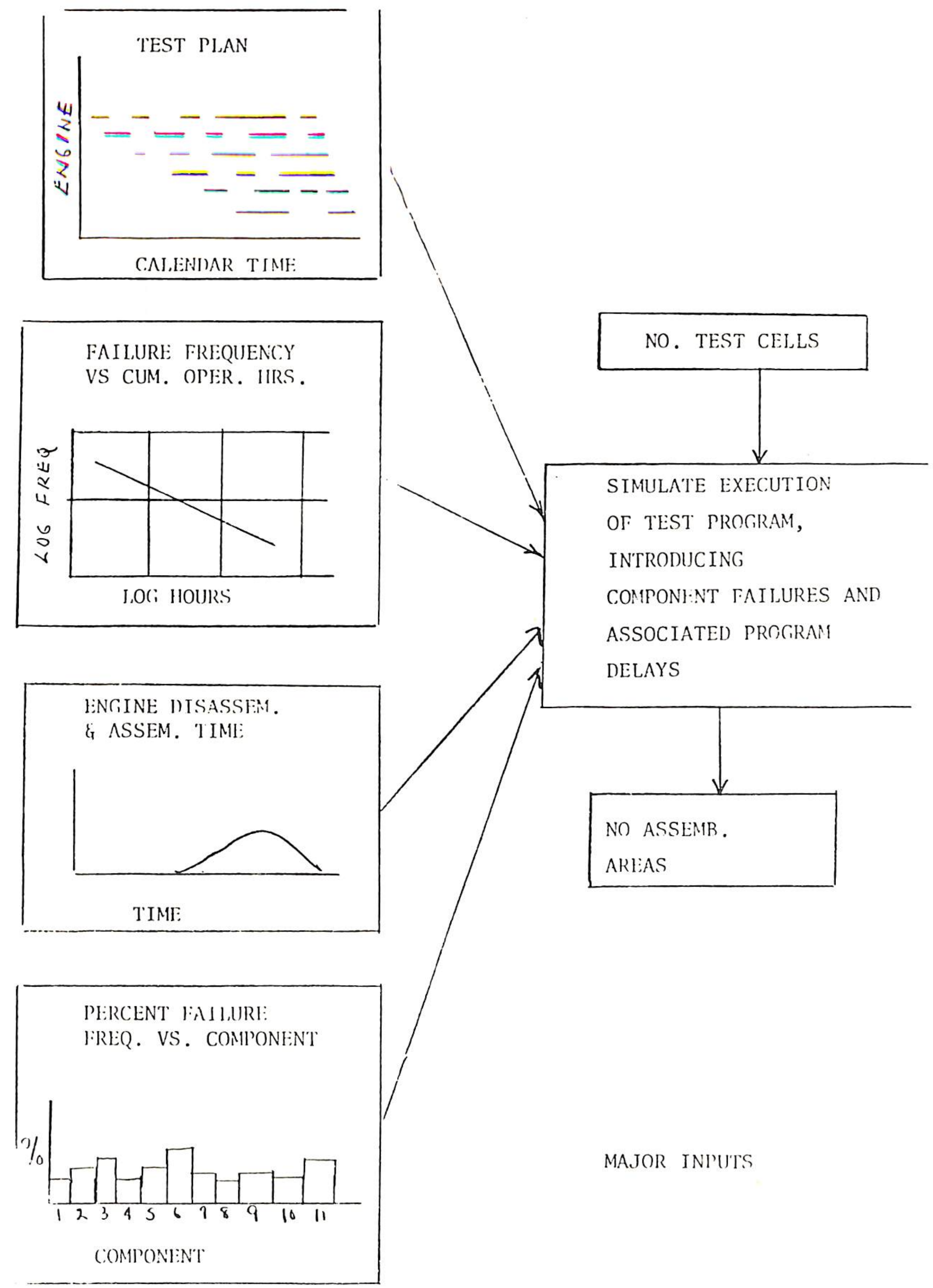
d) Waiting lines in test and assembly facilities are recorded as the simulation proceeds in time.

e) The execution of the specific test plan is repeated many times to generate a distribution of results at any point in the program and thereby establish probabilities of achieving certain results.

The major inputs into the program are shown in Figure 2. The alogorithm for such a program is sketched in Figure 3.

Conclusion and Recommendation

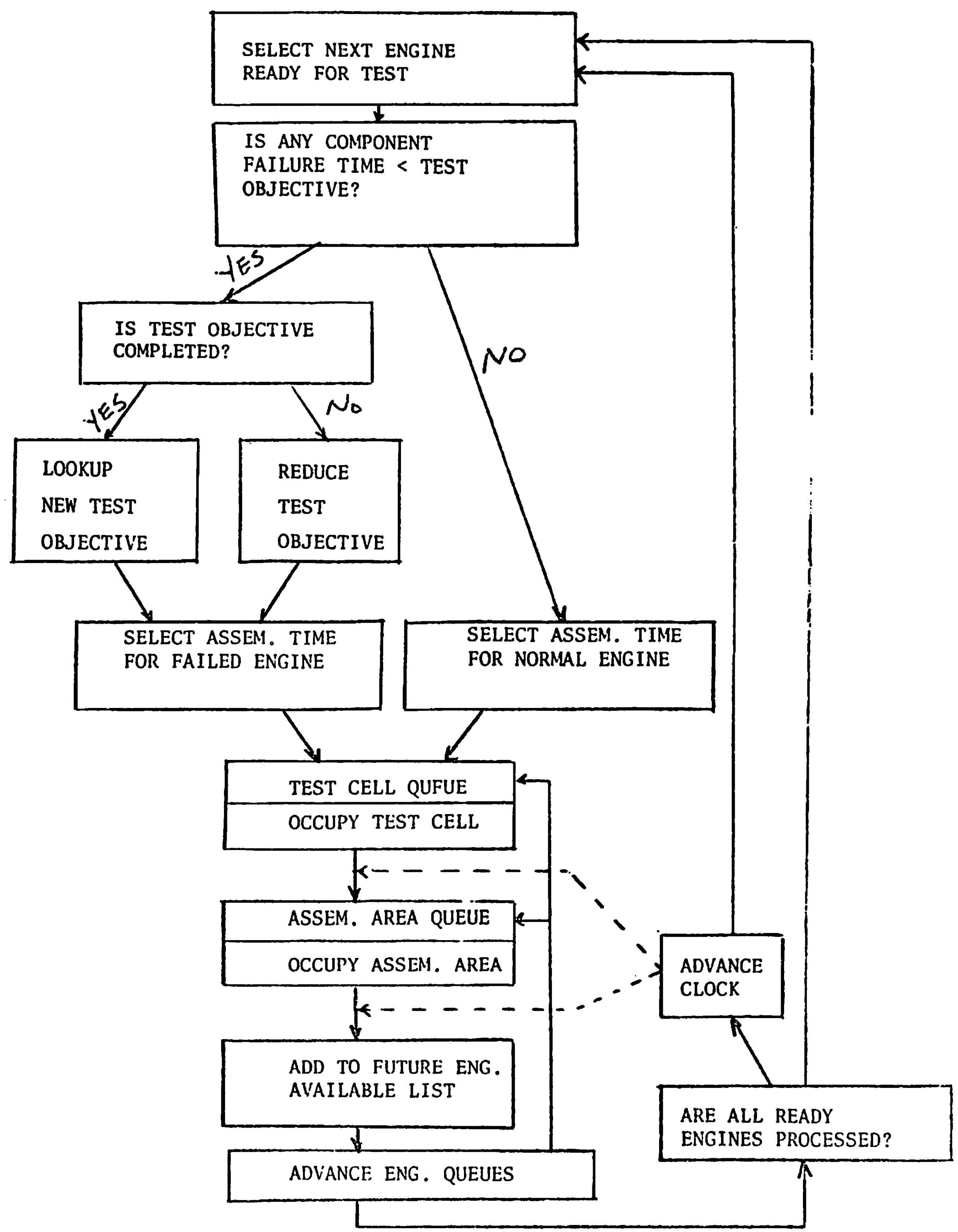
Reliability growth monitoring and modeling provides the engineering manager an opportunity to assess program status and progress. He can utilize the information to improve the utilization of his resources and estimate his chances of successfully meeting timing, cost and reliability goals. The inexorable trend of reliability growth of development programs has been established, but much remains to be done to provide a reliable data base for the input to the reliabilty growth models. I suggest, therefore, that the Army develop this important information by the study of past experience with several programs as was done several years ago by industry and that a continuing effort be established to maintain and update the technology of Reliability growth simulation.



MAJOR INPUTS

FIGURE 2

ENGINE TEST PROGRAM SIMULATION MODEL



APPENDIX VI

AMC ORGANIZATION FOR PRODUCT IMPROVEMENT

by

Dr. James J. Renier
Vice President for Data Systems
Honeywell, Incorporated

Chairman

The product improvement process starts with an item that exists and proceeds to an item that should be more useful to a user. An effective line management organization is required to effect such a product improvement process. Since the essential ingredients are three, i.e.;

1. A user that employs the improved item

2. Technology that is tailored to achieve the improvement

3. A satisfactory quantity of the improved item that is procured at a reasonable cost.

and since significant trade-off decisions among user acceptance, technology, quantity, and cost are always present it follows that the line management organization must be comprised of three distinct but interactive line elements. These are:

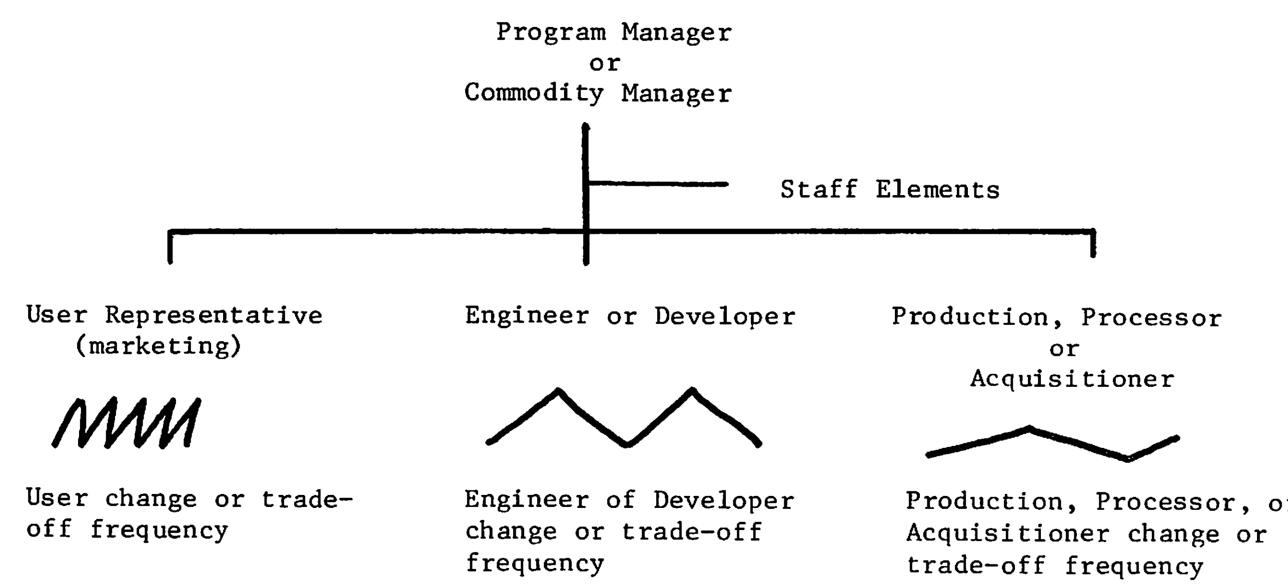
1. The user representative element (in industry referred to as marketing)

2. The engineer or development element

3. The production or procurement/acquisition element.

Product improvement responsibility and authority must be vested in each of these elements and they must execute their tasks competently on a continuous, full-time basis. These three functions should report to one program manager or a commodity manager who has the over-all responsibility for the Product Improvement.

The need for this type of self-contained, three element, line management function is best explained with the help of a diagram. Consider the simple management function depicted below, i.e.;



3 -- APPENDIX VI

Based upon changing competitive scenarios, engineering and procurement limitiations, and user understanding of needs, the user will operate with a trade-off frequency that is very high. With a regular rapid frequency a creative user will within the rough confines of any development concept conceive desirable changes to a materiel program at a very rapid rate. If managed properly, i.e., the user representative contains these proposed changes at a constructive level and integrates them properly. This user deliberation and input is perhaps the most significant input to the entire product improvement process. Without user involvement the improved item will probably receive begrudging acceptance and not be optimally suited for the intended mission. Delay will therefore be introduced and much work will have to be redone at increased cost.

The user trade-off or proposed change frequency is generally not appreciated by the engineer, developer, and production or procurement organization because these organizations cannot change directions as rapidly. The natural result is therefore an attempt to dominate or replace the user representative by these organizations. If the user representative element is weak or does not have project funding responsibility it is usually overridden by the engineer-developer element which forces the user into its mold. The result is generally disenchantment on the part of the user and a large technical establishment always knowing what is best for the user. PI's requested by the user are often second-guessed and delayed. Those suggested by the developer/acquisitioner are deemed more important and staff organizations at the higher management level are then created to represent the user - a most inefficient way to operate.

The engineer/developer must have a relatively low number of changes in direction during the course of a product improvement program. These lower frequencies are depicted in the diagram. Production or procurement can withstand even less oscillation than engineering. The program manager or commodity manager will be successful only if he understands and orchestrates those frequencies much like the conductor of an orchestra. If one of the key frequencies is missing or improperly contained, the program manager or the commodity manager must step in and fulfill the missing roles. This undoubtedly detracts from the execution of normal responsibilities and forces the program manager into an "acting" and almost always a dominant role amongst the three line elements. If the "acting" role happens to be that of the user representative, engineering or production can be made to suffer by too much change in direction.

AMC has always had a line element associated with engineering and production/procurement in the PI process. There does not however seem to be any line element that fulfills the user representative role. In major programs the Army Program Manager is often "acting" in this role. This would definitely seem to be less than optimum. Oftentimes the huge Army technical establishment fills the vacuum created by the absence of a user representative line function. The overpowering strength of the Army, i.e., its technical establishment, may well be a contributing factor to its weakness in rapid development and filling of new or PI items.

The US Army has many staff and other line elements involved in a staff capacity with the PI process. One agency, TRADOC, is usually cited as playing the role of user representative in the PI process. While playing a valuable role it clearly does not accomplish the role outlined above any more than OCRD plays the role of engineer/developer. In the product improvement process TRADOC develops and approves broad requirements and provides a liaision with the Army program manager or commodity manager. This is a valid and necessary function. This function with regard to product improvement is however much like that of a market research organization within industry and a user training organization. ACSFOR develops broad concepts and requirements and other staff elements like the DCSLOG and AMC headquarters staff seem to be heavily involved with neutralizing the effect of the engineer/developer dominance of the product improvement process.

A most essential ingredient in attaining an efficient and successful product improvement program is a whole cloth line management organization within AMC. Two of the three line elements exist. The user representative element does not. This must be corrected to achieve an efficient and meaningful PI program. The user representative organization should at least have the following responsibilities and be integrated directly within the organization that also has responsibility for engineering, producing/procuring the item.

Responsibilities of The User Representative (marketing element):

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1. Translation of the broad requirements developed by TRADOC and the force developer to real time user terms that the developer/acquisitioner can understand.

2. Identification of who is the user (there are many).

3. Definition of the improved product that will be accepted and used by the user.

4. Joint with the developer/acquisitioner - the development of a useful and saleable improved product. This responsibility must include a significant role in the control and management of project funds.

5. Selling of the improved product to the user.

6. Interpretation and iteration of the user's desires on a real time basis with the developer's/acquisitioner's problems and limitations throughout the product improvement process.

7. The conveyance and translation of real time user requirements to TRADOC and the Force Developer.

8. The iteration and requirements with TRADOC and the Force Developer.

9. The representation of the user in trade-offs related to the satisfaction of requirements by new or product improved materiel.