NASA Technical Paper 3421

1993

Prioritization Methodology for Chemical Replacement

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BACKGROUND

Since federal legislation has required ozone depleting chemicals (class I and II) to be banned from production, NASA and industry have been required to find other chemicals and methods to replace these target chemicals. The members of the Propulsion Technology Team (PT^2), as part of the NASA Operational Environment Team (NOET), were asked to provide a methodology to assure a consistent, measured development of appropriate replacement technologies. The project was initiated as a development of a prioritization methodology suitable for assessing and ranking existing processes for replacement "urgency."

The first phase of the project was to determine the chemicals and processes which would be assessed by this methodology. The target chemicals were defined as class I and II chemicals. The matrices, however, include other regulated chemicals. A list of the chemicals included for evaluation is included as checklist A. Specific determination of the processes could not be done until the chemicals were fully defined for each process; therefore, types or groups of processes were determined. The processes were grouped into the following general categories:

- Application of adhesive
- Foam blowing
- Application of insulation
- Brazing
- Cleaning/fine and precision cleaning
  - Degreasing
  - Dewaxing
  - Flushing
- Lab analysis
  - NVR analysis
- Other surface conditioning
  - Plating
  - Anodizing
  - Painting/priming
  - Application of sealants
  - Paint stripping.

Because of the broad scope of the original project, the next phase was to delineate the concerns that must be addressed when considering change impacts. It was determined that there were several areas to be addressed:

- Chemical and processing concerns and criteria
- Cost
- Scheduling
- Safety
- Laws and Regulations governing change.

Once these areas were determined, the concerns for each category were defined. This list of concerns and how they would be used was sent to the members of NOET and contractors for comment. The final product addresses and incorporates the comments and suggestions that were received.

By defining the areas of concern as a step toward the final goal, it became apparent that this methodology also provides a tool for replacement technology direct comparison as well as being a prioritization tool.

The project then became twofold: to produce a product that can be used either as a comparison tool or a prioritization tool—or both.

QFD Background

Quality Function Deployment (QFD) is a conceptual map that provides a method of transforming customer wants and needs into quantitative engineering terms. The methodology was developed in Japan in the early 1970's to help with product planning. The Japanese automobile industry applied QFD, thus resulting in reduced production cost, reductions in new model development time, and a production start-up free of a learning curve.

QFD was exported to the United States in the mid-1980's and was first used by Ford Motor Company after a study of the Japanese auto industry. QFD is still relatively new in the United States, but many companies are experiencing significant benefits from its application for planning and development. In the area of chemical replacement, the customer (NASA and Contractors) will be able to weight the full chemical, process, regulatory, safety, environmental, cost, and scheduling implications of replacement technology development to allow appropriate identification of viable candidates and programmatic alternatives.

INTRODUCTION

This workbook contains two tools, one for evaluation and one for prioritization. The two tools are interconnected because they were developed from one central theme—chemical replacement due to imposed laws and regulations. This workbook provides program managers with a usable tool containing matrices, detailed explanations of how to use them, and a detailed methodology for prioritization of replacement technology. The workbook containing the tools for prioritization and the tools for comparison is a guideline to help direct the research for replacement technology.

The approach for prioritization called for a system which would result in a numerical rating for the chemicals and processes being assessed. A QFD technique was used in order to determine

numerical values which would correspond to the concerns raised and their respective importance to the process. This workbook defines the approach and the application of the QFD matrix.

Members of NOET (MSFC) have adopted this approach for evaluation because it provides a NASA standard for evaluation that all contractors can follow. The Team felt that it was necessary to have a standard format for three reasons:

1. To provide a standard data base for technology that can be easily reviewed.

2. To provide a standard format for information when requesting resources for further research for chemical replacement technology.

3. To provide a standard format which compiles all necessary information when requesting a waiver for production from the EPA.

This workbook was originally to be used for class I and II chemicals, but it was specifically designed to be flexible enough to be used for any chemical used in a process (if the chemical and/or process needs to be replaced).

This methodology is set forth solely as a guideline for chemical replacement research and work. This workbook is provided for program managers to use, in whole or in part, as they determine the methodology is useful for their projects. The program managers then may request project team members and their support contractors to complete the parts that are deemed necessary.

This methodology is beneficial to both NASA and to contractors. The benefits of this method include the following:

- It is standardized and provides guidelines for use.

- It is made general to allow for many different chemicals and processes to be evaluated with the same format.

- It can be used in part(s) or as a whole as deemed necessary be the project.

- It provides a way for easy comparison of replacement technologies.

The methodology consists of comparison matrices (and the smaller comparison components) which allow replacement technology to be quantitatively compared in several categories and a QFD matrix which allows process/chemical pairs to be rated against one another for importance (using the same categories). Depending on the need for application, the program manager can choose the part(s) needed or have the methodology completed in its entirety. For example, if a program needs to show the risk of changing a process/chemical the program manager may choose to use part of matrix A and matrix C. If a chemical is being used, and the process must be changed; one might use the process concerns in matrix E for the existing process and all possible replacement processes. If the methodology is used in part for decision making, however, the program manager should be prepared to justify why concerns were omitted from the decision making process. If an overall analysis of a program is needed, the program manager may request the QFD to be completed.

EXPLANATION OF CHECKLISTS

Checklist A

Checklist A (appendix A) contains a list of target chemicals prioritized by phaseout date. This checklist is used to assist in defining target chemicals used by a given program. If the concern is only for one particular chemical, this checklist would not be used. An inventory of materials used could be a precursor to using this checklist to assure that a complete assessment of target chemicals is made. These target chemicals and their possible replacements will be used in all of the matrices. This checklist might be completed by a manufacturing group.

Checklist B

Checklist B (appendix A) is a listing of possible concerns which may apply when considering changing chemicals or processes. Checklist B was used to initially define matrices D through J. This list was included for reference to show the original concerns that were considered. This list was redefined following a review of comments; the final "list" was used to produce the final matrices. Spaces for "other" were included for those concerns left out.

EXPLANATION OF MATRICES

Matrix A

Matrix A is a "chemical and use" matrix. The objective of this matrix is to define the target chemicals by the part and process in which they are used (the how and where the targeted chemicals are used). This matrix has some optional "bookkeeping" areas to help in tracking the particular chemical/part/process combination in other matrices. Parts of matrix A will be used in all matrices. This matrix might be sent to a manufacturing group to be completed. The categories which are filled out are:

- The target chemical (from checklist A)
- A chemical registry number (optional)
- A chemical reference number (optional)
- Material
- The process in which the chemical is used
- A description of the part/component/subsystem which is being processed
- The surface being considered
- A process reference number (optional)
- A manufacturing process number
- The number of manufacturing processes

- A reference number for the specified part/component/subsystem
- The pounds of chemical used in the process (for the specified part) per year.

Each component of matrix A may not need to be filled out. The following is an explanation of the requested information for this matrix.

• The target chemical (from checklist A)

The class I or II chemical which has to be eliminated due to regulation should be put in this column. Any other chemical which needs evaluation for replacement could also be put in this column. It should be noted that some materials may contain several "target" chemicals. Those materials which have several chemicals should be grouped for identification purposes. This information will be necessary for subsequent matrices.

• A chemical registry number (optional)

This is the standard number for the chemical. This is requested so that actual values necessary for evaluation can be found.

• A chemical reference number (optional)

This a bookkeeping number. It is assigned by the person filling out the chart. It is recommended that for every chemical the number is consistent (i.e., for all uses of TCA the number is 1, for all uses of CFC113 the number is 2, etc.). This number will be used throughout the rest of the matrices in the "chem #" column.

• Material

This is the material that the chemical is in, identified for the specific process. This is a reference to assist defining the processes and parts. Generally this will be the manufacturing or common name (fig. 1).

Chemical	Chem # (Reference #)	Material
Trichloroethane	1	TCA/Solvent

Figure 1. Matrix A–material listing.

• The process in which the chemical is used

This is the current process for which the chemical is being used. This process is dependent on the part, surface, etc., that will be affected. The process will be necessary for subsequent matrices.

• A description of the part/component/subsystem which is being processed

The part/component/subsystem that will be processed will be completed in this part of the matrix (fig. 2).

Chemical	Chem # (Reference #)	Part/Component/Subsystem
Trichloroethane	1	Large Case Segment - RSRM
Trichloroethane	1	Bolts

Figure 2. Matrix A–component description.

• A reference number for the specified part/component/subsystem

This is a number assigned to the part/component/subsystem that will be processed. This number can be manufacturer specific as long as it can be referenced to the FMEA. This number will be used in matrix C–risk assessment and possibly in matrix D for specifications of surface requirements.

• The surface being considered

After the part has been defined, a surface on the part may need to be specified to better define the process and requirements.

• Process number (reference–optional)

This is the bookkeeping number for the process. It should be defined by the chemical, the material, the part (or group of parts), and the surface. The process (reference) number should be defined such that there will be no confusion between processes. Again this reference will be used in the other matrices for tracking purposes.

Example: If TCA is used for a final vapor degrease of a case segment, it should be denoted by a number such as 1–1–1. If TCA is to be used for a final vapor degrease of a bolt, it should be denoted as 1–1–2. The chemical number previously defined denotes the chemical (TCA = 1 for the example), the second number denotes the process (vapor degrease = 1 for the example), and the third number denotes the part (case segment = 1, and bolt = 2) (fig. 3).

Chemical	Chem # (Reference #)	Process	Proc # (Reference)
Trichloroethane	1	Vapor Degrease (Case Segment)	1-1-1
Trichloroethane	1	Vapor Degrease (Bolts)	1-1-2

Figure 3. Matrix A–process number.

• A manufacturing process number (optional)

This is another reference point for the matrix. The manufacturing process number allows a check on the stage of manufacturing in which this particular process is being done. Again this is an optional part of the matrix. It would be defined as a number (i.e., if it is the second process—it is 2).

• The number of manufacturing processes (optional)

This is the total number of processes a part goes through as defined by the part specifications (for a refurbished part and for a nonrenewable part).

• The pounds of chemical used in the process (for the specified part) per year

This category is strictly for informational purposes. It provides a prospective of the amount of the targeted chemicals used.

A blank matrix A is included in appendix C.

Matrix B

The technical maturity of the chemicals and processes are evaluated in matrix B. The existing chemical/process from matrix A and the developmental chemical/process are evaluated according to the number of parts to be processed (in the program life) and the testing which has been performed on the chemical, process, and processed parts. This matrix might be sent to the environmental, research and development, or manufacturing group for completion. This matrix was designed to accommodate the existing process and the possible replacement processes, but it can also be used specifically for comparison and evaluation of possible replacement chemicals. The matrix is broken into sections which ask for the identification of the chemical and process along with the corresponding reference numbers for each.

The reference numbers for the existing chemical/process were defined in matrix A; these same numbers should be used for the chemical/process in matrix B. For each existing chemical/process there should be a chemical/process replacement. For each "replacement" chemical a number should be assigned to correspond with the chemical it is replacing.

Example: TCA = chem # 1, replacement aqueous soap = 1R1, terpene (another alternative) = 1R2, where the first number is the existing chemical, R denotes replacement, and the last number is the replacement chemical number. These numbers should be kept consistent while filling out the matrices.

A space is provided to identify the existing (old) technology and the possible replacement technology (new). When describing an existing chemical/process pair, check the box under the "Old" column; check the column under "New" for possible replacement chemical/processes. This is done as another bookkeeping reference while completing this matrix. When a "New" chemical/process is being considered, however, the "Old" technology information should also be included for a point of reference.

For each replacement chemical, there will be a replacement process which has some process reference number.

Example: From a previous example, TCA used in a final degrease for a case segment was 1–1–1, one replacement process involves high pressure spray in air which would have a corresponding number 1R1–1–1. Another solution is agitated immersion which would be designated 1R2–1–1 where the first two numbers designate the existing process, the "R" denotes a replacement technology, and the last number represents the replacement process number (fig. 4). The process reference numbers for the processes should also remain consistent for the subsequent matrices.

Chemical	Chem # (Reference #)	Process	Proc # (Reference)
Trichloroethane	1	Vapor Degrease	1-1-1
Aqueous Soap	1R1	Spray in Air	1R1-1-1
Terpene	1R2	Vapor Degrease	1R2-1-1

Figure 4. Matrix B.

The next item to be completed is "Years of Existence." This is the years the chemical/process has been available for purchase on the market.

Subsequent items deal with chemical, material, and process testing. In effort to provide for every type of test, the "type tests" are very general in scope. This matrix is not necessarily complete for full analysis; it is provided to quantify the extent of testing for each chemical/material/process. Some materials and/or processes may not need a particular type (general) of test. For those areas where the test information requested is not applicable, note in the space that it was considered not necessary by placing a check in the corresponding box.

The following items are requested:

• Toxicity Testing

New chemicals must pass a series of toxicity tests before they are allowed to be used. By identifying the toxicity testing which has been completed, the new technology can be identified as a cost or scheduling conflict before completing the rest of the matrices.

• Environmental Testing

Environmental testing can be used to determine if the chemical/process is "environmentally safe." By identifying if the chemical/process has been tested, one can foresee the possibility of future environmental regulations.

• Chemical Reactivity Testing

By identifying the amount of chemical reactivity testing that has been done, one can see the amount of future necessary chemical reactivity testing that might possibility be needed before the chemical can be qualified for use.

• Age Sensitivity Testing

This category includes such areas as shelf-life, extensions of shelf life, viscosity changes over time, age sensitivity of the chemical while on the part, handling, etc. The information requested in this category is not restrictive in the nature of type of age testing; but when considering the extent of age testing for an existing chemical, the same type testing should be evaluated for the considered existing technology.

• Miscellaneous Testing

This category includes any other type testing required for this chemical/process that cannot be included in one of the other categories. Again, the same consideration should be taken for testing with the existing technology and the replacement technology.

• Parts to be Processed (Program Life)

The length of the program design for the part and the number of expected parts to be produced during that time should be entered in this space. This allows for judgment of the necessity of finding a replacement technology.

A blank matrix B is included in appendix C of this report.

Matrix C

Matrix C is a risk assessment matrix which provides a valuable tool for determination of the critical safety and reliability parts and processes. This matrix is designed to allow the risk of failure of the hardware to perform its function, due to the process change, to be calculated numerically.

The existing targeted chemicals, process, and drawing numbers (from matrix A) and the possible replacement chemicals and processes with appropriate drawing numbers should be filled in first. A space is provided to check which is "existing" technology and which is "new" technology.

The FMEA number is requested for reference purposes. The FMEA provides a ranking of criticality of the part and process which is given a "weight" or numerical value. This number will be assigned a 1, 3, or 9 for Crit 3, 2, and 1, respectively (fig. 5).

The probability of failure value is determined by weighting the factor of safety and the type inspection(s) performed. The scoring of 6-1 will be given to the inspections in the order listed in the legend below the evaluation matrix (6 being visual and 1 being plug or other hardware specific, destructive test). The safety factor should be inverted and multiplied by the Inspection value to get the probability value (fig. 6).

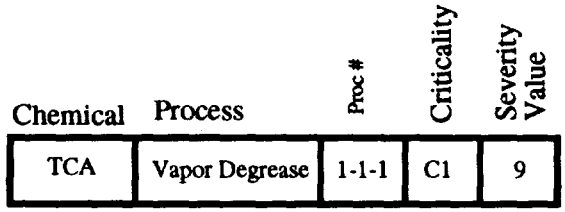


Figure 5. Matrix C–severity evaluation.

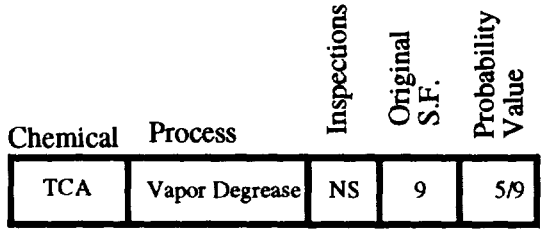


Figure 6. Matrix C–probability evaluation.

The risk evaluation (weight) is determined by multiplying the probability value by the severity value (fig. 7). This matrix might be sent to a risk assessment group or a FMEA group (safety and mission assurance).

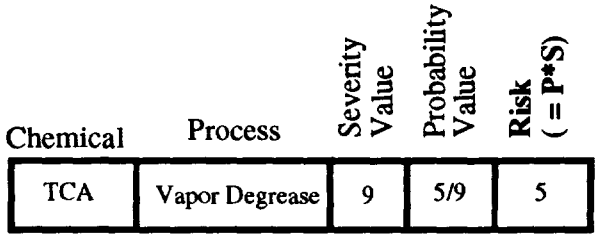


Figure 7. Matrix C–risk evaluation.

Again, a blank matrix C is included in appendix C.

Concerns

The following categories are the concern categories which are listed separately in the QFD matrix. Each concern category is given a separate matrix for simplification and facilitates the use of particular parts of the entire workbook. The format in specifying the chemical/process pairs is the same as matrix B. The code following each concern is specified by three letters (such as NMH) which are defined in the legend below the evaluation matrix (None, Minimal, High). The highest score is a 9, which in this case corresponds to "None". The lowest is 1 which corresponds to "High". For each concern, there is an explanation of the concern in the pages following the evaluation matrix. If the question is not applicable, then place a check mark in that box noting it was recognized as unnecessary. If the criteria described in the explanation can be rewritten to better evaluate the process, then make a note of the change in the explanation and use the updated criteria for all of the chemical/process pairs that are to be evaluated.

Each new process and chemical will be "scored" for each concern listed in matrices D through J. Each "score" will be shown as most positive, neutral, or negative (or blank for no relation). Matrices D through J will also allow the concerns to be weighted for importance. These weighted factors will need to be considered in the final prioritization calculations. Additional information such as risk factors for part failure and technical maturity of the chemical and process will be used when tradeoffs become necessary. These data will be evaluated using QFD methodology.

A combined set of example matrices D through J is included in appendix B of this workbook. Note that symbols, letters, or numbers can be used to fill in the blanks.

Appendix C includes blank matrices for use as guides in completing the prioritization process. (Separate categories are provided as working matrices, and combined categories are included for overall assessment.). The concern explanations are also included in appendix C.

Matrix D

Matrix D addresses the chemical concerns for the existing and replacement technologies. Again, this can be used alone or as a part of the QFD matrix. This matrix should give the user a firm understanding of how the chemical acts or reacts when left in its environment. An environmental engineering group and/or manufacturing should complete this matrix.

Matrix E

The process concerns deal with the way that a chemical acts or reacts during a process application. An environmental engineering group and/or manufacturing should complete this matrix.

Matrix F

Matrix F considers the regulatory impacts on a chemical/process. When completing this part of the matrix, one should consider the known dangers (i.e., known phase-out and reduction plans) when rating a chemical/process on meeting the laws. The regulatory concerns consider how OSHA requirements, federal, state, local environmental laws and regulations affect chemicals and processes. Sections of this matrix might be completed by safety, legal, and environmental management personnel.

Matrix G

The safety concerns are worker exposure, spill response, fire response, and explosion response. Sections of this matrix might be completed by safety, legal, and environmental management personnel.

Matrix H

The environmental concerns consider how chemicals impact the program environmentally. Sections of this matrix might be completed by safety, legal, and environmental management personnel.

Matrix I

The cost concerns evaluate how cost will deviate with the replacement of current technologies. This matrix might be completed by the project or program office (or their support personnel).

Matrix J

The scheduling concerns delineate how scheduling requirements will be met with respect to environmental regulations and NASA program schedules. This matrix might be completed by the project or program office (or their support personnel).

QFD APPLICATION

The QFD matrix will be completed by the project office or program manager. The basic QFD format is shown in figure 8.

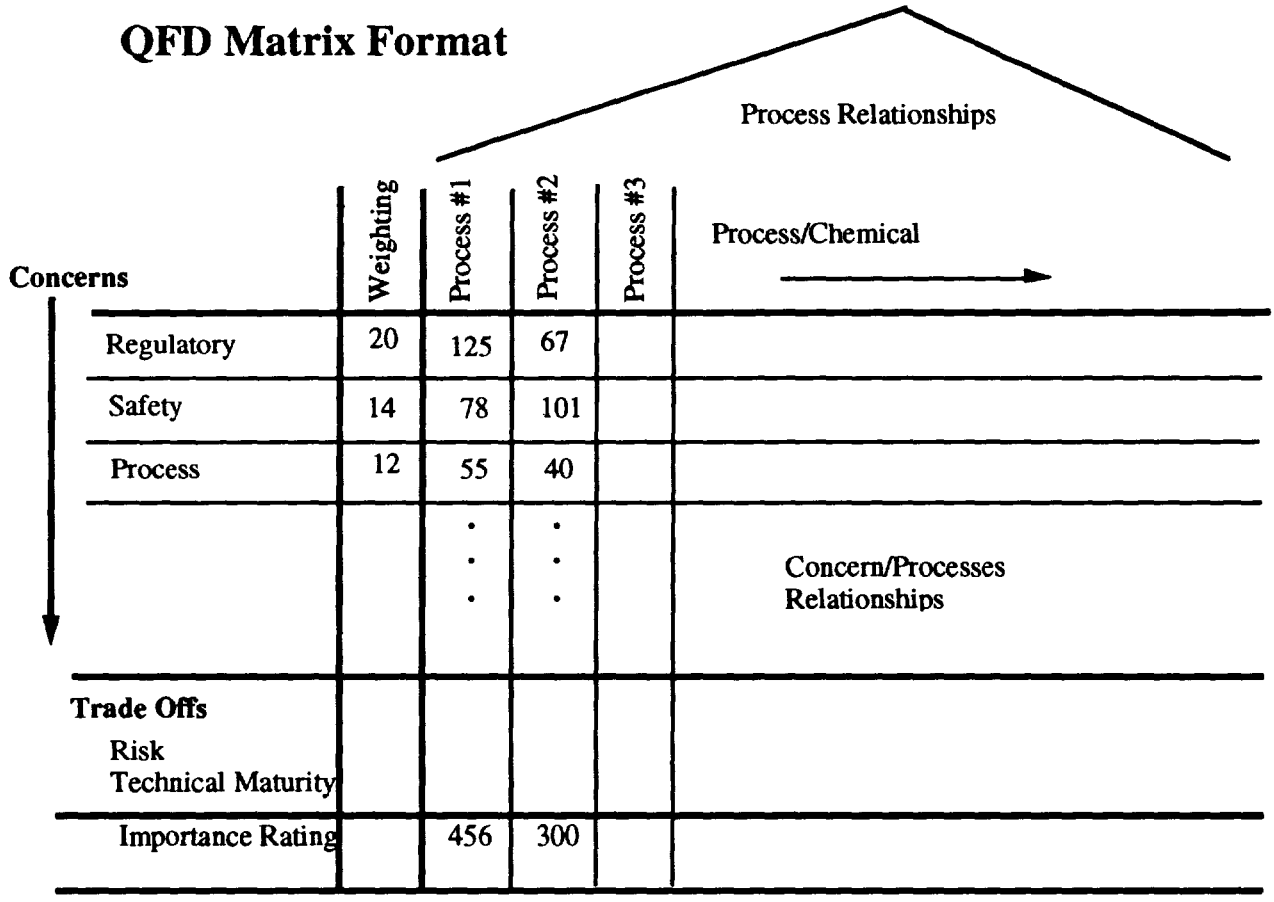


Figure 8. QFD general format.

The QFD matrix is quite easy to understand if it is approached one step at a time. In the case of the chemical replacement, first list the customer (NASA or contractor) concerns vertically on the left. Then list each chemical/process, old and new, horizontally. The relationship of each concern to each chemical/process is then rated on a scale of 1–weak, 3–medium, and 9–strong. Next, a weighting factor is given to each concern. That is, on a scale of 1 to 20 in this case, assign a number rating the importance of each concern. To get the overall rating of each chemical/process, multiply the weighting factor times the relationship rating for each process to concern and sum the total down the page.

	Weighting Factor	Chemical/ Process #1	Chemical/ Process #2	Chemical/ Process #3
Concern 1	10	3	9	1
Concern 2	15	1	9	3
Concern 3	12	9	1	9
Overall Rating		153	237	163

Figure 9. Example QFD scoring.

Example: Chemical/process #1 would have an overall rating of (10*3)+(15*1)+(12*9) = 30+15+108 = 153. Chemical/process #2 would be (10*9)+(15*9)+(12*1) = 90+135+12 = 237. Chemical/process #3 would be (10*1)+(15*3)+(12*9) = 10+45+108 = 163. This methodology would rank #2 as the "better" alternative of the three.

The roof at the top of the matrix simply shows how strong the chemicals/processes relate to each other. This knowledge can be applied when tradeoffs become necessary. In fact, the QFD matrix can include several different entries that could be included in tradeoff studies. The chemical replacement prioritization methodology applies only a limited use of the QFD capabilities.

Since this methodology is used as a guideline for comparison for replacement technology, it should be noted that there are times when a full QFD evaluation should not be performed. The times that the QFD evaluation is not recommended are:

- When another tool or system is more applicable, such as when decision, risk analysis, or analytical process models are all that are needed
- When there is not enough time or resources to do it right
- When critical elements of the process are missing (i.e., customer feedback).

In these cases, one should consider using the most relevant matrices to assist in making judgment on replacement technology. If the full QFD is not used, as stated before, one should be prepared to explain the reasons for not using it.

Our example has been put into QFD format and is included in appendix B. Again note, numbers or symbols can be used.

WEIGHTING

For each type of process, the weighting factors will vary (i.e., the weights for precision cleaning may differ from those in foam blowing). Therefore, a general QFD weighting application is enclosed as matrix K. This weighting box allows the concerns to be weighted against each other. The number in the box represents the score of that concern versus each of the other concerns. The more important concerns should be represented by higher numbers. matrix K (in appendix B) is an example weighting matrix. The matrix can be expanded to weight any category or all of the concerns together. For each category, the weights should be normalized by dividing the weight by the number of concerns. An example weighting worksheet is included in appendix B. A blank weighting worksheet is included in appendix C.

SCORING

Depending on the type of application, the scoring will be slightly different. If only part of the matrix packet is used, then the weights should be multiplied by the number corresponding to that code. (Example: weight = 11, code No. = 3, total = 33.) The total of these numbers is the "score" for that process. (Summation of total = 33, total = 27, total = 90, "score" = 150.) If the entire matrix packet is to be used as a QFD exercise, then for each of the concern matrices (D–J) the "score" should be determined as before by multiplying the weight by the number corresponding to the code, then getting a summation of those "totals."

- Matrix A carries no numerical weight.
- Matrix C "scores" should be multiplied by 100 and added to the total from the concerns if using the QFD matrix as a prioritization tool, or subtracted from the total if it is used as a replacement technology comparison tool.
- If the matrix packet is to be used as a comparison between alternate replacement chemicals/processes, then the percentage of testing completed as compared to the current technology (from matrix B) should be determined for each category of tests. The total of these numbers should be added to the accumulated numbers. If the matrix packet is to be used to determine the ranking of "urgency," then this chart could be used as a reference to show the technical maturity of the existing technology. This chart does not necessarily need to be completed if it is to be used for this type of application.

CONCLUSION

Prioritization and Determination for Selection

The objective of this exercise is to quantitatively determine the rating of replacement technologies. The QFD matrices are designed to produce a numerical "importance" value which is the total score for each chemical and process pair. If the QFD matrix is completed, the final total will be the importance value. The higher importance value number corresponds to the "higher priority," if used for prioritization, or "better selection," if used for comparison, chemical/process.

Using the Prioritization Methodology

The QFD methodology, shown as an example in appendix B, was applied using QFD/CAPTURE software which was acquired in May 1993 from International Technegroup Incorporated, 5303 Dupont Circle, Milford, Ohio 45150, telephone (513)576–3900. Questions concerning this software and its application in this report should be directed to Kurt Everhart, (205) 971–9309.

MAPTIS (Materials and Processes Technical Information System) is a Marshall information system containing a working prioritization data base. The data base can be found within the NASA Environmental Information System (NEIS) which is a part of MAPTIS. This prioritization data base will allow the user to enter a process and chemical to be evaluated, then the user can select the concerns associated with that process. The prioritization data base is designed to evaluate the processes and chemicals based on each of the matrices separately or a combination of any of the matrices together. Once the process, chemicals, and concerns are identified, the program requires weightings to be input for each concern. The program records the inputted weightings for each process and allows scores to be input for each chemical in that process. After all inputs are made, the program will compute a "total" for each chemical and process.

The NEIS information system is available through a public access VAX system to NASA and contractors as an aid to prioritization for chemical replacement. Questions concerning this data base should be directed to Beth Cook (205) 544–2545 or Marcia Clark-Ingram (205) 544–6229.

Other questions concerning the prioritization methodology should be directed to:

Dr. Ben Goldberg (205) 544–2683
Wendy Cruit (205) 544–1130
Scott Schutzenhofer (205) 544–8496

APPENDIX A

- Checklist A—Possible Target Chemicals
- Checklist B—Possible Program Concerns

APPENDIX A

CHECKLIST A -- Possible Target Chemicals

20 June 1993

Items Targeted for phase-out by 1994:

Halons
- Halon-1211
- Halon-1301
- Halon-2402

Items Targeted for phase-out by 1995:

Chlorofluorocarbons (CFC's)

CFC-11	CFC-211
CFC-12	CFC-212
CFC-13	CFC-213
CFC-111	CFC-214
CFC-112	CFC-215
CFC-113	CFC-216
CFC-114	CFC-217
CFC-115	

Methyl Chloroform (TCA, 111-Trichloroethane)
Carbon Tetrachloride

Items to be used at threshold levels by 1995 (these are considered Extremely Hazardous Substances):

Ammonia	Methyl Chloride
Anhydrous Ammonia	Phosgene
Bromine	Anhydrous Sulfur Dioxide
Chlorine	Sulfur Trioxide
Ethylene Oxide	Methyl Isocyanate
Anhydrous Hydrogen Chloride	Toluene Diisocyanate
Hydrogen Fluoride	Vinyl Chloride
Hydrogen Sulfide	
Hydrogen Cyanide	

APPENDIX A

CHECKLIST A -- Possible Target Chemicals

Items Targeted for 50 Percent Reduction (based on 1988 emissions) by 1995:

Benzene
Cadmium and Compounds
Chloroform
Chromium and Compounds
Cyanides
Dichloromethane (Methylene Chloride)
Lead and Compounds
Mercury and Compounds
Methyl Isobutyl Ketone
Nickel and Compounds
Tetrachloroethylene
Toluene
Trichloroethylene (TCE)
Xylenes

Items Targeted for phase-out by 2002

HCFC-141B

Items Targeted for phase-out by 2020

HCFC-22
HCFC-142B

Items Targeted for phase-out by 2030

Hydrochloroflurocarbons (HCFC's)

HCFC-21	HCFC-231
HCFC-31	HCFC-232
HCFC-121	HCFC-233
HCFC-122	HCFC-234
HCFC-123	HCFC-235
HCFC-124	HCFC-241
HCFC-131	HCFC-242
HCFC-132	HCFC-243
HCFC-133	HCFC-244
HCFC-221	HCFC-251
HCFC-222	HCFC-252
HCFC-223	HCFC-253
HCFC-224	HCFC-261
HCFC-225	HCFC-262
HCFC-226	HCFC-271

APPENDIX A

CHECKLIST B -- Possible Program Concerns

Regulatory Concerns
- Federal Environmental Laws/EPA Regulations
  - Permits and Requirements for Use of Materials/Chemicals
  - Permits and Requirements for Transportation of Materials/Chemicals
  - Permits and Requirements for storage of Materials/Chemicals
- State Environmental Laws
- Local Environmental Laws
- NASA Regulations (other than federal, state, and local laws)
- OSHA Requirements
- Possible Foreseen Federal Regulations

Cost Concerns
- Manpower $
  - Engineering
  - Environmental
  - Safety
  - Facility
- Operations $
- Facilities $
- Remaining Requirements $
- Materials $
- Subcontracts $
- Change of Specification $
- Change of Drawing $
- Change of Developing Alternate Procedures $
- Personnel Training $
- Specification Verification $
- Funding for Alternate Material
- Sole Source Material $
- Replacement Activity $
- Emissions Control Equipment $
- Emissions Control Testing $
- Implementation $
- Qualification (Testing) $

Safety Concerns
- Worker Exposure Guidelines
  - Toxicity
  - Carcinogenic
- Contingency Plans
  - Spill Response
  - Fire Response
  - Explosion Response
  - Community Response Plans
- Hazardous Waste
  - Storage
  - Transportation
- Manufacturing Safety
  - Loss of Capital
  - Loss of Health
- Product Safety
  - Flight Failure Probability

APPENDIX A

CHECKLIST B -- Possible Program Concerns

Environmental Concerns
- Pollution Prevention / Clean Air (Monitoring)
  - Air Toxic Effects
- Toxic Emissions

Environmental Concerns (cont.)
- Emissions Control
  - Minimize Ozone Depleting Potential
  - Minimize Volatile Organic Compounds (VOC's)
  - Minimize Other Hazardous Air Pollutants
  - Minimize Global Warming Potential (CO_2)
- Material Recycling
  - Resource Recovery
  - Ingredient Recycling
  - Oil Removal for Reuse of Waste Products
  - Reuse of Materials
  - Sell of Used Material
- Chemical Storage
- Hazardous Waste Management
  - Collection of Hazardous Waste
  - Disposal of Hazardous Waste
  - Hazardous Waste Storage
  - Waste Water Sludge Disposal
  - Waste Water Sludge Treatment
  - Filtration of Waste Products
  - Determination of Origin of Waste
  - Determination of Fate of Waste
  - Determination of Quantity of Waste
- System Concerns (Not Addressed by These Matrices)
  - Propellant Reclamation
  - Propellant Incineration
  - Capturing Toxic Motor Exhaust
  - Site Remediation
  - Groundwater Remediation
  - Acid Deposition/Rain (Exhaust Acid)
  - Local Health (Exhaust Particulate)
  - Visibility (Exhaust Particulate)
  - Cloud Nucleation (Exhaust Particulate)
  - Waste Propellant
    - Air Emissions
    - Soil Contamination
    - Surface Water Contamination
    - Ground Water Contamination

Chemical Concerns
- Base Metal Compatibility
- Stability
- Ease of Maintenance
- Flash Point
- Flammability
- Foaming
- Historical Data Base
- Reactivity
- Insulation Activations

APPENDIX A

CHECKLIST B -- Possible Program Concerns

- Lot-to-Lot Variability
- Bondline Thickness
- Chemical Interaction
- Toxicity
- General Cleaning Ability
  - Type of Contaminants to be Cleaned (Will it work for These?)
  - How Clean Does it Have to Be to not interfere with Bond Strength?
  - NVR Cleanliness Requirements
  - Cleaning Ability
  - Rinsing Ability
  - Drying Ability
  - Residue Removal
  - Paint Removal Ability
  - Process Tooling Cleaning Ability
  - Number of Contaminants to be Cleaned (How many is it "good" for?)
  - Bond Surface Cleaning Ability

Process Concerns

- # of Process Steps (Increase/Decrease)
- Max Quantity of Parts Processed at One Time (Increase/Decrease)
- Time of Process (Increase/Decrease)
- Process Alteration
- Surface Requirements (Plating, surface finish, corrosion, etc.)
  - Required Surface Finish
  - Peel Strength Requirements
  - Contamination Requirements
  - Tensile Strength Requirements
- Required Surface Preparation
- Process Interaction
- Chemical Interaction in Process
- Operator Sensitivity
- Lot-to-Lot Variability
- Bondline Thickness
- Other Damage Caused by Process
  - Stress Corrosion Cracking Due to New Chemical
- Methods of Application (of Chemicals)
- Method for Cleanliness Verification

Scheduling

- Cessation of Operations
- Manufacturing Impact

OTHER

- Production Goals Reached
- Sustain Reliability of Flight Hardware
- Loss Of Vendor or Material
- Number of Parts/Surfaces to be Cleaned by a Particular Cleaner
- Testing:
  - Repeatability
  - Bond Strength Analysis (Affect on Adhesives & Sealants by Cleaner)
  - Number of Surfaces
  - Need for Re-qualification
  - Erosion
  - Corrosion

APPENDIX A

CHECKLIST B -- Possible Program Concerns

Monitoring Ability
Modification in Planning
Shipping of Cleaned Parts
Assure Shuttle Availability
Chemical Availability
Other Agency Impacts
Sole Source Materials
Liability
Disruption in Efficiency
Disruption in Comfort
Test History Versus Life Requirement Scheduling Problems

APPENDIX B

– Example Matrices

– Example QFD

Example Matrices D and E -- Chemical and Process Concerns

Weighting Factors to be Inserted Here ⟶
1 - Less Important 20 - More Important

* NOTE: Either Numbers, Letters, or Symbols can be used to comple the Matrices.

Chemical	Chem #	Process	Proc #	New	Old	Chemical Concerns																Process Concerns																			
						# of Sources	Limited Resources for Manufacturing (NMH)	Availability (EMB)	Stability (Storage) (GFP)	Flammability (NMH)	Drying Ability (GFP)	Base Meterial Compatibility (GFP)	Toxicity (NMH)	Flash Point (NMH)	Ease of Maintenance (GFP)	Historical Data Base (CPN)	Desirable Reactivity (GFP)	Undesirable Reactivity (NMH)	Lot-to-Lot Variability (NMH)	Age Sensitivity - Processed Part (NMH)	Shelf Life (EMB)	Contaminants Removed: # Req.	Contaminants Removed: # Produced	Process Steps: #	Process Steps: Δ Increase/Decrease	Parts Processed at One Time: #	Parts Processed at One Time: Δ Increase/Decrease	Req. Surface Prep.: Time	Req. Surface Prep.: Δ Increase/Decrease	Bondline Thickness: # Req.	Bondline Thickness: # Produced	Process Time (Δ)	Process Interaction (#)	Process Interaction (GFP)	Bond Strength Required (EMB)	Operator Sensitivity (NMH)	Lot-to-Lot Variability (NMH)	General Cleaning Ability(GFP)	Surface Requirement (EMB)	Useful Life of Replacement Processed Parts (EMB)	Damage caused by Process (NMH)
TCA	1	V. D. - Final of Large metal part	1-1-1		x	2	N	B	G	H	G	G	M	H	G	C	/	N	N	N	M	?	-1	1	0	1	0	1m	0	/	/	0	1	G	/	N	M	G	M	M	M
Aqueous Soap	R1	Pressure Spray in Air - Large Metal Part	1-1R1-1	x		1	N	M	G	N	P	G	M	N	G	P	/	M	N	M	M	?	0	3	2	1	0	1m	0	/	/	-1	1	F	/	N	M	G	M	M	M
Terpene	R2	Aggitated Immersion	1-1R2-1	x		1	9	3	9	9	1	9	3	3	9	1	/	3	1	1	3	?	-2	2	1	1	0	1m	0	/	/	-1	1	9	3	9	1	3	3	3	3

NOET -- Prioritization Methodology for Chemical Replacement

Symbol				
⊙	Exceeds (E)	Good(G)	None (N)	Complete (C)
O	Meets (M)	Fair (F)	Minimal (M)	Partial(P)
✱	Below (B)	Poor (P)	High (H)	None (N)

27

Example of Matrices E - J -- Regulatory, Safety, Environmental, Cost, and Scheduling Concerns

Weighting Factors to be Inserted Here
1 - Less Important 20 - More Important

Concern group	Criterion	TCA	Aqueous Soap
	Chem #	1	1R
	Process	Vapor Degrease	Spray in Air
	Proc #	1-1-1	1-1R1-1
	New		x
	Old	x	
Regulatory Concerns	OSHA Requirements (EMB)	O	O
Regulatory Concerns	State Environmental Laws (EMB)	✻	O
Regulatory Concerns	Local Environmental Laws (EMB)	✻	O
Regulatory Concerns	Federal Environmental Requirements (EMB)	✻	⊙
Regulatory Concerns	Future Federal Regulations (EMB)	✻	⊙
Safety Concerns	Worker Exposure Limits (NMH)	O	O
Safety Concerns	Spill Response Plans (CPN)	O	O
Safety Concerns	Fire Response Plans (CPN)	O	⊙
Safety Concerns	Explosion Response Plans (CPN)	⊙	⊙
Environmental Concerns	Clean Air Monitoring (EMB)	✻	⊙
Environmental Concerns	Pollution Prevention (CPN)	⊙	⊙
Environmental Concerns	Toxic Emissions (NMH)	⊙	O
Environmental Concerns	Emissions Control (GFP)	✻	⊙
Environmental Concerns	Ozone Depletor Potential (NMH)	✻	⊙
Environmental Concerns	Chemical Storage Availability (CPN)	⊙	⊙
Environmental Concerns	Resource/Ingredient Recovery and Recycling (CPN)	⊙	O
Environmental Concerns	Hazardous Waste Management (EMB)	O	O
Cost Concerns	Labor $ (DNI)	O	X
Cost Concerns	Operations $ (DNI)	X	X
Cost Concerns	Facilities $ (DNI)	✻	X
Cost Concerns	Materials $ (DNI)	O	O
Cost Concerns	Chemical $ (DNI)	X	⊡
Cost Concerns	Other Hardware $ (DNI)	O	O
Cost Concerns	Contracts $ (DNI)	X	X
Cost Concerns	Change of Specifications $ (DNI)	O	X
Cost Concerns	Specification Verification $ (DNI)	O	✻
Cost Concerns	Change of Drawings $ (DNI)	O	X
Cost Concerns	Development of Procedure $ (DNI)	X	X
Cost Concerns	Waste Management $ (DNI)	O	O
Cost Concerns	Emissions Control Testing $ (DNI)	O	O
Scheduling Concerns – Federal, State, and Local Regulations	Research (EMB)	⊙	⊙
Scheduling Concerns – Federal, State, and Local Regulations	Trade Studies (EMB)	⊙	⊙
Scheduling Concerns – Federal, State, and Local Regulations	Modification in Planning (EMB)	⊙	O
Scheduling Concerns – Federal, State, and Local Regulations	Specification Documentation (EMB)	O	O
Scheduling Concerns – Federal, State, and Local Regulations	Drawing/Design Changes (EMB)	⊙	O
Scheduling Concerns – Federal, State, and Local Regulations	Production Time (EMB) (New Equip.)	O	⊙
Scheduling Concerns – Federal, State, and Local Regulations	Testing (EMB)	O	O
Scheduling Concerns – Federal, State, and Local Regulations	Vendor Selection & Certification (EMB)	O	O
Scheduling Concerns – Present Program Schedule	Research (EMB)	⊙	⊙
Scheduling Concerns – Present Program Schedule	Trade Studies (EMB)	⊙	⊙
Scheduling Concerns – Present Program Schedule	Modification in Planning (EMB)	⊙	✻
Scheduling Concerns – Present Program Schedule	Specification Documentation (EMB)	O	✻
Scheduling Concerns – Present Program Schedule	Drawing/Design Changes (EMB)	⊙	O
Scheduling Concerns – Present Program Schedule	Production Time (EMB) (New Equip.)	⊙	O
Scheduling Concerns – Present Program Schedule	Production Time $ (EMB) (Hardware Avail)	⊙	✻
Scheduling Concerns – Present Program Schedule	Testing (EMB)	⊙	O
Scheduling Concerns – Present Program Schedule	Vendor Selection & Certification (EMB)	⊙	O

Symbol	Meaning
⊙	Large Decrease (D)
⊡	Slight Decrease (D)
O	No Change(N)
X	Slight Increase (I)
✻	Large Increase (I)

Symbol				
⊙	Exceeds (E)	Good(G)	None (N)	Complete (C)
O	Meets (M)	Fair (F)	Minimal (M)	Partial(P)
✻	Below (B)	Poor (P)	High (H)	None (N)

NOET -- Prioritization Methodology for Chemical Replacement

-- Action Item NEP-0097

28.

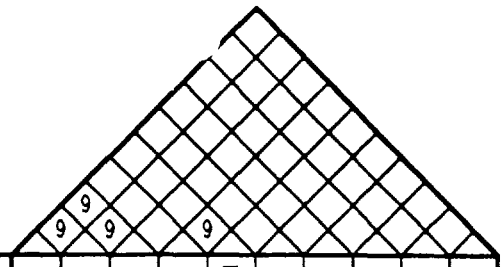
Example Matrix K

Weighting Worksheet

	Clean Air Monitoring	Pollution Prevention	Toxic Emissions	Ozone Depletor Potential	Chemical Storage Availability	Resourse Recycling	Hazardous Waste Management	Total
Clean Air Monitoring		15	13	20	17	18	20	103
Pollution Prevention	15		15	20	15	15	15	95
Toxic Emissions	13	15		20	13	13	13	77
Ozone Depletor Potential	20	20	20		20	20	20	120
Chemical Storage Availability	17	15	13	20		18	20	103
Resourse Recycling	18	15	13	20	18		20	104
Hazardous Waste Management	20	15	13	20	20	20		108

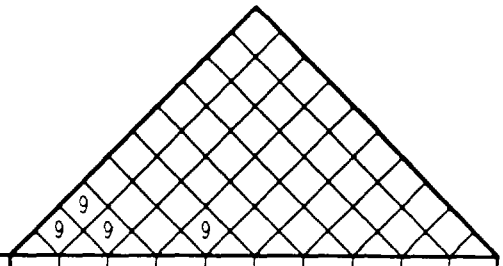
1 = Less Important
20 = More Important

CHEMICAL REPLACEMENT PRIORITIZATION



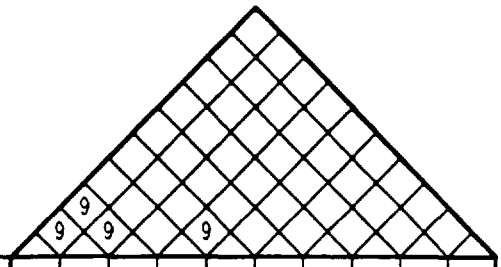
	WEIGHTING FACTOR	Vapor Degrease (1) - TCA	Pressure Spray in Air (1R1) - AQUEOUS SOAP	Aggitated Immersion (1R2) - TERPENE	Primer Paint - Low Pressure Fuel Duct (2) - CHROMATE	Wire Arc Spray - Low Pressure Fuel Duct (2R1) - ALUMINUM	PROCESS/CHEMICAL 6	PROCESS/CHEMICAL 7	PROCESS/CHEMICAL 8	PROCESS/CHEMICAL 9	PROCESS/CHEMICAL 10
Chemical Concerns											
# of Sources	7.0	3	1	1	1	9					
Limited Resources for Manufacturing	7.0	9	9	9	9	9					
Availability	14.0	1	3	3	3	9					
Stability (Storage) & Use - Includes Pit Life	15.0	9	9	9	3	9					
Toxicity	13.0	3	3	3	9	9					
Drying Ability	14.0	9	1	1	9	9					
Base Material Compatibility	17.0	9	9	9	9	9					
Flammability		1	9	9	3	3					
Flash Point	13.0	1	9	3	3	9					
Ease of Maintenance	8.0	9	9	9	9	9					
Historical Data Base	9.0	9	3	1	9	3					
Desirable Reactivity	13.0				9	9					
Undesirable Reactivity	13.0	9	3	3							
Lot-to-Lot Variability	11.0	9	9	1	3	3					
Age Sensitivity - Processed Parts	11.0	9	3	1	3	9					
Shelf Life	9.0	3	3	3	3	9					
Process Concerns											
Contaminants Removed	15.0	1		1							

CHEMICAL REPLACEMENT PRIORITIZATION

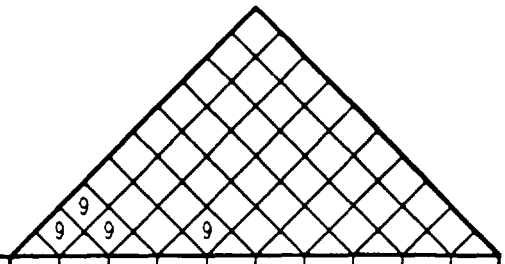


	WEIGHTING FACTOR	Vapor Degrease (1) - TCA	Pressure Spray in Air (1R1) - AQUEOUS SOAP	Agitated Immersion (1R2) - TERPENE	Primer Paint - Low Pressure Fuel Duct (2) - CHROMATE	Wire Arc Spray - Low Pressure Fuel Duct (2R1) - ALUMINUM	PROCESS/CHEMICAL 6	PROCESS/CHEMICAL 7	PROCESS/CHEMICAL 8	PROCESS/CHEMICAL 9	PROCESS/CHEMICAL 10
Process Steps (Increase/Decrease)	9.0		2	1		2					
Parts Processed At One Time	7.0	3	3	3	3	3					
Required Surface Preparation	12.0	3	3	3							
Bondline Thickness	7.0				3	6					
Process Time	9.0	1	3	3	3	9					
Process Interaction	9.0	9	3	9							
Operator Sensitivity	12.0	9	9	9	1	1					
Lot-to-Lot Variability	11.0	3	3	1	3	3					
General Cleaning Ability	13.0	9	9	3							
Surface Requirement	14.0	3	3	3	3	9					
Life of Replacement Processed Parts	14.0	3	3	3	3	9					
Damage Caused By Process	13.0	3	3	3	9	9					
Regulatory Concerns											
OSHA Requirements	13.0	3	3	3	3	3					
State Environmental Laws	14.0	1	3	9	3	9					
Local Environmental Laws	14.0	1	3	9	1	9					
Federal Environmental Requirements	15.0	1	9	9	3	3					
Future Federal Regulations	14.0	1	9	3	1	9					

CHEMICAL REPLACEMENT PRIORITIZATION

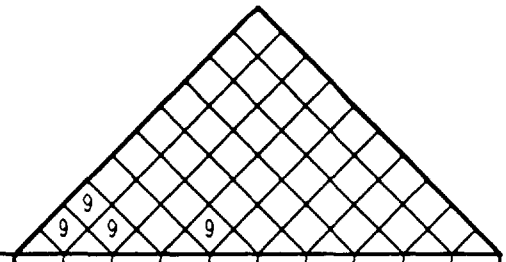


	WEIGHTING FACTOR	Vapor Degrease (1) - TCA	Pressure Spray in Air (1R1) - AQUEOUS SOAP	Agitated Immersion (1R2) - TERPENE	Primer Paint - Low Pressure Fuel Duct (2) - CHROMATE	Wire Arc Spray - Low Pressure Fuel Duct (2R1) - ALUMINUM	PROCESS/CHEMICAL 6	PROCESS/CHEMICAL 7	PROCESS/CHEMICAL 8	PROCESS/CHEMICAL 9	PROCESS/CHEMICAL 10
Safety Concerns											
Worker Exposure Limits	12.0	3	3	1	1	3					
Spill Response Plans	13.0	3	3	9	9	9					
Fire Response Plans	14.0	3	9	9	9	9					
Explosion Response Plans	16.0	9	9	9	9	9					
Environmental Concerns											
Clean Air Monitoring	12.0	1	9	9	1	3					
Pollution Prevention	12.0	9	9	1	3	9					
Toxic Emissions	15.0	9	3	9	1	9					
Emissions Control	12.0	1	9	9	3	9					
Ozone Depletor Potential	15.0	1	9	9	9	9					
Chemical Storage Availability	10.0	9	9	3	9	9					
Resource/Ingredient Recovery & Recycling	10.0	9	3	3	1	3					
Hazardous Waste Management	12.0	3	3	3	3	3					
Cost Concerns											
Labor $	17.0	3	2	2	2	2					
Operations $	14.0	2	2	3	2	6					
Facilities $	15.0	1	2	2	2	2					
Materials $	14.0	3	3	3	2	6					
Chemical $	16.0	2	6	3	3	3					



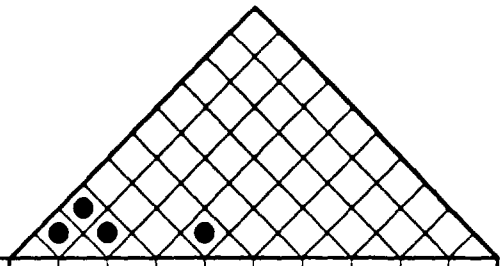
	WEIGHTING FACTOR	Vapor Degrease (1) - TCA	Pressure Spray in Air (1R1) - AQUEOUS SOAP	Agitated Immersion (1R2) - TERPENE	Primer Paint - Low Pressure Fuel Duct (2) - CHROMATE	Wire Arc Spray - Low Pressure Fuel Duct (2R1) - ALUMINUM	PROCESS/CHEMICAL 6	PROCESS/CHEMICAL 7	PROCESS/CHEMICAL 8	PROCESS/CHEMICAL 9	PROCESS/CHEMICAL 10
Other Hardware $	14.0	3	3	1	3	3					
Contracts $	12.0	2	2	3	2	2					
Change of Specifications $	13.0	3	2	2	2	2					
Specification Verification $	13.0	3	1	2	2	6					
Change of Drawings $	11.0	3	2	3	2	2					
Development of Procedure $	12.0	2	2	2	2	2					
Waste Management $		3	3	3	2	6					
Emissions Control Testing $	12.0	3	3	3	2	3					
Scheduling Concerns (Federal/State/Local)											
Research	9.0	9	9	9	1	9					
Trade Studies	8.0	9	9	3	1	3					
Modification in Planning	9.0	9	3	3	1	3					
Specification Documentation	10.0	3	3	3	1	3					
Drawing/Design Changes	8.0	9	3	3	1	3					
Production Time (New Equipment)	11.0	3	9	3	1	3					
Testing	14.0	3	3	3	1	3					
Vendor Selection & Certification	12.0	3	3	3	1	1					

CHEMICAL REPLACEMENT PRIORITIZATION



	WEIGHTING FACTOR	Vapor Degrease (1) - TCA	Pressure Spray in Air (1R1) - AQUEOUS SOAP	Agitated Immersion (1R2) - TERPENE	Primer Paint - Low Pressure Fuel Duct (2) - CHROMATE	Wire Arc Spray - Low Pressure Fuel Duct (2R1) - ALUMINUM	PROCESS/CHEMICAL 6	PROCESS/CHEMICAL 7	PROCESS/CHEMICAL 8	PROCESS/CHEMICAL 9	PROCESS/CHEMICAL 10
Present Program Schedule											
Research	10.0	9	9	9	3	3					
Trade Studies	11.0	9	9	3	3	3					
Modification in Planning	10.0	9	1	3	3	3					
Specification Documentation	11.0	3	1	3	3	3					
Drawing/Design Changes	10.0	9	3	3	3	3					
Production Time (New Equipment)	11.0	9	3	3	3	3					
Production Time (Hardware Available)	11.0	9	1	3	3	3					
Testing	12.0	9	3	3	3	3					
Vendor Selection & Certification	11.0	9	3	3	9	1					
Risk (Probability x Severity)											
OVERALL RATING		4116	3947	3631	2987	4542					

ROOF Legend	
Strong Positive	● 9
Positive	○ 3
Negative	× -3
Strong Negative	※ -9



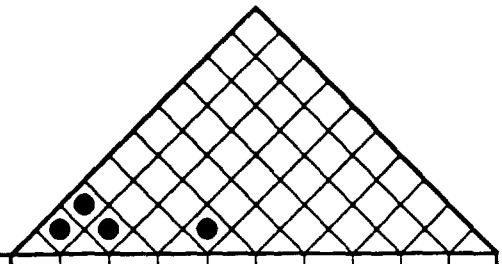
RELATIONSHIPS Legend	
Strong	● 9
Medium	○ 3
Weak	△ 1

	WEIGHTING FACTOR	Vapor Degrease (1) - TCA	Pressure Spray in Air (1R1) - AQUEOUS SOAP	Aggitated Immersion (1R2) - TERPENE	Primer Paint - Low Pressure Fuel Duct (2) - CHROMATE	Wire Arc Spray - Low Pressure Fuel Duct (2R1) - ALUMINUM	PROCESS/CHEMICAL 6	PROCESS/CHEMICAL 7	PROCESS/CHEMICAL 8	PROCESS/CHEMICAL 9	PROCESS/CHEMICAL 10
Chemical Concerns											
# of Sources	7.0	○	△	△	△	●					
Limited Resources for Manufacturing	7.0	●	●	●	●	●					
Availability	14.0	△	○	○	○	●					
Stability (Storage) & Use - Includes Pit Life	15.0	●	●	●	○	●					
Toxicity	13.0	○	○	○	●	●					
Drying Ability	14.0	●	△	△	●	●					
Base Material Compatibility	17.0	●	●	●	●	●					
Flammability		△	●	●	○	○					
Flash Point	13.0	△	●	○	○	●					
Ease of Maintenance	8.0	●	●	●	●	●					
Historical Data Base	9.0	●	○	△	●	○					
Desirable Reactivity	13.0				●	●					
Undesirable Reactivity	13.0	●	○	○							
Lot-to-Lot Variability	11.0	●	●	△	○	○					
Age Sensitivity - Processed Parts	11.0	●	○	△	○	●					
Shelf Life	9.0	○	○	○	○	●					
Process Concerns											
Contaminants Removed	15.0	△		△							

CHEMICAL REPLACEMENT PRIORITIZATION

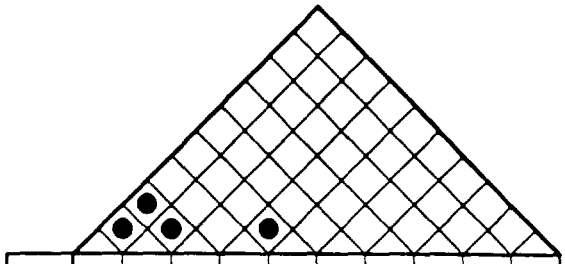
ROOF Legend	
Strong Positive	● 9
Positive	○ 3
Negative	× -3
Strong Negative	※ -9

RELATIONSHIPS Legend	
Strong	● 9
Medium	○ 3
Weak	△ 1



	WEIGHTING FACTOR	Vapor Degrease (1) - TCA	Pressure Spray in Air (1R1) - AQUEOUS SOAP	Agitated Immersion (1R2) - TERPENE	Primer Paint - Low Pressure Fuel Duct (2) - CHROMATE	Wire Arc Spray - Low Pressure Fuel Duct (2R1) - ALUMINUM	PROCESS/CHEMICAL 6	PROCESS/CHEMICAL 7	PROCESS/CHEMICAL 8	PROCESS/CHEMICAL 9	PROCESS/CHEMICAL 10
Process Steps (Increase/Decrease)	9.0		2	△		2					
Parts Processed At One Time	7.0	○	○	○	○	○					
Required Surface Preparation	12.0	○	○	○							
Bondline Thickness	7.0				○	6					
Process Time	9.0	△	○	○	○	●					
Process Interaction	9.0	●	○	●							
Operator Sensitivity	12.0	●	●	●	△	△					
Lot-to-Lot Variability	11.0	○	○	△	○	○					
General Cleaning Ability	13.0	●	●	○							
Surface Requirement	14.0	○	○	○	○	●					
Life of Replacement Processed Parts	14.0	○	○	○	○	●					
Damage Caused By Process	13.0	○	○	○	●	●					
Regulatory Concerns											
OSHA Requirements	13.0	○	○	○	○	○					
State Environmental Laws	14.0	△	○	●	○	●					
Local Environmental Laws	14.0	△	○	●	△	●					
Federal Environmental Requirements	15.0	△	●	●	○	○					
Future Federal Regulations	14.0	△	●	○	△	●					

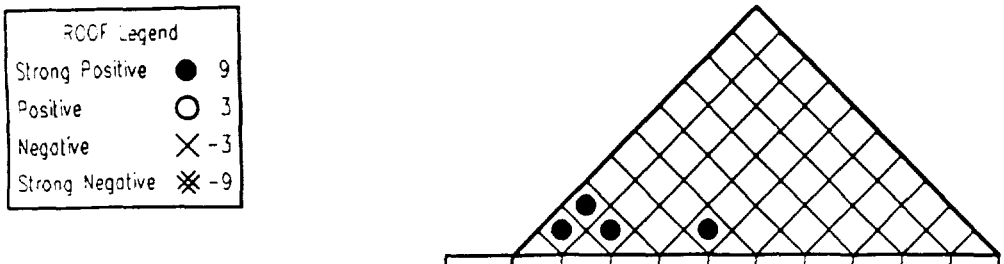
ROOF Legend
Strong Positive ● 9
Positive ○ 3
Negative × -3
Strong Negative ※ -9



RELATIONSHIPS Legend
Strong ● 9
Medium ○ 3
Weak △ 1

	WEIGHTING FACTOR	Vapor Degrease (1) - TCA	Pressure Spray in Air (1R1) - AQUEOUS SOAP	Aggitated Immersion (1R2) - TERPENE	Primer Paint - Low Pressure Fuel Duct (2) - CHROMATE	Wire Arc Spray - Low Pressure Fuel Duct (2R1) - ALUMINUM	PROCESS/CHEMICAL 6	PROCESS/CHEMICAL 7	PROCESS/CHEMICAL 8	PROCESS/CHEMICAL 9	PROCESS/CHEMICAL 10
Safety Concerns											
Worker Exposure Limits	12.0	○	○	△	△	○					
Spill Response Plans	13.0	○	○	●	●	●					
Fire Response Plans	14.0	○	●	●	●	●					
Explosion Response Plans	16.0	●	●	●	●	●					
Environmental Concerns											
Clean Air Monitoring	12.0	△	●	●	△	○					
Pollution Prevention	12.0	●	●	△	○	●					
Toxic Emissions	15.0	●	○	●	△	●					
Emissions Control	12.0	△	●	●	○	●					
Ozone Depletor Potential	15.0	△	●	●	●	●					
Chemical Storage Availability	10.0	●	●	○	●	●					
Resource/Ingredient Recovery & Recycling	10.0	●	○	○	△	○					
Hazardous Waste Management	12.0	○	○	○	○	○					
Cost Concerns											
Labor $	17.0	○	2	2	2	2					
Operations $	14.0	2	2	○	2	6					
Facilities $	15.0	△	2	2	2	2					
Materials $	14.0	○	○	○	2	6					
Chemical $	16.0	2	6	○	○	○					

CHEMICAL REPLACEMENT PRIORITIZATION



ROOF Legend

Strong Positive	●	9
Positive	○	3
Negative	×	-3
Strong Negative	※	-9

RELATIONSHIPS Legend

Strong	●	9
Medium	○	3
Weak	△	1

	WEIGHTING FACTOR	Vapor Degrease (1) - TCA	Pressure Spray in Air (1R1) - AQUEOUS SOAP	Agglated Immersion (1R2) - TERPENE	Primer Paint - Low Pressure Fuel Duct (2) - CHROMATE	Wire Arc Spray - Low Pressure Fuel Duct (2R1) - ALUMINUM	PROCESS/CHEMICAL 6	PROCESS/CHEMICAL 7	PROCESS/CHEMICAL 8	PROCESS/CHEMICAL 9	PROCESS/CHEMICAL 10
Other Hardware $	14.0	○	○	△	○	○					
Contracts $	12.0	2	2	○	2	2					
Change of Specifications $	13.0	○	2	2	2	2					
Specification Verification $	13.0	○	△	2	2	6					
Change of Drawings $	11.0	○	2	○	2	2					
Development of Procedure $	12.0	2	2	2	2	2					
Waste Management $		○	○	○	2	6					
Emissions Control Testing $	12.0	○	○	○	2	○					
Scheduling Concerns (Federal/State/Local)											
Research	9.0	●	●	●	△	●					
Trade Studies	8.0	●	●	○	△	○					
Modification in Planning	9.0	●	○	○	△	○					
Specification Documentation	10.0	○	○	○	△	○					
Drawing/Design Changes	8.0	●	○	○	△	○					
Production Time (New Equipment)	11.0	○	●	○	△	○					
Testing	14.0	○	○	○	△	○					
Vendor Selection & Certification	12.0	○	○	○	△	△					

ROOF Legend	
Strong Positive	● 9
Positive	○ 3
Negative	× -3
Strong Negative	✳ -9

RELATIONSHIPS Legend	
Strong	● 9
Medium	○ 3
Weak	△ 1

	WEIGHTING FACTOR	Vapor Degrease (1) - TCA	Pressure Spray in Air (1R1) - AQUEOUS SOAP	Agglated Immersion (1R2) - TERPENE	Primer Paint - Low Pressure Fuel Duct (2) - CHROMATE	Wire Arc Spray - Low Pressure Fuel Duct (2R1) - ALUMINUM	PROCESS/CHEMICAL 6	PROCESS/CHEMICAL 7	PROCESS/CHEMICAL 8	PROCESS/CHEMICAL 9	PROCESS/CHEMICAL 10
Present Program Schedule											
Research	10.0	●	●	●	○	○					
Trade Studies	11.0	●	●	○	○	○					
Modification in Planning	10.0	●	△	○	○	○					
Specification Documentation	11.0	○	△	○	○	○					
Drawing/Design Changes	10.0	●	○	○	○	○					
Production Time (New Equipment)	11.0	●	○	○	○	○					
Production Time (Hardware Available)	11.0	●	△	○	○	○					
Testing	12.0	●	○	○	○	○					
Vendor Selection & Certification	11.0	●	○	○	●	△					
Risk (Probability x Severity)											
OVERALL RATING		4116	3947	3631	2987	4542					

APPENDIX C

– Blank Matrices

– Concern Explanations

Matrix A - Chemicals and Uses For Prioritization Methodology

Chemical	Chem # (Registry #)	Chem # (Reference #)	Material	Process	Part/Component/Subsystem	Surface	Proc # (Reference)	Proc Step #	Total Process Steps (#)	Reference # (tracable to FMEA)	Amount Used In Process (lb/yr)

Matrix B - Technical Maturity of Substutite For Prioritzation Methodology

Chemical	Chem #	Process	Proc #	New	Old	Years of Existence	Toxicity Testing		Environmental Testing		Chemical Reactivity Testing			Age Sensivity Testing (shelf-life & aging)				Misc.Testing		# of parts to be processed (Program Life) -- old and new
							#	Type	#	Type	#	Results	Type	# Samples	Shelf Life	Type	Ext.	#	Type	

MATRIX C - Risk of System Failure for Prioritization Methodology

Chemical	Chem #	Process	Proc #	New	Old	Part/ Component/ Subsystem #	FMEA # (Ref.)	Severity (S)		Probability (P)				Risk (= P*S)
								Criticality	Severity Value	Inspections	Original S.F.	Anticipated S.F.	Probability Value	

	Inspections:		
6	V = Visual	3	W = Witness Panel
5	NS = NDE (UT, X-Ray, ect...)	2	WT = Witness Panel -- Tested
4	LC = LOX Cleanliness (NVR, Other)	1	P = Plug Test

Matrices D & E (Combined) - Chemical and Process Concerns for Prioritization Methodology

Weighting Factors to be Inserted Here →
1 - Less Important 20 - More Important

						Chemical Concerns																Process Concerns																			
Chemical	Chem #	Process	Proc #	New	Old	# of Sources	Limited Resources for Manufacturing (NMH)	Availability (EMB)	Stability (Storage) (GFP)	Toxicity (NMH)	Drying Ability (GFP)	Base Meterial Compatibility (GFP)	Flash Point (GFP)	Ease of Maintenance (GFP)	Historical Data Base (CPN)	Desirable Reactivity (GFP)	Undesirable Reactivity (NMH)	Lot-to-Lot Variability (NMH)	Age Sensitivity - Processed Part (NMH)	Shelf Life (EMB)	OTHER	Contaminants Removed (EMB)	Process Steps (DNI)	Parts Processed at One Time (EMB)	Required Surface Prep. (DNI)	Bondline Thickness/Strength (EMB)	Process Time (DNI)	Process Interaction (GFP)	Operator Sensitivity (NMH)	Lot-to-Lot Variability (NMH)	General Cleaning Ability(GFP)	Surface Requirement (EMB)	Life of Replacement Processed Parts (EMB)	Damage caused by Process (NMH)	OTHER	OTHER	OTHER	OTHER	OTHER	OTHER	OTHER

⊙	9	Exceeds (E)	Good(G)	None (N)	Complete (C)	Decrease (D)
O	3	Meets (M)	Fair (F)	Minimal (M)	Partial(P)	No Change (N)
✱	1	Below (B)	Poor (P)	High (H)	None (N)	Increase (I)

46.

Matrix F - J (Combined) - Regulatory, Safety, Environmental, Cost, and Scheduling Concerns for Prioritization Methodology

Weighting Factors to be Inserted Here
1 - Less Important 20 - More Important

Chemical	Chem #	Process	Proc #	New	Old	*Regulatory Concerns*					*Safety Concerns*				*Environmental Concerns*								*Cost Concerns*													*Scheduling Concerns*													
																																				Federal, State, and Local Regulations								**Present Program Schedule**									
						OSHA Requirements (EMB)	State Environmental Laws (EMB)	Local Environmental Laws (EMB)	Federal Environmental Requirements (EMB)	Future Federal Regulations (EMB)	Worker Exposure Limits (NMH)	Spill Response Plans (CPN)	Fire Response Plans (CPN)	Explosion Response Plans (CPN)	Clean Air Monitoring (EMB)	Pollution Prevention (CPN)	Toxic Emissions (NMH)	Emissions Control (GFP)	Ozone Depletor Potential (NMH)	Chemical Storage Availability (CPN)	Resource/Ingredient Recovery and Recycling (CPN)	Hazardous Waste Management (EMB)	Labor $ (DNI)	Operations $ (DNI)	Facilities $ (DNI)	Materials $ (DNI)	Chemical $ (DNI)	Other Hardware $ (DNI)	Contracts $ (DNI)	Change of Specifications $ (DNI)	Specification Verification $ (DNI)	Change of Drawings $ (DNI)	Development of Procedure $ (DNI)	Waste Management $ (DNI)	Emissions Control Testing $ (DNI)	Research (EMB)	Trade Studies (EMB)	Modification in Planning (EMB)	Specification Documentation (EMB)	Drawing/Design Changes (EMB)	Production Time (EMB) (New Equip.)	Testing (EMB)	Vendor Selection & Certification (EMB)	Research (EMB)	Trade Studies (EMB)	Modification in Planning (EMB)	Specification Documentation (EMB)	Drawing/Design Changes (EMB)	Production Time (EMB) (New Equip.)	Production Time $ (EMB) (Hardware Avail)	Testing (EMB)	Vendor Selection & Certification (EMB)

9	Large Decrease (D1)	
6	Slight Decrease (D2)	
3	No Change(N)	
2	Slight Increase (I2)	
1	Large Increase (I1)	

⊙	9	Exceeds (E)	Good(G)	None (N)	Complete (C)
○	3	Meets (M)	Fair (F)	Minimal (M)	Partial(P)
✳	1	Below (B)	Poor (P)	High (H)	None (N)

Chemical Concerns For Prioritization Methodology
MATRIX D

Weighting Factors to be Inserted Here →
1 - Less Important 20 - More Important

Chemical	Chem #	Process	Proc #	New	Old	# of Qualified Sources	Limited Resources for Man. (NMH)	Availability (EMB)	Stability (Use in Process) (GFP)	Toxicity (NMH)	Drying Ability (GFP)	Base Material Compatability (GFP)	Flash Point (GFP)	Ease of Maintenance (GFP)	Historical Data Base (CPN)	Desirable Reactivity (GFP)	Undesirable Reactivity (NMH)	Lot-to-Lot Variability (NMH)	Age Sensitivity - Processed Parts (NMH)	Shelf Life (EMB)	Other	Other	Other	Other	Other

⊙	9	Exceeds (E)	Good(G)	None (N)	Complete (C)
○	3	Meets (M)	Fair (F)	Minimal (M)	Partial(P)
✱	1	Below (B)	Poor (P)	High (H)	None (N)

Explanations of Matrices D for NOET Prioritization Methodology

CHEMICAL CONCERNS

- **Limits of Resources**

Expl: Are the natural resources used in making the chemicals (or needed in the process) limited to the extend that future production of the chemical or material will be limited?

Code: (NMH)

None -- no limited resources -- recyclable or abundant resources
Minimal -- some limited resources -- 15 year supply available for each
High -- some or many limited sources -- less than 15 year supply on one or more

- **Availability**

Expl: Is the chemical available for use - include present and future availability?

Code: (EMB)

Exceeds--more than 100% of needed chemical(s) available at any time (and/or) many sources for chemical
Meets--100% of needed chemical(s) available at any time (and/or) less than 3 sources for chemical(s)
Below--Less than 100% of needed chemical(s) needed available at any point in time (and/or) single source for chemical

- **Stability**

Expl: How stable is the chemical for use and storage (i.e. does it tend to explode or degrade when exposed to processing)?

Code: (GFP)

Good--Very stable -- no possibility of explosion or degradation
Fair -- Semi-stable -- not probable that explosion or degradation in process
Poor -- Unstable -- probably will explode or degrade during processing

- **Toxicity**

Expl: Is the chemical toxic to personnel?

Code: (NMH)

None -- The chemical is not toxic
Minimal -- The chemical has some toxic effects
High -- The chemical is very toxic

-**Drying Ability**

Expl: Does the chemical/process have the drying ability needed for the process?

Code: (GFP)

Good -- Above set standard
Fair -- At set standard
Poor -- Below set standard

- **Base Meterial Compatibility**

Expl: Does the chemical react with the surface in such a way that the metal is damaged or eroded beyond set standards?

Code: (NMH)

None -- Does not produce any adverse affects during processing
Minimal -- Has some affect, but generally only appearance is sacrificed
High -- Affects the material during processing, more than appearance is affected

- **Flash Point**

Expl: Does the flash point interfere with the process (i.e. is there a concern with personnel and hardware safety?)?

Code: (NMH)

None -- No flash point or Flash point is very high and there is no possibility of danger due to sparking (Above 200° F or will not burn)
Minimal -- Medium flash point with some possibility of danger (Below 200° F)
High -- Low flash point with the probability of danger (Below 100° F)

- **Ease of Maintenance**

Expl: How easy is this chemical to transport, store, and use (subjective)?

Code: (GFP)

Good -- No difficulties in any of these aspects
Fair -- Some difficulty but easily solved with training
Poor -- Extreme difficulty -- must have new equipment and/or extra personnel

- **Historical Data Base**

Expl: How much history on use, long term use, long term problems, ect. is available on this chemical/process?

Code: (CPN)

Complete -- Full study completed and/or very similar to one with completed study
Partial -- Study in progress and/or some studies on like chemicals/processes
None -- Have not started or have very little data to date

- **Desirable Reactivity**

Expl: Does the desired chemical reaction occur?

Code: (SMW)

Strong -- Good reactivity
Medium -- Partial reactivity
Weak -- No reactivity

- **Undesirable Reactivity (including foaming during processing)**
  Expl.: Does an undesirable chemical reaction occur?
  Code: (NMH)
  None -- No undesired reactivity
  Minimal -- Small amount of undesired reactivity
  High -- Large amount of undesired reactivity
- **Lot-to-Lot Variability**
  Expl.: Does the composition of the chemical vary within the tolerance limits?
  Code: (EMB)
  Exceeds -- Chemical stays within the tolerance limits (extremely small amount of variability
  Meets -- Chemical meets tolerance limits
  Below -- Chemical changes are beyond tolerance limits
- **Age Sensitivity**
  Expl.: Does the chemical produce adverse effects on part(s) at any time after processing?
  Code: (NMH)
  None -- The chemical does not produce adverse effects after any length of time after processing
  Minimal -- The chemical produces a minimal effect after a length time
  High -- The chemical produces adverse effects with time after processing
- **Shelf Life**
  Expl.: Can the chemical be stored before processing?
  Code: (EMB)
  Exceeds -- Chemical can stored beyond needed time
  Meets -- Chemical can stored for the needed time
  Below -- Chemical can not be stored for the needed time

Process Concerns For Prioritization Methodology
MATRIX E

Weighting Factors to be Inserted Here →
1 - Less Important 20 - More Important

Chemical	Chem #	Process	Proc #	New	Old	Contaminants Removed (EMB)	Process Steps (DNI)	Parts Processed at One Time (EMB)	Required Surface Prep. (DNI)	Bondline Thickness (EMB)	Process Time (DNI)	Process Interaction (GFP)	Operator Sensitivity (NMH)	Lot-to-Lot Variability (NMH)	General Cleaning Ability(GFP)	Surface Requirement (EMB)	Life of Replacement Processed Parts (EMB)	Damage caused by Process (NMH)	OTHER	OTHER	OTHER	OTHER	OTHER	OTHER	OTHER

◎	9	Exceeds (E)	Good(G)	None (N)	Complete (C)	Decrease (D)
○	3	Meets (M)	Fair (F)	Minimal (M)	Partial(P)	No Change (N)
✱	1	Below (B)	Poor (P)	High (H)	None (N)	Increase (I)

Explanations of Matrices E for NOET Prioritization Methodology

PROCESS CONCERNS

- **Contaminants Removed**
  - *Expl:* The number of contaminants removed by the chemical and process. (If applicable for this process)
  - *Code*: (EMB)
  - Exceeds -- Exceeds necessary requirements for this material
  - Meets-- Meets the requirements for this material
  - Below -- Does not fully meet the requirements
- **Process Steps**
  - *Expl:* The number of process steps for the process.
  - *Code*: (DNI)
  - Decrease -- Less process steps than the existing process
  - No change-- Same number of process steps as the existing process
  - Increase -- More process steps than the existing process are required
- **Parts Processed at One Time**
  - *Expl:* The number of parts processed at one time.
  - *Code*: (EMB)
  - Exceeds -- Exceeds necessary requirements for this part
  - Meets-- Meets the requirements for this part
  - Below -- Does not fully meet the requirements
- **Required Surface Preparation**
  - *Expl:* The time required to prepare a surface before processing begins.
  - *Code*: (DNI)
  - Decrease -- Less surface preparation time required than the existing process
  - No change-- Same amount of time required as the existing process
  - Increase -- More surface preparation time required than the existing process
- **Bondline Thickness**
  - *Expl:* The effects of the process on the bondline thickness. (If applicable for this process)
  - *Code*: (EMB)
  - Exceeds -- Exceeds necessary requirements for this material
  - Meets-- Meets the requirements for this material
  - Below -- Does not fully meet the requirements
- **Proces Time**
  - *Expl:* The amount of time the process takes from start to finish.
  - *Code*: (DNI)
  - Decrease -- Less process time required than the existing process
  - No change-- Same amount of time required as the existing process
  - Increase -- More process time required than the existing process
- **Process Interaction**
  - *Expl:* How well the processes interact with previous, concurrent, or subsequent processes?
  - *Code*: (GFP)
  - Good -- All process interactions occur favorably
  - Fair -- Most process interactions occur favorably
  - Poor -- Process interactions do not occur favorably
- **Operator Sensitivity**
  - *Expl:* How sensitive is the process to operator changes?
  - *Code*: (NMH)
  - None -- The process is not sensitive to operator change
  - Minimal -- The process is sensitive to operator change
  - High -- The process is very sensitive to operator change
- **Lot-to-Lot Variability**
  - *Expl:* Is the process repeatable within tolerance limits? (Do parts undergoing a particular process have different outcome when processed at different times?)
  - *Code*: (NMH)
  - None -- No measurable change in parts processed at different times
  - Minimal -- Variations in processed parts are within tolerance
  - High -- Variations in processed parts are not within tolerance

General Cleaning Ability --*Including Any of the Following which are Applicabale*

- **Process Tooling Cleaning Ability**
- **Bondline Surface Cleaning Ability**

Residue Removal
Rinsing Ability
NVR Cleaning
Expl: How well does the chemical process meet the general cleaning specifications?
Code: (GFP)
Good -- Above set standard
Fair -- At set standard
Poor -- Below set standard

- **Surface Requirements--*Including Any of the Following which are Applicabale***
  Surface Finish/Condition
  Bonding
  Contamination
  Expl: Does the processed part meet the surface requirements?
  Code: (EMB)
  Exceeds -- The processed part exceeds the surface requirements
  Meets -- The processed part meets the surface requirements
  Below -- The processed part does not meet the surface requirements
- **Possibility for Stress Corrosion Cracking**
  Expl: Is there a possibility for stress corrosion cracking?
  Code: (NMH)
  None -- There is no possibility for stress corrosion cracking
  Minimal -- There is a possibility for stress corrosion cracking
  High -- Stress corrosion cracking is probable
- **Useful Life of Replacement Processed Parts**
  Expl: What is the useful life of replacement processed parts?
  Code: (EMB)
  Exceeds -- The projected useful life is exceeded
  Meets -- The projected useful life is met
  Below -- The projected useful life is not met
- **Damage Caused by Process--*Including Any of the Following which are Applicabale***
  Stress Corrosion Cracking
  Swelling
  Cracking
  Corrosion
  Expl: Does the process cause damage to the part?
  Code: (NMH)
  None -- The process does not cause any measurable damage
  Minimal -- The process may cause minimal damage
  High -- The process causes critical damage

Regulatory Concerns For Prioritization Methodology
MATRIX F

Weighting Factors to be Inserted Here →
1 - Less Important 20 - More Important

Chemical	Chem #	Process	Proc #	New	Old	OSHA Requirements (EMB)	State Environmental Laws (EMB)	Local Environmental Laws (EMB)	Federal Environmental Requirements (EMB)	Future Federal Regulations (EMB)	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other

⊙	9	Exceeds (E)	Good(G)	None (N)	Complete (C)
○	3	Meets (M)	Fair (F)	Minimal (M)	Partial(P)
※	1	Below (B)	Poor (P)	High (H)	None (N)

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REGULATORY CONCERNS

For each category

Code :(EMB)

Exceeds -- This chemical/process (with facilities already in place) exceeds the present set requirements

Meets -- This chemical/process (with the facilities available) complies with the present set requirements

Below -- The facilities available for this chemical/process do not provide adequate compliance with present requirements

- **OSHA Requirements**

  Expl : Does this chemical/process comply with OHSA requirements?

  Code :(EMB)

- **State Environmental Laws/Regulations**

  Expl : Does this chemical/process comply with state environmental laws?

  Code :(EMB)

- **Local Environmental Laws/Regulations**

  Expl : Does this chemical/process comply with local environmental laws?

  Code :(EMB)

- **Federal Environmental Laws/Requirements**

  Expl : Does this chemical/process comply with additional federal requirements or potential future requirements?

  This includes:

  EPA Regulations

  Other NASA Regulations

  Requirements for use, transport, storage of hazardous chemicals

  Code :(EMB)

Safety Concerns For Prioritization Methodology
MATRIX G

Weighting Factors to be Inserted Here →
1 - Less Important 20 - More Important

Chemical	Chem #	Process	Proc #	New	Old	Worker Exposure Limits (NMH)	Spill Response Plans (CPN)	Fire Response Plans (CPN)	Explosion Response Plans (CPN)	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other

⊙	9	Exceeds (E)	Good(G)	None (N)	Complete (C)
○	3	Meets (M)	Fair (F)	Minimal (M)	Partial(P)
✱	1	Below (B)	Poor (P)	High (H)	None (N)

SAFETY CONCERNS

- **Worker Exposure Limits (Guidelines)**
  Expl : What are the worker exposure limitation associated with the chemical/process?
  Code :(NMH)
  None -- There are no limits -- this chemical/process has no known risk
  Minimal -- There are sight exposure limits -- special equipment for the worker can solve problem
  High -- There are extreme limits -- this chemical/process has documented risks that cannot be avoided by worker protection equipment
- **Spill Response Plans**
  Expl : Is there a spill response plan associated with the chemical/process?
  Code :(CPN)
  Complete -- There is a complete response plan and workers are trained in the event of a spill
  Partial -- There is a partial plan in place and workers are aware of this plan or there is a complete plan but workers are not trained in the event of a spill
  None -- There are no provisions for response to a spill
- **Fire Response Plans**
  Expl : Is there a fire response plan associated with the chemical/process?
  Code :(CPN)
  Complete -- There is a complete response plan and workers are trained in the event of a fire
  Partial -- There is a partial plan in place and workers are aware of this plan or there is a complete plan but workers are not trained in the event of a fire
  None -- There are no provisions for response to a fire
- **Explosion Response Plans**
  Expl : Is there a explosion response plan associated with the chemical/process?
  Code :(CPN)
  Complete -- There is a complete response plan -- workers are trained in the event of an explosion
  Partial -- There is a partial plan in place -- workers are aware of this plan or there is a complete plan but workers are not trained in the event of an explosion
  None -- There are no provisions for response to an explosion

Environmental Concerns For Prioritization Methodology
MATRIX H

Weighting Factors to be Inserted Here →
1 - Less Important 20 - More Important

Chemical	Chem #	Process	Proc #	New	Old	Clean Air Monitoring (EMB)	Pollution Prevention (CPN)	Toxic Emissions (NMH)	Emissions Control (GFP)	Ozone Depletor Potential (NMH)	Chemical Storage Availability (CPN)	Resource/Ingredient Recycling (CPN)	Hazardous Waste Management (EMB)	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other

⊙	9	Exceeds (E)	Good(G)	None (N)	Complete (C)
○	3	Meets (M)	Fair (F)	Minimal (M)	Partial(P)
✱	1	Below (B)	Poor (P)	High (H)	None (N)

ENVIRONMENTAL CONCERNS

- **Clean Air Monitoring**
  Expl : Are there provisions for a clean air monitoring for this chemical/process?
  Code :(EMB)
  Exceeds -- The provisions for air monitoring that are in place exceed the EPA set standards for clean air monitoring
  Meets -- The provisions that are in place meet the EPA set standards for air monitoring
  Below -- The provisions that are in place will have to be updated to meet EPA set standards
- **Pollution Prevention**
  Expl : Are there provisions for pollution prevention?
  Code :(CPN)
  Complete -- All known pollution prevention methods are available and ready for use
  Partial -- There are some (but not all) pollution prevention methods available for use
  None -- There is no pollution prevention available at this time
- **Toxic Emissions (including soil,water, etc. but excluding air)**
  Expl : Is there a potential for toxic emissions from this chemical/process?
  Code :(NMH)
  None -- There is no known possibility for toxic emissions
  Minimal -- There is little (within EPA standards) possibility for toxic emissions
  High -- There is a large potential for toxic emissions
- **Emissions Control**
  Expl : Are there provisions for toxic emissions control as needed for this chemical/process?
  This includes:
  Minimizing VOC emissions
  Minimizing air pollutants
  Code :(GFP)
  Good -- The provisions will provide for all known toxic emissions to be filtered from the air
  Fair -- The provisions will provide the toxic emissions to be filtered to present EPA standards
  Poor -- There is little to no filtering to prevent toxic emissions from this chemical/process
- **Ozone Depleting Potential**
  Expl : Does this chemical have an ozone depleting potential?
  Code :(NMH)
  None -- This chemical/process has no known ozone depleting potential
  Minimal -- This chemical/process has very little ozone depleting potential (EPA approved)
  High -- This chemical is a potential ozone depleting
- **Chemical Storage Availability**
  Expl : Are there provisions for chemical storage (before processing)?
  Code :(CPN)
  Complete -- There are complete facilities for storage of preprocessed chemicals/ personnel are trained for handling of chemicals to prevent environmental contamination
  Partial -- There are facilities to store some of the preprocessed chemicals and/or personnel need training for handling of chemicals to prevent environmental contamination
  None -- Facilities need building to house preprocessed chemicals and personnel need training for handling of chemicals to prevent environmental contamination
- **Resource/Ingredient Recovery and Recycling**
  Expl : Can the resources/ingredients be recovered or recycled for reuse?
  Code :(CPN)
  Complete -- A near complete recovery of resources/ingredients can be obtained after processing
  Partial -- A partial recovery of resources/ingredients can be obtained after processing
  None -- Nothing can be reused or recycled after processing
- **Hazardous Waste Management**
  Expl : Are there provisions for collection of hazardous waste from the chemical/process?
  This includes:
  Collection of hazardous waste
  Disposal of hazardous waste
  Filtration of waste products
  Hazardous waste storage
  Determination of origin of waste
  Waste water sludge disposal
  Determination of fate of waste
  Code :(CPN)
  Complete -- All known provisions for collection of hazardous waste are available and ready for use/personnel are trained for

collection and handling
Partial -- There some incomplete provisions for collection of hazardous waste available for use
None -- There are no provisions for collection of hazardous waste from chemical/process available at this time

Cost Concerns For Prioritization Methodology
MATRIX I

Weighting Factors to be Inserted Here
1 - Less Important 20 - More Important

						Chemical
						Chem #
						Process
						Proc #
						New
						Old
						Labor $ (DNI)
						Operations $ (DNI)
						Facilities $ (DNI)
						Materials $ (DNI)
						Chemical $ (DNI)
						Other Hardware $ (DNI)
						Contracts $ (DNI)
						Change of Specifications $ (DNI)
						Specification Verification $ (DNI)
						Change of Drawings $ (DNI)
						Development of Procedure $ (DNI)
						Waste Management $ (DNI)
						Emissions Control Testing $ (DNI)
						Other
						Other
						Other
						Other
						Other
						Other
						Other

⊙	9	Exceeds (E)	Good(G)	None (N)	Complete (C)
○	3	Meets (M)	Fair (F)	Minimal (M)	Partial(P)
✱	1	Below (B)	Poor (P)	High (H)	None (N)

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COST CONCERNS

For each category

Code:(DNI)
Large Decrease -- A decrease larger than $500,000
Slight Decrease -- A decrease of $1 to $499,999
No Change -- No change in cost
Slight Increase -- An increase of $1 to $499,999
Large Increase -- An increase larger than $500,000

(Manpower) $

For each category:

** *Expl* : What is the approximate man-hour cost change due to changing this chemical/process (compared to current $)?

- **Research Engineers $**
  Estimated $/year -- $_____
- **Development Engineers $**
  Estimated $/year -- $_____
  Code:(DNI)
- **Design Engineers $**
  Estimated $/year -- $_____
  Code:(DNI)
- **Test Engineers $**
  Estimated $/year -- $_____
  Code:(DNI)
- **Technicians $**
  Estimated $/year -- $_____
  Code:(DNI)
- **Environmental Personnel $**
  Estimated $/year -- $_____
  Code:(DNI)
- **Safety Personnel $**
  Estimated $/year -- $_____
  Code:(DNI)
- **Facilities Personnel $**
  Estimated $/year -- $_____
  Code:(DNI)
- **Management $**
  Estimated $/year -- $_____
  Code:(DNI)
- **Inspection Personnel $**
  Estimated $/year -- $_____
  Code:(DNI)
- **Total Man Power --$_____**

- **Operations $ (including operator, utility, fuel, etc.)**
  Expl : What is the approximated cost change of operations due to changing this chemical/process (compared to current $)?
  Code:(DNI)
- **Facilities $**

this cost includes:

Construction personnel — Modification personnel
Changes in maintenance fees — Equipment removal/installation
Process equipment

Expl : What is the approximate facilities cost change due to using this chemical/process (compared to current $)?
Estimated $/year -- $_____
Code:(DNI)

- **Materials $**
  Expl : What is the approximate cost change of materials due to using this chemical/process (compared to current $)?
  Estimated $/year -- $_____
  Code:(DNI)

- **Chemical $**
  Expl : What is the approximate cost change of chemicals due to using this chemical/process (compared to current $)?
  Estimated $/year -- $_____
  Code :(DNI)
- **Other Hardware $ (and other equipment - including safety equipment and transportation)**
  Expl : What is the approximate cost change of other hardware due to using this chemical/process (compared to current $)?
  Estimated $/year -- $_____
  Code :(DNI)
- **Contracts' $ / Subcontracts' $**
  Expl : What is the approximate contracts' cost change due to using this chemical/process (compared to current $)?
  Estimated $/year -- $_____
  Code :(DNI)
- **Change of Specifications $**
  Expl : What is the approximate cost for a change of specifications due to using this chemical/process (compared to current $)?
  Estimated $/year -- $_____
  Code :(DNI)
- **Specification Verification $**
  Expl : What is the approximate cost for specifications verification due to using this chemical/process (compared to current $)?
  Estimated $/year -- $_____
  Code :(DNI)
- **Change of Drawings $**
  Expl : What is the approximate cost for drawing changes due to using this chemical/process (compared to current $)?
  Estimated $/year -- $_____
  Code :(DNI)
- **Development of Procedure $ (including development and qualification testing)**
  Expl : What is the approximate cost for development of procedures for using this chemical/process (compared to current $)?
  Estimated $/year -- $_____
  Code :(DNI)
- **Emissions Control Equipment $**
  Expl : What is the approximate cost for changing emissions control equipment due to using this chemical/process (compared to current $)?
  Estimated $/year -- $_____
  Code :(DNI)
- **Emissions Control Testing $**
  Expl : What is the approximate cost of emissions control testing due to using this chemical/process (compared to current $)?
  Estimated $/year -- $_____
  Code :(DNI)

Scheduling Concerns For Prioritization Methodology
MATRIX J

Weighting Factors to be Inserted Here →
1 - Less Important 20 - More Important

Chemical	Chem #	Process	Proc #	New	Old	Research (EMB)	Trade Studies (EMB)	Modification in Planning (EMB)	Specification Documentation (EMB)	Drawing/Design Changes (EMB)	Production Time (EMB) (New Equip.)	Testing (EMB)	Vendor Selection & Certification (EMB)	Research (EMB)	Trade Studies (EMB)	Modification in Planning (EMB)	Specification Documentation (EMB)	Drawing/Design Changes (EMB)	Production Time (EMB) (New Equip.)	Production Time $ (EMB) (Avail)	Testing (EMB)	Vendor Selection & Certification (EMB)	Other	Other	Other

◎	9	Exceeds (E)	Good(G)	None (N)	Complete (C)
○	3	Meets (M)	Fair (F)	Minimal (M)	Partial(P)
✱	1	Below (B)	Poor (P)	High (H)	None (N)

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SCHEDULING CONCERNS

For each category

Code :(EMB)
Exceeds -- The time required for this chemical/process change allows for completion before timeline requirement
Meets -- The time required for this chemical/process change meets timeline requirements
Below -- The time required for this chemical/process change does not allow completion before timeline requirement

- **Research (Federal, State and Local Requirement)**
  Expl : Does the time required for research for this chemical/process allow schedules to be met?
  Estimated time -- _____months
  Code :(EMB)
- **Trade Studies (Federal, State and Local Requirement)**
  Expl : Does the time required for trade studies for this chemical/process allow schedules to be met?
  Estimated time -- _____months
  Code :(EMB)
- **Modification in Planning (Federal, State and Local Requirement)**
  Expl : Does the time required for modification in planning for this chemical/process allow schedules to be met?
  Estimated time -- _____months
  Code :(EMB)
- **Specification Documentation (Federal, State and Local Requirement)**
  Expl : Does the time required for specification documentation for this chemical/process allow schedules to be met?
  Estimated time -- _____months
  Code :(EMB)
- **Requirements Documentation (Federal, State and Local Requirement)**
  Expl : Does the time required for requirements documentation for this chemical/process allow schedules to be met?
  Estimated time -- _____months
  Code :(EMB)
- **Drawing /Design Changes (Federal, State and Local Requirement)**
  Expl : Does the time required for drawing/design changes for this chemical/process allow schedules to be met?

Drawing Changes
  Estimated time -- _____months
Design Changes
  Estimated time -- _____months
  Code :(EMB)

- **Production Time (Federal, State and Local Requirement)**
  Expl : Does the production time required for this chemical/process allow schedules to be met?
  Estimated time -- _____months
  Code :(EMB)
- **Testing (Federal, State and Local Requirement)**
  Expl : Does the time required for testing for this chemical/process allow schedules to be met?

Development testing
  Estimated time -- _____months
Qualification Testing
  Estimated time -- _____months
Life Cycle Testing
  Estimated time -- _____months
  Code :(EMB)

- **Vendor Selection and Certification (Federal, State and Local Requirement)**
  Expl : Does the time required for vendor selection and certification this chemical/process allow schedules to be met?
  Estimated time -- _____months
  Code :(EMB)
- **Research (Present Program Schedule)**
  Expl : Does the time required for research for this chemical/process allow present program flight schedules to be met?
  Estimated time -- _____months
  Code :(EMB)
- **Trade Studies (Present Program Schedule)**
  Expl : Does the time required for trade studies for this chemical/process allow present program flight schedules to be met?

Estimated time -- _____months
Code :(EMB)

- **Modification in Planning (Present Program Schedule)**
  Expl : Does the time required for modifications in planning for this chemical/process allow present program flight schedules to be met?
  Estimated time -- _____months
  Code :(EMB)
- **Specification Documentation (Present Program Schedule)**
  Expl : Does the time required for specification documentation for this chemical/process allow present program flight schedules to be met?
  Estimated time -- _____months
  Code :(EMB)
- **Requirements Documentation (Present Program Schedule)**
  Expl : Does the time required for requirements documentation for this chemical/process allow present program flight schedules to be met?
  Estimated time -- _____months
  Code :(EMB)
- **Drawing / Design Changes (Present Program Schedule)**
  Expl : Does the time required for drawing changes for this chemical/process allow present program flight schedules to be met?

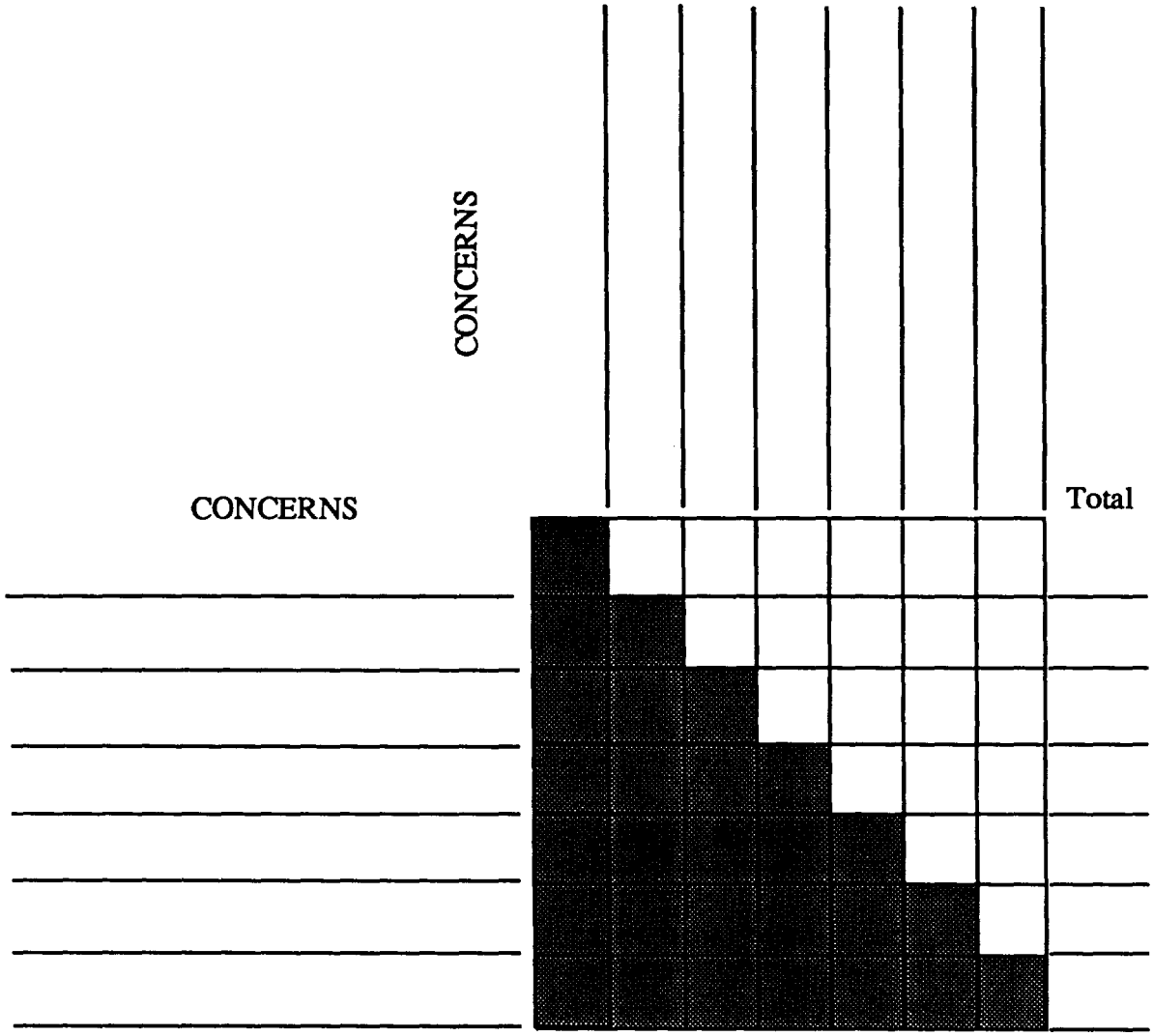
Drawing Changes
Estimated time -- _____months
Design Changes
Estimated time -- _____months
Code :(EMB)

- **Production Time (Present Program Schedule)**
  Expl : Does the time required for production for this chemical/process allow present program flight schedules to be met?
  Estimated time -- _____months
  Code :(EMB)
- **Testing (Present Program Schedule)**
  Expl : Does the time required for testing for this chemical/process allow present program flight schedules to be met?

Development testing
Estimated time -- _____months
Qualification Testing
Estimated time -- _____months
Life Cycle Testing
Estimated time -- _____months
Code :(EMB)

- **Vendor Selection and Certification (Present Program Schedule)**
  Expl : Does the time required for vendor selection and certification for this chemical/process allow present program flight schedules to be met?
  Estimated time -- _____months
  Code :(EMB)

Matrix K -- Weighting Worksheet



1 = Less Important
20 = More Important

☆ U.S. GOVERNMENT PRINTING OFFICE 1993—533-108/80131

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	October 1993	Technical Paper

4. TITLE AND SUBTITLE

Prioritization Methodology for Chemical Replacement

5. FUNDING NUMBERS

6. AUTHOR(S)

W. Cruit, S. Schutzenhofer, B. Goldberg, and K. Everhart

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

8. PERFORMING ORGANIZATION REPORT NUMBER

M-732

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Washington, DC 20546

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

NASA TP-3421

11. SUPPLEMENTARY NOTES

Prepared by NASA Operational Environment Team

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Unclassified—Unlimited
Subject Category: 29

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This project serves to define an appropriate methodology for effective prioritization of efforts required to develop replacement technologies mandated by imposed and forecast legislation. The methodology used is a semiquantitative approach derived from quality function deployment techniques (QFD Matrix). This methodology aims to weigh the full environmental, cost, safety, reliability, and programmatic implications of replacement technology development to allow appropriate identification of viable candidates and programmatic alternatives. The results are being implemented as a guideline for consideration for current NASA propulsion systems.

14. SUBJECT TERMS	15. NUMBER OF PAGES
NOET, replacement technology, QFD, prioritization, chemical replacement, process changes, PT^2	73
	16. PRICE CODE A04

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited