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**SECURE
AUTOMATED
FABRICATION**

**Phase I Interim Report -
A SYSTEMS ANALYSIS**

E. A. AITKEN

GENERAL ELECTRIC

**Advanced Reactor Systems Department
Sunnyvale, California**

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PHASE I INTERIM REPORT -
A SYSTEMS ANALYSIS

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SECURE AUTOMATED FABRICATION

A SYSTEMS ANALYSIS - INTERIM REPORT PHASE I

1.0 INTRODUCTION

The current breeder reactor fuel assembly is a high quality, proven fuel that is currently manually fabricated using glovebox technology. To provide improved fuel fabrication processes, and to assure meeting increasingly stringent health and safety criteria, an advanced Secure Automated Fabrication (SAF)* System is being developed for mixed uranium and plutonium fuel fabrication. SAF System development will ultimately result in systems which maximize personnel radiation protection, restrict and control access to SNM material, improve containment and detection systems for nuclear materials, provide adequate SNM accountability and improve product uniformity and quality. A systems requirement analysis study was initiated to establish the consistent and objective set of requirements within which the choice among alternatives represents the balanced viewpoints of performance, achievability and risk. The analysis activity pivots on the judgement and experience provided by a Task Force representing industrial companies engaged in fuel fabrication in licensed facilities. The Task Force members are listed in Appendix A. Input developed by this group is presented herein as a starting point for the systems requirements analysis.

Requirements may be divided into three categories: product requirements, process requirements, and SAF requirements. Requirements categorized as SAF relate to attributes built into the development and design of a facility, which protect the public and employee from the operation of the facility. Safety, safeguards and environmental discharge have an impact on public and employee interests, and criteria are needed to establish prudent requirements for SAF. SAF criteria are often identified in intangible terms (for example, "as safe as possible," or "as low as reasonably achievable"). There is a need to state these criteria in an explicit form that can be used for development purposes. Since experience is limited we must rely on judgements

*Early stages of this system analysis used Zero Risk in place of SAF as the acronym describing the activity.

and trends of existing operations of industry to establish SAF criteria. This report identifies the range of opportunities for achieving a SAF posture. Completeness of definition of SAF attributes and exploration of range of values open for each attribute of SAF is the objective of this report. In addition, a requirements analysis is performed to evaluate this range of possible attributes from the viewpoint of feasibility, practicality, reasonability, and achievability.

The application of these criteria in a systems engineering approach to the development programs is described in Appendix B where the reader may trace the anticipated logic pattern to be used in establishing the system requirements.

1.1 STATEMENT OF THE PROBLEM FOR SYSTEMS ANALYSIS

Present fabrication procedures may not be adequate to assure meeting the increasingly stringent health and safety criteria that may be imposed upon future breeder fuel fabrication processes. To develop system criteria for the SAF concept the assistance of industry, national laboratory and government agencies involved in design and development of fuel fabrication facilities was requested. The SAF criteria definitions are translated into requirements which, when combined with product and process requirements, can be used in guiding the development effort.

2.0 OBJECTIVE

The general objective is to establish candidate SAF criteria in the form of alternatives and to develop a rational approach in a systems requirements analysis. By documentation of the step-wise input, an understanding and traceability of the judgements made can be preserved and reevaluated as new or additional information becomes available during the development program.

Specific Task Force objectives for this report are to:

- o Define a complete list of attributes associated with SAF (low risk)
- o Give each attribute a scale of measure ranging from current practices to the limit of scientific plausibility

- o Define attributes in specific terms on an established scale and group them into a set of alternative approaches which achieves low risk
- o Organize this input into a form useful for expert judgements by sub-system function.
- o Collect these expert judgements and analyze findings related to operating costs and to development costs.
- o Select a set of attribute values which balance practicality, achievability and low risk.

3.0 PREMISING

The objectives of this systems analysis activity are based on assumptions and guidelines stated below:

- o The overall development strategy will follow the objectives and recommendations defined in the Fuel Fabrication Development Committee Report, June 13, 1979. Specific objectives are to achieve a demonstrated FBR fuel fabrication technology by 1995 and to provide fuel fabrication for initial (delivered May, 1989) and reload FBR cores. Specific recommendations are listed in Appendix C.
- o Initial fuel supply facilities for FBR cores will use developmental equipment where appropriate.
- o A fuel fabrication development activity will proceed in the following sequence:
 - 1) The development of individual equipment and support processes;
 - 2) systems testing, and;
 - 3) a final integrated demonstration in a pilot scale facility.
- o The systems analysis will follow systems engineering principles using documentation, traceability, integration, and iteration procedures.
- o System Requirements analysis will use Task Force input from industry representatives with follow-up review and comment by national lab/industry/DOE at appropriate stages of the analysis.

- o Detailed functional analysis of the fabrication system will be performed in parallel with the requirements analysis and used to justify judgments made by the contributing Task Force representatives.
- o Requirements analysis is intended for guiding RF&M-TMC development activity, and not for design input to a specific facility project or industrial enterprise.

4.0 SELECTION OF SAF ATTRIBUTES

Four kinds of risk are associated with any enterprise: Public Risk, Employee Risk, Customer Risk, and Business Risk. The first three kinds of risk relate to a particular body or organization and the consequences of these risks ultimately impact on the business risk. For purposes of defining SAF requirements, the definition of attributes is limited to public and employee risks. Customer risks such as product quality and product availability are more applicable to product and process requirements which will be examined later. The task group listed the attributes shown in Table 4.1 as appropriate for risk mitigation to the employee and those shown in Table 4.2 as appropriate to the public. There were five topics identified for consideration as employee risk and five as public risk. These topics were further divided into appropriate elements each requiring some scale of measure. Some elements were dropped after it was determined their input on development activities was minimal. Those elements deleted from consideration were: P 1.4 (Sabotage), P 2.1.3 (ID), and P 4 (Third Party Protection). As described later, some elements required more than one yardstick or scale of measure. These expanded elements are detailed later in this report.

The dominant basis for selection of most of the attribute elements was a requirement in existing Federal or State Regulations. The regulations were searched for applicability in defining scale of measure as shown in Appendix D. In some cases the regulation is summarized rather than reproduced verbatim.

TABLE 4.1

ATTRIBUTE DEFINITIONS FOR EMPLOYEE RISKS

No.	ATTRIBUTE DESCRIPTION	BASIS
E1	Radiation Exposure to Employee Within Plant	Federal Regulations
	1.1 External	
	1.1.1 - Neutron	
	1.1.2 - Gamma	
	1.1.3 - Total	
	1.2 Internal (ingestion)	
E2	Criticality	Federal Regulations
	2.1 Equipment	
	2.2 Storage	
	2.3 Undetected holdups	
E3	Personnel Contamination & Detection	Federal Regulations
	3.1 Within plant	
	3.2 Prior to normal exit	
	3.3 Emergency Evacuation with Theft	
E4	Employee Training	Federal Regulations
	4.1 Radiological	Federal Regulations/Corporate Requirements
	4.2 Equipment/System Operation	Federal Regulations/Corporate Requirements
	4.3 Management	
E5	Containment and Detection	Federal Regulations
	5.1 Airborne concentrations	
	5.1.1 Normal	
	5.1.2 Abnormal	
	5.1.3 Maintenance	
	5.2 Non-Nuclear hazardous materials	OSHA/State Requirements
	5.3 Smearable Surface Contamination	Federal Regulations
	Outside Process Area	

TABLE 4.2

ATTRIBUTE DEFINITIONS FOR PUBLIC RISKS

<u>ATTRIBUTE DESCRIPTION</u>		<u>BASIS</u>
<u>No.</u>		
P1	Discharge to Environment normal/abnormal State	Regulations -
	1.1 Vent discharge (gas, particulate & liquid)	Federal 1.1, 1.2, 1.3
	1.2 Liquid discharge (waste)	State 1.1, 1.2, 1.3
	1.3 Solid discharge (waste)	Design to DBA 1.1, 1.2
P2	Diversion/Theft	Regulations -
	2.1 Accountability	Federal 2.1, 2.2
	2.1.1 No. of MBA's	
	2.1.2 Inventory frequency	
	2.1.3 ID	
	2.1.4 LEID	
	2.2 Physical Protection	
	2.2.1 Detection; 2.1.1.1 Electronics Personnel Radiation Metallic	
	2.2.2 Barriers	
	2.2.3 Guards	
	2.2.4 Strike force	
	2.3 Sabotage	Anticipated Regulations 2.3
P3	Decontamination and Decommissioning	Regulations -
	3.1 Packaging and Shipping	Federal All
	3.1.1 Decon level	State 3.1.2
	3.1.2 Shipping container and mode	
	3.1.3 Volume reduction	
	3.2 Facility conditions	
	3.2.1 Decon levels	
	3.2.2 Conditions (reuse or tear down)	

TABLE 4.2 (Continued)

No.	ATTRIBUTE DESCRIPTION	BASIS
P4	Third Party Protection	Regulations -
	4.1 Shipments	Federal
	4.1.1 Product	4.1
	4.1.2 Raw material	
	4.1.3 Waste	
	4.2 Employee decon of personnel (hospital)	
P5	Facility Construction	Regulations - Federal & State

5.0 IDENTIFICATION OF SCALES OF MEASURE FOR EACH ATTRIBUTE

For each attribute element a yardstick was assigned and a range of values was determined to indicate the degree of sophistication possible. The major intent was to scale the yardstick between current operating values (which are deemed practical) and extreme values (which are deemed scientifically plausible and may become practical, given sufficient time and development funding). In this way, the level of risk assurance through technological development activity could be established. The issue of practicality and value gained was not addressed at this stage. The purpose of the exercise was to examine only what was plausible.

The task group developed the scales of measure shown in Table 5.1. Table 5.1 lists the attributes and each corresponding yardstick. The yardstick was given a numerical unit, where possible, but some attributes involved procedure only. The column labeled current value is based on present practice. In most cases, present practice is defined in federal or state regulations. For clarity, the actual values have not been stated but may be found through cross-referencing in Appendix D. The column labeled extreme value represents a plausible value based on scientific achievability after appropriate development but without regard to practicality. The range of values between the current value column and the extreme value column represents the transition between what is practical and what is plausible. This exercise establishes the boundary, in the judgement of the Task Force, for which an attribute can contribute to SAF risk mitigation. It also describes how well one might be able to perform technologically. It does not follow, necessarily, that there is a one-to-one correspondence between extreme value and absence of risk.

TABLE 5.1
ATTRIBUTE MEASURES

ATTRIBUTE TITLE		YARDSTICKS	CURRENT VALUE	INTERMEDIATE VALUE	EXTREME VALUE
NO.	Whole Body Exposure				
E1.1.1	External - Neutron	mRem/time	within total below	within total below	within total below
E1.1.2	External - Gamma	mRem/time	within total below	within total below	within total below
E1.1.3	External - Total (Single planned event)	mRem/time	Current Fed. Regs.	1000 mR/year	0.1 Current Fed. Reg.
E1.2	Internal	Fixed μ c/ind/isotope	Fed. Reg.	1/4 Fed. Reg.	1/10 Fed. Reg.
E2.1	Criticality - Equipment	Coincidental Events (.45 cm)	2	2	3
E2.2	Criticality - Storage	Coincidental Events (.45 cm)	2	2	3
E2.3	Criticality - Inadvertent Holdup	% of Critical Mass	Inv Control 2 Month	Cont Y Monitor	Cont Y Monitor/all equipment geometrically safe
E3.2	Pers. Cont. & Detect.- Prior to Normal Exit	Procedure	Self Monitor (hand & foot)	Hand & Foot monitor verified	Verified 100% body surface
E3.1	Pers. Cont. & Detect.- Within Plant	Monitoring Frequency	Current Fed. Reg. (one/entire facility)	One/function	One per work station
E4.1	Training - Radiological	Times/Year	1	2	4 for rad. workers; 1 for all others
E4.2	Training - Equip/System Oper.	Proficiency & Requalification	Initial	Training w/Proficiency Demonstration	Training w/periodic (1/yr) Proficiency Demonstration
E4.3	Emergency Training	Proficiency & Requalification	1/year	1 type emergency/quarter	All types of emer- gency/quarter
E5.1.1	Airborne Conc. - Normal	μ Ci/cc	Fed. Reg.	1/4 Fed. Reg.	0.1 Fed. Reg.
E5.1.2	Airborne Conc.- Abnormal	μ Ci/cc	Fed. Reg.	Fed. Reg.	Fed. Reg.
E5.1.3	Airborne Conc.-Maint.	μ Ci/cc	Fed. Reg.	Fed. Reg.	Fed. Reg.
E5.2	Non-Nuclear Hazardous Material		Federal & State Reg.	Federal and State Reg.	Federal and State Reg.
E5.3	Smearable Surface Contamination outside Process Area	dpm/100 cm ²	Fed. Reg.	1/2 Fed. Reg.	2 times detectable limit above background

TABLE 5.1 (Cont'd)

ATTRIBUTE TITLE		YARDSTICKS	CURRENT VALUE	INTERMEDIATE VALUE	EXTREME VALUE
NO.		NO.			
P1.1	Vent Discharge	1.1.1	Activity (curies/volume) and curies/time)	Normal = Fed. Regs. Abnormal = Fed. Regs.	1/2 Fed. Regs. + CAM Fed. Regs.
		1.1.2	Concentrations (ppm)	Fed. and State Regs.	Fed. and State Regs.
P1.2	Liquid Discharge	1.2.1	Activity (curies/volume/time)	Fed. Regs.	1/2 Fed. Regs.
		1.2.2	Concentrations (ppm)	Fed. and State Regs.	Fed. and State Regs.
P1.3	Solid Discharge Non-Nuclear	1.3.1	Activity (curies/mass)	Fed. Regs.	< 100 nanocuries/gm TRU
		1.3.2	Concentrations (ppm)	Fed. and State Regs.	Fed. and State Regs.
P2.1	Accountability	2.1.1	No. MBA/fac.	1/Facility	1/Function
		2.1.2.1	Inv. Freq. (days)	60	60
		2.1.2.2	Response Time to Reconcile (days)	30	30
		2.1.4	LEID (mass)	.50% of throughput per period	.3% of throughput per period
P2.2	Physical Protection	2.2.1.1	Personnel Elect. Detection	Perimeter Surveillance Picture Badge	Perimeter + Internal Surveillance Key Card
		2.2.1.2	Grams	.5 gms Pu	.5 gms Pu
		2.2.1.3(a)	Metallic (mass)	200 gms	200 gms
		2.2.1.3(b)	Shielding (mass)	50 gms	50 gms
		2.2.1.4	TNT (equiv. mass)	200	200
		2.2.2	Time Delay/Intrusion	4 Barriers + Alarm	Add 200 barriers + Alarm
		2.2.3	No. of Sets	1/set	1 set + CCTV + response team
		2.2.4	Number	Local Law Enforcement Agency = 1 team	Team + increased proficiency

TABLE 5.1 (Cont'd)

ATTRIBUTE TITLE	YARDSTICKS	CURRENT VALUE	INTERMEDIATE VALUE	EXTREME VALUE
<u>NO.</u>				
P3.1 Packaging & Shipping				
P3.1.1 Decon Level	Activity Surface (dpm/100 cm ²) Content (nanocuries/gm) Rad. Level (mR/hr) Total Curies	Fed. Regs.	3/4 Fed. Regs.	1/2 Fed. Regs.
P3.1.2 Shipping Containers & Transport Mode	Container Type	Fed. Regs.	Fed. Regs.	Increased container reliability
P3.1.3 Volume Reduction	Mass/vol.	No limits on mass/vol.	10% Theor. Density	50% Theor. Density
P3.2 Facility Condition				
P3.2.1 Decon Level	Activity	100 nanocuries/gm	10 nanocuries/gm with tear down	<10 nanocuries/gm with reuse
P4.1 Third Party Protection in Shipment				
P4.1.1 Product and Waste	Containment	Double Containment with Shielding	Escorted truck & current value	All rail shipment
P4.1.2 Raw Material	Containment	Exist. Regs. State & Fed.	Double containment	Double containment
P5 Facility Construction		Fed. Regs.	Fed. Regs.	Fed. Regs.

5.1 IMPLICATIONS FROM THE ATTRIBUTE SCALE

Since risk is an elusive quantity, it is not possible to relate the attribute value directly to a risk quantity. However, one may identify from the scales of measure, attitudes about potential reduction in risk and incentives for accepting an extreme value for a given attribute. The approach is to choose an intermediate value between current and extreme values as shown in Table 5.1. With the aid of Figure 5.1, several different attitudes may be derived depending on the relative differences between extreme value (EV), intermediate value (IV), and current value (CV). Beginning with the concept that the current value corresponds to a current risk (CR) value, ($CR > 0$), one may postulate possible directions toward lowering the risk. These vectors shown in Figure 5.1 are represented by five possible relationships between the three values; EV, IV, CV. The implications from these relationships are described in Table 5.2.

In the next section, discrete attribute values will be selected for a series of alternates which represent approaches to meeting SAF requirements. The ramifications of these attitudes become apparent in the choice of attribute values among a set of alternatives to lowering risk. If there are three values (CV, IV, EV) for a given attribute in Table 5.1 but the Task Force chooses only one value to use in a series of alternates the attitude is indicated by curve (3) in Figure 5.1. If there is only one value for a given attribute in Table 5.1 ($CV = IV = EV$) then a series of attributes has only one choice indicative of the attitude associated with curve (1). Both attitudes would indicate that technological development would be inappropriate but for different reasons. The attitudes of the Task Force for each of the attributes will be summarized in the next section.

FIGURE 5.1. Possible Relationships Between Attribute Values and Risk.

TABLE 5.2

POSSIBLE ATTITUDES FROM ATTRIBUTE VALUE CONDITIONS

ATTITUDE TYPE CURVE N	ATTRIBUTE CONDITION	ATTITUDE
1	$CV = IV = EV$	There is only one value and no distinction between EV and CV; therefore, current value is the best one can expect. No technological development is needed since current practice is sufficient.
2	$CV \neq IV$	A stepwise advance from CV to IV results in lower risk. Technological development is viewed as beneficial to lowering risk.
2a	$CV \neq IV \neq EV$	Stepwise advance from IV to EV results in further lowering of risk. Technological development to make IV or EV practical is beneficial to lowering risk.
2b	$CV \neq (IV \equiv EV)$	Special case where a step from CV to EV is possible but a final step from IV to EV is not considered as beneficial to lowering risk. Technological development of IV is beneficial but EV is not.
2c	$CV \neq IV \neq EV$ $(CV \equiv IV) \neq EV$	Special case where steps from CV to EV are possible but only a final step from IV to EV is considered beneficial to lowering risk.
3	$CV = IV = EV$	This contrasts with (1) where technological development improves attribute capability but there is no expectation of lowering risk. Risk in this case is determined by non-technological factors.

6.0 PLAUSIBLE ALTERNATIVES TO LOWERING RISK

Having defined attributes which are relevant to a SAF posture and having assigned a range of possible values to each attribute, it is necessary to organize these specific attribute values into a set of alternatives which can be used as a basis for a requirements analysis. The only constraint is that the specific attribute values should fall within the range of values shown in Table 5.1. Many alternatives may be envisioned; however, for ease of analysis, three alternatives have been selected.*

One possible approach is to equate the three alternatives to the three columns in Table 5.1 (i.e., Current Value, Intermediate Value, Extreme Value). However, because of the attitudes about the relationship between attribute value change and lowering of risk described in the previous section, it does not follow, necessarily, that one should accept this approach in generating alternatives.

To focus thought in general concepts, a list of principles which might depict the three levels of stringency were developed by the Task Force as a first step toward designing alternatives. These principles are shown in Table 6.1 (a), (b), and (c) for the corresponding three levels of alternatives.

For some principles, a possible process approach has been identified (i.e., remote maintenance vs contact maintenance) to indicate degree of stringency desired in the alternative. It does not follow that the identified process approach is the only process approach available for this alternative. Several process approaches may satisfy a given set of attribute values. This aspect of the requirements analysis will be discussed in a later report.

*Mathematically speaking an alternative may be viewed as a multidimensional vector, where each attribute is a component to a vector. These alternatives then represent three vectors in the dimension space which characterizes SAF.

To identify a specific set of attribute values for each alternative, the Task Force generated Table 6.2. This table lists each attribute, the attribute yardstick, and its assigned value for the three alternatives. These attribute values are candidate requirements for SAF. The collective set of attribute values in a given alternative represents components to a vector in SAF dimension space. The next step for the Task Force is to find the vector which represents the desired SAF posture based on attitudes of practicality and attitudes of effectiveness about lowering risk.

Examination of attribute value selection for the three alternatives indicates that a spectrum of attitudes discussed in Section 5.1 was evident in Table 6.2. The last column lists the indicated attitude relationship assigned in Table 5.2 and shown in Figure 5.1. The breakdown in attitude type was as follows:

<u>Attitude Type</u>	<u>Number of Attributes</u>
1	8
2(a)	16
2(b)	3
2(c)	8
3	<u>1</u>
Total	36

This breakdown suggests, in the judgement of the Task Force, that 27 (16+3+8) out of 36 attributes would contribute to a lower risk if appropriate technological development was carried out to make intermediate and extreme attribute values as practical as current attribute values.

Table 6.2, and supporting Tables 5.1 and 4.1 comprise the input data for a requirements analysis. The three attributes are to be evaluated in terms of practicality and reasonability based on the approach described in the next section.

TABLE 6.1(A)

ALTERNATIVE I - REFERENCE LEVEL

<u>PRINCIPLE - POSSIBLE FEATURE</u>	<u>TRIAL DESCRIPTORS/ATTRIBUTES/CHARACTERISTICS</u>
Operating Principle - Near Remote Operation	Contact Adjustments Allowed (Approp. Shielding) Approach During Emergency Sidestream (Contact as Approp.)
Maintenance Principle - Contact Maintenance	Contact Allowed Without Product In-Line (Time)(Exposure Rate) 10% of Yearly Exposure Allowance Or Go To Replaceable Module
Process & Material Control Principle - Control Around Each Function	1 MBA/Function, Process Parameters Monitored and Executed At Meter Position, Parameter Limits Controlled By Operating Procedure (Manual). Hold Times Consistent With Allowed Manual Support (Anal. Chem., QC) Operations.
Security Principle - Current Fed. Regs.	
Structural Design Principles - Current Fed. Regs.	Permanent Shielding Around Points of Storage. Portable Shielding Optional.
Management Principle - Approval Chains	1 Over 1 Starting at Functional Level 1 Accountability Manager/Facility Normal Management Practices
Employment Principle - Current Training Req.	
Inventory Storage Principle	No Limits On In-Process Storage

TABLE 6.1(B)

ALTERNATIVE II - MID LEVEL

<u>PRINCIPLE - POSSIBLE FEATURE</u>	<u>TRIAL DESCRIPTORS/ATTRIBUTES/CHARACTERISTICS</u>
Operating Principle - Remote Operation	Contact Manual Adjustments Allowed With Admin. Controls Approach During Emergency With Admin. Controls Contact On Sidestream Operations (Anal. Chem., Etc.) Allowed With Admin. Controls
Maintenance Principle - Maintenance	Contact Maintenance On Decontaminated Equipment Allowed. Standby Redundancy Or Modeling Replacement Allowed (Time) (Exposure Rate) 10% of Yearly Exp. Allowance
Process & Material Control Principle - Control Around Each Function	1 MBA/Function, Process Parameters Monitored Plus Executed At Meter/Control Point With Admin. Controls. Parameter Limits Controlled and Alarmed At Remote Control Site. Hold Times Consistent With Allowed Remote Support (Anal. Chem., Etc.) Operations. On-Line Analy- tical As Appropriate.
Security Principle - Anticipated Fed. Regs.	In-Plant Access Across MBA Boundary Monitored and Controlled
Structural Design Principles - Current Fed. Regs.	Permanent Shielding Around Points of Storage. Portable Shielding Optional.
Management Principle - Approval Chains	1 Over 1 Starting at Functional Level 1 Accountability Manager/Facility Normal Management Practices
Employment Principle - Stringent Training Req.	
Inventory Storage Principle	No Limits On In-Process Storage

TABLE 6.1(C)

ALTERNATIVE III - EXTENDED LEVEL

<u>PRINCIPLE - POSSIBLE FEATURE</u>	<u>TRIAL DESCRIPTORS/ATTRIBUTES/CHARACTERISTICS</u>
Operating Principle - Fully Remote Operations	Contact Manual Adjustments <u>Not</u> Allowed No Approach During Emergency No Contact On Sidestream Operations (Anal. Chem., Etc.)
Maintenance Principle - Remote Maintenance	Contact Maintenance On Decontaminated Equipment Allowed. Standby Redundancy Or Modular Replacement Allowed (Time) (Exposure Rate) 10% of Yearly Exp. Allowance
Process & Material Control Principle - Control Around Each Unit Operation Or Hold Point	1 MBA/Unit Operation Or Hold Point, Process Parameters And Execution At Control Point, Parameter Limits Control- led And Alarmed At Remote Control Site, Hold Times Con- sistent With Allowed Remote Support (Anal. Chem., Etc.) Operations. On-Line Analytical. Near "Real-Time" Accountability.
Security Principle - Anticipated Fed. Regs.	Strike Force In-Plant Access Across MBA Boundary Moni- tored And Controlled
Structural Design Principles - Current Fed. Regs.	Permanent Shielding Around Points of Storage. Portable Shielding Optional.
Management Principle - Approval Chains	1 Over 1 Starting At Or Above Functional Level 1 Accountability Manager/Facility Normal Management Practices Plus Outside Overseer Multi-Approved Computer Program Changes
Employment Principle - Stringent Training Req.	
In-Line Storage Principle	No Limits On In-Process Storage

TABLE 6.2
ATTRIBUTE MEASURE BY ALTERNATIVES

ATTRIBUTE TITLE	ATTRIBUTE YARDSTICK	ATTRIBUTE REQUIREMENT (MEASURE)			ATTITUDE
		I	II	III	
E-1.1.3	mRem/yr	5,000	2,500	1,000	2B
E-1.2	Fixed $\mu\text{Ci}/\text{ind.}/\text{isotope}$	Fed. Regs.	1/4 Fed Regs	1/4 Fed Regs.	2B
E-2.1 & 2.2	Coincidental events	2	2	2	3
E-2.3	% of Critical Mass	Inv. Control 2 Month	γ monitor cont.	γ monitor cont. all equipment geometrically safe	2A
E-3.1	Monitoring Freq.	1/Facility	1/Function	1/Work Station	2A
E-3.2	Procedure	Self Monitor Hand & Foot	Verified Hand & Foot	Verified 100% Body Surface	2A
E-4.1	Times/year	1	2	4	2C
E-4.2	Proficiency and requalification	Initial	Initial	Periodic (1/yr)	2C
E-4.3	Proficiency and requalification	1/Year	One type of emergency each quarter	All types of emergencies each quarter	2A
E-5.1.1	$\mu\text{Ci}/\text{cc}$	Fed. Reg.	Fed. Reg.	1/4 Fed. Reg.	2B
E-5.1.2 & 5.1.3	$\mu\text{Ci}/\text{cc}$	Fed. Reg.	Fed. Reg.	Fed. Reg.	1
E-5.2		Fed. & State Regs.	Fed. & State Regs.	Fed. & State Regs.	1
E-5.3	dpm/100 cm^2	Fed. Regs. (500 dpm)	1/2 Fed. Regs.	2X detectable limit above background	2A
P-1.1.1	Activity/Vol. & Act./time	Normal-Fed. Regs. Abnormal-Fed. Regs.	1/2 Fed. Regs. & CAM Fed. Regs.	1/2 Fed. Regs. & CAM Fed. Regs.	2A

TABLE 6.2 (Cont'd)

ATTRIBUTE TITLE	ATTRIBUTE YARDSTICK	ATTRIBUTE REQUIREMENT (MEASURE)			ATTITUDE
		I	II	III	
P-1.1.2 non-radioactive	ppm	Fed. & State Regs.	Fed. & State Regs.	Fed. & State Regs.	1
P-1.2.1	curies/vol/time	Fed. Reg.	1/2 Fed. Reg.	Zero (no. liq. discharge)	2A
P-1.2.2 non-radioactive	ppm	Fed. & State Regs.	Fed. & State Regs.	Fed. & State Regs.	1
P-1.3.1	curies/mass	Fed. Regs.	<100 nano- curies/gm TRU	<10 nanocuries/ gm TRU	2C
P-1.3.2 non-radioactive	ppm	Fed. & State Regs.	Fed. & State Regs.	Fed. & State Regs.	1
P2.1.1	No. of MBA/Facility	1/Facility	1/Function	1/Work Station	2A
P2.1.2.1	Inv. Period (days)	60	60	1/3 (near real-time)	2C
P-2.1.2.2	Response time to reconcile (days)	30	30	7	2C
P-2.1.4	LEID	0.5% of throughput	0.3% of throughput	< Trigger Quantity (0.1% of throughput)	2A
P-2.2.1.1	Personnel Detection	Perimeter Surveillance Picture Badge	Perim. & Inter. Surveillance Key Card	Increased Perim. & Inter. Positive Identification	2A
P-2.2.1.2	grams	0.5 gms/Pu	0.5 gms/Pu	2X Min. Detectable with Label	2A
P-2.2.1.3 (a) (incoming)	Mass	200 gms	200 gms	200 gms plus shape	2C
P-2.2.1.3 (b) (outgoing)	Mass (Shielding)	50 gms	50 gms	50 gms	1
P-2.2.1.4	Mass (TNT equiv.) gms	200	200	200	1
P-2.2.2	Time Delay/Intrusion Alarm	4 Barriers + Alarm	Add Barriers + Alarm	Strengthen Barriers + Alarm	2A

TABLE 6.2 (Cont'd)

ATTRIBUTE TITLE	ATTRIBUTE YARDSTICK	ATTRIBUTE REQUIREMENT (MEASURE)			ATTITUDE
		I	II	III	
P-2.2.3	No. of sets	Fed. Regs. 1 set	1 Set + CCTV + Response Team	1 Set + CCTV + Increased Response Team	2A
P-2.2.4	No. of teams	Local law Enforcement Agency = 1 team	1 Team + increased proficiency	Increased Proficiency + increased response team	2A
P-3.1.1	Surface (dpm/100 cm ²) Content (nanocuries/g) Rad. Level (mr/hr) Total Curies	Fed. Regs.	3/4 Fed. Regs.	1/2 Fed. Regs.	2A
P-3.1.2	Container Type	Fed. Regs.	Fed. Regs.	Increased Container Reliability	2C
P-3.1.3	Mass/Unit Vol.	No Limits On Mass/Vol.	10% Theor. Density	50% Theor. Density	2A
P-3.2.1	Activity	100 nano- curies/gm with tear- down	100 nanocuries/ gm with tear- down	<10 nanocuries/gm with reuse	2C
P-5	Facility Construction	Fed. Regs.	Fed. Regs.	Fed. Regs.	1

7.0 EVALUATION OF ALTERNATIVES

7.1 General Overview of Basis for Evaluating Alternatives

The alternative approaches to Secure Automated Fabrication identified in Section 6.0 represent vectors in "Secure Automated Fabrication" dimension space. Each vector has 36 components and selecting the "best" vector depends on criteria for evaluation of what is "best" for the whole system. Defining the "best" criteria is also subject to the objectives or purpose of the systems analysis. From an engineering standpoint "best" performance is the usual criteria, but this must be deferred until all requirements (process, product and SAF) are identified.

At this stage of the requirements analysis, the goal is to examine the merits of achieving SAF posture based on criteria involving practicality issues. The Task Force approach is to establish judgements on each attribute by responding to the following questions: (1) what operating penalties, if any, are associated with lowering risk? (2) what development costs are anticipated by lowering risk? and (3) what are chances of success once such a development effort has been completed? Responses to these questions are to be supplied by functional experts. By systematic examination of the functions to be performed, a system-wide perspective can be developed for selecting a set of attribute values which may be defined as SAF requirements.

To establish a basis for expert judgements, a functional flow analysis is being performed by the Task Force in parallel with the requirements analysis. The system has been divided into broad functions which in turn will be subdivided into smaller scope functions until they reach the lowest level of impact on SAF attributes. The abstract description of the final level of subdivision will provide justification for providing quantitative answers to the practicality issues involved in the evaluation of SAF attributes among the three alternatives.

The functional analysis for the fuel fabrication system has been divided into seven subfunctions and each subfunction has been assigned to a Task Force representative. Each of the seven subfunctions will be detailed in three states of existence: normal operating mode, maintenance mode, and Design Basis Accident (DBA) mode. These three steps of existence should provide the major events for which the attribute may be evaluated.

The functional analysis will be issued in a separate report later in the program and is viewed as a control document to be used after the system requirements analysis is complete. The functional analysis describes what is to be done. For each function there may be one or more process options and these options will be identified and evaluated in the second phase of the requirements analysis when all performance requirements (process, product, SAF) are identified.

7.2 Basis for Evaluation - Reaction Viewpoints

Each member of the Task Force was asked to supply several reaction viewpoints to the alternative choices of attribute values for his specific functional area.

Six reaction viewpoints were requested for each attribute relative to Alternate I:

1. The anticipated additional investment/operating cost.
2. The anticipated additional manpower.
3. The anticipated additional space.
4. The anticipated additional development funding.
5. The anticipated development time including demonstration period.
6. A subjective judgment about the chances of success if the above development activity is undertaken (3 if success is between 70 and 100%, 2 if success is between 30 and 70%, and 1 if success is between 10 and 30%).

In addition, each functional expert ranked the attributes in importance from his functional viewpoint where at least one attribute required the highest ranking of 10. The other attributes could be ranked from 1 to 10.

These reaction viewpoints formed the basis for comparison of operating and development costs among the alternate choices of attribute values. The ranking provided a comparison of the above costs between attributes. The input of these viewpoints from the seven functions provided a means of comparing cost impacts among major segments of the fuel fabrication system.

This arrangement of comparisons was used to construct a profile of cost impacts by attribute, by function and by priority of an attribute. A priority index was defined as the product of the ranking and the success factor (maximum value of 30 and minimum value of 1). Use of the priority index in the decision process will be developed in a later section. The reader is reminded that the purpose of these comparisons of the reaction viewpoints is to establish a scale for lowering risk in terms of cost burden among the alternative choices of attribute values. It is expected that Alternative III attribute values will require the largest cost burden relative to Alternative I values and Alternative II values will have an intermediate burden.

The seven functions of the fuel fabrication system are:

1. Conversion
2. Powder and Green Pellet
3. Sintering and Rod Loading
4. Assembly Fabrication
5. Scrap Recovery
6. Waste Treatment
7. Facility

The last function provided the necessary physical protection, supporting services, inventory storage and plant accountability system to allow the other six functions to perform production operations. Reaction viewpoints from certain attributes were expected only from Function 7 since the other functions had no impact. No reaction viewpoints were expected from attributes which had only one value for all three alternatives. Also no reaction viewpoints were expected from Alternative I as this was the reference case for comparison as described in an earlier section.

The expected reaction viewpoint value for these no-impact or Alternate I cases was zero except for the success factor. The success factors for the Alternate I case was 3 for all attributes, as expected. The input of the functional experts and results of the various reaction viewpoints are summarized in the subsequent sections.

7.3 Subjective Viewpoints - Ranking, Success Factor and Priority Index

The ranking of attributes for the seven functions and the average ranking value are shown in Table 7.1. The two highest average rankings were related to personnel exposure (E1.1.3 and E1.2). The next highest ranking was related to criticality of undetected holdup (E2.3). The lowest average rankings were related to non-nuclear discharge to the environment (P1.2.2 and P1.3.2). The other attributes had rankings more or less uniformly distributed between these extremes. Some of these intermediate rankings were the result of a dispersion in rankings among the functions. This situation could occur due to the attitudes of the functional expert and to the relative impact of the attribute on each function.

The success factors for the attributes and the average values are shown in Table 7.2(a) for Alternate II and 7.2(b) for Alternate III. As mentioned above, Alternate I was unanimously given a success factor of 3, an indication that present attribute values have a high degree of achievability. For Alternate II, no attribute was given a success factor of 1. The attribute receiving the lowest average value was P1.3.1 (activity level for solid waste discharge). For Alternate III, several attributes were assigned success factors of 1. The lowest average success factors were P1.3.1 and P2.1.4 (LEID for accountability). The next lowest average values were E5.1.1 (airborne concentration in-plant) and P2.1.2.1 (inventory frequency). These averages give a composite judgement that chances of success are near 50%.

The priority indices for Alternates II and III are shown in Tables 7.3(a) and (b), respectively. Alternate I priority indices have values three times the ranking value shown in Table 7.1. The average priority indices have been rounded to the nearest whole number. The average indices represent a composite priority and can be used to rank attributes in a cost burden analysis which subordinates an individual function's reaction in favor of a smeared reaction over all seven functions. Since various attributes impact differently on each function, it may be important to preserve the priority index for each function. Listing cost burdens by individual priority index might result in one function feeling an intolerable burden for Alternate III for a given

TABLE 7.1

RANKING FACTORS

Attribute	Function							Avg.
	1	2	3	4	5	6	7	
E1.1.3	10	10	10	9	10	9	10	9.71
E1.2	10	5	10	9	10	10	10	9.14
E2.1&2.2	10	8	9	10	1	7	9	7.71
E2.3	10	8	9	10	6	7	10	8.57
E3.1	5	1	5	7	3	9	7	5.29
E3.2	9	1	7	9	5	10	9	7.14
E4.1	7	3	8	8	7	9	8	7.14
E4.2	5	7	6	8	6	7	8	6.71
E4.3	5	3	6	8	6	9	7	6.86
E5.1.1	5	5	5	6	5	10	7	6.14
E5.1.2&5.1.3	7	5	8	8	7	10	7	7.43
E5.2	2	4	2	7	3	8	8	4.86
E5.3	3	1	4	6	5	7	6	4.57
P1.1.1.1	6	5	8	9	3	9	9	7.29
P1.1.1.2	1	1	1	2	2	4	3	2.83
P1.2.1	5	5	1	9	3	9	9	5.86
P1.2.2	1	1	1	2	2	4	2	1.86
P1.3.1	5	5	1	9	3	9	9	5.86
P1.3.2	1	1	1	2	2	4	2	1.86
P2.1.1.1	8	3	2	5	4	3	3	4.33
P2.1.1.2.1	8	3	3	5	5	3	3	4.57
P2.1.1.2.2	4	1	3	5	3	3	3	3.43
P2.1.4	7	8	1	6	7	3	3	5.29
P2.2.1.1	4	1	4	9	6	5	3	5.43
P2.2.1.1.2	8	1	7	9	8	5	3	6.71
P2.2.1.1.3 ^a	5	1	6	7	6	2	3	5.14
P2.2.1.1.3 ^b	5	1	4	8	8	2	3	4.86
P2.2.1.1.4	4	1	8	9	8	2	3	5.57
P2.2.2	2	7	4	6	2	1	3	4.33
P2.2.3	4	1	4	8	2	1	7	3.86
P2.2.4	2	1	1	6	2	1	3	2.57
P3.1.1.1	1	4	2	7	2	7	5	4.33
P3.1.1.2	1	1	2	7	2	7	5	3.86
P3.1.1.3	2	1	1	5	4	7	4	3.43
P3.2.1	4	8	4	4	5	7	3	5.29
P5	7	8	8	10	6	6	10	7.86

TABLE 7.2(a)

SUCCESS FACTORS - ALTERNATE II

Attribute	Function							Avg.
	1	2	3	4	5	6	7	
F1.1.3	2	3	3	3	3	3	3	2.86
F1.2	2	2	3	3	3	3	3	2.71
F2.1&2.2	3	3	3	3	3	3	3	3.00
F2.3	2	3	3	3	2	3	3	2.71
F3.1	3	3	3	3	3	3	3	3.00
F3.2	3	3	3	3	3	3	3	3.00
F4.1	3	3	3	3	3	3	3	3.00
F4.2	3	3	3	3	3	3	3	3.00
F4.3	3	3	3	3	3	3	3	3.00
F5.1.1	3	3	3	3	3	3	3	3.00
F5.1.2&5.1.3	3	3	3	3	3	3	3	3.00
F5.2	3	3	3	3	3	3	3	3.00
F5.3	3	3	3	3	3	3	3	3.00
P1.1.1	3	3	3	3	3	3	3	3.00
P1.1.2	3	3	3	3	3	3	3	3.00
P1.2.1	3	3	3	3	3	3	3	3.00
P1.2.2	3	3	3	3	3	3	3	3.00
P1.3.1	2	3	3	3	2	3	2	2.57
P1.3.2	3	3	3	3	3	3	3	3.00
P2.1.1	3	3	3	3	3	2	3	2.86
P2.1.2.1	3	3	3	3	3	3	3	3.00
P2.1.2.2	3	3	3	3	3	3	3	3.00
P2.1.4	2	3	3	3	2	3	3	2.71
P2.2.1.1	3	3	3	3	3	3	3	3.00
P2.2.1.2	3	3	3	3	3	3	3	3.00
P2.2.1.3a	3	3	3	3	3	3	3	3.00
P2.2.1.3b	3	3	3	3	3	3	3	3.00
P2.2.1.4	3	3	3	3	3	3	3	3.00
P2.2.2	3	3	3	3	3	3	3	3.00
P2.2.3	3	3	3	3	3	3	3	3.00
P2.2.4	3	3	3	3	3	3	3	3.00
P3.1.1	3	3	3	3	3	3	3	3.00
P3.1.2	3	3	3	3	3	3	3	3.00
P3.1.3	3	3	3	3	3	3	3	3.00
P3.2.1	3	3	3	3	3	3	3	3.00
P5	3	3	3	3	3	3	3	3.00

TABLE 7.2(b)

SUCCESS FACTORS - ALTERNATE III

Attribute	Function							Avg.
	1	2	3	4	5	6	7	
E1.1.3	2	2	2	3	2	3	3	2.43
E1.2	2	2	3	3	3	3	3	2.71
E2.1&2.2	3	3	3	3	3	3	3	3.00
E2.3	1	3	3	3	1	3	3	2.43
E3.1	3	3	3	3	3	3	3	3.00
E3.2	3	3	3	3	3	3	2	2.86
E4.1	3	3	3	3	3	3	3	3.00
E4.2	3	3	3	3	3	3	3	3.00
E4.3	3	3	3	3	3	3	3	3.00
E5.1.1	1	3	2	3	1	3	3	2.29
E5.1.2&5.1.3	3	3	3	3	3	3	3	3.00
E5.2	3	3	3	3	3	3	3	3.00
E5.3	3	3	3	3	2	3	3	2.86
P1.1.1	3	3	3	3	3	3	3	3.00
P1.1.2	3	3	3	3	3	3	3	3.00
P1.2.1	3	3	3	3	3	3	3	3.00
P1.2.2	3	3	3	3	3	3	3	3.00
P1.3.1	1	3	3	3	1	2	2	2.14
P1.3.2	3	3	3	3	3	3	3	3.00
P2.1.1	3	3	3	3	3	2	3	2.86
P2.1.2.1	1	3	1	3	3	2	3	2.29
P2.1.2.2	3	3	3	3	3	3	1	2.71
P2.1.4	1	3	1	3	1	3	3	2.14
P2.2.1.1	3	3	3	3	3	3	3	3.00
P2.2.1.2	3	3	3	3	3	3	2	2.86
P2.2.1.3 ^a	3	3	3	3	3	3	3	3.00
P2.2.1.3 ^b	3	3	3	3	3	3	3	3.00
P2.2.1.4	3	3	3	3	3	3	3	3.00
P2.2.2	3	3	3	3	3	3	3	3.00
P2.2.3	3	3	3	3	3	3	3	3.00
P2.2.4	3	3	3	3	3	3	3	3.00
P3.1.1	3	3	3	3	3	3	3	3.00
P3.1.2	3	3	3	3	3	3	1	2.71
P3.1.3	3	3	3	3	3	3	3	3.00
P3.2.1	3	3	3	3	3	3	3	3.00
P5	3	3	3	3	3	3	3	3.00

TABLE 7.3(a)

PRIORITY INDEX - ALTERNATE II

Attribute	Function							Avg.
	1	2	3	4	5	6	7	
E1.1.3	20	30	30	27	30	27	30	28
E1.2	20	10	30	27	30	30	30	26
E2.1&2.2	30	24	27	30	3	21	27	23
E2.3	20	24	27	30	12	21	30	23
E3.1	15	3	15	21	3	27	21	16
E3.2	27	3	21	27	15	30	27	21
E4.1	21	3	24	24	21	27	24	21
E4.2	15	21	18	24	18	21	24	20
E4.3	15	3	18	24	18	18	21	18
E5.1.1	15	15	15	18	15	30	21	18
E5.1.2&5.1.3	21	15	24	24	21	30	21	22
E5.2	6	12	6	21	3	24	24	15
E5.3	3	3	12	18	15	21	18	14
P1.1.1	18	15	24	27	3	27	27	21
P1.1.2	3	3	3	6	3	12	3	6
P1.2.1	15	15	3	27	3	27	27	18
P1.2.2	3	3	3	6	3	12	3	6
P1.3.1	18	15	3	27	3	27	18	16
P1.3.2	3	3	3	6	3	12	3	6
P2.1.1	24	3	3	15	12	6	3	12
P2.1.2.1	24	3	3	15	15	3	15	14
P2.1.2.2	12	3	3	15	3	3	15	12
P2.1.4	14	24	3	18	14	3	15	14
P2.2.1.1	12	3	12	27	18	15	27	16
P2.2.1.2	24	3	21	27	24	15	27	22
P2.2.1.3a	15	3	18	21	18	3	27	16
P2.2.1.3b	15	3	12	24	18	3	24	16
P2.2.1.4	12	3	24	27	18	3	27	17
P2.2.2	6	21	12	18	6	3	18	12
P2.2.3	12	3	12	24	3	3	21	12
P2.2.4	6	3	3	18	3	3	15	8
P3.1.1	3	12	3	21	3	21	15	12
P3.1.2	3	3	3	21	3	21	15	11
P3.1.3	6	3	3	15	12	21	12	12
P3.2.1	12	24	12	12	15	21	15	16
P5	21	24	24	30	18	18	30	24

Priority Index = Importance x Chance of Success

TABLE 7.3(b)

PRIORITY INDEX - ALTERNATE III

Attribute	Function							Avg.
	1	2	3	4	5	6	7	
E1.1.3	20	20	20	27	20	27	30	23
E1.2	20	10	30	27	30	30	30	25
E2.1&2.2	30	24	27	30	3	21	27	23
E2.3	10	24	27	30	6	21	30	21
E3.1	15	3	15	21	9	27	21	16
E3.2	27	3	21	27	15	30	18	20
E4.1	21	9	24	24	21	27	24	21
E4.2	15	21	18	24	18	21	24	20
E4.3	15	9	18	24	18	18	21	18
E5.1.1	5	15	10	18	5	30	21	15
E5.1.2&5.1.3	21	15	24	24	21	30	21	22
E5.2	6	12	6	21	9	24	24	15
E5.3	9	3	12	18	10	21	18	13
P1.1.1	18	15	24	27	9	27	27	21
P1.1.2	3	3	3	6	6	12	9	6
P1.2.1	15	15	3	27	9	27	27	18
P1.2.2	3	3	3	6	6	12	6	6
P1.3.1	5	15	3	27	3	18	18	13
P1.3.2	3	3	3	6	6	12	6	6
P2.1.1	24	9	6	15	12	6	9	12
P2.1.2.1	8	9	3	15	15	6	15	10
P2.1.2.2	12	3	9	15	9	9	5	9
P2.1.4	7	24	1	18	7	9	15	12
P2.2.1.1	12	3	12	27	18	15	27	16
P2.2.1.2	24	3	21	27	24	15	18	19
P2.2.1.3a	15	3	18	21	18	6	27	15
P2.2.1.3b	15	3	12	24	18	6	24	15
P2.2.1.4	12	3	24	27	18	6	27	17
P2.2.2	6	21	12	18	6	3	18	12
P2.2.3	12	3	12	24	6	3	21	12
P2.2.4	8	3	3	18	6	3	15	8
P3.1.1	3	12	6	21	6	21	15	12
P3.1.2	3	3	6	21	6	21	5	9
P3.1.3	6	3	3	15	12	21	12	10
P3.2.1	12	24	12	12	15	21	15	16
P5	21	24	24	30	18	18	30	24

Priority Index = Importance x Chance of Success

attribute whereas another function would be satisfied with the burden for Alternate III. The distinctions between the use of average (or composite) priority index and individual priority index will be discussed in Section 7.6.

7.4 Operating Cost Viewpoints

Three reaction viewpoints which relate to an operating cost burden are investment, manpower and space. These reaction viewpoints are summarized in Appendix E by attribute and by function for Alternates II and III. The relevant cost burden is a combination of these three viewpoints. The task force converted these three inputs to an annual operating cost burden in the following fashion:

$$\text{Annual Operating Cost} = \frac{\text{Investment}}{7 \times 10^6} + \frac{25000(\text{Manpower})}{10^6} + \frac{10^3(\text{Area})}{30 \times 10^6}$$

The annual operating cost (in millions of dollars) is the sum of investment, manpower and space in equivalent dollars. Investment was depreciated over a seven year life. Space was depreciated over a 30 year life at an initial cost of \$1000/sq. ft. Manpower costs were estimated at \$25000/yr.

The total operating cost burden for Alternate II relative to Alternate I was \$15.4M and for Alternate III relative to I was \$54.8M. These values were based on a production rate scale of 150 MTHM/yr. Therefore, corresponding cost of product burden is \$100/Kg and \$361/Kg for Alternates II and III, respectively.

The attributes which contribute most to the Alternate II and III cost burden are E1.1.3 and E1.2 (personnel exposure). The values are shown in Tables 7.4(a) for II and 7.4(b) for III.

7.5 Development Cost Viewpoints

Two reaction viewpoints which relate to development are the cost and time to complete the development. The development cost by attribute and function is shown in Table 7.5(a) for Alternate II and Table 7.5(b) for Alternate III. The total cost was \$55M for II and \$439M for III. Over half the development cost in Alternate III was attributed to the Accountability attributes, P2.1.4 and P2.1.2.1. It is noted that these attributes did not have the highest priority indices.

TABLE 7.4(a)

ANNUAL OPERATING COST (M \$) - ALTERNATE II

Attribute	Function							Total	Cum. Total
	1	2	3	4	5	6	7		
E1.1.3	0.908	0.321	0.453	0.056	1.575	1.97	2.21	7.491	7.491
E1.2	0.	0.223	0.592	0.	1.793	*	0.	2.608	10.099
E2.1&2.2	0.	0.	0.	0.	0.	0.	0.	0.	10.099
E2.3	0.1	0.014	0.025	0.024	0.193	0.042	0.	0.398	10.497
E3.1	0.0001	0.	0.006	0.01	0.	0.	0.114	0.131	10.628
E3.2	0.	0.	0.	0.	0.	0.	0.108	0.108	10.736
E4.1	0.025	0.	0.013	0.01	0.004	0.005	0.025	0.082	10.818
E4.2	0.	0.	0.	0.	0.	0.	0.	0.	10.818
E4.3	0.003	0.	0.003	0.0006	0.001	0.0005	0.	0.007	10.825
E5.1.1	0.	0.	0.	0.	0.	*	0.	0.	10.825
E5.1.2&5.1.3	0.	0.	0.	0.	0.	0.	0.	0.	10.825
E5.2	0.	0.	0.	0.	0.	0.	0.	0.	10.825
E5.3	0.	0.	0.025	0.	1.504	0.025	0.	1.554	12.379
P1.1.1	0.	0.	0.	0.	0.	0.	0.	0.	12.379
P1.1.2	0.	0.	0.	0.	0.	0.	0.	0.	12.379
P1.2.1	0.	0.	0.	0.	0.	0.27	0.	0.27	12.649
P1.2.2	0.	0.	0.	0.	0.	0.	0.	0.	12.649
P1.3.1	0.	0.	*	0.	0.	0.323	0.394	0.717	13.366
P1.3.2	0.	0.	0.	0.	0.	0.	0.	0.	13.366
P2.1.1	0.	0.	0.18	0.	0.	0.11	0.	0.27	13.636
P2.1.2.1	0.	0.	0.	0.	0.	0.	0.	0.	13.636
P2.1.2.2	0.	0.	0.	0.	0.	0.	0.	0.	13.636
P2.1.4	0.143	0.	0.	0.	0.293	0.	0.	0.438	14.072
P2.2.1.1	0.	0.	0.	0.	0.	0.	0.371	0.371	14.443
P2.2.1.2	0.	0.	0.	0.	0.	0.	0.	0.	14.443
P2.2.1.3a	0.	0.	0.	0.	0.	0.	0.	0.	14.443
P2.2.1.3b	0.	0.	0.	0.	0.	0.	0.	0.	14.443
P2.2.1.4	0.	0.	0.	0.	0.	0.	0.	0.	14.443
P2.2.2	0.	0.	0.	0.	0.	0.	0.014	0.014	14.457
P2.2.3	0.	0.	0.	0.	0.	0.	0.61	0.61	15.067
P2.2.4	0.	0.	0.	0.	0.	0.	0.2	0.2	15.267
P3.1.1	0.	0.	0.	0.	0.	0.	0.	0.	15.267
P3.1.2	0.	0.	0.	0.	0.	0.	0.176	0.176	15.443
P3.1.3	0.	0.	0.	0.	0.	0.	0.	0.	15.443
P3.2.1	0.	0.	0.	0.	0.	0.	0.	0.	15.443
PS	0.	0.	0.	0.	0.	0.	0.	0.	15.443

Total 1.177 0.558 1.277 0.181 5.363 2.745 4.222

* Funct. 3 Groups E2.3/P1.3.1 & Funct. 8 Groups E1.1.3/E1.2/E5.1.1

TABLE 7.4(b)

ANNUAL OPERATING COST (M \$) - ALTERNATE III

Attribute	Function							Total	Cum. Total
	1	2	3	4	5	6	7		
E1.1.3	1.279	1.031	10.733	0.14	2.293	10.440	3.1	29.024	29.024
E1.2	0.	0.233	0.592	0.	1.793	*	0.	2.607	31.631
E2.1&2.2	0.	0.	0.	0.	0.	0.	0.	0.	31.631
E2.3	0.257	0.014	0.034	0.031	1.529	0.120	0.043	2.035	33.667
E3.1	0.002	0.	0.049	0.055	-0.033	0.051	0.257	0.301	34.048
E3.2	0.357	0.	0.	0.	0.025	0.	0.200	0.67	34.710
E4.1	0.073	0.	0.025	0.020	0.012	0.013	0.05	0.2	34.910
E4.2	0.110	0.	0.113	0.013	0.021	0.005	0.	0.269	35.107
E4.3	0.000	0.	0.013	0.003	0.004	0.002	0.	0.029	35.216
E5.1.1	0.000	0.	*	0.	0.126	*	0.036	0.167	35.303
E5.1.2&5.1.3	0.	0.	0.	0.	0.	0.	0.	0.	35.303
E5.2	0.	0.	0.	0.	0.	0.	0.	0.	35.303
E5.3	0.	0.	0.106	0.025	1.064	0.103	0.029	2.127	37.51
P1.1.1	0.	0.	0.	0.	0.	0.	0.	0.	37.51
P1.1.2	0.	0.	0.	0.	0.	0.	0.	0.	37.51
P1.2.1	0.	0.	*	0.	0.	1.25	0.	1.25	38.76
P1.2.2	0.	0.	0.	0.	0.	0.	0.	0.	38.76
P1.3.1	0.	0.	0.	0.	0.	0.629	0.49	1.119	39.879
P1.3.2	0.	0.	0.	0.	0.	0.	0.	0.	39.879
P2.1.1	0.0004	0.	0.675	0.090	0.459	0.643	0.	1.874	41.753
P2.1.2.1	0.314	1.143	1.405	0.210	-0.116	0.299	0.104	3.446	45.199
P2.1.2.2	0.	0.	0.	0.075	0.	0.	0.075	0.15	45.350
P2.1.4	0.500	0.	1.405	0.	1.729	0.	0.	3.0	49.150
P2.2.1.1	0.	0.	0.	0.002	0.	0.	1.007	1.009	50.240
P2.2.1.2	0.	0.	0.	0.	0.	0.	0.071	0.071	50.311
P2.2.1.3a	0.	0.	0.	0.	0.	0.	0.014	0.014	50.325
P2.2.1.3b	0.	0.	0.	0.	0.	0.	0.	0.	50.325
P2.2.1.4	0.	0.	0.	0.	0.	0.	0.	0.	50.325
P2.2.2	0.	0.	0.	0.	0.	0.	0.071	0.071	50.396
P2.2.3	0.	0.	0.	0.	0.	0.	0.024	0.024	51.22
P2.2.4	0.	0.	0.	0.	0.	0.	0.5	0.5	15.72
P3.1.1	0.	0.	0.	0.	0.	0.	0.	0.	51.72
P3.1.2	0.	0.	0.	0.	0.	0.1	0.89	0.99	52.711
P3.1.3	0.	0.	0.	0.	0.	1.424	0.477	1.901	54.611
P3.2.1	0.	0.	0.096	0.096	0.	0.	*	0.192	54.803
P5	0.	0.	0.	0.	0.	0.	0.	0.	54.803

Total 2.999 2.411 15.405 0.063 9.705 15.094 0.326

* Funot. 3 Groups E1.1.3/E5.1.1 & E2.3/P1.2.1

Funot. 8 Groups E1.1.3/E1.2/E5.1.1 & P2.1.1/P2.1.2.1(Men Only)

Funot. 7 Groups E3.1.3/P3.2.1

TABLE 7.5(a)

DEVELOPMENT COST (M \$) - ALTERNATE II

Attribute	Function							Total	Cum. Total
	1	2	3	4	5	6	7		
E1.1.3	3.	2.	5.	0.	3.	0.	0.	13.	13.
E1.2	0.	5.	0.5	0.	3.	0.	0.	0.5	21.5
E2.1&2.2	0.	0.	0.	0.	0.	0.	0.	0.	21.5
E2.3	2.	0.	0.	0.	2.	0.	0.	4.	25.5
E3.1	0.	0.	0.	0.	0.	0.	0.	0.	25.5
E3.2	0.	0.	0.	0.	0.	0.	0.	0.	25.5
E4.1	0.	0.	0.	0.	0.	0.	0.	0.	25.5
E4.2	0.	0.	0.	0.	0.	0.	0.	0.	25.5
E4.3	0.	0.	0.	0.	0.	0.	0.	0.	25.5
E5.1.1	0.	0.	0.	0.	0.	0.	0.	0.	25.5
E5.1.2&5.1.3	0.	0.	0.	0.	0.	0.	0.	0.	25.5
E5.2	0.	0.	0.	0.	0.	0.	0.	0.	25.5
E5.3	0.	0.	0.	0.	1.5	0.	0.	1.5	27.
P1.1.1	0.	0.	0.	0.	0.	0.	0.	0.	27.
P1.1.2	0.	0.	0.	0.	0.	0.	0.	0.	27.
P1.2.1	0.	0.	0.	0.	0.	0.	0.	0.	27.
P1.2.2	0.	0.	0.	0.	0.	0.	0.	0.	27.
P1.3.1	0.	0.	0.	0.	0.	3.	3.	6.	33.
P1.3.2	0.	0.	0.	0.	0.	0.	0.	0.	33.
P2.1.1	0.	0.	0.	0.	0.	10.	0.	10.	43.
P2.1.2.1	0.	0.	0.	0.	0.	0.	0.	0.	43.
P2.1.2.2	0.	0.	0.	0.	0.	0.	0.	0.	43.
P2.1.4	10.	0.	0.	0.	2.	0.	0.	12.	55.
P2.2.1.1	0.	0.	0.	0.	0.	0.	0.	0.	55.
P2.2.1.2	0.	0.	0.	0.	0.	0.	0.	0.	55.
P2.2.1.3a	0.	0.	0.	0.	0.	0.	0.	0.	55.
P2.2.1.3b	0.	0.	0.	0.	0.	0.	0.	0.	55.
P2.2.1.4	0.	0.	0.	0.	0.	0.	0.	0.	55.
P2.2.2	0.	0.	0.	0.	0.	0.	0.	0.	55.
P2.2.3	0.	0.	0.	0.	0.	0.	0.	0.	55.
P2.2.4	0.	0.	0.	0.	0.	0.	0.	0.	55.
P3.1.1	0.	0.	0.	0.	0.	0.	0.	0.	55.
P3.1.2	0.	0.	0.	0.	0.	0.	0.	0.	55.
P3.1.3	0.	0.	0.	0.	0.	0.	0.	0.	55.
P3.2.1	0.	0.	0.	0.	0.	0.	0.	0.	55.
P5	0.	0.	0.	0.	0.	0.	0.	0.	55.
Total	15.000	7.000	5.500	0.000	11.500	13.000	3.000		

TABLE 7.5(b)
DEVELOPMENT COST (M \$) - ALTERNATE III

Attribute	Function							Total	Cum. Total
	1	2	3	4	5	6	7		
E1.1.3	6.	2.75	15.	0.55	3.	0.	0.	27.3	27.3
E1.2	0.	5.	0.5	0.	3.	0.	0.	0.5	35.8
E2.1&2.2	0.	0.	0.	0.	0.	0.	0.	0.	35.8
E2.3	20.	0.	3.	0.	20.	0.	0.	43.	78.8
E3.1	0.	0.	0.	0.	0.	0.	0.	0.	78.8
E3.2	0.	0.	0.	0.	0.	0.	1.	1.	79.8
E4.1	0.	0.	0.	0.	0.	0.	0.	0.	79.8
E4.2	0.	0.	1.	0.	0.	0.	0.	1.	80.8
E4.3	0.	0.	0.	0.	0.	0.	0.	0.	80.8
E5.1.1	0.4	5.	*	0.	0.45	0.	0.5	6.35	87.15
E5.1.2&5.1.3	0.	0.	0.	0.	0.	0.	0.	0.	87.15
E5.2	0.	0.	0.	0.	0.	0.	0.	0.	87.15
E5.3	0.	0.	0.	0.	2.	0.	0.3	2.3	89.45
P1.1.1	0.	0.	0.	0.	0.	0.	0.	0.	89.45
P1.1.2	0.	0.	0.	0.	0.	0.	0.	0.	89.45
P1.2.1	0.	0.	*	0.	0.	0.	0.	0.	89.45
P1.2.2	0.	0.	0.	0.	0.	0.	0.	0.	89.45
P1.3.1	0.	0.	0.	0.	0.	5.	3.	8.	97.45
P1.3.2	0.	0.	0.	0.	0.	0.	0.	0.	97.45
P2.1.1	0.	0.	0.	0.	0.	12.	0.	12.	109.45
P2.1.2.1	20.	5.	00.	0.	0.	20.	0.	125.	234.45
P2.1.2.2	0.	0.	0.	0.	0.	0.	0.	0.	234.45
P2.1.4	10.	0.	100.	0.	20.	0.	0.	190.	424.45
P2.2.1.1	0.	0.	0.	0.	0.	0.	0.	0.	424.45
P2.2.1.2	0.	0.	0.	0.	0.	0.	0.5	0.5	424.95
P2.2.1.3a	0.	0.	0.	0.	0.	0.	0.1	0.1	425.05
P2.2.1.3b	0.	0.	0.	0.	0.	0.	0.	0.	425.05
P2.2.1.4	0.	0.	0.	0.	0.	0.	0.	0.	425.05
P2.2.2	0.	0.	0.	0.	0.	0.	0.	0.	425.05
P2.2.3	0.	0.	0.	0.	0.	0.	0.	0.	425.05
P2.2.4	0.	0.	0.	0.	0.	0.	0.	0.	425.05
P3.1.1	0.	0.	0.	0.	0.	0.	0.	0.	425.05
P3.1.2	0.	0.	0.	0.	0.	0.	3.	3.	428.05
P3.1.3	0.	0.	0.	0.	0.	10.	1.	11.	439.05
P3.2.1	0.	0.	0.	0.	0.	0.	*	0.	439.05
P5	0.	0.	0.	0.	0.	0.	0.	0.	439.05

Total 56.40 17.75 259.50 0.55 40.45 47.00 9.40

* Funot. 3 Groupe E1.1.3/E5.1.1 & E2.3/P1.2.1

Funot. 7 Groupe P3.1.3/P3.2.1

Estimates of the development times by attribute and function for Alternates II and III are shown in Tables 7.6(a) and 7.6(b), respectively. The maximum development times were 10 years except in a few instances where 20 years was estimated.

7.6 Basis for Selection of Attribute Values

7.6.1 Establishing Lowest Risk Posture

As discussed in Section 6.0, the attitudes of risk mitigation are implied in the choice of alternate values ranging from the present value (Alternate I) to an extended value (Alternate III). Clearly, where a choice is available, Alternate III would be preferred to establish a lower risk posture.

However, choices must also be made between attributes. The task force used the priority index as a measure of this importance. Selection would favor, therefore, assignment of Alternate III values to attributes with the highest priority index and Alternate II or I values to attributes with a lower priority index. Any given combination of choices would result in a given operating and development cost burden. This approach may be applied in two ways. The priority indices for each attribute may be averaged over all functions to obtain a composite ranking. Selection of one attribute value then results in a cost burden contributed by all functions for the same alternate level. Alternatively, the priority index of an attribute assigned by a given function may be preserved and all cost burdens associated with a given priority index accumulated. In this latter case, each function might have separately assigned attribute values of varying alternate levels. The first case will be defined as the composite selection method and the last case as the individual selection method. The process used ultimately in the selection by the Task Force will be described later.

7.6.2 Selection Based on Operating Cost Burden

To establish the impact of a given set of selected attribute values, the Task Force preferred initially to use the individual selection method based on operating cost burden. The selection of attribute values could range from all Alternate I choices having no incremental operating cost burden, to all Alternate II choices having an incremental annual cost burden of \$15.4M, or to all Alternate III choices having an incremental annual cost burden of

TABLE 7.6(a)

DEVELOPMENT TIME (YEARS) - ALTERNATE II

Attribute	Function						
	1	2	3	4	5	6	7
E1.1.1	10.	4.	4.	0.	20.	0.	0.
E1.2	0.	5.	3.	0.	10.	0.	0.
E2.1&2.2	0.	0.	0.	0.	0.	0.	0.
E2.3	10.	0.	0.	0.	10.	0.	0.
E3.1	0.	0.	0.	0.	0.	0.	0.
E3.2	0.	0.	0.	0.	0.	0.	0.
E4.1	0.	0.	0.	0.	0.	0.	0.
E4.2	0.	0.	0.	0.	0.	0.	0.
E4.3	0.	0.	0.	0.	0.	0.	0.
E5.1.1	0.	0.	0.	0.	0.	0.	0.
E5.1.2&5.1.3	0.	0.	0.	0.	0.	0.	0.
E5.2	0.	0.	0.	0.	0.	0.	0.
E5.3	0.	0.	0.	0.	10.	0.	0.
P1.1.1	0.	0.	0.	0.	0.	0.	0.
P1.1.2	0.	0.	0.	0.	0.	0.	0.
P1.2.1	0.	0.	0.	0.	0.	0.	0.
P1.2.2	0.	0.	0.	0.	0.	0.	0.
P1.3.1	0.	0.	0.	0.	0.	3.	5.
P1.3.2	0.	0.	0.	0.	0.	0.	0.
P2.1.1	0.	0.	0.	0.	0.	3.	0.
P2.1.2.1	0.	0.	0.	0.	0.	0.	0.
P2.1.2.2	0.	0.	0.	0.	0.	0.	0.
P2.1.4	5.	0.	0.	0.	10.	0.	0.
P2.2.1.1	0.	0.	0.	0.	0.	0.	0.
P2.2.1.2	0.	0.	0.	0.	0.	0.	0.
P2.2.1.3a	0.	0.	0.	0.	0.	0.	0.
P2.2.1.3b	0.	0.	0.	0.	0.	0.	0.
P2.2.1.4	0.	0.	0.	0.	0.	0.	0.
P2.2.2	0.	0.	0.	0.	0.	0.	0.
P2.2.3	0.	0.	0.	0.	0.	0.	0.
P2.2.4	0.	0.	0.	0.	0.	0.	0.
P3.1.1	0.	0.	0.	0.	0.	0.	0.
P3.1.2	0.	0.	0.	0.	0.	0.	0.
P3.1.3	0.	0.	0.	0.	0.	0.	0.
P3.2.1	0.	0.	0.	0.	0.	0.	0.
P5	0.	0.	0.	0.	0.	0.	0.

TABLE 7.6(b)

DEVELOPMENT TIME (YEARS) - ALTERNATE III

Attribute	Function						
	1	2	3	4	5	6	7
E1.1.3	10.	6.	12.	0.5	10.	0.	0.
E1.2	0.	5.	3.	0.	10.	0.	0.
E2.1&2.2	0.	0.	0.	0.	0.	0.	0.
E2.3	10.	0.	3.	0.	10.	0.	0.
E3.1	0.	0.	0.	0.	0.	0.	0.
E3.2	0.	0.	0.	0.	0.	0.	5.
E4.1	0.	0.	0.	0.	0.	0.	0.
E4.2	0.	0.	3.	0.	0.	0.	0.
E4.3	0.	0.	0.	0.	0.	0.	0.
E5.1.1	5.	5.	*	0.	5.	0.	2.
E5.1.2&5.1.3	0.	0.	0.	0.	0.	0.	0.
E5.2	0.	0.	0.	0.	0.	0.	0.
E5.3	0.	0.	0.	0.	10.	0.	0.1
P1.1.1	0.	0.	0.	0.	0.	0.	0.
P1.1.2	0.	0.	0.	0.	0.	0.	0.
P1.2.1	0.	0.	*	0.	0.	0.	0.
P1.2.2	0.	0.	0.	0.	0.	0.	0.
P1.3.1	0.	0.	0.	0.	0.	5.	5.
P1.3.2	0.	0.	0.	0.	0.	0.	0.
P2.1.1	0.	0.	0.	0.	0.	4.	0.
P2.1.2.1	0.	5.	20.	0.	0.	5.	0.
P2.1.2.2	0.	0.	0.	0.	0.	0.	0.
P2.1.4	5.	0.	20.	0.	10.	0.	0.
P2.2.1.1	0.	0.	0.	0.	0.	0.	0.
P2.2.1.2	0.	0.	0.	0.	0.	0.	5.
P2.2.1.3a	0.	0.	0.	0.	0.	0.	2.
P2.2.1.3b	0.	0.	0.	0.	0.	0.	0.
P2.2.1.4	0.	0.	0.	0.	0.	0.	0.
P2.2.2	0.	0.	0.	0.	0.	0.	0.
P2.2.3	0.	0.	0.	0.	0.	0.	0.
P2.2.4	0.	0.	0.	0.	0.	0.	0.
P3.1.1	0.	0.	0.	0.	0.	0.	0.
P3.1.2	0.	0.	0.	0.	0.	0.	5.
P3.1.3	0.	0.	0.	0.	0.	3.	3.
P3.2.1	0.	0.	0.	0.	0.	0.	*
P5	0.	0.	0.	0.	0.	0.	0.

* Funot. 3 Groups E1.1.3/E5.1.1 & E2.3/P1.2.1

\$54.4M. The differential cost burden between Alternate I attribute values and Alternate II values is small but the differential cost burden between Alternate II and III is large. Therefore, it is prudent to develop a selection basis which allows for choices involving a mixture of Alternate II and Alternate III attribute values.

The incremental cost burden for Alternates II and III relative to Alternate I are plotted in Figure 7.1 in a cumulative manner in the order of decreasing priority index using the individual ranking method. It is evident that the cumulative steps between attributes of a given priority index are small for Alternate II after the initial step at priority index 30 whereas for Alternate III there are three distinct jumps in cumulative cost burden. Inspection of Tables 7.7(a) and (b) show that the jump at priority index 30 for Alternate II is primarily due to attributes E1.1.3 and E1.2 which pertain to personnel exposure. For Alternate III, the jumps which occur at priority indices 30 and 20 are also associated with attributes E1.1.3 and E1.2. The more gradual jump which occurs at priority indices 6 and 7 are associated with criticality-undetected holdup (E2.3), number of MBA's (P2.1.1), LEMUF for accountability (P2.1.4), and inventory frequency (P2.1.2.1).

With the aid of Tables 7.7(a) and (b), one can select a set of attribute values constrained to a given cost burden. If the allowed burden is, for example 75% of the total burden for Alternate III, then the selection will be based on choosing the attribute values for Alternate III having the highest priority indices and then choosing the remaining attribute values from Alternate II. The constraining condition is that the cumulative cost burden is less than or equal to 75% of the total cost burden for Alternate III. This selection system can be applied to any other desired cost burden level and insures that those attributes of greatest importance are given the primary attention to achieving the lowest risk possible.

The choice of attribute values based on various operating cost burden constraints are shown in Tables 7.8, 7.9, 7.10 and 7.11. The constraints were 28% (\$15.4M), 54% (\$29.3M), 76% (\$42.3M), and 100% (\$54.8M) of the total cost burden for Alternate III, respectively. The 0% case would represent selection of all Alternate I values which represents the reference case and no addition-

TABLE 7.7(a)

PRIORITY RANKING OF OPERATING COSTS (M \$) - ALTERNATE II

INDIVIDUAL SELECTION METHOD

P.I.	Attribute	Function							Cum. Total
		1	2	3	4	5	6	7	
30	E1.1.3		0.321	0.453		1.575		2.21	4.559
	E1.2			0.582		1.793	1.97		4.355
	E2.3				0.024				0.024
	E5.1.1						*		0.
27	E1.1.3				0.056		*		0.056
	E2.3			0.025					0.025
	E3.2							0.108	0.108
	E4.1						0.005		0.005
	P1.2.1						0.27		0.27
	P1.3.1						0.323		0.323
	P2.2.1.1							0.371	0.371
24	E2.3		0.014						0.014
	E4.1			0.013	0.01			0.025	0.048
	E4.3				0.001				0.001
21	E2.3						0.042		0.042
	E3.1				0.01			0.114	0.124
	E4.1	0.025				0.004			0.029
	E5.3						0.025		0.025
	P2.2.3							0.61	0.61
20	E1.1.3	0.906							0.906
	E2.3	0.1							0.1
18	E4.3			0.003		0.001	0.001		0.004
	P1.3.1							0.394	0.394
	P2.2.2							0.014	0.014
15	E3.1	0.0001		0.006					0.006
	E4.3	0.003							0.003
	E5.3					1.504			1.504
	P2.2.4							0.2	0.2
	P3.1.2							0.176	0.176
14	P2.1.4	0.143				0.293			0.435
12	E2.3					0.193			0.193
	E5.3			0.025					0.025
10	E1.2		0.223						0.223
8	P2.1.1			0.16			0.11		0.27
3	P1.3.1			*					0.
Total		1.177	0.558	1.277	0.101	5.363	2.745	4.222	

* Funot. 3 Groups E2.3/P1.3.1 & Funot. 6 Groups E1.1.3/E1.2/E5.1.1

TABLE 7.7(b)

PRIORITY RANKING OF OPERATING COSTS (M \$) - ALTERNATE III

INDIVIDUAL SELECTION METHOD

P.I.	Attribute	Function							Total	Cum. Total
		1	2	3	4	5	6	7		
30	E1.1.3							3.1	3.1	3.1
	E1.2			0.592		1.793	10.448		12.833	15.933
	E2.3				0.031			0.043	0.074	16.007
	E5.1.1						*		0.	16.007
27	E1.1.3				0.14		*		0.14	16.147
	E2.3			0.034					0.034	16.18
	E3.1						0.051		0.051	16.231
	E3.2	0.357							0.357	16.588
	E4.1						0.013		0.013	16.601
	P1.2.1						1.25		1.25	17.851
	P2.2.1.1				0.002			1.007	1.009	18.94
	P2.2.1.3a							0.014	0.014	18.954
24	E2.3		0.014						0.014	18.968
	E4.1			0.025	0.020			0.05	0.103	19.071
	E4.2				0.013				0.013	19.083
	E4.3				0.003				0.003	19.086
	P2.1.1	0.0003							0.0003	19.086
21	E2.3						0.120		0.120	19.214
	E3.1				0.055			0.257	0.312	19.526
	E4.1	0.073				0.012			0.085	19.611
	E4.2						0.005		0.005	19.616
	E5.1.1							0.036	0.036	19.652
	E5.3						0.103		0.103	19.755
	P2.2.3							0.024	0.024	20.579
	P3.1.2						0.1		0.1	20.679
	P3.1.3						1.424		1.424	22.103
20	E1.1.3	1.279	1.031	10.733		2.293			15.336	37.439
18	E3.2							0.200	0.200	37.727
	E4.2			0.113		0.021			0.134	37.861
	E4.3			0.013		0.004	0.002		0.019	38.00
	E5.3				0.025			0.029	0.054	37.935
	P1.3.1						0.629	0.49	1.119	39.054
	P2.2.1.2							0.071	0.071	39.125
	P2.2.2							0.071	0.071	39.196

TABLE 7.7(b) CONTINUED

PRIORITY RANKING OF OPERATING COSTS (M \$) - ALTERNATE III

INDIVIDUAL SELECTION METHOD

P.I.	Attribute	Function							Cum. Total
		1	2	3	4	5	6	7	
15	E3.1	0.002		0.049					0.05 39.246
	E3.2					0.025			0.025 39.271
	E4.2	0.118							0.118 39.389
	E4.3	0.008							0.008 39.397
	P2.1.1				0.098				0.098 39.495
	P2.1.2.1				0.218	-0.116		0.104	0.208 39.701
	P2.1.2.2				0.075				0.075 39.776
	P2.2.4							0.5	0.5 40.276
	P3.2.1							0.477	0.477 40.753
12	E5.3			0.106					0.106 40.859
	P2.1.1					0.459			0.459 41.318
	P3.1.3							*	0. 41.318
	P3.2.1			0.096	0.096				0.192 41.51
10	E1.2		0.223						0.223 41.733
	E2.3	0.257							0.257 41.99
	E5.1.1			*					0. 41.99
	E5.3					1.864			1.864 43.854
9	E3.1					-0.033			-0.033 43.821
	P2.1.2.1		1.143						1.143 44.964
8	P2.1.2.1	0.314							0.314 45.278
7	P2.1.4	0.588				1.729			2.314 47.592
6	E2.3					1.529			1.529 49.121
	P2.1.1			0.675			0.843		1.318 50.439
	P2.1.2.1						0.299		0.299 50.738
5	E5.1.1	0.006				0.126			0.131 50.869
	P2.1.2.2							0.075	0.075 50.944
	P3.1.2							0.89	0.89 51.833
3	P1.2.1			*					0. 51.833
	P2.1.2.1			1.485					1.485 53.318
	P2.1.4			1.485					1.485 54.803
		2.999	2.411	15.405	0.863	9.705	15.094	8.326	

* Funot. 3 Groups E1.1.3/E5.1.1 & E2.3/P1.2.1

Funot. 6 Groups E1.1.3/E1.2/E5.1.1 & P2.1.1/P2.1.2.1(Men Only)

Funot. 7 Groups P3.1.3/P3.2.1

TABLE 7.8

ATTRIBUTE SELECTION FOR \$15.4 MIL. COST BURDEN

Attribute	Function						
	1	2	3	4	5	6	7
E1.1.3	II	II	II	II	II	II	II
E1.2	O	II	II	O	II	II	O
E2.1&2.2	O	O	O	O	O	O	O
E2.3	II	II	II	II	II	II	II
E3.1	II	O	II	II	II	II	II
E3.2	II	O	O	O	II	O	II
E4.1	II	O	II	II	II	II	II
E4.2	II	O	II	II	II	II	O
E4.3	II	O	II	II	II	II	O
E5.1.1	II	II	O	O	II	II	II
E5.1.2&5.1.3	O	O	O	O	O	O	O
E5.2	O	O	O	O	O	O	O
E5.3	O	O	II	II	II	II	II
P1.1.1	O	O	O	O	O	O	O
P1.1.2	O	O	O	O	O	O	O
P1.2.1	O	O	O	O	O	II	O
P1.2.2	O	O	O	O	O	O	O
P1.3.1	O	O	II	O	O	II	II
P1.3.2	O	O	O	O	O	O	O
P2.1.1	II	O	II	II	II	II	O
P2.1.2.1	II	II	II	II	II	II	II
P2.1.2.2	O	O	O	II	O	O	II
P2.1.4	II	O	II	O	II	O	O
P2.2.1.1	O	O	O	II	O	O	II
P2.2.1.2	O	O	O	O	O	O	II
P2.2.1.3a	O	O	O	O	O	O	II
P2.2.1.3b	O	O	O	O	O	O	O
P2.2.1.4	O	O	O	O	O	O	O
P2.2.2	O	O	O	O	O	O	II
P2.2.3	O	O	O	O	O	O	II
P2.2.4	O	O	O	O	O	O	II
P3.1.1	O	O	O	O	O	O	O
P3.1.2	O	O	O	O	O	II	II
P3.1.3	O	O	O	O	O	II	O
P3.2.1	O	O	II	II	O	O	II
P5	O	O	O	O	O	O	O

TABLE 7.9

ATTRIBUTE SELECTION FOR \$29.3 MIL. COST BURDEN

Attribute	Function						
	1	2	3	4	5	6	7
E1.1.3	II	II	II	III	II	III	III
E1.2	O	II	III	O	III	III	O
E2.1&2.2	O	O	O	O	O	O	O
E2.3	II	III	III	III	II	III	III
E3.1	II	O	II	III	II	III	III
E3.2	III	O	O	O	II	O	II
E4.1	III	O	III	III	III	III	III
E4.2	II	O	II	III	II	III	O
E4.3	II	O	II	III	II	II	O
E5.1.1	II	II	O	O	II	III	III
E5.1.2&5.1.3	O	O	O	O	O	O	O
E5.2	O	O	O	O	O	O	O
E5.3	O	O	II	II	II	III	II
P1.1.1	O	O	O	O	O	O	O
P1.1.2	O	O	O	O	O	O	O
P1.2.1	O	O	III	O	O	III	O
P1.2.2	O	O	O	O	O	O	O
P1.3.1	O	O	O	O	O	II	II
P1.3.2	O	O	O	O	O	O	O
P2.1.1	III	O	II	II	II	II	O
P2.1.2.1	II	II	II	II	II	II	II
P2.1.2.2	O	O	O	II	O	O	II
P2.1.4	II	O	II	O	II	O	O
P2.2.1.1	O	O	O	III	O	O	III
P2.2.1.2	O	O	O	O	O	O	II
P2.2.1.3a	O	O	O	O	O	O	III
P2.2.1.3b	O	O	O	O	O	O	O
P2.2.1.4	O	O	O	O	O	O	O
P2.2.2	O	O	O	O	O	O	II
P2.2.3	O	O	O	O	O	O	III
P2.2.4	O	O	O	O	O	O	II
P3.1.1	O	O	O	O	O	O	O
P3.1.2	O	O	O	O	O	III	II
P3.1.3	O	O	O	O	O	III	O
P3.2.1	O	O	II	II	O	O	II
P5	O	O	O	O	O	O	O

TABLE 7.10

ATTRIBUTE SELECTION FOR \$42.3 MIL. COST BURDEN

Attribute	Function						
	1	2	3	4	5	6	7
E1.1.3	III	III	III	III	III	III	III
E1.2	O	II	III	O	III	III	O
E2.1&2.2	O	O	O	O	O	O	O
E2.3	II	III	III	III	II	III	III
E3.1	II	O	II	III	II	III	III
E3.2	III	O	O	O	II	O	III
E4.1	III	O	III	III	III	III	III
E4.2	II	O	III	III	III	III	O
E4.3	II	O	III	III	III	III	O
E5.1.1	II	II	III	O	II	III	III
E5.1.2&5.1.3	O	O	O	O	O	O	O
E5.2	O	O	O	O	O	O	O
E5.3	O	O	II	III	II	III	III
P1.1.1	O	O	O	O	O	O	O
P1.1.2	O	O	O	O	O	O	O
P1.2.1	O	O	III	O	O	III	O
P1.2.2	O	O	O	O	O	O	O
P1.3.1	O	O	O	O	O	III	III
P1.3.2	O	O	O	O	O	O	O
P2.1.1	III	O	II	II	II	II	O
P2.1.2.1	II	II	II	II	II	II	II
P2.1.2.2	O	O	O	II	O	O	II
P2.1.4	II	O	II	O	II	O	O
P2.2.1.1	O	O	O	III	O	O	III
P2.2.1.2	O	O	O	O	O	O	III
P2.2.1.3a	O	O	O	O	O	O	III
P2.2.1.3b	O	O	O	O	O	O	O
P2.2.1.4	O	O	O	O	O	O	O
P2.2.2	O	O	O	O	O	O	III
P2.2.3	O	O	O	O	O	O	III
P2.2.4	O	O	O	O	O	O	II
P3.1.1	O	O	O	O	O	O	O
P3.1.2	O	O	O	O	O	III	II
P3.1.3	O	O	O	O	O	III	O
P3.2.1	O	O	II	II	O	O	II
P5	O	O	O	O	O	O	O

TABLE 7.11

ATTRIBUTE SELECTION FOR \$54.8 MIL. COST BURDEN

Attribute	Function						
	1	2	3	4	5	6	7
E1.1.3	III	III	III	III	III	III	III
E1.2	O	III	III	O	III	III	O
E2.1&2.2	O	O	O	O	O	O	O
E2.3	III	III	III	III	III	III	III
E3.1	III	O	III	III	III	III	III
E3.2	III	O	O	O	III	O	III
E4.1	III	O	III	III	III	III	III
E4.2	III	O	III	III	III	III	O
E4.3	III	O	III	III	III	III	O
E5.1.1	III	III	III	O	III	O	III
E5.1.2&5.1.3	O	O	O	O	O	O	O
E5.2	O	O	O	O	O	O	O
E5.3	O	O	III	III	III	III	III
P1.1.1	O	O	O	O	O	O	O
P1.1.2	O	O	O	O	O	O	O
P1.2.1	O	O	III	O	O	III	O
P1.2.2	O	O	O	O	O	O	O
P1.3.1	O	O	O	O	O	III	III
P1.3.2	O	O	O	O	O	O	O
P2.1.1	III	O	III	III	III	III	O
P2.1.2.1	III	III	III	III	III	III	III
P2.1.2.2	O	O	O	III	O	O	III
P2.1.4	III	O	III	O	III	O	O
P2.2.1.1	O	O	O	III	O	O	III
P2.2.1.2	O	O	O	O	O	O	III
P2.2.1.3a	O	O	O	O	O	O	III
P2.2.1.3b	O	O	O	O	O	O	O
P2.2.1.4	O	O	O	O	O	O	O
P2.2.2	O	O	O	O	O	O	III
P2.2.3	O	O	O	O	O	O	III
P2.2.4	O	O	O	O	O	O	III
P3.1.1	O	O	O	O	O	O	O
P3.1.2	O	O	O	O	O	III	III
P3.1.3	O	O	O	O	O	III	III
P3.2.1	O	O	III	III	O	O	III
P5	O	O	O	O	O	O	O

al cost burden. The first table represents a cost burden corresponding to all Alternate II values. The next two tables represent mixtures of Alternates II and III while the last table represents all Alternate III values.

Since the individual selection method was used, the tables are constructed with a matrix format to permit easier comparison between tables. For brevity, the attribute values have been coded II or III based on the alternate selected. A zero has been used in the matrix where a given function had no reaction viewpoint. This indicates that the attribute value had no impact and that the functional experts' attitude would be indifferent to what attribute value was assigned.

If the attribute has zero for all functions there are no choices available. If the attribute has zero for all functions but Function 7 (facilities), then the attribute has only a facility impact.

Inspection of the above tables indicates that Alternate II values predominate at the incremental cost burden of \$29.3M and Alternate III values predominate at the incremental cost burden of \$42.3M. Inspection of Figure 7.1 shows that Alternate III values for attributes having a priority index of 21 or above can be assimilated in a cost burden of \$29.3M. However, to include the next lower priority index, 20, the cost burden jumps to nearly \$40M. Table 7.7(a) and 7.7(b) show that the \$29.3M cost burden permits selection of Alternate III values down through priority index 21 for a total of \$22.1M (Alternate II contributes a burden of \$4.5M for the priority indices below 21 for a total cost burden of \$26.2M). The \$42.3M cost burden permits selection of Alternate III values down through priority index 18 for a total of \$39.2M (Alternate II contributes \$3.1M for a total cost burden of \$42.3M). As can be seen from Table 7.7(b), the major cost burden increment between the two cost burdens is due to large cost elements from functions 1, 2, 3 and 5 for attribute E1.1.3 which are allowed at the \$42.3M cost burden level. Inclusion of the index 18 values at Alternate III adds only \$1.8M to the cost burden increment which is mostly due to P1.3.1 (solid waste discharge). Further, Table 7.7(b) shows that approximately one-half of the \$29.3M cost burden is due to the personnel exposure attributes E1.1.3 and E1.2 while approximately

two-thirds of the \$42.3M burden is due to the same attributes. The significance of this finding is that from a cost burden standpoint one must choose the personnel exposure attribute values as either Alternate II or III. Once this choice is made, other attribute selections between II and III have relatively minor impact on cost burden.

7.6.3 Selection Based on Incremental Development Cost

As with the operating cost burden, the individual selection method can be applied to incremental development cost. The cumulative development costs for Alternates II and III are shown in Figure 7.2 in order of decreasing priority index. In contrast to the operating cost burden, it is seen that the Alternate III development cost increments are largest for attributes with low priority index. This would imply that choosing an operating cost burden slightly below that for Alternate III for the lower ranked attributes would produce relatively large reductions in the development cost. The benefits from this exercise are shown in Table 7.12. The reader should be reminded that these development costs are increments above the Alternate I level. The total development effort does not include the development cost to achieve Alternate I levels which was not part of this requirements analysis.

7.6.4 Recommended Attribute Values

To summarize, the position taken by the Task Force in choosing a set of attribute values is as follows:

- o The operating cost burden has been used as the basis for selection. The desire for a low risk posture requires that as many Alternate III values be selected as possible for a given cost burden. The remaining values should be Alternate II.
- o The Task Force preferred to allow the selection process to follow individual ranking.
- o The findings of the reaction viewpoint study show that the personnel exposure attributes primarily control the cost burden interval between Alternate II and Alternate III.

TABLE 7.12

DEVELOPMENT COSTS COMPARED TO OPERATING COST BURDEN

	Operating	Incremental	
Case	Cost Burden (M \$)	Development Cost (M \$)	Attribute Values
1	0.	0.	All Alternate I
2	15.4	55.	All Alternate II
3	29.3	69.2	Mostly Alter. II
4	42.3	87.7	Mostly Alter. III
5	54.8	439.	All Alternate III

The Task Force recommended that the selection be based on a criterion that the cost burden be at a level to allow for all functions to achieve Alternate III values for the personnel exposure attributes. The Alternate III values are 1000 mRem/yr/man for E1.1.3 and 1/4 Federal Regulations for E1.2. As discussed in Section 7.6.2, this recommendation requires a cost burden of \$37.4M and includes Alternate III values for attributes having a priority index 20 or above and Alternate II values for priority indices 18 and below. To include attributes with priority index 18 at Alternate III would add only \$1.8M giving a total cost burden of \$42.3M. The development cost would increase from \$85.7M to \$87.7M. These small increases provide some latitude for choosing the cut-off point between Alternate III and Alternate II. The task force selected priority index 18 and above as the point of partition. This selection led to the Task Force decision to accept the attribute value of P1.3.1 (solid waste discharge) at 10 nanocuries/gram. The issues arising from this decision will be discussed later.

By inspection of Table 7.10, the Task Force then determined that there should be uniform application of the attribute values to all functions in the fabrication system. In other words, a composite ranking made better sense. This was drawn by individually examining each function's position on each attribute where unanimity did not exist in Table 7.10. This process resulted in the final selection which is shown in Table 7.13. This final selection raised the operating cost burden from \$42.3M to \$43.9M and the development cost from \$81.7M to \$94.1M.

This approach to arriving at a composite selection by modification of individual ranking was preferred over the composite method described earlier in Section 7.6.1 because individual priorities could prevail until the final adjustment. If the composite ranking method was used at the outset, individual priorities would have been muted by other functions, particularly those with an indifferent attitude about a given attribute. Therefore, it was deemed appropriate to arrive at a consensus or composite position by inspection and modification of the individual ranking method. This issue was particularly germane in the selection of the attribute value for E2.3 (criti-

TABLE 7.13

RECOMMENDED ATTRIBUTE VALUES AS REQUIRED

FOR A SECURE AUTOMATED FABRICATION SYSTEM

Attribute	Description	Alternate	Assigned Measure
E1.1.3	Total E. Exp.-External	III	1000 mRem/yr
E1.2	Total E. Exp.-Internal	III	1/4 Fed. Regs.
E2.1&2.2	Crit. Equip. & Storage	I-II-III	2 Coincidental Events
E2.3	Crit. Undetect. Holdup	II	Monitor Continuously
E3.1	E. Cont./Det.-In Plant	III	Monitor Freq.: 1/Work Station
E3.2	E. Cont./Det.-Normal Exit	III	Verify 100% Of Body Surface
E4.1	Rad. Train. Of Employee	III	4 Times/year
E4.2	Equip./Systm. Op. Training	III	Prof. & Requal.: Periodic(1/yr)
E4.3	Managment Training	III	All Types Of Emerg. Each Quarter
E5.1.1	N. Airb. Cone Cont./Det.	III	1/4 Fed. Regs.
E5.1.2&5.1.3	Abn./Mnt. Cone Cont./Det.	I-II-III	Fed. Reg.
E5.2	Non Nuc. Hazrd. Materials	I-II-III	Fed. & State Regs.
E5.3	Smr. Srf. Cont. O. P. A.	III	2X Detect. Limit Above Backgrnd.
P1.1.1	Vent Discharg.-Nuclear	III	Non.: 1/2 Fed. & CAM Abnor.: Fed. Regs.
P1.1.2	Vent Dischrg.-Non Nuc.	I-II-III	Fed. & State Regs.
P1.2.1	Liquid Discharg.-Nuclear	III	Zero (No Liquid Discharge)
P1.2.2	Liquid Discharg.-Non Nuc.	I-II-III	Fed. & State Regs.
P1.3.1	Solid Discharg.-Nuclear	III	<10 nanocuries/gm TRU
P1.3.2	Solid Discharg.-Non Nuc.	I-II-III	Fed. & State Regs.
P2.1.1	Number Of MBA's	II	1/Work Station
P2.1.2.1	Acc.-Inventory Freq.	III	Inv. Prd.: 1/3 Day (Near Real Time)
P2.1.2.2	Acc.-Reconcil. Period	III	7 Days
P2.1.4	LEMUF	II	0.4% Of Throughput
P2.2.1.1	Detect.- Personnel	III	Incred. Perim. & Positive Ident.
P2.2.1.2	Detect.- Rad.(Pu)	III	2X Min. Detect. With Label
P2.2.1.3a	Detect.-Metal	III	200 gms Plus Shape
P2.2.1.3b	Detect.-Metal Shielding	I-II-III	50 gms
P2.2.1.4	Detect.-Explosives	I-II-III	Mass(TNT equiv.): 220 gms
P2.2.2	Barriers	III	Strengthen Barriers + Alarm
P2.2.3	Guards	III	1 Set + CCTV + Incred. Repn. Team
P2.2.4	Strike Force	II	1 Team + Increased Proficiency
P3.1.1	Don./Dom.-Lvl. For Ship.	III	1/2 Fed. Regs.
P3.1.2	Don./Dom.-Ship. Container	III	Increased Container Reliability
P3.1.3	Don./Dom.-Vol. Reduction	III	50% Theoretical Density
P3.2.1	Don./Dom.-Lvl. For F.C.	II	120 nanocuries/gm With Teardown
P5	Facility Construction	I-II-III	Fed. Regs.

NOTE: I-II-III Indicates No Choice Of Alternates

cality of undetected holdup). Those functions involved in liquid handling were most concerned and their views prevailed in choosing Alternate II whereas the composite ranking method would have selected Alternate III because Functions 1 and 5 were lost in the priority index ranking of the other functions.

The recommended attribute values were arrived at through a preferred set of Task Force positions described above. Should these positions change, then another set of values would follow.

It is intended that the values selected are to be used in establishing requirements for development activities involving subsystems and components. As development activity proceeds and as a fabrication project is defined, these requirements may need alteration. The systems analysis described herein provides the basis for measuring the impact of any change on development cost and on annual operating cost from an industrial viewpoint.

7.7 Uncertainties In the Selection Process

During analysis of the attribute selections, several questions were raised concerning the effect of certain reaction viewpoints. Since some of these viewpoints are subjective and the process of selection has many branches, these effects need to be discussed.

7.7.1 Influence of the Success Factor

Some functions considered Alternate III such a severe penalty that the chances of success were low. This was reflected in the priority index. If all these low factors of success are revised to a high degree of success then the choice of Alternate values as well as attribute values shown in Table 7.10 are changed somewhat. Eleven attributes would have a change in individual selection of at least one function. Nine fewer attributes (E3.1, E5.3, P2.1.1, P2.2.1.1, P2.2.1.3a, P2.2.2, P2.2.3, P3.1.2, and P3.1.3) were selected for Alternate III values than in the previous selection. All changes result in a cost burden of \$41.2M as compared to \$42.3M for the arrangement shown in Table 7.10. The change with the largest impact pertains to attribute E2.3 (criticality of undetected holdup). With a new success factor, this attribute was selected as Alternate III and resulted in an increase in development cost

burden for the attribute from \$7M to \$43M. All other commonly selected attributes resulted in an incremental change in operating cost burden of < \$1M. It should be noted that the Task Force selected Alternate II for E2.3 although Alternate III selections predominated regardless of the success factor.

7.7.2 Influence of Composite Ranking

As previously discussed, the Task Force preferred to use individual rankings until the final adjustment. The effect of using a composite ranking in the preliminary analysis instead of individual rankings of all functions is discussed below.

Compared to Table 7.10, again, eleven attributes would have a change in individual selection by at least one function. Five attributes (E5.3, P2.1.1, P2.2.2, P2.2.3, and P3.1.2) selected by the individual method for Alternate II values were not selected by the composite method. However, the composite method selected attribute P3.2.1 (decontamination and decommissioning of facility). The composite ranking results in an operating cost burden of \$42.2M compared to the individual ranking burden of \$41.7M. Again the change with the largest impact was selection of all Alternate III values for attribute E2.3. As stated previously, this results in increasing the development cost burden for the attribute from \$7M to \$43M. The Task Force, during final selection, preferred Alternate II for E2.3. The composite method also selected all Alternate III values for attribute E5.3. The individual method selected part Alternate II and part Alternate III. The Task Force preferred to select all Alternate III values for this attribute. The cost and development burdens associated with this selection are small. The operating cost increment is \$0.3M and the development cost increment is \$0.5M. All other changes result in an operating cost burden increment of < \$0.6M. The major difference between the individual ranking method and the composite ranking method is the selection of attribute E3.2.1. However, the composite method selects five less attributes for Alternate III values.

7.7.3 Influence of Partition Point for Alternate III Values

As described before, the Task Force selected Alternate III values for attributes having priority index 18 and above. This partition point included selection of 10 nanocuries/gram TRU as the requirement for P1.3.1 (solid waste discharge). From inspection of Table 7.10, functions 6 and 7 provided the only reaction viewpoints for P1.3.1 as the other functions had no impact. Because this attribute is on the boundary between Alternate II and Alternate III values and because the 10 nanocuries/gram requirement is viewed as an ambitious target, the Task Force carefully scrutinized this issue. The majority of the Task Force voted for 10 nanocuries/gram as a prudent requirement in the long term development perspective. Analysis of the operating and development cost burdens did not appear excessive. The main concern was detecting and proving that the 10 nanocuries/gram discharge requirement could be met. These activities impact the probability of success more than they impact cost. The processing of waste for discharge at 10 nanocuries/gram level is nearly the same as for 100 nanocurie/gram (Alternate II), therefore operating and development cost increments are small. Development costs for solid waste discharge processes to achieve the Alternate I requirement are much larger than for increments from I to II or I to III. However, to achieve these low levels of uniform discharges, it is important that the waste treatment function not be burdened with handling contaminated materials not easily dissolved by chemical treatment. Primary concern was insulating bricks and ceramic manifolds associated with many types of furnaces. The waste treatment function must invade the equipment requirements of other functions including its own incinerating operation to be sure that its chance of meeting the 10 nanocurie/gram requirement is met. Dissolvability is a crucial process requirement which follows from this Task Force decision.

A second concern is proving that contaminated equipment after disposal meets uniform discharge requirement of P1.3.1. In this case, the Task Force did not feel that smelting of disposed equipment was prudent at the discharge point of a fuel factory. Since this issue is generic to all facilities in the nuclear business, if smelting was required before permanent disposal, such an activity would best be accomplished at the disposal site. Decontamination of equipment for transportation (P3.1.1) to the disposal site would still be a functional requirement for waste treatment.

8.0 DEFINITION OF THE FUEL FABRICATION SYSTEM

The fuel fabrication system is a part of a larger system called the fuel cycle. The scope of this requirements analysis is limited to fuel fabrication but events in other parts of the fuel cycle can impact on fuel fabrication performance and on the choice of alternatives. To properly qualify the systems analysis problem it is appropriate to explicitly define the boundaries of the fuel fabrication system, to identify important interfaces and state appropriate assumptions about the system environment.

8.1 SYSTEM BOUNDARY DEFINITION

For purposes of the systems analysis, the system boundary is defined to include conversion, powder and pellet preparation, rod loading, assembly fabrication, scrap recovery and waste treatment. The facility which houses these functions provides the support services needed to maintain and manage these functions. The first material-flow function of the fuel fabrication system is to receive and store nitrate solution; the last function is to load assemblies into casks and waste products into containers.

Inputs to the fuel fabrication system are blended solutions of uranium and plutonium nitrate at a composition that requires only addition of uranyl nitrate or uranium oxide powder to satisfy product composition requirements. No restrictions are placed on the radioactive content of the solutions at this time but a firm definition will be generated in the later stages of the requirements analysis. The second major input is the hardware used to contain and secure the fuel for later use. Other inputs to the system involve the supplemental uranium feed supply mentioned above, nonradioactive chemicals and utility services needed to carry out the process functions. None of these other inputs are expected to play a significant role in the Secure Automated Fabrication requirements analysis except for the loss of electrical power and limits on water supply. An internal source of electric power will be needed as a back-up to the external supply. If water is involved in the process function it must be treated before discharge. The input supply however may be above discharge standards and this condition could require additional treatment functions and influence the choice of alternatives related to liquid discharge. This situation could apply also to the use of air which is later discharged to the environment.

The outputs from the fuel fabrication functions include finished assemblies, solid waste containers containing radioactive solids, liquids and gases discharged to the environment after treatment.* The solid wastes consist of three types: process waste which is discharged continuously, discarded machinery which is discharged intermittently, and decommissioned facility material which is discharged once.

Information inputs and outputs are as follows:

- o Shipper/receiver transactions on SNM content
- o Specifications and quality certifications of input materials and output materials
- o Accountability records for audit by regulatory agencies
- o Environmental survey records for audit by regulatory agencies
- o Training and proficiency qualification records of employees for audit
- o Personnel exposure records of employees for audit
- o Safety analysis reports (PSAR and FSAR) on facilities and equipment
- o Emergency plans
- o Physical protection procedure (restricted distribution)
- o Operating license for SNM

8.2 EX-FUNCTION INTERFACES

The following interfaces are involved in material flow with the fuel fabrication system:

Reprocessing Facility	- Supplies uranium-plutonium nitrate mixture
Hardware Manufacturers	- Supplies hardware for rod loading and assembly fabrication

*Scrap generated within the fuel fabrication function will be recycled within the system. The alternate choice of recycling scrap through the reprocessing plant would create another output channel and would have a strong impact on accountability attributes related to Secure Automated Fabrication.

- Utility Institutions - Supply basic utilities (water, electricity, etc.). Receives discharged liquids and gases
- Solid Waste Disposal Facility - Receives discharged solids, equipment and decommissioned material
- Other Fuel Fabricators - Supplies and receives fuel for inventory balancing
- Transportation Agencies - Carries material to/from fuel fabrication facilities
- Fast Reactor Sites - Receives finished fuel assemblies

The following interfaces are involved in information flow with the fuel fabrication system:

- Regulatory Agencies - PSAR, FSAR, Licensing Submittals, Audit and Compliance Records on Regulated Materials
- Reprocessing Facilities - Certifications and data packages on feed supply
- Reactor Facilities - Certifications and data packages on products delivered
- Waste Disposal Facility - Certifications on disposed material
- Law Enforcement Agency - Emergency plan, physical protection procedures
- Public/Community - Environmental Impact Reports, Site Performance Data
- Employees - Training Requirements, Exposure Data

8.3 ASSUMPTIONS ON ENVIRONMENT

The following assumptions are being used relative to the environment outside the fuel fabrication functions:

- o Feed supply will be available as required to meet production schedules
- o Feed supply will have a constant U/Pu but isotopic ratios will change between batch shipments from reprocessing plant
- o Shipper/Receiver accountability differences will not impact scheduled use of feed supply or product
- o No restrictions on in-plant inventory quantities or residence time due to fuel cycle economics
- o No requirements to clean up input water or gas supply to meet discharge requirements
- o No restrictions on employee qualifications prior to employment

APPENDICES

- A. SECURE AUTOMATED FABRICATION TASK FORCE
- B. SYSTEMS ENGINEERING FOR SECURE AUTOMATED FABRICATION PROGRAM
- C. RECOMMENDATIONS AND CONCLUSIONS - FUEL FABRICATION DEVELOPMENT COMMITTEE REPORT
- D. REGULATIONS APPLICABLE TO THE SECURE AUTOMATED FABRICATION SYSTEM ANALYSIS
- E. INVESTMENT AND MANPOWER COST - MANPOWER AND FLOOR SPACE REACTION VIEWPOINTS.

APPENDIX A

SECURE AUTOMATED FABRICATION TASK FORCE

ORGANIZATION

NAME

AI - Rockwell

L. J. Jones

Babcock & Wilcox

C. R. Woods

Battelle - PNL

E. J. Wheelwright

Combustion Engineering

N. Fuhrman

Exxon

L. G. Merker

General Electric

M. L. Thompson

Westinghouse - ARD

B. Newman

General Electric

E. A. Aitken, Chairman -
Systems Analysis Coordinator

Westinghouse - Hanford

M. C. J. Carlson, RF&M-TMC
Coordinator

APPENDIX B

SYSTEMS ENGINEERING FOR SECURE AUTOMATED FABRICATION PROGRAM

1.0 GENERAL PROGRAM OBJECTIVES

The fuels fabrication development program has been assigned to the Reactor Fuels and Materials Technology Management Center by DOE with the objectives of (1) providing a fuel supply for FBR reactors needed in the national development schedule and (2) developing the technology base for future large scale fabrication plants operating in the period of 1995. The system and its requirements for development and demonstration are to be defined prior to the fuel cycle decision date. The completed fabrication system has the target of operating at low risk to the public and its employees. A subelement of the program will be systems engineering activity which is the subject of this document.

2.0 PROGRAM STRATEGY AND BACKGROUND

A TMC committee was convened in April 1979 to recommend a strategy and development program to meet the above objectives. This report has been received by TMC and is under review. The committee recommended the following sequence in the development effort: development of individual equipment and support processes, systems testing and then final integrated demonstration in a pilot scale facility. A decision to proceed with further development of the FBR would require a fuel fabrication development effort. Later in the 1990's recycled plutonium will require remotely operated fabrication systems placed in a new facility. The demonstration of new equipment, subsystems and process control networks will use facilities ranging from industrial UO_2 lines to fully remote pilot plant lines for requirements verification testing for the final production facility.

3.0 SYSTEMS ENGINEERING OBJECTIVE AND JUSTIFICATION

The general objective of systems engineering is to create a traceable and measured systems engineering structure that guides the TMC development program for target low risk fuel fabrication over the anticipated development period of 10-15 years. The purpose of systems engineering is to interrelate all levels in this structure to an overall system requirements plan as the program passes through various stages of completion.

The goal of cost effectiveness at low risk in the fuel fabrication part of the LMFBR fuel cycle requires a disciplined approach from the beginning of a development program. The system and its connecting parts must operate cohesively to satisfy overall objectives. How does one establish low risk targets from intangible beginnings? How does one assess cost effectiveness with a tangible industrial base? The answer is to apply systems engineering in a documented and disciplined manner so that decisions, events and perspectives are traceable and not obliterated by the passage of people and time. The need is for program flexibility due to shifting schedules, resources, constraints and assumptions without loss of objectivity and end goal targets. The systems analysis program presented herein is aimed at providing objectivity and flexibility in the environment of change.

4.0 SYSTEMS ENGINEERING SCOPE

The purpose of systems engineering is to interrelate all levels of work to a common system objective. This relationship is established through a set of performance requirements that are transformed in a disciplined manner through a hierarchy structure into a series of specifications for subsystem and components. Performance requirements include process and product requirements such as cost, availability, capacity, etc. In addition, we have added a third group of requirements which we have named Secure Automated Fabrication (SAF) requirements. These SAF requirements are not easily defined in tangible terms and their definition requires a consensus of judgement, experience and foresight among industrial fuel fabricators. Because the SAF requirements interact with process requirements, optimum choice of process alternatives and component specifications depends on a systematic examination of the requirements issues. The first part of the systems engineering scope therefore involves a detailed understanding of the functions of the systems and of the systems requirements. Trade-offs and effectiveness of conflicting requirements must be analyzed in terms of evaluation criteria.

These evaluated requirements provide the basis for guiding follow-on development efforts. Furthermore, the system requirements may be reevaluated in a systematic manner should new objectives, and/or new information based on development data appear during the development and test phase. To provide for consistency, all requirements and changed requirements must be controlled throughout the hierarchy breakdown structure of components and subsystems.

The systems engineering scope operates in concert with a technical management scope as a project proceeds from the conceptual phase through development to a completed project or operational phase. The generic activities usually required in this sequence are identified in Figure B-1. The blocks identify basic activities that should be performed and completed in sequence to properly establish a hierarchy of instructions and data before the next block to the right is initiated. Above the sequence blocks are shown typical technical management activities and below the blocks are shown the typical systems engineering activities. Proper coordination of these two activities ensures a high probability of success. The detailed systems engineering approach for the SAF development program is described later.

5.0 TECHNICAL MANAGEMENT SCOPE

The purpose of the technical management activity is to organize the resources available to meet the fuel fabrication development objectives within the estimated cost and schedule. This activity includes creation of a work breakdown structure to efficiently portion pieces of the work and to follow the work performance. In addition, the scope includes the technical management activities shown in Figure B-1. These activities are conducted across and within the work breakdown structure. After completion of the systems requirements analysis, configuration control is implemented. After completion of system definition, development test plans are issued and design reviews are scheduled. A major aspect of the technical management scope is preparation of a requirements verification plan to ensure that each component or subsystem is properly tested. To test the complete range of process, product and SAF requirements, a complex verification network may be needed. Candidate verification facilities are remote mechanical mock-ups, computerized process control demonstrations, demonstrations during UO_2 production conditions, demonstrations during FBR fabrication campaigns and integrated pilot plant operations. The appropriate mix of these test facilities for the various components and subsystems to be tested will require an innovative planning exercise.

Figure B-1

TECHNICAL MANAGEMENT AND SYSTEMS ENGINEERING

6.0 TECHNICAL MANAGEMENT WORK BREAKDOWN STRUCTURE

The work breakdown scheduled will be established in a hierarchy document to be published at a later date.

7.0 SYSTEMS ENGINEERING APPROACH FOR SECURE AUTOMATED FABRICATION

Following from the general guidelines for the systems engineering scope described in Section 4.0, a detailed systems engineering approach is presented here for the SAF development. From Figure B-1, the initial systems engineering activity involves a functional flow analysis and a systems requirements analysis. These two activities precede the major development and design activity. Inputs to the systems analysis such as objectives and goals of the national FBR program have been given (Section 1). No system requirements have been given at the outset although tentative requirements will be considered and evaluated during the requirements analysis. The systems engineering approach used in this development program will provide for opportunities to iterate the requirements. The iteration process will be fixed so that traceable and documented decisions for selecting the requirements is maintained. After completion of the requirements analysis, configuration control is established and the requirements will become progressively hardened as the development program proceeds through developmental testing.

The detailed approach to fuel fabrication development is shown in Figure B-3 (two pages). The figure embraces all the activities described in Figure B-1, however, the activity sequence has been altered to provide an approach that recognizes some specific issues peculiar to fabrication development.

For the fuel fabrication functions, three types of requirements are required: process requirements, product requirements and SAF operating requirements. Process requirements include system throughput, capacity, system availability and system response time and control. Product requirements include attributes of the output items, such as density, enrichment, size and tolerances on these attributes. SAF requirements include most of the intangible attributes which relate to safety, safeguards, discharge to the environment and other licensing issues. It is this last category of requirements which needs special attention since the category is the most difficult to describe as a

tangible system requirement. In the systems engineering approach we have focused on this category of requirements first to determine what SAF requirements mean and how specific SAF requirements are to be established. This exercise is depicted on the first page of Figure B-3. At the bottom of this page SAF requirements have been analyzed and evaluated and then are included with the product and process requirements for another requirements analysis exercise shown at the top of the second page of Figure B-3. These two exercises are defined as Phase I and Phase II of the systems requirements analysis.

7.1 SYSTEMS REQUIREMENTS ANALYSIS (PHASE I)

The purpose of the requirements analysis for Phase I is (1) to define SAF requirements, (2) to provide a scale of measure for each SAF requirement, (3) to provide system alternatives that include specific SAF requirements within the scale of measure established for each requirement (4) to set criteria for evaluating the activity box labeled "SAF criteria" in Figure B-3. Item 3 is part of the activity box labeled "plausible alternatives for low risk objective." Item 4 is part of the activity box labeled "objective function definition, SAF perspective." These activities are to be accomplished by a TMC task force of industry representatives. These representatives will provide judgments based on experience and will enable consensus views to be established during the evaluation period. The task force will make its judgments in a systematic sequence to provide for traceability in future iterations.

The steps are as follows:

- (1) Define the SAF attributes, listing as many as are needed to bound the SAF issue involving the public and employees.
- (2) For each attribute provide a scale of measure ranging from current or accepted practice to the lowest risk possible after allowance for significant development activity. The scale of measures may be a quantifiable unit or may be a procedure that has various levels of stringency or control. Intermediate values on the scale of measures should be specified when possible.

FIGURE B-3
FUEL FABRICATION PROGRAM
A SYSTEMS ENGINEERING APPROACH

FUEL FABRICATION PROGRAM
SYSTEMS ENGINEERING APPROACH

- (3) Select at least three system approaches that may be used in achieving low risk. These approaches or alternatives contain the attributes defined above, each specified at some value on its scale of measure. These alternatives must apply generally throughout all subsystems of the fuel fabrication system.

After completion of the above steps, the fuel fabrication system will be divided into about seven major subsystems which have discrete and identifiable functions to perform. Functional experts for each subsystem will prepare judgments about the attribute listed in each alternative. To provide a basis for the functional experts' judgment and reactions to these alternatives, the expert will prepare a detailed functional analysis of his subsystem. The functional analysis will be constructed as block diagrams and contain as many sublevel functions as are necessary to delineate the specific SAF attributes which impact on the lowest functional level that must be performed. The functional analysis will be used later to assign specific system requirements for subsystem, component and equipment. This activity will enable traceability of system requirements in the hierarchy.

The judgments that each functional expert makes about the attributes in each alternative will form a complex matrix. The matrix shown in Figure B-3 is a simplified representation of a multidimensional matrix which will include judgments on each attribute. The judgments to be made should involve the following issues:

- (1) The relative operating cost because of a specified attribute used in one of the alternatives. The operating cost should include manpower and investment.
- (2) The relative judgment that if a given attribute is developed for a given alternative, what are the chances of success.
- (3) The relative development cost to achieve the attribute desired in each alternative.

After completion of the functional experts' judgments of the alternatives an assessment can be made of relative effectiveness of a given alternative. Also patterns may develop in the complex matrix which would justify formulating a new alternative which is a composite of the other alternatives. The merits

of overall system effectiveness of one universal alternative versus the summed effectiveness of a matrix of alternatives among the subsystem functions may also be determined. The output of this exercise in Phase I is to systematically arrive at a set of SAF requirements which can be stated explicitly as tangible measures of performance. The exercise blends system-wide judgments with functional judgments to give a balance in the integrated assessment of the requirements. Furthermore, should new alternatives or new attributes become available, a systematic procedure has been followed which allows any of these items to be compared with previously evaluated alternatives or attributes.

7.2 SYSTEMS REQUIREMENTS ANALYSIS (PHASE II)

During Phase II, all requirements important for the performance of a fuel fabrication facility are identified. In addition to the "SAF" requirements evaluated during Phase I, the process and product requirements are established by the Task Force of industrial representatives based on guidelines from TMC. The purpose of Phase II activity is to evaluate various process options within each function to determine the utility of developing a particular option. The intent is not to restrict development to only one option, but to establish a relative pay-off among the options consistent with the performance requirements. This activity will provide the justification for distributing resources for development, for scheduling milestones and for making decisions as development proceeds. To determine utility of various process options an objective function must be formulated by the Task Force based on guidelines from TMC. The most straightforward objective function is that of product cost which includes the cost impacts of equipment availability, capability, overall system integration, etc. Other objective functions may be considered, if desired. The formalization of systems analysis will be applied following principles described in various texts.* The formalization provides the traceability of value judgments derived from the requirements analysis and provides for iterations as new development information becomes available.

*Example Texts:

- (1) Systems Analysis Techniques, Ralph Deutsch, Prentice-Hall Englewood Cliffs, N.J. 1969.
- (2) Techniques of Systems Engineering, Stanley M. Shinnars, McGraw-Hill Book Corp. N.Y. 1967.

The process options to be considered in the Phase II evaluation include intra-system, inter-systems process choices such as position in main line for blending powders, placement of accountability stations, degree of control of process parameters. Process options may also include those derived from reactor performance needs such as choice of oxides, carbide or metal fuels or choice of sphere-pac fuels instead of pellet fuels.

7.3 SYSTEM DEFINITION PHASE

As shown in Figure B-1, system definition follows functional and system requirements analysis described in Section 8.2 and the function analysis in Section 8.1 provides the basis for assuring that system requirements are passed down the hierarchy of the functional levels. Equipment that is needed for the lowest functional level reflects these system requirements. Additional requirements may be added at each lower functional level if necessary and assurance that these requirements are passed down to lower levels is provided. These activities are formulated during the system definition phase.

The system definition phase includes the following activities:

- (1) Updating of functional analysis based on final iterations during requirements analysis phase.
- (2) Listing of requirements at lowest functional levels.
- (3) Grouping of lowest level functions which have identical or similar requirements.
- (4) Assigning functional level groupings and their requirements to a work breakdown structure (WBS).
- (5) Assigning function level groupings and their requirements to a system design description (SDD) network which starts with an Operating Fuel Fabrication Facility Description (OPDD). The first section of each SDD and the OPDD defines the requirements of the assigned system and must be consistent with lowest level functional requirements.
- (6) The SDD network and the WBS are organized for technical management of each activity. The requirements section of the SDD becomes the measure of success of the development activity assigned to a contractor for a given amount of resources and time listed in the WBS.

The SDD network becomes the documentation system on which configuration control is implemented. The technical management and systems engineering activities are coordinated through this documentation system. Changes caused by new technical management objectives or by systems analysis evaluations of performance requirements are implemented through the SDD network. Interface boundaries between subsystems and components are defined in the SDD network as part of Section 1 of each SDD.

During the system definition phase, a requirements verification plan is issued outlining the specifications for testing of equipment and control systems to assure that the requirements are verified. This plan should delineate available facilities and list options for which different testing schemes may be carried out. Using systems analysis techniques, the cost effectiveness of various testing options may be measured and justified in the verification plan.

The development test plan prepared by each contractor during the development and design phase should draw from the requirement verification plan appropriate segments of work pertinent to the contractors development objectives.

Following the activity boxes in Figure 3 (second page), the completion of the system design definition phase completes the front end systems engineering effort and releases the development activity to be carried out in as many branches as required in the Work Breakdown Structure. The detail plan in Figure 3 shows only two branches, one aimed at component/subsystem developments and the other aimed at system integration development.

7.4 COMPONENT/SUBSYSTEM DEVELOPMENT PHASE

This category which deals with specific equipment and subsystem component has as many branches as needed to carry out the work activity. Each branch operates under constraints and requirements outlined in a specific SDD document. The design and development activity results in descriptions of the equipment which become Section 2 of the applicable SDD. Because this work is in a development stage, the equipment descriptions will pass through stages of conceptual design, preliminary design and final design. Design reviews appropriate to each stage of the design will be part of the milestone structure. The final design should include information sufficient to issue procurement specifications to outside vendors. The preliminary design should include information sufficient to carry out the Title I facility designs. During this

development phase a reference conceptual facility design should be available to the development organizations to maintain an overall design perspective on the systems and subsystems development activities.

A development test plan for each component/subsystem will be prepared which delineates how the requirements are verified, and how the testing is integrated with the conceptual/preliminary/final design sequence described above. At or near the completion of the development and testing stage, detailed procedures for various condition states; steady state operation, maintenance state and emergency states as described in the functional analysis flows will be prepared and become parts of Section 3 in the applicable SDD.

7.5 SYSTEMS INTEGRATION DEVELOPMENT PHASE

Each subsystem of the fuel fabrication facility is interdependent on other subsystems surrounding it. To ensure performance requirements of the overall system it is necessary to consider system integration as a development activity. This development activity includes:

- (1) Delineation of the degree of interdependency when a given subsystem neighbor changes its state (i.e., operation, maintenance or emergency).
- (2) Formulation and development of control actions on a system-wide basis to accommodate system neighbor changes.
- (3) Network simulation to test for instabilities in the system operation based on transfer functions derived from component/subsystem development and testing.
- (4) Integrated testing of crucial subsystem pairs of multiples as appropriate prior to pilot plant testing of the entire system.

This activity will be a major source of systems evaluations derived from maintenance analysis, operation analysis, etc., and will provide the justification for implementing requirements changes during the development phase. Also during this phase constraint analyses associated with changes due to ex-system environment guidelines will be made to understand the impact on development activities.

8.0 SYSTEMS ENGINEERING-TECHNICAL MANAGEMENT INTEGRATION

The control documentation for the development program shown in Figure B-1 and listed below contains input from the technical management (TM) and system

engineering (SE) aspects. The integrated responsibility of each aspect is described as follows:

8.1 CONFIGURATION CONTROL PLAN

- TM - Provides the program objectives and justifications for changes in objectives or premises of the original plan.
- SE - Provides the justification for original requirements based on TM objectives and for changes caused by internal technical development data.

8.2 REQUIREMENTS VERIFICATION PLAN

- TM - Provides the resources for verification testing and implements the plan.
- SE - Provides the requirements which must be verified during development, design and testing.
 - Provides the analytical basis for justifying verification approaches.

8.3 OPERATING PLANT DESIGN DESCRIPTION (OPDD)

- TM - Establishes the OPDD and subsidiary SDD network for technical management/WBS of the development program.
- SE - Provides the requirements (Section 1) under TM guidelines.
 - Performs intra-system integration analysis.
 - Performs constraint analyses due to ex-system environment changes.

8.4 SYSTEM DESIGN DESCRIPTION (SDD)

- TM - Implements document as basis for performance measurement of development activity.
 - Monitors design reviews and administers other sections of SDD.
- SE - Provides the requirements (Section 1) and basis for establishing requirements.
 - Uses other sections of the SDD to perform operational and maintenance analyses.

9.0 SYSTEMS ENGINEERING MILESTONES

The milestones listed below are for the initial phases of the systems engineering activities. The milestone schedule is attached.

9.1 FUNCTIONAL ANALYSIS PHASE

- 9.1.1 Issue preliminary draft of assigned functional flow diagram
- 9.1.2 Issue interface boundary definitions between functions
- 9.1.3 Review and comment on functional flow diagrams
- 9.1.4 Document comments, resolve issues and assure completeness of functions for defined fuel fabrication system
- 9.1.5 Revise and update assigned functional flow and issue as Revision 0
- 9.1.6 Provide reaction viewpoints to SAF alternatives/attributes
- 9.1.7 Update and revise (controlled) functional flow diagrams after completion of Phase II requirements
- 9.1.8 Assign system and subsystem requirements to each functional level, categorize functions and collect common functions having same or different requirements.

9.2 SYSTEM REQUIREMENTS ANALYSIS (PHASE I)

- 9.2.1 Define SAF attributes
- 9.2.2 Assign a scale of measure to each attribute
- 9.2.3 Establish alternative approaches to SAF
- 9.2.4 Review and comment on items 9.2.1, 9.2.2, and 9.2.3.
- 9.2.5 Issue final set of SAF alternates and attributes for analysis. Establish objective functions for analysis
- 9.2.6 Issue analysis reaction viewpoints by functional experts
- 9.2.7 Review and comment by Industry Representatives
- 9.2.8 Update analysis and issue SAF requirements (completes Phase I)

9.3 SYSTEMS ENGINEERING ANALYSIS (PHASE II)

- 9.3.1 Establish product requirements
- 9.3.2 Establish process requirements
- 9.3.3 Establish objective function for evaluating process alternatives
- 9.3.4 Establish plausible process alternates for each function down to lowest level
- 9.3.5 Provide reaction viewpoints on process alternates for each function
- 9.3.6 Issue analysis of process alternates
 - (a) Functional Level
 - (b) System Level
- 9.3.7 Review and comment on analysis of process alternates
- 9.3.8 Issue evaluation of process alternates

9.4 SYSTEM DEFINITION PHASE

- 9.4.1 Establish Operating Plan design requirements (OPDD Section 1)
- 9.4.2 Establish a system design description network
- 9.4.3 Assign functions to SDD network element
- 9.4.4a Industry review of draft SDD Section 1
 - b Issue SDD requirements (Section 1)
- 9.4.5 Assign SDD to WBS element
- 9.4.6 Issue Requirements Verification Plan
- 9.4.7 Issue Configuration Control Plan
- 9.4.8 Issue contractors Development Test Plan

9.5 SUBSEQUENT DEVELOPMENT PHASES

- 9.5.1 Participate in design reviews
- 9.5.2 Participate in requirements verification reviews
- 9.5.3 Perform selected systems analysis from test data
 - Operating Condition Analysis
 - Maintenance Condition Analysis
 - Emergency Condition Analysis

9.0 SYSTEM ENGINEERING SCHEDULE

APPENDIX C

RECOMMENDATIONS AND CONCLUSIONS

FUEL FABRICATION DEVELOPMENT COMMITTEE REPORT

RECOMMENDATIONS AND CONCLUSIONS

- o The integrated technology demonstration to support commitment to the fabrication plant is feasible for any of the fuel options considered by 1995.
 - near remote fuel fabrication could be demonstrated up to three years earlier
- o To retain this schedule, key decisions must be made on schedule to establish priorities and effectively focus resources selection of:
 - FBR fuel type
 - decision to proceed with FBR and schedule
 - near remote or remote fuel fabrication
 - regulatory requirements for fabrication plants (if not available, assumptions will be necessary)
- o At this time, the recommendation is to keep all options open by supporting parallel development paths until the breeder decision and schedule are firm.
- o Remote fuel development is applicable to both breeder and denatured LWR.
- o New facilities required to meet the program goals are:
 - Advanced Technology Pilot Plant (and/or)
 - o integrated remote technology demonstration, near remote or remote operation, particle or pellet, oxide or carbide
 - Small Scale Fabrication Facility
 - o FBR fuel supply beyond 1990
 - o nearl remote

- o Irradiation testing is necessary to qualify particulate fuel and economic pellet fuel.
- o FBR initial fuel supply requirements can be met on the schedule of Core 1 delivery in 1989 utilizing modified existing facilities.
 - near remote pellet fuels
 - oxide or carbide
 - 14% ^{240}Pu
 - modification of facilities and acquisition of equipment will have to be a high priority effort
- o The role of industrial facilities for fuel supply/development must be defined in fiscal 1980 to assure their continued availability.
- o The Special Nuclear Material (SNM) supply must be defined by 1982 to be consistent with FBR core fabrication commencing in 1986 (key interface issue).
- o Gel-sphere fuel cannot be qualified for consideration for 1989 delivery of a core loading for the FBR, but the technology can be demonstrated by 1995.
- o A simultaneous decision is required to construct both the FBR and the Small Scale Fabrication Facility for high ^{240}Pu material and to assure a reliable long-term breeder reactor fuel supply to be established.
- o A standing fuel fabrication review committee (industry, national, laboratory, government contract) should be formed to review and recommend the activities to assure FBR fuel and technology development.
 - mechanism for industry participation
 - recommendations on new required facilities
 - decision tree analysis to ensure achievement of objectives

APPENDIX D

REGULATIONS APPLICABLE TO THE
SECURE AUTOMATED FABRICATION
SYSTEMS ANALYSIS

APPENDIX D

GENERAL ELECTRIC COMPANY
310 DeGuigne Drive
P.O. Box 5020
Sunnyvale, California 94086

CDC: XL-273-90095
P2809

September 25, 1979

TO : "Zero Risk" Task Force

E. A. Aitken - GE	L. G. Merker - Exxon
B. Bowen - W-ARD	C. Milner - Exxon
M. C. J. Carlson - HEDL	T. Nagamoto - W-ARD
N. Fuhrman - CE	M. L. Thompson - GE
L. J. Jones - AI-Rockwell	C. R. Woods - B&W
B. Matthews - PNL	

FROM : E. A. Aitken, Task Force Member

SUBJECT : REGULATIONS APPLICABLE TO THE "ZERO RISK" SYSTEMS ANALYSIS

Reference: Task Force Meeting Letter from E. A. Aitken, dated 9/11/79

A need was identified at the August 27-28, 1979 TMC "Zero Risk" Task Force Meeting to document pertinent regulations applicable to the "zero risk" attributes identified by the committee concerning risks to employees and the public.

The following documentation provides regulatory references and some applicable specific values. Further refinement of the regulation applicability may be necessary as selection of specific requirements is carried out. As noted in the documentation, the attributes are listed with the applicable regulation(s) referenced. Specific regulation limits are indicated for areas where values are appropriate and were readily definable.

MLT:rjy

Attachments

cc: D. E. Bailey - DOE Headquarters
R. E. Dahl - HEDL-TMC
E. A. Evans - HEDL-TMC
E. Gerber - HEDL-TMC

E. C. Norman - TMC Rep.
J. M. Yatabe - HEDL
C. A. Burgess - HEDL

bcc: E. F. Kurtz G. L. O'Neill
I. N. Taylor J. J. Zimmer
M. L. Thompson P. C. Miller
D. H. Imhoff

Attribute Number	Attribute Title	Applicable Regulations	Specific Value	
			Limits (rem)	
E-1.1 (1.1.3)	Total External Exposure	10CFR 20 "Standards for Protection Against Radiation"		
		10CFR 20.101 "Exposure of Individuals to Radiation in Restricted Areas"		
		Whole Body	1-1/4 (3 max. in any one qtr.)	5 accum. 5(N-18)
		Skin & Thyroid Extremities	7-1/2 18-3/4	30 75
E-1.2	Internal Exposure	10CFR 20 "Standards for Protection Against Radiation"		
		10CFR 20.103 "Exposure of Individuals to Concentrations of Radioactive Materials in Restricted Areas"	not exceed that which would result from inhalation for 40 hrs/wk for 13 weeks at uniform concentrations of radioactive material in air specified in Appendix B, Table 1, Column 1. (See Attached Appendix B)	
E-2.1/2.3	Criticality	10CFR 70 "Domestic Licensing of SNM"		
		10CFR 70.24 "Criticality Accident Requirements"		
		Additional References:		
		ANSI Standard N16.1 "Nuclear Criticality Safety Standard for Operation with Fissionable Materials Outside Reactors"		
		ANSI Standard N16.5 "American National Standard Guide for Nuclear Criticality Safety In Storage of Fissile Materials"		
		ANSI Standard N16.9 "Validation of Calculational Methods of Nuclear Criticality Safety"		
		Reg. Guide 3.4.1 "Validation of Calculational Methods for Nuclear Criticality Safety"		

Attribute Number	Attribute Title	Applicable Regulations	Specific Value
E-3	Personnel Contamination & Detection	10CFR 20 "Standards for Protection Against Radiation" 10CFR 20.108 "Orders Requiring Furnishing Bio-Assay Services" 10CFR 20.201 "Surveys" 10CFR 20.202 "Personnel Monitoring"	(a) Each licensee shall supply appropriate monitoring equipment to and shall require the use of such equipment by: (1) likely to receive, a dose in any calendar quarter in excess of 25% of the applicable value specified in Par. (a) of 20.101
E-4	Personnel Training	10CFR 19 "Notices, Instructions and Reports to Workers; Inspections" 10CFR 19.12 "Instructions to Workers"	
E-5	Containment & Detection		
(5.1)	Airborne Contamination	10CFR 20 "Standards for Protection Against Radiation" (Also see E1.2 above)	
(5.2)	Non-Nuclear Hazardous Materials	EPA Regulations (believed to be applicable - depends on state requirements) <u>Air</u> 40CFR 50 "EPA Regulations on National Primary & Secondary Ambient Air Qual. Stds." 40CFR 51 "EPA Regulations on Implementation Plans"	

Attribute Number	Attribute Title	Applicable Regulations	Specific Value
E-5 (Cont'd)		<p>40CFR 52 "EPA Regulations on Approval and Promulgation of Implementation Plans"</p> <p>40CFR 60 "EPA Regulations on Standards of Performance for New Stationary Sources"</p> <p>40CFR 81 "EPA Regulations Designating Areas for Air Quality Planning"</p> <p>40CFR 58 "EPA Ambient Air Qual. Surveillance Regulations"</p> <p><u>Solid</u></p> <p>40CFR 256 "EPA Guidelines for State Solid Waste Management Plans"</p> <p><u>Water (along with others)</u></p> <p>40CFR 116 "Designation of Hazardous Substances"</p> <p>40CFR 117 "Determination of Reportable Quantities of Hazardous Substances"</p> <p>40CFR 118 "Determination of Harmful Quantities for Hazardous Substances"</p> <p>40CFR 119 "Determination of Units of Measurement and Rates of Penalty for Hazardous Substances"</p> <p>Section 311 of Clean Water Act</p>	

Attribute Number	Attribute Title	Applicable Regulations	Specific Value
E-5 (Cont'd)		40CFR 122 "Consolidated Permit 40CFR 123 Regulations: RCRA 40CFR 124 Hazardous Waste; SDWA Underground Injection Control; CAA Prevention of Significant Deterior- ation; CWA National Pollutant Discharge Elimination System; and Section 404 Dredge or Fill Programs	
		40CFR 121 "State Certification of Activities Requiring a Federal License or Permit"	
		40CFR 125 "Criteria & Standards for the National Pollutant Discharge Elimination System"	
		33CFR 153 "Control of Pollution by Oil & Hazardous Substances, Discharge and Removal"	
P1 1.1/1.3	Discharge to Environ- ment	10CFR 20 "Standards for Protec- tion Against Radiation"	
		10CFR 20.106 "Radioactivity in Effluents to Unrestricted Areas	(a) not ... exceed the limits specified in Appendix B, Table II...
1.4	Sabotage	10CFR 73 "Physical Protection of Plants and Materials"	

Attribute Number	Attribute Title	Applicable Regulations	Specific Value
P1 1.4 (Cont'd)			
	Non-Nuclear Hazardous Materials	(See E5.2 above)	
	Exposure	10CFR 20.105 "Permissible Levels of Radiation in Unrestricted Areas"	(a) not ... exceed a dose to the whole body in any period of one calendar year in excess of 0.5 rem.
P2	Diversion/Theft		
(2.1)	Accountability	10CFR 70 "Domestic Licensing of Special Nuclear Material"	
		10CFR 70.51 "Material Balance, Inventory and Records Requirements"	2 mo. inventories MUF = BI+AI-EI-R LEMUF = 200 gms, or 0.5% of Pu throughput (1.0% of throughput for reprocessing)
		10CFR 70.57 "Measurement Control Program for SNM Control and Accounting"	
		10CFR 70.58 "Fundamental Nuclear Material Control"	MBA/ICA
(2.2)	Physical Protection	10CFR 73 "Physical Protection of Plants and Materials"	Formula 5000 gms = (gms U_{235}) + 2.5 (gms U_{233} + Pu)
P3	Decontamination & Decommissioning		
(3.1)	Packaging & Shipping	10CFR 20 "Standards for Protection Against Radiation"	
		49CFR 171-178 (transportation)	

Attribute Number	Attribute Title	Applicable Regulations	Specific Value
P3 (Cont'd)			
(3.2)	Facility Conditions	NRC Annex C "Guidelines for Decontamination of Facilities and Equipment Prior to Use for Unrestricted Use or Termination of Licenses for Byproduct, Source, or SNM", November, 1976 (proposed Regulations are forthcoming)	
P4	Third Party Protec- tion		
(4.1)	Shipments	10CFR 71 "Packaging of Radioactive Material for Transport and Trans- portation of Radioactive Materials Under Certain Conditions"	
		10CFR 73 "Physical Protection of Plants and Materials"	
		49CFR 171-178 (transportation)	Transport groups, contamination control, packaging, etc.

ATTACHMENT TO APPENDIX D

10CFR20, "STANDARDS FOR PROTECTION AGAINST IRRADIATION", APPENDIX B:

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND

APPENDIX B
CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND
(See notes at end of appendix)

Element (atomic number)	Isotope ¹	Table I		Table II	
		Col. 1	Col. 2	Col. 1	Col. 2
		Air ($\mu\text{Ci}/\text{ml}$)	Water ($\mu\text{Ci}/\text{ml}$)	Air ($\mu\text{Ci}/\text{ml}$)	Water ($\mu\text{Ci}/\text{ml}$)
Actinium (89)	Ac 227	8	3	8	3
	I	2×10^{-10}	6×10^{-9}	8×10^{-10}	2×10^{-8}
	I	3×10^{-11}	9×10^{-9}	9×10^{-11}	3×10^{-8}
	Ac 228	8	3	8	3
	I	8×10^{-9}	3×10^{-8}	3×10^{-9}	9×10^{-8}
	I	2×10^{-9}	3×10^{-8}	6×10^{-10}	9×10^{-8}

APPENDIX B—Continued

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND

[See notes at end of appendix]

Element (atomic number)	Isotope ¹	Table I		Table II	
		Col. 1 Air ($\mu\text{Ci}/\text{ml}$)	Col. 2 Water ($\mu\text{Ci}/\text{ml}$)	Col. 1 Air ($\mu\text{Ci}/\text{ml}$)	Col. 2 Water ($\mu\text{Ci}/\text{ml}$)
Americium (95)	Am 241	S	6×10^{-12}	1×10^{-11}	2×10^{-12}
	I		1×10^{-10}	8×10^{-12}	4×10^{-12}
	Am 242m	S	6×10^{-12}	1×10^{-11}	2×10^{-12}
	I		3×10^{-10}	3×10^{-11}	9×10^{-12}
	Am 242	S	4×10^{-12}	4×10^{-12}	1×10^{-11}
	I		5×10^{-11}	4×10^{-12}	2×10^{-11}
	Am 243	S	6×10^{-12}	1×10^{-11}	2×10^{-12}
	I		1×10^{-10}	8×10^{-12}	4×10^{-12}
	Am 244	S	4×10^{-12}	1×10^{-11}	1×10^{-11}
	I		2×10^{-10}	1×10^{-11}	5×10^{-12}
Antimony	Sb 122	S	2×10^{-11}	8×10^{-12}	6×10^{-12}
	I		1×10^{-10}	8×10^{-12}	5×10^{-12}
	Sb 124	S	2×10^{-11}	7×10^{-12}	5×10^{-12}
	I		2×10^{-10}	7×10^{-12}	2×10^{-11}
	Sb 125	S	5×10^{-12}	3×10^{-12}	2×10^{-12}
Argon (18)	A 37	Sub ²	3×10^{-12}	3×10^{-12}	9×10^{-12}
	A 41	Sub	2×10^{-12}		1×10^{-11}
Arsenic (33)	As 73	S	2×10^{-12}	1×10^{-11}	7×10^{-12}
	I		4×10^{-11}	1×10^{-11}	5×10^{-12}
	As 74	S	3×10^{-12}	2×10^{-12}	1×10^{-11}
	I		1×10^{-10}	2×10^{-12}	5×10^{-12}
	As 76	S	1×10^{-11}	6×10^{-12}	4×10^{-12}
	I		1×10^{-10}	6×10^{-12}	3×10^{-12}
Astatine (85)	At 211	S	7×10^{-12}	5×10^{-12}	2×10^{-12}
	I		3×10^{-10}	2×10^{-12}	1×10^{-11}
	At 212	S	1×10^{-11}	5×10^{-12}	4×10^{-12}
Barium (56)	Ba 131	S	4×10^{-12}	5×10^{-12}	1×10^{-11}
	I		1×10^{-10}	8×10^{-12}	4×10^{-12}
Berkelium (97)	Bk 249	S	9×10^{-12}	2×10^{-12}	3×10^{-12}
	I		1×10^{-10}	2×10^{-12}	4×10^{-12}
	Bk 250	S	1×10^{-11}	6×10^{-12}	5×10^{-12}
Beryllium (4)	Be 7	S	6×10^{-12}	5×10^{-12}	2×10^{-12}
	I		1×10^{-10}	5×10^{-12}	4×10^{-12}
Bismuth (83)	Bi 206	S	2×10^{-12}	1×10^{-11}	6×10^{-12}
	I		1×10^{-10}	1×10^{-11}	5×10^{-12}
	Bi 207	S	2×10^{-12}	2×10^{-12}	6×10^{-12}
	I		1×10^{-10}	2×10^{-12}	5×10^{-12}
	Bi 210	S	6×10^{-12}	1×10^{-11}	2×10^{-12}
Bromine (35)	Br 82	S	1×10^{-11}	1×10^{-11}	3×10^{-12}
	I		2×10^{-10}	1×10^{-11}	6×10^{-12}
	Br 81	S	5×10^{-12}	5×10^{-12}	2×10^{-12}
Cadmium (48)	Cd 109	S	7×10^{-12}	8×10^{-12}	3×10^{-12}
	I		4×10^{-10}	7×10^{-12}	1×10^{-11}
	Cd 115m	S	4×10^{-12}	7×10^{-12}	1×10^{-11}
	I		4×10^{-10}	7×10^{-12}	3×10^{-12}
Calcium (20)	Ca 45	S	2×10^{-11}	1×10^{-11}	8×10^{-12}
	I		2×10^{-10}	1×10^{-11}	6×10^{-12}
	Ca 47	S	3×10^{-12}	3×10^{-12}	1×10^{-11}
Californium (98)	Cf 249	S	1×10^{-11}	5×10^{-12}	4×10^{-12}
	I		2×10^{-10}	1×10^{-11}	6×10^{-12}
	Cf 250	S	2×10^{-11}	1×10^{-11}	6×10^{-12}
	I		1×10^{-10}	7×10^{-12}	3×10^{-12}

APPENDIX B—Continued

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND

(See notes at end of appendix)

Element (atomic number)	Isotope ¹	Table I		Table II	
		Col. 1	Col. 2	Col. 1	Col. 2
		Air ($\mu\text{Ci}/\text{ml}$)	Water ($\mu\text{Ci}/\text{ml}$)	Air ($\mu\text{Ci}/\text{ml}$)	Water ($\mu\text{Ci}/\text{ml}$)
Californium (98)	Cf 251	S	2×10^{-10}	1×10^{-10}	6×10^{-10}
	I		1×10^{-10}	8×10^{-10}	3×10^{-10}
	Cf 252	S	6×10^{-10}	2×10^{-10}	2×10^{-10}
	I		3×10^{-10}	2×10^{-10}	7×10^{-10}
	Cf 253	S	8×10^{-10}	4×10^{-10}	3×10^{-10}
	I		8×10^{-10}	4×10^{-10}	3×10^{-10}
Carbon (6)	Cf 254	S	5×10^{-10}	4×10^{-10}	2×10^{-10}
	I		5×10^{-10}	4×10^{-10}	2×10^{-10}
	C 14	S	4×10^{-10}	2×10^{-10}	1×10^{-10}
Cerium (58)	(CO ₂)	Sub	5×10^{-10}	1×10^{-10}	
	Ce 141	S	4×10^{-10}	3×10^{-10}	2×10^{-10}
	I		2×10^{-10}	3×10^{-10}	5×10^{-10}
Cesium (55)	Ce 143	S	3×10^{-10}	1×10^{-10}	9×10^{-10}
	I		2×10^{-10}	1×10^{-10}	7×10^{-10}
	Ce 144	S	1×10^{-10}	3×10^{-10}	3×10^{-10}
Chlorine (17)	I		6×10^{-10}	3×10^{-10}	2×10^{-10}
	Cs 131	S	1×10^{-10}	7×10^{-10}	4×10^{-10}
	I		3×10^{-10}	3×10^{-10}	1×10^{-10}
	Cs 134m	S	4×10^{-10}	2×10^{-10}	1×10^{-10}
	I		6×10^{-10}	3×10^{-10}	2×10^{-10}
	Cs 134	S	4×10^{-10}	3×10^{-10}	1×10^{-10}
	I		1×10^{-10}	1×10^{-10}	4×10^{-10}
	Cs 136	S	5×10^{-10}	3×10^{-10}	2×10^{-10}
	I		9×10^{-10}	7×10^{-10}	3×10^{-10}
	Cs 136	S	4×10^{-10}	2×10^{-10}	1×10^{-10}
	I		2×10^{-10}	2×10^{-10}	6×10^{-10}
	Cs 137	S	6×10^{-10}	4×10^{-10}	2×10^{-10}
Chromium (24)	I		1×10^{-10}	1×10^{-10}	5×10^{-10}
	Cl 36	S	4×10^{-10}	2×10^{-10}	1×10^{-10}
	I		2×10^{-10}	2×10^{-10}	8×10^{-10}
Cobalt (27)	Cl 38	S	3×10^{-10}	1×10^{-10}	9×10^{-10}
	I		2×10^{-10}	1×10^{-10}	7×10^{-10}
	Cr 51	S	1×10^{-10}	5×10^{-10}	4×10^{-10}
Copper (29)	I		2×10^{-10}	5×10^{-10}	8×10^{-10}
	Co 57	S	3×10^{-10}	2×10^{-10}	1×10^{-10}
	I		2×10^{-10}	1×10^{-10}	6×10^{-10}
	Co 58m	S	2×10^{-10}	8×10^{-10}	6×10^{-10}
	I		9×10^{-10}	6×10^{-10}	3×10^{-10}
	Co 58	S	8×10^{-10}	4×10^{-10}	3×10^{-10}
Curium (96)	I		5×10^{-10}	3×10^{-10}	2×10^{-10}
	Co 60	S	3×10^{-10}	1×10^{-10}	1×10^{-10}
	I		9×10^{-10}	1×10^{-10}	3×10^{-10}
Curtium (96)	Cu 64	S	2×10^{-10}	1×10^{-10}	7×10^{-10}
	I		1×10^{-10}	6×10^{-10}	4×10^{-10}
	Cm 242	S	1×10^{-10}	7×10^{-10}	4×10^{-10}
	I		2×10^{-10}	7×10^{-10}	6×10^{-10}
	Cm 243	S	6×10^{-10}	1×10^{-10}	2×10^{-10}
	I		1×10^{-10}	7×10^{-10}	3×10^{-10}
	Cm 244	S	9×10^{-10}	2×10^{-10}	3×10^{-10}
	I		1×10^{-10}	8×10^{-10}	3×10^{-10}
	Cm 245	S	5×10^{-10}	1×10^{-10}	2×10^{-10}
	I		1×10^{-10}	8×10^{-10}	4×10^{-10}
	Cm 246	S	5×10^{-10}	1×10^{-10}	2×10^{-10}
	I		1×10^{-10}	8×10^{-10}	4×10^{-10}
Dysprosium (64)	Cm 247	S	5×10^{-10}	1×10^{-10}	2×10^{-10}
	I		1×10^{-10}	6×10^{-10}	4×10^{-10}
	Cm 248	S	6×10^{-10}	1×10^{-10}	2×10^{-10}
	I		1×10^{-10}	4×10^{-10}	4×10^{-10}
	Cm 249	S	1×10^{-10}	6×10^{-10}	4×10^{-10}
	I		1×10^{-10}	6×10^{-10}	4×10^{-10}
Dysprosium (64)	Dy 165	S	3×10^{-10}	1×10^{-10}	9×10^{-10}
	I		2×10^{-10}	1×10^{-10}	7×10^{-10}

APPENDIX B—Continued

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND

[See notes at end of appendix]

Element (atomic number)	Isotope ¹	Table I		Table II	
		Col. 1	Col. 2	Col. 1	Col. 2
		Air ($\mu\text{Ci/ml}$)	Water ($\mu\text{Ci/ml}$)	Air ($\mu\text{Ci/ml}$)	Water ($\mu\text{Ci/ml}$)
Dysprosium (66)	Dy 166	S	2×10^{-7}	1×10^{-8}	8×10^{-8}
		I	2×10^{-7}	1×10^{-8}	4×10^{-8}
Einsteinium (99)	Es 253	S	8×10^{-10}	7×10^{-9}	3×10^{-11}
		I	6×10^{-10}	7×10^{-9}	2×10^{-11}
	Es 254m	S	5×10^{-9}	5×10^{-8}	2×10^{-10}
		I	6×10^{-9}	5×10^{-8}	2×10^{-10}
	Es 254	S	2×10^{-11}	4×10^{-8}	6×10^{-10}
		I	1×10^{-10}	4×10^{-8}	4×10^{-10}
	Es 255	S	5×10^{-10}	8×10^{-8}	2×10^{-11}
		I	4×10^{-10}	8×10^{-8}	1×10^{-11}
Erbium (68)	Er 169	S	6×10^{-7}	3×10^{-8}	2×10^{-8}
		I	4×10^{-7}	3×10^{-8}	1×10^{-8}
	Er 171	S	7×10^{-7}	3×10^{-8}	2×10^{-8}
		I	6×10^{-7}	3×10^{-8}	1×10^{-8}
Europium (63)	Eu 152	S	4×10^{-7}	2×10^{-8}	1×10^{-8}
	(T/2=9.2 hrs)	I	3×10^{-7}	2×10^{-8}	1×10^{-8}
	Eu 152	S	1×10^{-8}	2×10^{-8}	4×10^{-10}
	(T/2=13 yrs)	I	2×10^{-8}	2×10^{-8}	6×10^{-10}
	Eu 154	S	4×10^{-8}	6×10^{-8}	1×10^{-10}
		I	7×10^{-8}	6×10^{-8}	2×10^{-10}
	Eu 155	S	9×10^{-8}	6×10^{-8}	3×10^{-8}
		I	7×10^{-8}	6×10^{-8}	3×10^{-8}
Fermium (100)	Fm 254	S	6×10^{-8}	4×10^{-8}	2×10^{-8}
		I	7×10^{-8}	4×10^{-8}	2×10^{-8}
	Fm 255	S	2×10^{-8}	1×10^{-8}	6×10^{-10}
		I	1×10^{-8}	1×10^{-8}	4×10^{-10}
	Fm 256	S	3×10^{-8}	3×10^{-8}	1×10^{-10}
		I	2×10^{-8}	3×10^{-8}	6×10^{-11}
Fluorine (9)	F 18	S	5×10^{-8}	2×10^{-8}	2×10^{-8}
		I	3×10^{-8}	1×10^{-8}	9×10^{-9}
Gadolinium (64)	Gd 153	S	2×10^{-7}	6×10^{-8}	8×10^{-8}
		I	9×10^{-8}	6×10^{-8}	3×10^{-8}
	Gd 159	S	5×10^{-7}	2×10^{-8}	2×10^{-8}
		I	4×10^{-7}	2×10^{-8}	1×10^{-8}
Gallium (31)	Ga 72	S	2×10^{-7}	1×10^{-8}	8×10^{-8}
		I	2×10^{-7}	1×10^{-8}	6×10^{-8}
Germanium (32)	Ge 71	S	1×10^{-8}	5×10^{-8}	4×10^{-7}
		I	6×10^{-8}	5×10^{-8}	2×10^{-7}
Gold (79)	Au 196	S	1×10^{-8}	5×10^{-8}	4×10^{-8}
		I	6×10^{-8}	4×10^{-8}	2×10^{-8}
	Au 198	S	3×10^{-7}	2×10^{-8}	1×10^{-8}
		I	2×10^{-7}	1×10^{-8}	8×10^{-8}
	Au 199	S	1×10^{-8}	5×10^{-8}	4×10^{-8}
		I	8×10^{-7}	4×10^{-8}	3×10^{-8}
Hafnium (72)	Hf 181	S	4×10^{-8}	2×10^{-8}	1×10^{-8}
		I	7×10^{-8}	2×10^{-8}	3×10^{-8}
Holmium (67)	Ho 166	S	2×10^{-7}	9×10^{-8}	7×10^{-8}
		I	2×10^{-7}	9×10^{-8}	6×10^{-8}
Hydrogen (1)	H3	S	5×10^{-8}	1×10^{-8}	2×10^{-7}
		I	5×10^{-8}	1×10^{-8}	2×10^{-7}
	Sub		2×10^{-8}		4×10^{-8}
Indium (49)	In 113m	S	8×10^{-8}	4×10^{-8}	3×10^{-8}
		I	7×10^{-8}	4×10^{-8}	2×10^{-8}
	In 114m	S	1×10^{-7}	5×10^{-8}	4×10^{-8}
		I	2×10^{-8}	5×10^{-8}	7×10^{-10}
	In 115m	S	2×10^{-8}	1×10^{-8}	8×10^{-8}
		I	2×10^{-8}	1×10^{-8}	6×10^{-8}
	In 115	S	2×10^{-7}	3×10^{-8}	9×10^{-8}
		I	3×10^{-8}	3×10^{-8}	1×10^{-8}
Iodine (53)	I 125	S	5×10^{-8}	4×10^{-8}	8×10^{-11}
		I	2×10^{-7}	6×10^{-8}	6×10^{-8}
	I 126	S	8×10^{-8}	5×10^{-8}	9×10^{-11}
		I	3×10^{-7}	3×10^{-8}	1×10^{-8}

APPENDIX B—Continued

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND

(See notes at end of appendix)

Element (atomic number)	Isotope ¹	Table I		Table II	
		Col. 1	Col. 2	Col. 1	Col. 2
		Air ($\mu\text{Ci/ml}$)	Water ($\mu\text{Ci/ml}$)	Air ($\mu\text{Ci/ml}$)	Water ($\mu\text{Ci/ml}$)
Iodine (53)	I 129	S	2×10^{-9}	1×10^{-10}	2×10^{-11}
	I 131	I	7×10^{-9}	6×10^{-9}	2×10^{-9}
	I 131	S	9×10^{-9}	6×10^{-9}	1×10^{-10}
	I 132	I	3×10^{-7}	2×10^{-8}	1×10^{-9}
	I 132	S	2×10^{-7}	2×10^{-8}	3×10^{-9}
	I 133	I	9×10^{-7}	5×10^{-8}	3×10^{-9}
	I 133	S	3×10^{-8}	2×10^{-8}	4×10^{-10}
	I 134	I	2×10^{-7}	1×10^{-8}	7×10^{-9}
	I 134	S	5×10^{-7}	4×10^{-8}	6×10^{-9}
	I 135	I	3×10^{-7}	2×10^{-8}	1×10^{-9}
Iridium (77)	Ir 190	S	1×10^{-6}	7×10^{-7}	1×10^{-6}
	Ir 190	I	4×10^{-7}	2×10^{-7}	1×10^{-6}
	Ir 192	S	1×10^{-7}	1×10^{-7}	1×10^{-6}
	Ir 192	I	3×10^{-7}	1×10^{-7}	9×10^{-10}
	Ir 194	S	2×10^{-7}	1×10^{-7}	8×10^{-8}
Iron (26)	Fe 55	I	2×10^{-7}	9×10^{-8}	5×10^{-8}
	Fe 55	S	9×10^{-7}	2×10^{-7}	3×10^{-8}
	Fe 59	I	1×10^{-6}	7×10^{-7}	3×10^{-8}
	Fe 59	S	1×10^{-7}	2×10^{-7}	5×10^{-8}
Krypton (36)	Kr 85m	I	5×10^{-9}	2×10^{-9}	2×10^{-9}
	Kr 85	Sub	6×10^{-9}	1×10^{-9}	1×10^{-9}
	Kr 87	Sub	1×10^{-8}	3×10^{-9}	3×10^{-9}
	Kr 88	Sub	1×10^{-8}	2×10^{-9}	2×10^{-9}
Lanthanum (57)	La 140	S	1×10^{-7}	7×10^{-8}	5×10^{-9}
	La 140	I	2×10^{-7}	7×10^{-8}	4×10^{-9}
Lead (82)	Pb 203	S	1×10^{-7}	7×10^{-8}	4×10^{-9}
	Pb 203	I	3×10^{-7}	1×10^{-7}	9×10^{-8}
	Pb 210	S	2×10^{-8}	1×10^{-8}	6×10^{-9}
	Pb 210	I	1×10^{-10}	4×10^{-10}	4×10^{-10}
	Pb 212	S	2×10^{-10}	5×10^{-10}	8×10^{-10}
Lutetium (71)	Lu 177	S	2×10^{-9}	6×10^{-9}	6×10^{-10}
	Lu 177	I	6×10^{-7}	3×10^{-7}	2×10^{-8}
Manganese (25)	Mn 52	S	5×10^{-7}	3×10^{-7}	2×10^{-8}
	Mn 52	I	2×10^{-7}	1×10^{-7}	7×10^{-8}
	Mn 54	S	1×10^{-7}	9×10^{-8}	5×10^{-8}
	Mn 54	I	4×10^{-7}	4×10^{-7}	1×10^{-8}
	Mn 56	S	4×10^{-7}	3×10^{-7}	1×10^{-8}
Mercury (80)	Hg 197m	S	8×10^{-7}	4×10^{-7}	3×10^{-8}
	Hg 197m	I	5×10^{-7}	3×10^{-7}	2×10^{-8}
	Hg 197	S	7×10^{-7}	6×10^{-7}	3×10^{-8}
	Hg 197	I	8×10^{-7}	5×10^{-7}	3×10^{-8}
	Hg 203	S	1×10^{-6}	1×10^{-6}	9×10^{-8}
Molybdenum (42)	Mo 99	S	3×10^{-7}	2×10^{-7}	2×10^{-8}
	Mo 99	I	7×10^{-7}	5×10^{-7}	3×10^{-8}
Neodymium (60)	Nd 144	S	1×10^{-7}	3×10^{-7}	4×10^{-8}
	Nd 144	I	2×10^{-7}	1×10^{-7}	7×10^{-8}
	Nd 147	S	8×10^{-11}	2×10^{-11}	3×10^{-11}
	Nd 147	I	3×10^{-10}	2×10^{-10}	1×10^{-10}
	Nd 149	S	4×10^{-10}	2×10^{-10}	1×10^{-10}
Neptunium (93)	Np 237	S	2×10^{-10}	8×10^{-10}	6×10^{-10}
	Np 237	I	2×10^{-10}	8×10^{-10}	6×10^{-10}
	Np 239	S	1×10^{-10}	8×10^{-10}	3×10^{-10}
	Np 239	I	4×10^{-10}	9×10^{-10}	1×10^{-10}
	Np 239	S	1×10^{-10}	9×10^{-10}	4×10^{-10}
Nickel (28)	Ni 59	S	8×10^{-7}	4×10^{-7}	3×10^{-8}
	Ni 59	I	7×10^{-7}	4×10^{-7}	2×10^{-8}
	Ni 59	S	5×10^{-7}	6×10^{-7}	2×10^{-8}

APPENDIX B—Continued

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND

(See notes at end of appendix)

Element (atomic number)	Isotope ¹	Table I		Table II	
		Col. 1	Col. 2	Col. 1	Col. 2
		Air ($\mu\text{Ci/ml}$)	Water ($\mu\text{Ci/ml}$)	Air ($\mu\text{Ci/ml}$)	Water ($\mu\text{Ci/ml}$)
Nickel (28)	Ni 63	S	6×10^{-3}	8×10^{-4}	2×10^{-3}
	Ni 65	I	3×10^{-3}	2×10^{-4}	1×10^{-3}
	Ni 65	S	9×10^{-3}	4×10^{-4}	3×10^{-3}
Niobium (Columbium) (41)	Nb 93m	I	5×10^{-3}	3×10^{-4}	2×10^{-3}
	Nb 93m	S	1×10^{-3}	1×10^{-4}	4×10^{-4}
	Nb 95	I	2×10^{-3}	1×10^{-4}	5×10^{-4}
	Nb 95	S	5×10^{-3}	3×10^{-4}	2×10^{-3}
	Nb 97	I	1×10^{-3}	3×10^{-4}	3×10^{-4}
Osmium (76)	Os 185	S	8×10^{-3}	3×10^{-4}	2×10^{-3}
	Os 185	I	5×10^{-3}	3×10^{-4}	2×10^{-3}
	Os 191m	S	5×10^{-3}	2×10^{-4}	2×10^{-3}
	Os 191m	I	2×10^{-3}	2×10^{-4}	7×10^{-4}
	Os 191	S	9×10^{-3}	7×10^{-4}	3×10^{-3}
Palladium (46)	Pd 103	I	1×10^{-3}	5×10^{-4}	4×10^{-4}
	Pd 103	S	4×10^{-3}	5×10^{-4}	2×10^{-3}
	Pd 109	I	1×10^{-3}	1×10^{-4}	2×10^{-3}
	Pd 109	S	3×10^{-3}	1×10^{-4}	6×10^{-4}
	Pd 109	I	7×10^{-3}	9×10^{-4}	5×10^{-3}
Phosphorus (15)	P 32	S	1×10^{-3}	1×10^{-4}	3×10^{-4}
Platinum (78)	Pt 191	I	8×10^{-3}	3×10^{-4}	3×10^{-3}
	Pt 191	S	8×10^{-3}	4×10^{-4}	2×10^{-3}
	Pt 193	I	6×10^{-3}	3×10^{-4}	2×10^{-3}
	Pt 193m	S	1×10^{-3}	3×10^{-4}	1×10^{-3}
	Pt 193m	I	3×10^{-3}	2×10^{-4}	1×10^{-3}
Plutonium (94)	Pu 238	S	6×10^{-3}	3×10^{-4}	2×10^{-3}
	Pu 238	I	5×10^{-3}	3×10^{-4}	9×10^{-4}
	Pu 239	S	8×10^{-3}	4×10^{-4}	1×10^{-3}
	Pu 239	I	2×10^{-3}	3×10^{-4}	1×10^{-3}
	Pu 240	S	2×10^{-3}	3×10^{-4}	1×10^{-3}
Polonium (84)	Po 210	S	4×10^{-3}	3×10^{-4}	2×10^{-3}
	Po 210	I	9×10^{-3}	7×10^{-4}	3×10^{-3}
	Po 210	S	2×10^{-3}	2×10^{-4}	2×10^{-3}
	Po 210	I	4×10^{-3}	1×10^{-4}	1×10^{-3}
	Po 210	S	2×10^{-3}	1×10^{-4}	1×10^{-3}
Potassium (19)	K 42	S	8×10^{-3}	3×10^{-4}	1×10^{-3}
	K 42	I	2×10^{-3}	3×10^{-4}	1×10^{-3}
	K 42	S	2×10^{-3}	3×10^{-4}	1×10^{-3}
	K 42	I	2×10^{-3}	3×10^{-4}	1×10^{-3}
	K 42	S	2×10^{-3}	3×10^{-4}	1×10^{-3}
Praseodymium (59)	Pr 142	S	2×10^{-3}	3×10^{-4}	1×10^{-3}
	Pr 142	I	2×10^{-3}	3×10^{-4}	1×10^{-3}
	Pr 143	S	3×10^{-3}	1×10^{-4}	5×10^{-4}
	Pr 143	I	2×10^{-3}	1×10^{-4}	5×10^{-4}
	Pr 143	S	2×10^{-3}	1×10^{-4}	5×10^{-4}
Promethium (61)	Pm 147	S	6×10^{-3}	2×10^{-4}	2×10^{-3}
	Pm 147	I	1×10^{-3}	6×10^{-4}	3×10^{-4}
	Pm 149	S	3×10^{-3}	1×10^{-4}	4×10^{-4}
	Pm 149	I	2×10^{-3}	1×10^{-4}	4×10^{-4}
	Pm 149	S	2×10^{-3}	1×10^{-4}	4×10^{-4}
Protoactinium (91)	Pa 230	S	2×10^{-3}	7×10^{-4}	6×10^{-4}
	Pa 230	I	8×10^{-3}	7×10^{-4}	3×10^{-3}

APPENDIX B—Continued

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND

(See notes at end of appendix)

Element (atomic number)	Isotope ¹	Table I		Table II	
		Col. 1	Col. 2	Col. 1	Col. 2
		Air ($\mu\text{Ci}/\text{ml}$)	Water ($\mu\text{Ci}/\text{ml}$)	Air ($\mu\text{Ci}/\text{ml}$)	Water ($\mu\text{Ci}/\text{ml}$)
Protoactinium (91)	Pa 231	S	1×10^{-12}	3×10^{-12}	4×10^{-12}
		I	1×10^{-10}	8×10^{-10}	4×10^{-10}
	Pa 233	S	6×10^{-12}	4×10^{-12}	2×10^{-12}
Radium (88)		I	2×10^{-12}	3×10^{-12}	6×10^{-12}
	Ra 223	S	2×10^{-10}	2×10^{-10}	6×10^{-10}
		I	2×10^{-10}	1×10^{-10}	8×10^{-10}
	Ra 224	S	5×10^{-10}	7×10^{-10}	2×10^{-10}
		I	7×10^{-10}	2×10^{-10}	2×10^{-10}
	Ra 226	S	3×10^{-11}	4×10^{-11}	3×10^{-11}
		I	5×10^{-11}	9×10^{-11}	2×10^{-11}
Radon (86)	Ra 228	S	7×10^{-11}	8×10^{-11}	2×10^{-11}
		I	4×10^{-11}	7×10^{-11}	1×10^{-11}
	Rn 220	S	1×10^{-12}		3×10^{-12}
		I			
Rhenium (75)	Rn 222 ¹	S	3×10^{-10}		1×10^{-10}
	Re 183	S	3×10^{-10}	2×10^{-10}	9×10^{-10}
		I	2×10^{-10}	8×10^{-10}	5×10^{-10}
	Re 186	S	6×10^{-10}	3×10^{-10}	2×10^{-10}
		I	2×10^{-10}	1×10^{-10}	8×10^{-10}
	Re 187	S	9×10^{-10}	7×10^{-10}	3×10^{-10}
Rhodium (45)		I	5×10^{-10}	4×10^{-10}	2×10^{-10}
	Re 188	S	4×10^{-10}	2×10^{-10}	1×10^{-10}
		I	2×10^{-10}	9×10^{-10}	6×10^{-10}
	Rh 103m	S	8×10^{-10}	4×10^{-10}	3×10^{-10}
		I	6×10^{-10}	3×10^{-10}	2×10^{-10}
	Rh 105	S	8×10^{-10}	4×10^{-10}	3×10^{-10}
Rubidium (37)		I	5×10^{-10}	3×10^{-10}	2×10^{-10}
	Rb 86	S	3×10^{-10}	2×10^{-10}	1×10^{-10}
		I	7×10^{-10}	7×10^{-10}	2×10^{-10}
Ruthenium (44)	Rb 87	S	5×10^{-10}	3×10^{-10}	2×10^{-10}
		I	7×10^{-10}	5×10^{-10}	2×10^{-10}
	Ru 97	S	2×10^{-10}	1×10^{-10}	8×10^{-10}
		I	2×10^{-10}	1×10^{-10}	6×10^{-10}
	Ru 103	S	5×10^{-10}	2×10^{-10}	2×10^{-10}
		I	8×10^{-10}	2×10^{-10}	3×10^{-10}
Samarium (62)	Ru 105	S	7×10^{-10}	3×10^{-10}	2×10^{-10}
		I	5×10^{-10}	3×10^{-10}	2×10^{-10}
	Ru 106	S	8×10^{-10}	4×10^{-10}	3×10^{-10}
		I	6×10^{-10}	3×10^{-10}	2×10^{-10}
	Sm 147	S	7×10^{-11}	2×10^{-11}	2×10^{-11}
		I	3×10^{-10}	2×10^{-10}	9×10^{-10}
Scandium (21)	Sm 151	S	6×10^{-10}	1×10^{-10}	2×10^{-10}
		I	1×10^{-10}	1×10^{-10}	5×10^{-10}
	Sm 153	S	5×10^{-10}	2×10^{-10}	2×10^{-10}
		I	4×10^{-10}	2×10^{-10}	1×10^{-10}
Selenium (34)	Sc 46	S	2×10^{-10}	1×10^{-10}	8×10^{-10}
		I	2×10^{-10}	1×10^{-10}	8×10^{-10}
	Sc 47	S	6×10^{-10}	3×10^{-10}	2×10^{-10}
		I	5×10^{-10}	3×10^{-10}	2×10^{-10}
	Sc 48	S	2×10^{-10}	8×10^{-10}	6×10^{-10}
		I	1×10^{-10}	8×10^{-10}	5×10^{-10}
Silicon (14)	Se 75	S	1×10^{-10}	9×10^{-10}	4×10^{-10}
		I	1×10^{-10}	8×10^{-10}	4×10^{-10}
	Si 31	S	6×10^{-10}	3×10^{-10}	2×10^{-10}
Silver (47)		I	1×10^{-10}	6×10^{-10}	3×10^{-10}
	Ag 108	S	6×10^{-10}	3×10^{-10}	2×10^{-10}
		I	8×10^{-10}	3×10^{-10}	3×10^{-10}
	Ag 110m	S	2×10^{-10}	9×10^{-10}	7×10^{-10}
Sodium (11)		I	1×10^{-10}	9×10^{-10}	3×10^{-10}
	Ag 111	S	3×10^{-10}	1×10^{-10}	1×10^{-10}
		I	2×10^{-10}	1×10^{-10}	8×10^{-10}
	Na 22	S	2×10^{-10}	1×10^{-10}	6×10^{-10}
		I	9×10^{-10}	9×10^{-10}	3×10^{-10}

APPENDIX B—Continued

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND

(See notes at end of appendix)

Element (atomic number)	Isotope	Table I		Table II	
		Col. 1	Col. 2	Col. 1	Col. 2
		Air ($\mu\text{Ci/ml}$)	Water ($\mu\text{Ci/ml}$)	Air ($\mu\text{Ci/ml}$)	Water ($\mu\text{Ci/ml}$)
Sodium (11)	Na 24	1×10^{-6}	8×10^{-6}	4×10^{-6}	2×10^{-6}
	I	1×10^{-7}	8×10^{-7}	5×10^{-7}	3×10^{-7}
Strontium (38)	Sr 85m	4×10^{-7}	2×10^{-7}	1×10^{-6}	7×10^{-7}
	I	3×10^{-7}	2×10^{-7}	1×10^{-6}	7×10^{-7}
	Sr 85	2×10^{-7}	3×10^{-7}	8×10^{-7}	1×10^{-6}
	I	1×10^{-7}	5×10^{-7}	4×10^{-7}	2×10^{-6}
	Sr 89	3×10^{-7}	3×10^{-7}	3×10^{-7}	3×10^{-6}
	I	4×10^{-7}	8×10^{-7}	1×10^{-6}	3×10^{-6}
	Sr 90	1×10^{-7}	1×10^{-6}	3×10^{-7}	3×10^{-7}
	I	5×10^{-7}	1×10^{-6}	2×10^{-6}	4×10^{-6}
	Sr 91	4×10^{-7}	2×10^{-6}	2×10^{-6}	7×10^{-6}
	I	3×10^{-7}	1×10^{-6}	9×10^{-6}	5×10^{-6}
	Sr 92	4×10^{-7}	2×10^{-6}	2×10^{-6}	7×10^{-6}
	I	3×10^{-7}	2×10^{-6}	1×10^{-6}	6×10^{-6}
Sulfur (16)	S 35	3×10^{-7}	2×10^{-6}	9×10^{-6}	6×10^{-6}
	I	3×10^{-7}	8×10^{-7}	9×10^{-6}	3×10^{-6}
Tantalum (73)	Ta 182	4×10^{-7}	1×10^{-6}	1×10^{-6}	4×10^{-6}
	I	2×10^{-7}	1×10^{-6}	7×10^{-6}	4×10^{-6}
Technetium (43)	Tc 96m	8×10^{-7}	4×10^{-6}	3×10^{-6}	1×10^{-6}
	I	3×10^{-6}	3×10^{-6}	1×10^{-6}	1×10^{-6}
	Tc 96	6×10^{-7}	3×10^{-6}	2×10^{-6}	1×10^{-6}
	I	2×10^{-7}	1×10^{-6}	8×10^{-6}	5×10^{-6}
	Tc 97m	2×10^{-6}	1×10^{-6}	8×10^{-6}	4×10^{-6}
	I	2×10^{-7}	5×10^{-6}	5×10^{-6}	2×10^{-6}
	Tc 97	1×10^{-6}	5×10^{-6}	4×10^{-6}	2×10^{-6}
	I	3×10^{-7}	2×10^{-6}	1×10^{-6}	8×10^{-6}
	Tc 99m	4×10^{-6}	2×10^{-6}	1×10^{-6}	6×10^{-6}
	I	1×10^{-6}	8×10^{-6}	5×10^{-6}	3×10^{-6}
	Tc 99	2×10^{-6}	1×10^{-6}	7×10^{-6}	3×10^{-6}
	I	6×10^{-6}	5×10^{-6}	2×10^{-6}	2×10^{-6}
Tellurium (52)	Te 125m	4×10^{-7}	5×10^{-6}	1×10^{-6}	2×10^{-6}
	I	1×10^{-7}	3×10^{-6}	4×10^{-6}	1×10^{-6}
	Te 127m	1×10^{-7}	2×10^{-6}	5×10^{-6}	6×10^{-6}
	I	4×10^{-6}	2×10^{-6}	1×10^{-6}	5×10^{-6}
	Te 127	2×10^{-6}	8×10^{-6}	6×10^{-6}	3×10^{-6}
	I	9×10^{-7}	5×10^{-6}	3×10^{-6}	2×10^{-6}
	Te 129m	8×10^{-7}	1×10^{-6}	3×10^{-6}	3×10^{-6}
	I	3×10^{-6}	6×10^{-6}	1×10^{-6}	2×10^{-6}
	Te 129	5×10^{-6}	2×10^{-6}	2×10^{-6}	8×10^{-6}
	I	4×10^{-6}	2×10^{-6}	1×10^{-6}	8×10^{-6}
	Te 131m	4×10^{-7}	2×10^{-6}	1×10^{-6}	8×10^{-6}
	I	2×10^{-7}	1×10^{-6}	6×10^{-6}	4×10^{-6}
	Te 132	2×10^{-7}	9×10^{-6}	7×10^{-6}	3×10^{-6}
	I	1×10^{-7}	8×10^{-6}	4×10^{-6}	2×10^{-6}
Terbium (65)	Tb 160	1×10^{-7}	1×10^{-6}	3×10^{-6}	4×10^{-6}
	I	3×10^{-6}	1×10^{-6}	1×10^{-6}	4×10^{-6}
Thallium (81)	Tl 200	3×10^{-6}	1×10^{-6}	9×10^{-6}	4×10^{-6}
	I	1×10^{-6}	7×10^{-6}	4×10^{-6}	2×10^{-6}
	Tl 201	2×10^{-6}	9×10^{-6}	7×10^{-6}	3×10^{-6}
	I	9×10^{-7}	5×10^{-6}	3×10^{-6}	2×10^{-6}
	Tl 202	8×10^{-7}	4×10^{-6}	3×10^{-6}	1×10^{-6}
	I	2×10^{-7}	2×10^{-6}	8×10^{-6}	7×10^{-6}
	Tl 204	6×10^{-7}	3×10^{-6}	2×10^{-6}	1×10^{-6}
	I	3×10^{-6}	2×10^{-6}	9×10^{-6}	6×10^{-6}
Thorium (90)	Th 227	3×10^{-10}	5×10^{-10}	1×10^{-11}	2×10^{-10}
	I	2×10^{-10}	5×10^{-10}	6×10^{-11}	2×10^{-10}
	Th 228	9×10^{-10}	2×10^{-9}	3×10^{-10}	7×10^{-10}
	I	6×10^{-10}	4×10^{-9}	2×10^{-10}	10^{-10}
	Th 230	2×10^{-10}	5×10^{-9}	8×10^{-11}	2×10^{-10}
	I	10^{-11}	9×10^{-10}	3×10^{-10}	3×10^{-10}
	Th 231	1×10^{-9}	7×10^{-9}	5×10^{-10}	2×10^{-10}
	I	1×10^{-9}	7×10^{-9}	4×10^{-10}	2×10^{-10}

APPENDIX B—Continued

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND

(See notes at end of appendix)

Element (atomic number)	Isotope ¹	Table I		Table II		
		Col. 1	Col. 2	Col. 1	Col. 2	
		Air ($\mu\text{Ci}/\text{ml}$)	Water ($\mu\text{Ci}/\text{ml}$)	Air ($\mu\text{Ci}/\text{ml}$)	Water ($\mu\text{Ci}/\text{ml}$)	
Thorium (90)	Th 232	S	3×10^{-11}	5×10^{-9}	10^{-12}	2×10^{-9}
		I	3×10^{-11}		10^{-12}	4×10^{-9}
	Th natural	S	6×10^{-11}	6×10^{-9}	2×10^{-12}	2×10^{-9}
		I	6×10^{-11}	6×10^{-9}	2×10^{-12}	2×10^{-9}
	Th 234	S	6×10^{-9}	5×10^{-9}	2×10^{-9}	2×10^{-9}
Thulium (69)		I	3×10^{-9}	5×10^{-9}	10^{-9}	2×10^{-9}
	Tm 170	S	4×10^{-9}	1×10^{-9}	1×10^{-9}	5×10^{-9}
		I	3×10^{-9}	1×10^{-9}	1×10^{-9}	5×10^{-9}
	Tm 171	S	1×10^{-7}	1×10^{-9}	4×10^{-9}	5×10^{-9}
		I	2×10^{-7}	1×10^{-9}	8×10^{-9}	5×10^{-9}
Tin (50)	Sn 113	S	4×10^{-7}	2×10^{-9}	1×10^{-9}	9×10^{-9}
		I	5×10^{-9}	2×10^{-9}	2×10^{-9}	8×10^{-9}
	Sn 125	S	1×10^{-7}	5×10^{-9}	4×10^{-9}	2×10^{-9}
Tungsten (Wolfram) (74)		I	8×10^{-9}	5×10^{-9}	3×10^{-9}	2×10^{-9}
	W 181	S	2×10^{-9}	1×10^{-9}	8×10^{-9}	4×10^{-9}
		I	1×10^{-7}	1×10^{-9}	4×10^{-9}	3×10^{-9}
	W 185	S	8×10^{-7}	4×10^{-9}	3×10^{-9}	1×10^{-9}
		I	1×10^{-7}	3×10^{-9}	4×10^{-9}	1×10^{-9}
Uranium (92)	U 187	S	4×10^{-7}	2×10^{-9}	2×10^{-9}	7×10^{-9}
		I	3×10^{-7}	2×10^{-9}	1×10^{-9}	6×10^{-9}
	U 230	S	3×10^{-10}	1×10^{-9}	1×10^{-10}	5×10^{-9}
		I	1×10^{-10}	1×10^{-9}	4×10^{-10}	5×10^{-9}
	U 232	S	1×10^{-10}	8×10^{-10}	3×10^{-10}	3×10^{-9}
		I	3×10^{-11}	8×10^{-10}	9×10^{-10}	3×10^{-9}
	U 233	S	5×10^{-10}	9×10^{-10}	2×10^{-10}	3×10^{-9}
		I	1×10^{-10}	9×10^{-10}	4×10^{-10}	3×10^{-9}
	U 234 ⁴	S	6×10^{-10}	9×10^{-10}	2×10^{-10}	3×10^{-9}
		I	1×10^{-10}	9×10^{-10}	4×10^{-10}	3×10^{-9}
	U 235 ⁴	S	6×10^{-10}	8×10^{-10}	2×10^{-10}	3×10^{-9}
		I	1×10^{-10}	8×10^{-10}	4×10^{-10}	3×10^{-9}
	U 236	S	6×10^{-10}	1×10^{-9}	2×10^{-10}	3×10^{-9}
		I	1×10^{-10}	1×10^{-9}	4×10^{-10}	3×10^{-9}
	U 238 ⁴	S	7×10^{-11}	1×10^{-9}	3×10^{-10}	4×10^{-9}
	I	1×10^{-10}	1×10^{-9}	5×10^{-10}	4×10^{-9}	
Uranium (92)	U 240	S	2×10^{-7}	1×10^{-9}	8×10^{-9}	3×10^{-9}
		I	2×10^{-7}	1×10^{-9}	6×10^{-9}	3×10^{-9}
	U-natural ⁴	S	1×10^{-10}	1×10^{-9}	5×10^{-10}	3×10^{-9}
		I	1×10^{-10}	1×10^{-9}	5×10^{-10}	3×10^{-9}
	V 46	S	2×10^{-7}	9×10^{-9}	6×10^{-9}	3×10^{-9}
Vanadium (23)		I	6×10^{-9}	8×10^{-9}	2×10^{-9}	3×10^{-9}
	Xe 131m	Sub	2×10^{-9}		4×10^{-7}	
	Xe 133	Sub	1×10^{-9}		3×10^{-7}	
Xenon (54)	Xe 133m	Sub	1×10^{-9}		3×10^{-7}	
	Xe 135	Sub	4×10^{-9}		1×10^{-7}	
	Yb 175	S	7×10^{-7}	3×10^{-9}	2×10^{-9}	1×10^{-9}
		I	6×10^{-7}	3×10^{-9}	2×10^{-9}	1×10^{-9}
Ytterbium (70)	Y 90	S	1×10^{-7}	6×10^{-9}	4×10^{-9}	2×10^{-9}
		I	1×10^{-7}	6×10^{-9}	3×10^{-9}	2×10^{-9}
	Y 91m	S	2×10^{-9}	1×10^{-9}	8×10^{-9}	3×10^{-9}
		I	2×10^{-9}	1×10^{-9}	6×10^{-9}	3×10^{-9}
	Y 91	S	4×10^{-9}	8×10^{-9}	1×10^{-9}	3×10^{-9}
Yttrium (39)		I	3×10^{-9}	8×10^{-9}	1×10^{-9}	3×10^{-9}
	Y 92	S	4×10^{-7}	2×10^{-9}	1×10^{-9}	6×10^{-9}
		I	3×10^{-7}	2×10^{-9}	1×10^{-9}	6×10^{-9}
	Y 93	S	2×10^{-7}	8×10^{-9}	6×10^{-9}	3×10^{-9}
		I	1×10^{-7}	8×10^{-9}	5×10^{-9}	3×10^{-9}
Zinc (30)	Zn 65	S	1×10^{-7}	3×10^{-9}	4×10^{-9}	1×10^{-9}
		I	6×10^{-9}	5×10^{-9}	2×10^{-9}	2×10^{-9}
	Zn 69m	S	4×10^{-7}	2×10^{-9}	1×10^{-9}	7×10^{-9}
		I	3×10^{-7}	2×10^{-9}	1×10^{-9}	6×10^{-9}
	Zn 69	S	7×10^{-9}	5×10^{-9}	2×10^{-9}	2×10^{-9}
	I	9×10^{-9}	5×10^{-9}	3×10^{-9}	2×10^{-9}	

APPENDIX B—Continued

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND

(See notes at end of appendix)

Element (atomic number)	Isotope ¹	Table I		Table II	
		Col. 1 Air ($\mu\text{Ci}/\text{ml}$)	Col. 2 Water ($\mu\text{Ci}/\text{ml}$)	Col. 1 Air ($\mu\text{Ci}/\text{ml}$)	Col. 2 Water ($\mu\text{Ci}/\text{ml}$)
Zirconium (40).....	Zr 93	S	1×10^{-7}	2×10^{-8}	4×10^{-8}
	I	3×10^{-7}	2×10^{-8}	1×10^{-8}	8×10^{-9}
	Zr 95	S	1×10^{-7}	2×10^{-8}	4×10^{-8}
	I	3×10^{-7}	2×10^{-8}	1×10^{-8}	8×10^{-9}
	Zr 97	S	1×10^{-7}	5×10^{-8}	4×10^{-8}
Any single radionuclide not listed above with decay mode other than alpha emission or spontaneous fission and with radioactive half-life less than 2 hours.	I	9×10^{-8}	5×10^{-8}	3×10^{-8}	2×10^{-8}
	Sub	1×10^{-8}		3×10^{-8}	
Any single radionuclide not listed above with decay mode other than alpha emission or spontaneous fission and with radioactive half-life greater than 2 hours.		3×10^{-8}	9×10^{-9}	1×10^{-8}	3×10^{-8}
					
Any single radionuclide not listed above, which decays by alpha emission or spontaneous fission.		6×10^{-10}	4×10^{-7}	2×10^{-10}	3×10^{-8}
					

¹Soluble (S); Insoluble (I).

"Sub" means that values given are for submersion in a semispherical infinite cloud of airborne material.

*These radon concentrations are appropriate for protection from radon-222 combined with its short-lived daughters. Alternatively, the value in Table I may be replaced by one-third ($\frac{1}{3}$) "working level." (A "working level" is defined as any combination of short-lived radon-222 daughters, polonium-218, lead-214, bismuth-214 and polonium-214, in one liter of air, without regard to the degree of equilibrium, that will result in the ultimate emission of 1.3×10^5 MeV of alpha particle energy.) The Table II value may be replaced by one-thirtieth ($\frac{1}{30}$) of a "working level." The limit on radon-222 concentrations in restricted areas may be based on an annual average.

*For soluble mixtures of U-238, U-234 and U-235 in air chemical toxicity may be the limiting factor. If the percent by weight-enrichment of U-235 is less than 5, the concentration value for a 40-hour workweek, Table I, is 0.2 milligrams uranium per cubic meter of air average. For any enrichment, the product of the average concentration and time of exposure during a 40-hour workweek shall not exceed 8×10^{-4} SA $\mu\text{Ci-hr}/\text{ml}$, where SA is the specific activity of the uranium inhaled. The concentration value for Table II is 0.007 milligrams uranium per cubic meter of air. The specific activity for natural uranium is 6.77×10^{-7} curies per gram U. The specific activity for other mixtures of U-238, U-235 and U-234, if not known, shall be:

$$\text{SA} = 3.6 \times 10^{-7} \text{ curies/gram U} \quad \text{U-depleted}$$

$$\text{SA} = (0.4 + 0.38 E + 0.0034 E^2) 10^{-6} \quad E \geq 0.72$$

where E is the percentage by weight of U-235, expressed as percent.

NOTE: In any case where there is a mixture in air or water of more than one radionuclide, the limiting values for purposes of this Appendix should be determined as follows:

1. If the identity and concentration of each radionuclide in the mixture are known, the limiting values should be derived as follows: Determine, for each radionuclide in the mixture, the ratio between the quantity present in the mixture and the limit otherwise established in Appendix B for the specific radionuclide when not in a mixture. The sum of such ratios for all the radionuclides in the mixture may not exceed "1" (i.e., "unity").

EXAMPLE: If radionuclides A, B, and C are present in concentrations C_A , C_B , and C_C , and if the applicable MPC's are MPC_A , MPC_B , and MPC_C respectively, then the concentrations shall be limited so that the following relationship exists:

$$(C_A/\text{MPC}_A) + (C_B/\text{MPC}_B) + (C_C/\text{MPC}_C) \leq 1$$

2. If either the identity or the concentration of any radionuclide in the mixture is not known, the limiting values for purposes of Appendix B shall be:

a. For purposes of Table I, Col. 1— 6×10^{-10} b. For purposes of Table I, Col. 2— 4×10^{-7} c. For purposes of Table II, Col. 1— 2×10^{-10} d. For purposes of Table II, Col. 2— 3×10^{-8}

3. If any of the conditions specified below are met, the corresponding values specified below may be used in lieu of those specified in paragraph 2 above.

a. If the identity of each radionuclide in the mixture is known but the concentration of one or more of

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the radionuclides in the mixture is not known the concentration limit for the mixture is the limit specified in Appendix "B" for the radionuclide in the mixture having the lowest concentration limit; or

b. If the identity of each radionuclide in the mixture is not known, but it is known that certain radionuclides specified in Appendix "B" are not present in the mixture, the concentration limit for the mixture is the lowest concentration limit specified in Appendix "B" for any radionuclide which is not known to be absent from the mixture; or

c. Element (atomic number) and isotope	Table I		Table II	
	Col. 1 Air ($\mu\text{Ci/ml}$)	Col. 2 Water ($\mu\text{Ci/ml}$)	Col. 1 Air ($\mu\text{Ci/ml}$)	Col. 2 Water ($\mu\text{Ci/ml}$)
If it is known that Sr 90, I 125, I 126, I 129, I 131 (I 133, table II only), Pb 210, Po 210, At 211, Ra 223, Ra 224, Ra 226, Ac 227, Ra 228, Th 230, Pa 231, Th 232, Th-nat, Cm 248, Cf 254, and Fm 256 are not present.		9×10^{-6}		3×10^{-6}
If it is known that Sr 90, I 125, I 126, I 129 (I 131, I 133, table II only), Pb 210, Po 210, Ra 223, Ra 226, Ra 228, Pa 231, Th-nat, Cm 248, Cf 254, and Fm 256 are not present.		6×10^{-6}		2×10^{-6}
If it is known that Sr 90, I 129 (I 125, I 126, I 131, table II only), Pb 210, Ra 226, Ra 228, Cm 248, and Cf 254 are not present.		2×10^{-6}		6×10^{-7}
If it is known that (I 129, table II only), Ra 226, and Ra 228 are not present.		3×10^{-6}		1×10^{-6}
If it is known that alpha-emitters and Sr 90, I 129, Pb 210, Ac 227, Ra 228, Pa 230, Pu 241, and Bk 249 are not present.	3×10^{-6}		1×10^{-6}	
If it is known that alpha-emitters and Pb 210, Ac 227, Ra 228, and Pu 241 are not present.	3×10^{-6}		1×10^{-6}	
If it is known that alpha-emitters and Ac 227 are not present.	3×10^{-6}		1×10^{-6}	
If it is known that Ac 227, Th 230, Pa 231, Pu 238, Pu 239, Pu 240, Pu 242, Pu 244, Cm 248, Cf 249 and Cf 251 are not present.	3×10^{-6}		1×10^{-6}	

4. If a mixture of radionuclides consists of uranium and its daughters in ore dust prior to chemical separation of the uranium from the ore, the values specified below may be used for uranium and its daughters through radium-226, instead of those from paragraphs 1, 2, or 3 above.

a. For purposes of Table I, Col. 1— 1×10^{-10} $\mu\text{Ci/m}$ gross alpha activity; or 5×10^{-11} $\mu\text{Ci/ml}$ natural uranium or 75 micrograms per cubic meter of air natural uranium.

b. For purposes of Table II, Col. 1— 3×10^{-10} $\mu\text{Ci/ml}$ gross alpha activity; 2×10^{-10} $\mu\text{Ci/ml}$ natural uranium; or 3 micrograms per cubic meter of air natural uranium.

5. For purposes of this note, a radionuclide may be considered as not present in a mixture if (a) the ratio of the concentration of that radionuclide in the mixture (C_i) to the concentration limit for that radionuclide specified in Table II of Appendix "B" (MPC_i) does not exceed $\frac{1}{10}$, (i.e. $C_i/MPC_i \leq 1/10$) and (b) the sum of such ratios for all the radionuclides considered as not present in the mixture does not exceed $\frac{1}{10}$, i.e. $(C_i/MPC_i + C_j/MPC_j + \dots) \leq \frac{1}{10}$.

[25 FR 10914, Nov. 17, 1960, as amended at 25 FR 13953, Dec. 30, 1960; 26 FR 11046, Nov. 25, 1961; 29 FR 14435, Oct. 21, 1964; 30 FR 15801, Dec. 22, 1965; 31 FR 86, Jan. 5, 1966; 37 FR 23319, Nov. 2, 1972; 38 FR 29314, Oct. 24, 1973; 39 FR 23990, June 28, 1974; 39 FR 25463, July 11, 1974; 39 FR 27121, July 25, 1974; 40 FR 50705, Oct. 31, 1975]

APPENDIX E

INVESTMENT OPERATING COST-MANPOWER

AND FLOOR SPACE REACTION VIEWPOINTS

TABLE E.1(a)

INVESTMENT COST (M \$) - ALTERNATE II

Attribute	Function							Total	Cum. Total
	1	2	3	4	5	6	7		
E1.1.3	1.8	1.9	1.5	0.16	10.5	10.	15.	40.86	40.86
E1.2	0.	1.	0.9	0.	11.5	*	0.	13.4	54.26
E2.1&2.2	0.	0.	0.	0.	0.	0.	0.	0.	54.26
E2.3	0.7	0.1	0.06	0.055	1.	0.1	0.	2.015	56.275
E3.1	0.001	0.	0.02	0.25	0.	0.	0.1	0.171	56.246
E3.2	0.	0.	0.	0.	0.	0.	0.01	0.01	56.256
E4.1	0.	0.	0.	0.	0.029	0.	0.	0.029	56.285
E4.2	0.	0.	0.	0.	0.	0.	0.	0.	56.285
E4.3	0.	0.	0.	0.	0.	0.	0.	0.	56.285
E5.1.1	0.	0.	0.	0.	0.	*	0.	0.	56.285
E5.1.2&5.1.3	0.	0.	0.	0.	0.	0.	0.	0.	56.285
E5.2	0.	0.	0.	0.	0.	0.	0.	0.	56.285
E5.3	0.	0.	0.	0.	10.	0.	0.	10.	66.285
P1.1.1	0.	0.	0.	0.	0.	0.	0.	0.	66.285
P1.1.2	0.	0.	0.	0.	0.	0.	0.	0.	66.285
P1.2.1	0.	0.	0.	0.	0.	1.4	0.	1.4	67.685
P1.2.2	0.	0.	0.	0.	0.	0.	0.	0.	67.685
P1.3.1	0.	0.	*	0.	0.	1.5	2.	3.5	71.185
P1.3.2	0.	0.	0.	0.	0.	0.	0.	0.	71.185
P2.1.1	0.	0.	0.	0.	0.	0.2	0.	0.2	71.385
P2.1.2.1	0.	0.	0.	0.	0.	0.	0.	0.	71.385
P2.1.2.2	0.	0.	0.	0.	0.	0.	0.	0.	71.385
P2.1.4	1.	0.	0.	0.	1.	0.	0.	2.	73.385
P2.2.1.1	0.	0.	0.	0.	0.	0.	0.5	0.5	73.885
P2.2.1.2	0.	0.	0.	0.	0.	0.	0.	0.	73.885
P2.2.1.3a	0.	0.	0.	0.	0.	0.	0.	0.	73.885
P2.2.1.3b	0.	0.	0.	0.	0.	0.	0.	0.	73.885
P2.2.1.4	0.	0.	0.	0.	0.	0.	0.	0.	73.885
P2.2.2	0.	0.	0.	0.	0.	0.	0.1	0.1	73.985
P2.2.3	0.	0.	0.	0.	0.	0.	0.3	0.3	74.285
P2.2.4	0.	0.	0.	0.	0.	0.	0.	0.	74.285
P3.1.1	0.	0.	0.	0.	0.	0.	0.	0.	74.285
P3.1.2	0.	0.	0.	0.	0.	0.	1.	1.	75.285
P3.1.3	0.	0.	0.	0.	0.	0.	0.	0.	75.285
P3.2.1	0.	0.	0.	0.	0.	0.	0.	0.	75.285
P5	0.	0.	0.	0.	0.	0.	0.	0.	75.285

Total 3.301 3.000 2.480 0.285 34.029 13.200 19.010

* Funct. 3 Groupe E2.3/P1.3.1 & Funct. 6 Groupe E1.1.3/E1.2/E5.1.1

TABLE E.1(b)
INVESTMENT COST (M \$) - ALTERNATE III

Attribute	Function							Total	Cum. Total
	1	2	3	4	5	6	7		
E1.1.3	2.8	5.9	67.2	0.75	15.	88.	21.	180.65	180.65
E1.2	0.	1.	0.9	0.	11.5	*	0.	13.4	194.25
E2.1&2.2	0.	0.	0.	0.	0.	0.	0.	0.	184.25
E2.3	1.8	0.1	0.12	0.105	12.	0.5	0.3	12.925	208.975
E3.1	0.012	0.	0.12	0.3	0.12	0.3	0.4	1.252	208.227
E3.2	2.5	0.	0.	0.	0.	0.	0.5	3.	211.227
E4.1	0.	0.	0.	0.	0.087	0.	0.	0.087	211.314
E4.2	0.	0.	0.5	0.	0.145	0.	0.	0.645	211.958
E4.3	0.	0.	0.	0.	0.	0.	0.	0.	211.958
E5.1.1	0.04	0.	*	0.	0.18	*	0.25	0.47	212.429
E5.1.2&5.1.3	0.	0.	0.	0.	0.	0.	0.	0.	212.429
E5.2	0.	0.	0.	0.	0.	0.	0.	0.	212.429
E5.3	0.	0.	0.1	0.003	12.	0.1	0.2	12.403	224.832
P1.1.1	0.	0.	0.	0.	0.	0.	0.	0.	224.832
P1.1.2	0.	0.	0.	0.	0.	0.	0.	0.	224.832
P1.2.1	0.	0.	*	0.	0.	7.	0.	7.	231.832
P1.2.2	0.	0.	0.	0.	0.	0.	0.	0.	231.832
P1.3.1	0.	0.	0.	0.	0.	3.	2.5	5.5	237.332
P1.3.2	0.	0.	0.	0.	0.	0.	0.	0.	237.332
P2.1.1	0.003	0.	0.	0.1	0.08	1.	0.	1.163	238.494
P2.1.2.1	1.5	0.	10.	1.	0.08	2.	0.2	22.78	261.254
P2.1.2.2	0.	0.	0.	0.	0.	0.	0.5	0.5	261.754
P2.1.4	1.3	0.	10.	0.	10.	0.	0.	21.3	283.054
P2.2.1.1	0.	0.	0.	0.05	0.	0.	0.75	0.8	283.854
P2.2.1.2	0.	0.	0.	0.	0.	0.	0.	0.	283.854
P2.2.1.3a	0.	0.	0.	0.	0.	0.	0.1	0.1	283.954
P2.2.1.3b	0.	0.	0.	0.	0.	0.	0.	0.	283.954
P2.2.1.4	0.	0.	0.	0.	0.	0.	0.	0.	283.954
P2.2.2	0.	0.	0.	0.	0.	0.	0.5	0.5	284.454
P2.2.3	0.	0.	0.	0.	0.	0.	0.4	0.4	284.854
P2.2.4	0.	0.	0.	0.	0.	0.	0.	0.	284.854
P3.1.1	0.	0.	0.	0.	0.	0.	0.	0.	284.854
P3.1.2	0.	0.	0.	0.	0.	0.5	0.	0.5	291.354
P3.1.3	0.	0.	0.	0.	0.	9.5	2.	11.5	302.854
P3.2.1	0.	0.	0.1	0.1	0.	0.	*	0.2	303.054
P5	0.	0.	0.	0.	0.	0.	0.	0.	303.054

Total 9.955 15.388 89.840 2.408 58.152 91.900 35.600

* Funot. 3 Groups E1.1.3/E5.1.1 & E2.3/P1.2.1

Funot. 6 Groups E1.1.3/E1.2/E5.1.1 & Funot. 7 Groups P3.1.3/P3.2.1

TABLE E.2(a)
 ADDITIONAL MEN - ALTERNATE II

Attribute	Function							Total	Cum. Total
	1	2	3	4	5	6	7		
E1.1.3	24.	0.	9.	1.	3.	15.	0.	52.	52.
E1.2	0.	0.	18.	0.	8.	*	0.	24.	76.
E2.1&2.2	0.	0.	0.	0.	0.	0.	0.	0.	76.
E2.3	0.	0.	0.5	0.5	2.	1.	0.	4.	80.
E3.1	0.	0.	0.1	0.1	0.	0.	4.	4.2	84.2
E3.2	0.	0.	0.	0.	0.	0.	4.	4.	88.2
E4.1	1.	0.	0.5	0.4	0.	0.2	1.	3.1	91.3
E4.2	0.	0.	0.	0.	0.	0.	0.	0.	91.3
E4.3	0.1	0.	0.1	0.025	0.05	0.02	0.	0.295	91.595
E5.1.1	0.	0.	0.	0.	0.	*	0.	0.	91.595
E5.1.2&5.1.3	0.	0.	0.	0.	0.	0.	0.	0.	91.595
E5.2	0.	0.	0.	0.	0.	0.	0.	0.	91.595
E5.3	0.	0.	1.	0.	3.	1.	0.	5.	96.595
P1.1.1	0.	0.	0.	0.	0.	0.	0.	0.	96.595
P1.1.2	0.	0.	0.	0.	0.	0.	0.	0.	96.595
P1.2.1	0.	0.	0.	0.	0.	2.	0.	2.	98.595
P1.2.2	0.	0.	0.	0.	0.	0.	0.	0.	98.595
P1.3.1	0.	0.	*	0.	0.	3.	3.	6.	104.595
P1.3.2	0.	0.	0.	0.	0.	0.	0.	0.	104.595
P2.1.1	0.	0.	0.	0.	0.	3.	0.	9.	113.595
P2.1.2.1	0.	0.	0.	0.	0.	0.	0.	0.	113.595
P2.1.2.2	0.	0.	0.	0.	0.	0.	0.	0.	113.595
P2.1.4	0.	0.	0.	0.	0.	0.	0.	0.	119.595
P2.2.1.1	0.	0.	0.	0.	0.	0.	12.	12.	131.595
P2.2.1.2	0.	0.	0.	0.	0.	0.	0.	0.	131.595
P2.2.1.3a	0.	0.	0.	0.	0.	0.	0.	0.	131.595
P2.2.1.3b	0.	0.	0.	0.	0.	0.	0.	0.	131.595
P2.2.1.4	0.	0.	0.	0.	0.	0.	0.	0.	131.595
P2.2.2	0.	0.	0.	0.	0.	0.	0.	0.	131.595
P2.2.3	0.	0.	0.	0.	0.	0.	20.	20.	151.595
P2.2.4	0.	0.	0.	0.	0.	0.	0.	0.	159.595
P3.1.1	0.	0.	0.	0.	0.	0.	0.	0.	159.595
P3.1.2	0.	0.	0.	0.	0.	0.	0.	0.	159.595
P3.1.3	0.	0.	0.	0.	0.	0.	0.	0.	159.595
P3.2.1	0.	0.	0.	0.	0.	0.	0.	0.	159.595
P5	0.	0.	0.	0.	0.	0.	0.	0.	159.595

Total 25.100 0.000 35.200 2.025 20.050 25.220 52.000

* Funot. 3 Groups E2.3/P1.3.1 & Funot. 6 Groups E1.1.3/E1.2/E5.1.1

TABLE E.2(b)
 ADDITIONAL MEN - ALTERNATE III

Attribute	Function							Total	Cum. Total
	1	2	3	4	5	6	7		
E1.1.3	32.	3.	36.	0.5	8.	20.	0.	97.5	97.5
E1.2	0.	0.	18.	0.	8.	*	0.	24.	121.5
E2.1&2.2	0.	0.	0.	0.	0.	0.	0.	0.	121.5
E2.3	0.	0.	0.5	0.5	4.	2.	0.	7.	128.5
E3.1	0.	0.	1.	0.3	-2.	0.2	0.	7.5	136.
E3.2	0.	0.	0.	0.	1.	0.	0.	9.	145.
E4.1	2.8	0.	1.	1.1	0.	0.5	2.	7.5	152.5
E4.2	4.7	0.	1.	0.5	0.	0.2	0.	6.4	158.9
E4.3	0.3	0.	0.5	0.12	0.15	0.09	0.	1.16	160.06
E5.1.1	0.	0.	*	0.	4.	*	0.	4.	164.06
E5.1.2&5.1.3	0.	0.	0.	0.	0.	0.	0.	0.	164.06
E5.2	0.	0.	0.	0.	0.	0.	0.	0.	164.06
E5.3	0.	0.	3.	1.	6.	3.	0.	13.	177.06
P1.1.1	0.	0.	0.	0.	0.	0.	0.	0.	177.06
P1.1.2	0.	0.	0.	0.	0.	0.	0.	0.	177.06
P1.2.1	0.	0.	*	0.	0.	6.	0.	6.	183.06
P1.2.2	0.	0.	0.	0.	0.	0.	0.	0.	183.06
P1.3.1	0.	0.	0.	0.	0.	6.	4.	10.	193.06
P1.3.2	0.	0.	0.	0.	0.	0.	0.	0.	193.06
P2.1.1	0.	0.	25.	3.	18.	18.	0.	64.	257.06
P2.1.2.1	4.	0.	2.	3.	-5.	*	3.	7.	264.06
P2.1.2.2	0.	0.	0.	3.	0.	0.	3.	6.	270.06
P2.1.4	16.	0.	2.	0.	12.	0.	0.	30.	300.06
P2.2.1.1	0.	0.	0.	3.	0.	0.	36.	39.	339.06
P2.2.1.2	0.	0.	0.	0.	0.	0.	0.	0.	339.06
P2.2.1.3a	0.	0.	0.	0.	0.	0.	0.	0.	339.06
P2.2.1.3b	0.	0.	0.	0.	0.	0.	0.	0.	339.06
P2.2.1.4	0.	0.	0.	0.	0.	0.	0.	0.	339.06
P2.2.2	0.	0.	0.	0.	0.	0.	0.	0.	339.06
P2.2.3	0.	0.	0.	0.	0.	0.	20.	20.	367.06
P2.2.4	0.	0.	0.	0.	0.	0.	20.	20.	387.06
P3.1.1	0.	0.	0.	0.	0.	0.	0.	0.	387.06
P3.1.2	0.	0.	0.	0.	0.	1.	0.	1.	388.06
P3.1.3	0.	0.	0.	0.	0.	2.	5.	7.	395.06
P3.2.1	0.	0.	3.	3.	0.	0.	*	6.	401.06
P5	0.	0.	0.	0.	0.	0.	0.	0.	401.06

Total 59.98 3.00 83.00 19.02 50.15 58.99 117.00

* Funct. 3 Groups E1.1.3/E5.1.1 & E2.3/P1.2.1

 Funct. 6 Groups E1.1.3/E1.2/E5.1.1 & P2.1.1/P2.1.2.1

 Funct. 7 Groups P3.1.3/P3.2.1

TABLE E.3(a)

 ADDITIONAL SPACE (1000 FT.^2) - ALTERNATE II

Attribute	Function							Total	Cum. Total
	1	2	3	4	5	6	7		
E1.1.3	2.333	1.5	0.4	0.25	0.	5.	2.	11.483	11.483
E1.2	0.	2.4	0.4	0.	0.	*	0.	2.8	14.283
E2.1&2.2	0.	0.	0.	0.	0.	0.	0.	0.	14.283
E2.3	0.	0.	0.12	0.1	0.	0.09	0.	0.31	14.593
E3.1	0.	0.	0.025	0.025	0.	0.	0.	0.05	14.643
E3.2	0.	0.	0.	0.	0.	0.	0.2	0.2	14.843
E4.1	0.	0.	0.	0.	0.	0.	0.	0.	14.843
E4.2	0.	0.	0.	0.	0.	0.	0.	0.	14.843
E4.3	0.	0.	0.	0.	0.	0.	0.	0.	14.843
E5.1.1	0.	0.	0.	0.	0.	*	0.	0.	14.843
E5.1.2&5.1.3	0.	0.	0.	0.	0.	0.	0.	0.	14.843
E5.2	0.	0.	0.	0.	0.	0.	0.	0.	14.843
E5.3	0.	0.	0.	0.	0.	0.	0.	0.	14.843
P1.1.1	0.	0.	0.	0.	0.	0.	0.	0.	14.843
P1.1.2	0.	0.	0.	0.	0.	0.	0.	0.	14.843
P1.2.1	0.	0.	0.	0.	0.	0.6	0.	0.6	15.443
P1.2.2	0.	0.	0.	0.	0.	0.	0.	0.	15.443
P1.3.1	0.	0.	*	0.	0.	1.	1.	2.	17.443
P1.3.2	0.	0.	0.	0.	0.	0.	0.	0.	17.443
P2.1.1	0.	0.	0.3	0.	0.	0.2	0.	0.5	17.943
P2.1.2.1	0.	0.	0.	0.	0.	0.	0.	0.	17.943
P2.1.2.2	0.	0.	0.	0.	0.	0.	0.	0.	17.943
P2.1.4	0.	0.	0.	0.	0.	0.	0.	0.	17.943
P2.2.1.1	0.	0.	0.	0.	0.	0.	0.	0.	17.943
P2.2.1.2	0.	0.	0.	0.	0.	0.	0.	0.	17.943
P2.2.1.3a	0.	0.	0.	0.	0.	0.	0.	0.	17.943
P2.2.1.3b	0.	0.	0.	0.	0.	0.	0.	0.	17.943
P2.2.1.4	0.	0.	0.	0.	0.	0.	0.	0.	17.943
P2.2.2	0.	0.	0.	0.	0.	0.	0.	0.	17.943
P2.2.3	0.	0.	0.	0.	0.	0.	2.	2.	19.943
P2.2.4	0.	0.	0.	0.	0.	0.	0.	0.	19.943
P3.1.1	0.	0.	0.	0.	0.	0.	0.	0.	19.943
P3.1.2	0.	0.	0.	0.	0.	0.	1.	1.	20.943
P3.1.3	0.	0.	0.	0.	0.	0.	0.	0.	20.943
P3.2.1	0.	0.	0.	0.	0.	0.	0.	0.	20.943
P5	0.	0.	0.	0.	0.	0.	0.	0.	20.943

Total 2.333 3.900 1.245 0.375 0.000 6.890 6.200

* Funct. 3 Groups E2.3/P1.3.1 & Funct. 6 Groups E1.1.3/E1.2/E5.1.1

TABLE E.3(b)

 ADDITIONAL SPACE (1000 FT.^2) - ALTERNATE III

Attribute	Function							Total	Cum. Total
	1	2	3	4	5	6	7		
E1.1.3	2.367	3.4	7.	0.6	0.	7.	3.	23.367	23.367
E1.2	0.	2.4	0.4	0.	0.	*	0.	2.8	26.167
E2.1&2.2	0.	0.	0.	0.	0.	0.	0.	0.	26.167
E2.3	0.	0.	0.12	0.1	0.	0.2	0.	0.42	26.587
E3.1	0.	0.	0.2	0.15	0.	0.1	0.	0.45	27.037
E3.2	0.	0.	0.	0.	0.	0.	0.5	0.5	27.537
E4.1	0.	0.	0.	0.	0.	0.	0.	0.	27.537
E4.2	0.	0.	0.5	0.	0.	0.	0.	0.5	28.037
E4.3	0.	0.	0.	0.	0.	0.	0.	0.	28.037
E5.1.1	0.	0.	*	0.	0.	*	0.	0.	28.037
E5.1.2&5.1.3	0.	0.	0.	0.	0.	0.	0.	0.	28.037
E5.2	0.	0.	0.	0.	0.	0.	0.	0.	28.037
E5.3	0.	0.	0.5	0.	0.	0.4	0.	0.9	28.937
P1.1.1	0.	0.	0.	0.	0.	0.	0.	0.	28.937
P1.1.2	0.	0.	0.	0.	0.	0.	0.	0.	28.937
P1.2.1	0.	0.	*	0.	0.	3.	0.	3.	31.937
P1.2.2	0.	0.	0.	0.	0.	0.	0.	0.	31.937
P1.3.1	0.	0.	0.	0.	0.	1.5	1.	2.5	34.437
P1.3.2	0.	0.	0.	0.	0.	0.	0.	0.	34.437
P2.1.1	0.	0.	1.5	0.25	0.	1.5	0.	3.25	37.687
P2.1.2.1	0.	0.	0.2	0.	0.	0.4	0.	0.6	38.287
P2.1.2.2	0.	0.	0.	0.	0.	0.	0.	0.	38.287
P2.1.4	0.	0.	0.2	0.	0.	0.	0.	0.2	38.487
P2.2.1.1	0.	0.	0.	0.	0.	0.	0.	0.	38.487
P2.2.1.2	0.	0.	0.	0.	0.	0.	0.	0.	38.487
P2.2.1.3a	0.	0.	0.	0.	0.	0.	0.	0.	38.487
P2.2.1.3b	0.	0.	0.	0.	0.	0.	0.	0.	38.487
P2.2.1.4	0.	0.	0.	0.	0.	0.	0.	0.	38.487
P2.2.2	0.	0.	0.	0.	0.	0.	0.	0.	38.487
P2.2.3	0.	0.	0.	0.	0.	0.	2.	2.	40.487
P2.2.4	0.	0.	0.	0.	0.	0.	0.	0.	40.487
P3.1.1	0.	0.	0.	0.	0.	0.	0.	0.	40.487
P3.1.2	0.	0.	0.	0.	0.	0.1	1.	1.1	41.587
P3.1.3	0.	0.	0.	0.	0.	0.5	2.	2.5	44.087
P3.2.1	0.	0.	0.2	0.2	0.	0.	*	0.4	44.487
P5	0.	0.	0.	0.	0.	0.	0.	0.	44.487

Total 2.367 5.800 10.820 1.300 2.200 14.700 9.520

* Funot. 3 Groups E1.1.3/E5.1.1 & E2.3/P1.2.1

Funot. 8 Groups E1.1.3/E1.2/E5.1.1 & Funot. 7 Groups P3.1.3/P3.2.1

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