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Report to the Director, Defense Nuclear Agency

May 1991

NUCLEAR WEAPONS

A Model for Evaluating the Tritium Reservoir Exchange

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National Security and
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May 6, 1991

Major General Gerald G. Watson
Director
Defense Nuclear Agency

Dear General Watson:

As we were gathering and analyzing the data which supported our June 1990 classified report on management of tritium supplies we developed the computer based Tritium Impact Model to support data comparison, analysis and display. Your staff requested that we share the model with them for their continued analysis of the tritium reservoir exchange process for deployed nuclear weapons. This we are pleased to do. We view the model as an analytical tool to assist management in making decisions by providing a means to measure not only the efficiencies of past and current reservoir exchange practices, but efficiencies which could result from alternative practices. We have prepared the material on the model to assist your staff in its use.

The earlier work focused on efficiencies in the Department of Defense's (DOD's) tritium reservoir supply pipeline and the timing of tritium reservoir exchanges for nuclear weapons in the stockpile. More explicitly, we examined the feasibility of reducing the amount of "tritium overhead" carried in the supply pipeline, and identified the extent the reduction can extend the time period which tritium supplies will support the nation's nuclear arsenal.

A summary of the four technical appendixes to this report describing the computer model we developed to evaluate the nuclear weapons tritium reservoir exchange process follows:

- Appendix I details the assumptions we made about the support pipeline for the process, its efficiencies, and how we measure the impact of differing efficiencies.
- Appendix II describes how a user would exercise the computer model. Materials included in this appendix include an overview of the model, as well as descriptions of a benchmark case and five variations; how to manipulate case selection parameters; and how to read the output reports.
- Appendix III describes how we integrated various source data to prepare our database and presents listings of the items contained in the databases used by the model.

- Appendix IV presents the operational FORTRAN IV source code used to implement the model on both a microcomputer and DEC MicroVAX 3500 minicomputer.

The June 1990 report, which included a discussion of methodology, was commented on by DOD and appropriate revisions were made before it was issued. Therefore, we did not obtain agency comments on this report. We will send copies of this report to the Secretaries of Defense and Energy. Copies will be made available to other interested parties upon request.

We appreciate the cooperation your staff provided us during the assignment on the tritium reservoir exchange process for nuclear weapons. Please call me at (202) 275-6504 if you have any questions. Mr. W.E. Sykes, Director, Design, Methodology and Technical Assistance Group, (202) 275-3935, is also available to discuss the computer model with your staff. Other major contributors to this report are listed in appendix V.

Sincerely yours,

Martin M Ferber
Director, Navy Issues

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Abbreviations

CONUS	contiguous United States
DNA	Defense Nuclear Agency
DOD	Department of Defense
DOE	Department of Energy
GAO	General Accounting Office

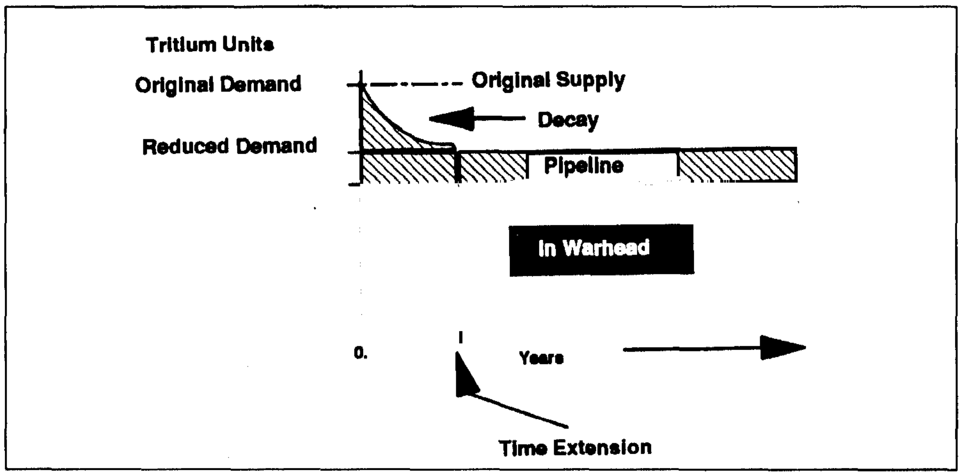
Methodological Approach

Radioactive decay of tritium is constant and unrelenting. It decays at the same rate, whether it is kept in bulk storage, placed in shipment, or inserted in operational warheads. In short, tritium cannot be saved for future use and can be replenished only through new production.

The Department of Energy (DOE) produces tritium, fills tritium reservoirs, and provides the DOD with reservoirs to replace existing reservoirs nearing the end of their life span. The military services install newly filled reservoirs in deployed warheads and return the expiring reservoirs to DOE for recycling, that is, recovery and reuse of remaining tritium.

To model the effect of an interruption in tritium production, we consider a state of supply-demand equilibrium, without any surplus tritium stocks. In this setting, we assume that the total tritium supply would be apportioned between warheads and their supply pipeline (see figure I.1). Notice, therefore, that if the amount of tritium in this pipeline were held constant, then any shrinkage of the supply (through radioactive decay, or other diversion, such as commercial sales) will have to be accommodated by a reduction of tritium in the warhead inventory.

Figure I.1: Tritium Supply and Demand



By contrast, improvements in pipeline efficiency—actions which reduce the amount of tritium needed solely to support the pipeline—will actually reduce the overall demand for tritium. With the supply in excess of this reduced demand, a temporary surplus is created. Until the surplus is consumed by radioactive decay or other diversion, all shrinkage of the tritium supply can be absorbed without a compensating removal of warheads from the active inventory.

In short, pipeline efficiencies buy time. They extend the time period for which the tritium supply will support a given warhead inventory.

Characteristics of Efficient Reservoir Exchange Processes

In the process of tritium reservoir exchanges, two reservoirs—one deployed in the warhead, and another in the pipeline—must co-exist for a period of time. Each reservoir burdens the tritium supply. It follows, therefore, that an efficient exchange process will minimize this burden. It should seek to:

(1) reduce the length of time that an individual reservoir remains in the pipeline (this is characterized by expeditious shipping and handling practices); and also,

(2) reduce the number of times that a reservoir must be placed in the pipeline during a weapon's life-cycle (this is characterized by timing the exchange to coincide with the expiration of the old reservoir, thereby achieving the maximum use of each reservoir's life-expectancy).

Measuring the Impact of Pipeline Efficiencies

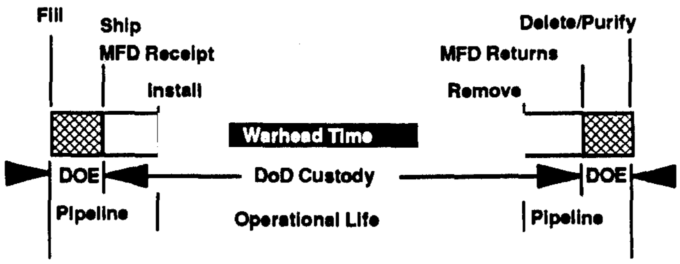
Pipeline efficiencies buy time. But, How much time? To calculate the time impact of various reservoir exchange practices, our computer model requires measures of

(1) a benchmark case that defines the level of tritium supplies needed to support current operations (the "what is", or "what was" condition) and

(2) a reduction or variance from that benchmark which would result from alternative reservoir exchange practices (the comparison "what if", or "what might be" condition).

To obtain the first measure, we focus on the entire life cycle of a tritium reservoir. This included the time the reservoir is in the custody of DOD and DOE (see fig. I.2). Assuming that the scarce tritium supply is allocated among either the warheads or their support pipeline, we use the collection of all tritium reservoirs as a proxy measure for the total tritium supply. To keep things manageable and avoid the specific details of DOE's internal operations, we further assume that the current amount of DOE's custody time is adequate for recycling tritium reservoirs.

Figure I.2: Reservoir Life Cycle



We then calculate the ratio of a reservoir's time in "warhead" to the pipeline time.[1] This ratio reflects the fact that each day of "warhead" time is obtained at the expense of an additional fractional day in the supply support system. A ratio of 1.2000, for example, is logically equivalent to saying that a total tritium supply of 1.2000 units is needed to support every 1.0000 unit required in a warhead. Since this ratio is based on actual experience, it provides a benchmark against which alternatives can be compared.[2]

The second step of analysis follows the same pattern to establish the ratio of "warhead" time to the supply pipeline time which would be obtained under alternative reservoir exchange practices.[3] The model derives both the benchmark and comparison cases from the same set of reservoir exchange data ensuring, in the context of analysis, that "all other things are held constant." Thus, any change in tritium demand may be attributed to the change in reservoir exchange practices.

To forecast the time savings that a difference between the benchmark and comparison cases might provide, the model compares their ratio

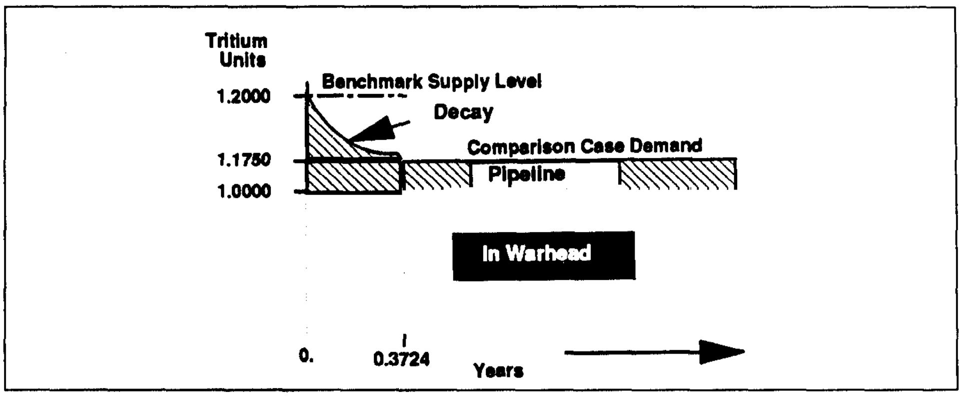
[1]A standardized dimensionless variable. We assume each reservoir within a class has the same capacity, and that all reservoirs are filled to capacity. Actual measurements taken over the reservoir's life cycle as well as weighted averages are used to account for differences in reservoir size and life expectancies.

[2]Our calculations employ a "reservoir life cycle" that is an amalgam of histories from both the installed and removed reservoirs in the exchange process. To reflect the most current time lines, information on the "fill-to-install" period is based on the new reservoir; data on the "remove-to-delete" period is based on the old reservoir. In all instances, the reservoir's "in-warhead" time is based on life expectancy (or, if greater, the removal date) less the "fill-to-install" interval.

[3]To create comparison cases, we (1) substituted proposed policy time frames for the supply pipeline segments in DOD custody, and (2) assumed the exchange occurred at the end of a reservoir's life expectancy.

values in the sense that each represents the total tritium supply necessary to support an identical set of warheads. For example, consider a benchmark case that encompasses all weapons in an exchange data base for the hypothetical fiscal year 19xx (see fig I.3).

Figure I.3: Impact of Efficiencies on Tritium Supplies



A tritium supply of 1.2000 units would be necessary to support the continuing operations of this benchmark case. One unit would be in "warhead" and another 0.2000 units would be in the tritium supply pipeline. For the comparison case, let us assume a set of reduced shipping rules that provide delivery lead times of 60 and 90 days (and returns of 30 and 90 days) for CONUS and outside CONUS, respectively. Our model calculates that a tritium supply pipeline of 1.1750 would be necessary to support this comparison case.

Since both the benchmark and comparison cases support the same warheads, the more efficient comparison case lowers the pipeline demand from a benchmark level of 0.2000 tritium units to the more efficient level of 0.1750 tritium units. This reduction produces a temporary surplus of 0.0250 tritium units.

If the conditions represented by our benchmark case were to continue, the demand placed on the tritium supply would not change; but, because of radioactive decay, the tritium supply would become inadequate to meet the demand for reservoir exchanges. The need for tritium in the supply pipeline would have to be met by reductions in the nuclear warhead inventory. Conversely, the alternative shipping rules reduce pipeline demand. They create a temporary surplus which can offset losses due to radioactive decay. Other things being equal, more efficient reservoir exchange practices delay the inevitability of reducing the warhead inventory.

But for how long? Using "pipeline-to-warhead" ratios and a computational base of 1.0 units of tritium in the warheads, the longevity of a temporary tritium surplus is the same as the time required for the benchmark tritium supply (1.2000 units) to decay to the level required by our comparison case (1.1750 units). For the fiscal year 19xx comparison, this decay would take about 4.5 months (0.3743 years).

Using the Tritium Impact Model

This appendix explains the general manner in which the Tritium Impact Model is used. We emphasize the setup and use of the model, and the interpretation of its output. Computer examples are presented, and short illustrations of the model's computational logic are provided throughout the text.

The model is written in the FORTRAN-IV language; a program listing may be found in Appendix IV. This listing reflects the input/output file conventions used by Microsoft FORTRAN version 4.10. File layouts and a description of the model's EXCHGxx.DAT database are included as Appendix III. We assume that the reader is already moderately familiar with the FORTRAN-IV language.

Overview

To examine alternative reservoir exchange practices, the model compares "pipeline demand" and the "longevity" of tritium supplies against a historical benchmark of shipping and handling experience. The examination may include (1) an overall analysis by fiscal year; or (2) the in-depth study of selected reservoir subpopulations (distinguished by the weapon or reservoir type, geographic location, the military service having custody, the weapon's strategic/nonstrategic classification, etc.).

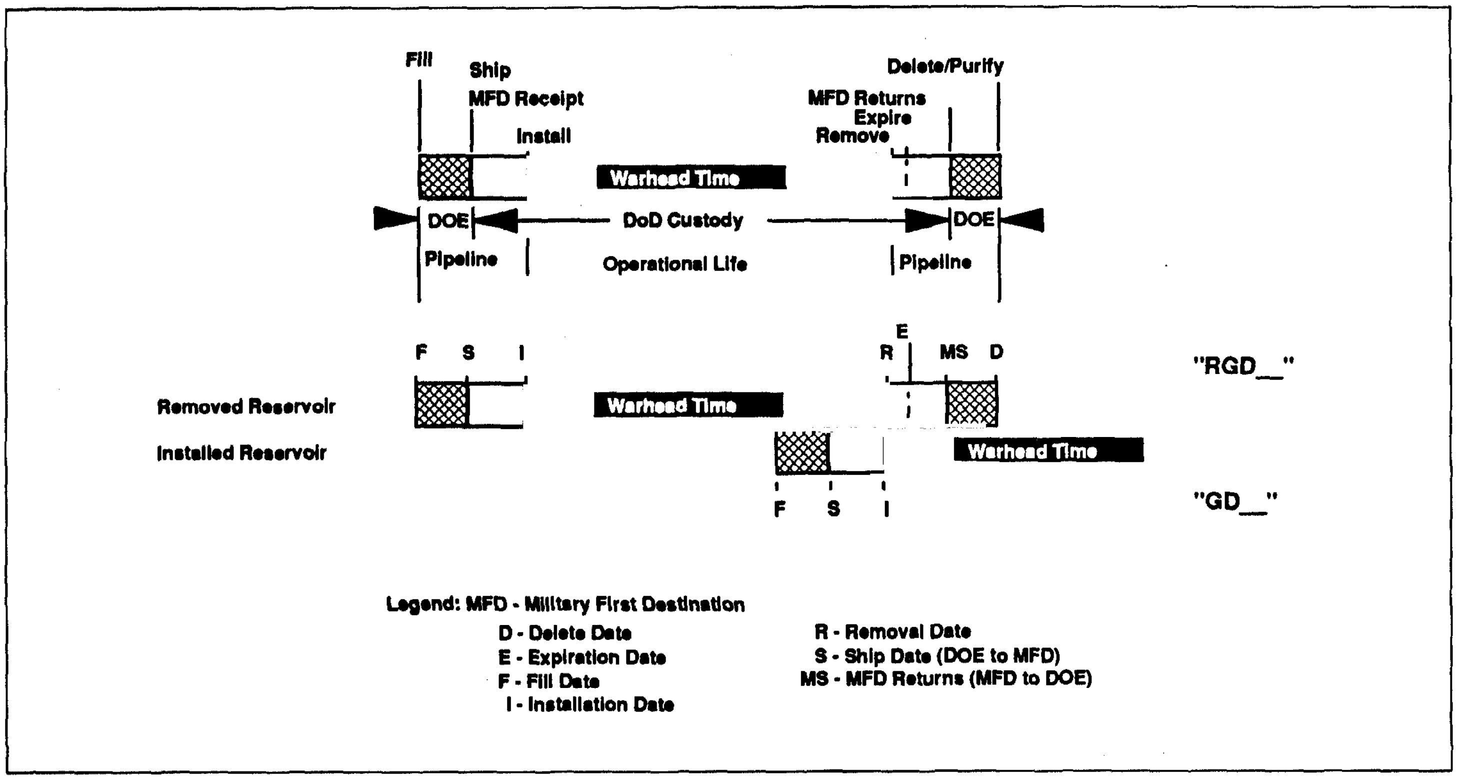
Some Important Variables and Concepts

The DOE produces tritium, fills tritium reservoirs, and provides them to the DOD to replace existing reservoirs nearing the end of their life span. The military services install the newly filled reservoirs in warheads in their custody and return the expiring reservoirs to DOE for recycling, that is, recovery and reuse of remaining tritium.

Figure II.1 illustrates this process, not only in terms of an individual reservoir's life cycle, but also in the context of relationships between the "removed" and "installed" reservoirs of an exchanged pair. Notice the intervals which delineate "pipeline" and "warhead" time. Our examples will be especially concerned with the ratio of "pipeline-to-warhead" time, and with efficiencies in DOD's portion of the "pipeline".[1]

[1] A simplifying assumption that is intended to avoid the specific details of DOE's internal operations. We assume the available tritium supplies are allocated between warheads and their supply pipeline; and that the collection of all tritium reservoirs is an adequate proxy measure for the total tritium stockpile. We also assume that the current amount of DOE's custody time is adequate for recycling tritium reservoirs.

Figure II.1: Reservoir Exchange Process



Dates associated with a "Removed" reservoir are identified by the prefix "RGD ", where the "R" signifies removal, and the "GD" denotes "Day of the Gregorian Calendar".[2] Thus "RGDF" identifies the Fill date for a removed reservoir; "RGDS" identifies the Ship date, and so on. For an "Installed" reservoir, the "R" is omitted. Thus, "GDF" identifies the Fill date, and "GDS" identifies the Ship date for the Installed reservoir.[3]

[2]Within the model, calendar dates are expressed as a "Day-of-the-Gregorian Calendar" (i.e., a sequential number beginning with the first day of the Gregorian calendar).

[3]A suffix is appended to this notation when necessary to identify the source from which a calendar date is obtained (1=DOE, 2=DNA). For events which are reported by only one agency, we omit the appendage—as say, for Fill Date, we use the notation RGDF, or GDF. But, when the same event is reported by both agencies, the appendage is used to distinguish between—say, the New Reservoir's Install Date provided by DOE (GDI1), and the corresponding GDI2 provided by DNA.

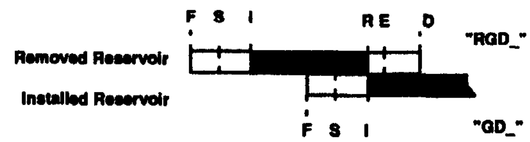
Benchmark and Comparison Cases

The model uses a "Benchmark Case" and five "Comparison Cases." The Benchmark Case (Case 1) provides a surrogate for actual experience. Cases 2 through 6 represent "What might have been" comparisons, had the exchange taken place under different shipping and handling rules.

"Pipeline" and "Warhead" times for the Benchmark and Comparison Cases are computed in lines 157 through 213 of the model's coding (Appendix IV). Here, we illustrate the formulae used in calculating these intervals.

The mathematical logic for computing actual pipeline and warhead times is presented in figure II.2. Notice, however, that the old reservoir's "fill-to-install" interval may precede its Removal Date by several years. Therefore, to represent current reservoir exchange practices, our model employs a Benchmark Case which is an amalgam of histories from both the installed and removed reservoirs. Information on the "fill-to-install" period is based on the new reservoir; data on the "remove-to-delete" period is based on the old reservoir.

Figure II.2: Defining the Benchmark Case



Actual, as occurred:

Pipeline = (RGDI - RGDF) + (RGDD - RGDR)
In-Weapon = (RGDR - RGDI)
Life Expectancy = (RGDE - RGDF)

Benchmark

Actual, but assuming latest Fill-to-Install

Pipeline = (GDI - GDF) + (RGDD - RGDR)
In-Weapon = (RGDR - RGDF) - (GDI - GDF)

For comparison, "Case 2" depicts "What might have been" had shipping and handling times remained the same, and if the exchange had been timed to coincide with the expiration of the old reservoir. Cases 3 through 5 describe the effects of graduated reductions in the mean "pipeline" time; and Case 6 identifies the maximum theoretical impact—if DoD's pipeline time were reduced to zero.

A capsule description for each comparison case follows; the associated mathematical formulae are presented in figure II.3. For simplicity, only

CONUS exchange formulae are detailed. Notice that for each comparison, the reservoir's "in-warhead" time is based on life expectancy (or, if greater, the removal date) less the "fill-to-install" interval.

Case 2: Shipping and handling times are identical to the Benchmark Case; but the exchange date coincides with the old reservoir's expiration date.

Case 3: CONUS sites require 90 days to receive and install a new reservoir from DOE; 60 days are required for return of the old reservoir. (Sites outside CONUS require 120 days to receive and install a new reservoir; the return requires 90 days.)

Case 4: CONUS sites require 60 days to receive and install a new reservoir from DOE; 30 days are required for return of the old reservoir. (Sites outside CONUS require 90 days to receive and install a new reservoir; the return requires 90 days.)

Case 5: CONUS sites require 15 days to receive a new reservoir from DOE; installation requires an additional 30 days; and 15 days are required for return of the old reservoir. (Sites outside CONUS require 45 days for receipt; 30 days for installation; and 45 days for return of the old reservoir.)

Case 6: DOD's "pipeline time" is reduced to zero. DOE's recycling time is held constant, at say 60 days. This represents a situation where CONUS and outside CONUS exchange sites receive new reservoirs, make the exchange, and return the old reservoir on the same day.

Figure II.3: Defining the Comparison Cases

Comparison Cases

Case 2: Exchange at Old Reservoir's Expiration
Pipeline = (GDI2 - GDF) + (RGDD - RGDR2)
In-Warhead = (RGDE2 - RGDF) - (GDI2 - GDF)

Case 3: DOE Time + 90 & 60 day Shipping and Handling Rule
Pipeline = DOE Time + 90 + 60
In-Warhead = (RGDR2 - RGDF) - (GDI2 - GDF)

Case 4: DOE Time + 60 & 30 day Shipping and Handling Rule
Pipeline = DOE Time + 60 + 30
In-Warhead = (RGDR2 - RGDF) - (GDI2 - GDF)

Case 5: DOE Time + 15 day Shipping & 30 day Handling Rule
Pipeline = DOE Time + 15 + 30 + 15
In-Warhead = (RGDR2 - RGDF) - (GDI2 - GDF)

Case 6: DOE Time of 60 days + Zero DOD Pipeline
Pipeline = 60 + 0
In-Warhead = (RGDR2 - RGDF) - (GDI2 - GDF)

Notes:

a) When Removal Date is later than Exchange Date,
RGDE2 is set equal to RGDR2

b) DOE Time = (Fill-to-Ship) + (MFD Ships-to-DOE Delete)
= (GDS - GDF) + (RGDD - RGDMS)

Simulation Reports

Figure II.4 is an example of the model's summary report. First, the input filename and record count are printed. Then follows the User's "Selection Criteria" and the number of input file records which met that criteria (in our example, "ALL FY19xx WEAPONS", and the entire input file of 1000 records). Finally, a count of records which pass the program's "Date Screens" is presented.[4]

The mid-section of our summary report shows the "pipeline-to-warhead" ratio for each of the six cases. As shown for Case 1, the Benchmark Case exchange required a tritium supply of 1.20000 units—0.20000 units in the pipeline to support every 1 unit in

[4]The phrase "Date Screens" connotes a sieve of validity and logical edits which assure the integrity of computations based on calendar date information.

Figure II.4: The Summary Report

```
**** PROGRAM H3IMPACT:  FILE= C:\EXCHGxx.DAT     RCDS I/P = 1000 ****

              SELECTION CRITERIA:  ALL FY19xx WEAPONS
                     RCDS SELECTED =  1000
               RCDS PASSING DATE SCREENS =   990

                                          MATERIAL REQUIREMENTS
                                                PROPORTION
CASE                                          PIPELINE to WARHEAD

BENCHMARK:
  1   Using GDI2-GDF & Removal at RGDR2             .20000 : 1

EXCHANGE ON EXPIRATION DATE:
  2  Using GDI2-GDF & Removal at Max(RGDR2, RGDE2)   .19000 : 1

SHIPPING RULES:
  3  GDF-to-GDS + 90/120 & 60/90 SHIPPING Rule       .17500 : 1
  4     ...          60/90  & 30/90 SHIPPING Rule    .15000 : 1
  5     ...    15/30/15 & 45/30/45 SHIPPING Rule     .12500 : 1

MAXIMUM DEFERRAL:
  6  ASSUMING ZERO DOD PIPELINE                      .10000 : 1


                     DEFERRAL IN WEAPON CUTS
              VIS-A-VIS  BENCHMARK  (CASE #1)   -----   YEARS
CASE

EXCHANGE ON EXPIRATION DATE:
  2  Using GDI2-GDF & Removal at Max(RGDR2, RGDE2)       .14878

SHIPPING RULES:
  3 GDF-to-GDS + 90/120 & 60/90 SHIPPING Rule            .37430
  4     ...          60/90 & 30/90 SHIPPING Rule         .75665
  5     ...    15/30/15 & 45/30/45 SHIPPING Rule        1.14741

MAXIMUM DEFERRAL:
  6  ASSUMING ZERO DOD PIPELINE                         1.54694


======>       IN-WARHEAD MATERIAL DEMAND = XX.YYYYY Kg
      (INCLUDES    .WWWWW Kg IN RCDS FAILING DATE SCREENS)
```

the warhead.[5] Conversely, had the exchange been timed to coincide with the old reservoir's expiration (Case 2); then the pipeline's tritium demand would have been lowered to 0.19000 units.

The next set of statistics shows the "DEFERRAL IN WEAPON CUTS". Recall that if the benchmark practices are continued, the pipeline demand for tritium will remain constant. Because tritium is lost to radioactive decay, the materials to satisfy that demand will have to be taken from the only available supply--warhead inventory.

However, a more efficient exchange practice reduces the pipeline demand. It creates a temporary surplus of tritium which can be used to offset losses due to radioactive decay. Case 2, for example, creates a surplus by replacing the Benchmark Case's overall demand (1.20000 units— 1 unit in warhead and 0.2 units in the pipeline) with a reduced demand of 1.19000 units. Other things being equal, a more efficient exchange practice will delay the inevitability of reducing the warhead inventory.

But for how long? To continue our example, the longevity of Comparison Case 2's temporary tritium surplus would be the same as the time required for the Benchmark tritium supply (1.20000 units) to decay to the level required by our Comparison Case (1.19000 units). This decay-time would "Defer Weapon Cuts" by about 1-3/4 months (0.14878 years). The measurement of "Deferral Time" is, of course, relative to the Benchmark Case.

The last section of our summary report identifies the "In-Warhead Material Demand". This section identifies the total tritium loading for all warheads that met the user's selection criteria. The "All FY19xx Weapons" criteria, for example, shows a warhead inventory loaded with tritium. That figure includes 0.001 Kg of tritium which was associated with records that failed the program's date screens. (The model imputes missing values for "Records Failing Date Screens" in order to preserve the overall demand and distribution of reservoirs.

Since the model's analyses use large administrative and operational databases, the program may encounter occasional data entry errors. Also, depending on a study's time-frame, it may be impractical to obtain

[5]Tritium is fungible in bulk storage; but, when loaded into a reservoir, the material is "committed" to a definite purpose for some period of time. Realize, therefore, that the commitment—both in magnitude and timing—constitutes a demand for tritium. Since the model is demand-based, all measurements and ratios correspond to the tritium element-weight at the time of reservoir loading.

data which spans the entire period from each "installed reservoir's" manufacture, to the deletion of every "removed reservoir". Reservoir exchanges during fiscal year 1990, for example, include a number of "installed reservoirs", that were actually manufactured and filled during fiscal year 1989. Depending on transportation, and the lag-time in reporting processes, a number of "removed reservoirs" may not be reported as returned to the Department of Energy until sometime in fiscal year 1991. "Date Screens" provide a validity edit of these computationally important date fields. Reservoirs failing the edit are excluded from processing, and the entire reservoir is considered a "missing observation".

- Tritium quantities differ significantly between types of reservoirs; and reservoir shipment times differ between CONUS and overseas destinations. Further, pipeline times may be affected by decisions of the individual services, or by differences in the structure and operations of strategic and nonstrategic forces.

It is important, therefore, for the analysis to maintain fidelity with the overall population's distribution of "reservoir weights" and pipeline times. Missing observations can distort this distribution, and the model is designed to eliminate such errors of distortion. The program classifies and groups reservoirs having similar characteristics, and then obtains overall statistics for each group. Unless the user consciously intervenes, the model will assign missing observations an imputed value which is based on the average pipeline-to-warhead ratio obtained for the counterpart "observed" group.

Figure II.5 is an example of the model's "Missing Observations" report. The heading information is essentially the same as that shown in our "Summary Report". The report's main body, however, presents statistics on the "pipeline-to-warhead ratio" for each combination of reservoir type (IRT), geographic location (GLOC), military service having custody (KSVC), and the weapon's strategic/nonstrategic code (KSTRAT).[6] We thought that these characteristics would have an important influence on the priorities, timing, and shipping and handling practices of the reservoir exchange cycle.

As can be seen in the figure, there are a total of 30 reservoirs coded as "reservoir type one" (IRT = 1), located in the contiguous United States (GLOC = 1) in the Air Force's custody (KSVC = 1), and configured

[6]Codings for the Analysis Database are shown in appendix III.

within a nonstrategic weapon (KSTRAT = 2). Twenty-four of the 30 reservoirs passed the "Date Screens" and six (6) were considered as missing observations. For the Benchmark Case (Case 1), the 24 "Observed" reservoirs had an average pipeline-to-warhead ratio of 0.11602 units in the pipeline for every 1.0 unit in-warhead. This ranged from a low of 0.06181, to a high of 0.17990 units in the pipeline. A display of statistics for Cases 2 through 6 follows. Then the statistics for subsequent categories of reservoir type, location, service and so on, are presented.

Figure II.5: The Missing Observations Report

**** PROGRAM H3IMPACT: FILE= C:\EXCHGxx.DAT RCDS I/P = 1000 ****
SELECTION CRITERIA: ALL FY19xx WEAPONS
RCDS SELECTED = 1000
RCDS PASSING DATE SCREENS = 990

** PIPELINE TO WARHEAD RATIO **

IRT	GLOC	KSVC	KSTRAT	CASE	MEAN	STD.DEV	MIN.	MAX.	OBS.	MISS.OBS.	TOTAL
1	1	1	2	1	.11602	.03517	.06181	.17990	24	6	30
				2	.10353	.03161	.05866	.17064			
				3	.17391	.01300	.15208	.20820			
				4	.12593	.01229	.10522	.15809			
				5	.10273	.01196	.08256	.13388			
				6	.04147	.00000	.04147	.04149			
1	1	3	1	1	.11804	.00061	.11760	.11847	2	1	3
				2	.11299	.00677	.10821	.11778			
				3	.16560	.01759	.15316	.17803			
				4	.11791	.01658	.10618	.12963			
				5	.09484	.01610	.08345	.10623			
				6	.04147	.00001	.04147	.04147			
1	3	3	1	1	.64530	.74505	.11847	1.17213	2	0	2
				2	.11147	.00905	.10507	.11786			
				3	.17266	.00759	.16729	.17803			
				4	.12451	.00725	.11938	.12963			
				5	.10122	.00708	.09621	.10623			
				6	.04170	.00033	.04147	.04193			
2	2	1	1	1	.17677	.02210	.15680	.23072	14	6	20
				2	.17379	.02223	.15380	.22803			
				3	.17495	.01099	.16637	.19215			
				4	.15422	.01063	.14594	.17092			
				5	.11791	.01026	.10995	.13412			
				6	.03311	.00002	.03309	.03315			
3	2	1	1	1	.17464	.03276	.15148	.22406	6	6	12
				2	.16965	.03250	.14738	.22256			
				3	.17516	.01610	.15562	.20111			
				4	.15469	.01557	.13547	.17935			
				5	.11883	.01502	.09971	.14183			
				6	.03310	.00001	.03309	.03311			

Setup Procedures

Implementation of the model is comparatively straight-forward. For each simulation, the user must specify[7].

1. The Input and Output Files.

Filenames and their input-output devices are specified on lines 35-37 of the program code. If the "Missing Observations" report is required, the variable "IKEY" should be set equal to 1 on line 34 of the program code. Otherwise, this report is not printed.

2. The Universe of Reservoirs which will serve as a surrogate for the total tritium supply.

Reservoirs that will serve as a surrogate for the total tritium supply are specified on lines 76-80 of the program code. The "Selection Criteria" is further annotated in Format 411 (lines 307-312 of the program code) to provide a descriptive heading for the program's output reports.

GAO's earlier report used the in-warhead and pipeline material that was associated with reservoir exchanges during fiscal years 1988 and 1989. In general, we believe that fiscal year segmentation will be the most practical approach. It requires no change in program coding.

3. The Comparison Case Conditions.

Current program coding assumes that the "pipeline" changes for Comparison Cases 2 through 6 apply equally to all reservoirs.

To examine "Deferral Time" when the pipeline is changed for only a portion of the force, the user must specify the selection criteria on lines 178-185 of the program code. For example, let us presume that pipeline changes would only affect CONUS-based ICBM forces. This could be modeled by entering one or more statements in lieu of line 185, such as:

"IF((IWT.EQ.nn).AND.(KFLAG.EQ.1)) SELKEY=1" where 'nn' is the weapon-type-code for an ICBM, and 'KFLAG=1' defines a CONUS exchange.

The statement(s) would assure that reservoirs affected by the change process are modeled as a comparison case, while unaffected reservoirs

[7]Line numbers in the examples given refer to the program listings in appendix IV.

would be given the same pipeline-to-warhead ratio as that established in the Benchmark Case.

Preparing the Database

Source Data

Source data for creating the Analysis Database (File EXCHGxx.DAT) were provided by the Department of Energy (DOE) and the Defense Nuclear Agency (DNA). DNA's Field Command provided a transaction file which cited each DOD shipment, receipt, installation or removal of a tritium reservoir during fiscal years 1988 and 1989. DOE supplied the life-cycle history for each reservoir which was removed or installed during the same time period. (See figure III.1, Files DNA.DAT and DOE.DAT, respectively).

Figure III.1: Original Data Files Provided by DNA and DOE

File: DNA.DAT

RCD Posn		Field Name	Format
1 - 8	WHEADX	DNA Warhead Name, Noun	A8
9		Not used	1x
10 - 17	WS	Warhead Serial Number	A8
18		Not used	1x
19 - 23	RTX	DNA Reservoir Type, Noun	A5
24 - 26		Not used	3x
27 - 34	RS	Reservoir Serial Number	A8
35 - 40	TDATE	Date of Transaction YYMMDD	I 6
41	TC	Transaction Code (See below)	A1
42 - 45		Not used	4x
46 - 48	ALOC	Transaction Location Code, Alfa	A3
49	KSVCX	Service Code, DNA	I 1
50 - 53	RDIE	Reservoir Expiration, YYMM	I 4
54 - 56		Reserved for ALOC To / From when TC = 'A' or 'B'	3x

LRECL = 56

TC = A Receipt
B Shipment
J Removal
K Installation

KSVCX = 1 Army
2 Navy (Pacific)
3 Navy (Atlantic)
4 Air Force

File: DOE.DAT

RCD Posn		Field Name	Format
1 - 9	WHEAD	DOE Warhead Name, Noun	A9
10 - 17	WS	Warhead Serial Number	A8
18 - 26	RT	DOE Reservoir Type, Noun	A9
27 - 34	RS	Reservoir Serial Number	A8
35 - 37	COEI	COEI Code (Cmp Ending Inv)	A3
38		Not used	1x
39 - 41	ALOC	Location Code, Alfa (Not used)	A3
42 - 45	LEXP	Life Expectancy (months)	I 4
46 - 51	DTMFG	Date Manufactured YYMMDD	I 6
52 - 57	DTSHIP	Date Shipped YYMMDD	I 6
58 - 63	DTINST	Date Installed YYMMDD	I 6
64 - 69	DTREMV	Date Removed YYMMDD	I 6
70 - 75	DTDEL	Date Deleted YYMMDD	I 6
76 - 80		Not used	5x

LRECL = 80

The Integration of Source Data

DNA transactions which reported the installation or removal of a reservoir served as the basis for creating our EXCHGxx.DAT analysis file. Thus, reservoir exchanges taking place within DOE facilities, or otherwise outside of DOD's custody, were excluded. Each DNA transaction which reported the installation or removal of a reservoir was matched with an associated DOE history record to create a composite life-cycle history for that reservoir. Then, each set of records for an "installed reservoir" was matched with a similar set of records for the "removed reservoir". (This match required the identical weapon type and serial number, and reservoir type.)

The "matched records", however, included not only reservoir exchanges but also (1) installations in newly manufactured weapons, (2) removals from weapons being retired, and (3) replacements intended to modify or upgrade the performance of earlier reservoirs. Because we wanted to examine the programming of tritium reservoir exchanges according to schedules based on the physics of radioactive decay and not the consequence of modernization or unanticipated circumstances, we adopted a very narrow definition of "reservoir exchange".

To identify "reservoir exchanges", we excluded "installation-only", "removal-only", and "early-support" transactions. We also excluded transactions for which a reservoir was removed and subsequently reinstalled in the same weapon. This narrowed the population of interest, but still accounted for over 86 percent of all installations and removals during the period.

We examined the entire population rather than a sampling from the transaction file, because the mix of weapon types and their associated exchange schedules might fluctuate between the years. This focus on individual reservoirs had additional benefits: we were able to assess the efficiency and timeliness of individual reservoir exchanges, and we were able to estimate the impact on tritium availability that would result if DOE and the Defense Nuclear Agency effected different reservoir exchange practices.

The following limitations of our database should be recognized:

- The tritium demand may be cyclical. Observations taken in one year might not be representative of other time periods.
- The database was drawn from DOE and Defense Nuclear Agency records. While it exhibited "face validity" throughout our analysis and in

presentations before agency representatives, the accuracy of source records has not been independently verified.

Reference Data Files

Three "reference files" were created to facilitate the integration of DNA and DOE data— the WEAPON.DAT, RESERVOIR.DAT, and LOCATION.DAT files (see fig. III.2). The WEAPON.DAT file provided a single record with uniform information about each type of warhead in the database. Each record provided a cross-walk between DOE and DNA's naming conventions—as say, between the DOE warhead name "BO 57" and its DNA counterpart(s), "B57810BN", etc. Also, they enabled a sequentially assigned number (IWTX and IWT) to replace the longer Warhead Name (WHEADX and WHEAD) in machine processing. This uniformity conserved storage and simplified machine processing requirements. The RESERVOIR.DAT and LOCATION.DAT files provided similar information on types of reservoirs, and for military locations.

Figure III.2: Reference Data Files

File: WEAPON.DAT

RCD Posn		Field Name		Format
1 - 3	IWTX	-	DNA Warhead Type, Code Number	I 3
4			Delimiter ','	1x
5 - 6	IWT	-	DOE Warhead Type, Code Number	I 2
7			Delimiter ','	1x
8 - 15	WHEADX	-	DNA Warhead Name, Noun	A8
16			Delimiter ','	1x
17 - 25	WHEAD	-	DOE Warhead Name, Noun	A9
26			Delimiter ','	1x
27	KSTRAT	-	Strategic / Nonstrategic Code	I 1

LRECL = 27

File: RESERVOIR.DAT

RCD Posn		Field Name		Format
1 - 2	IRT	-	Reservoir Type, Code Number	I 2
3 - 7	RTX	-	DNA Reservoir Type, Noun	A5
8			Delimiter ','	1x
9 - 17	RT	-	DOE Reservoir Type, Noun	A9
18			Delimiter ','	1x
19 - 22	LEXP	-	Life Expectancy (months)	I 4
23			Delimiter ','	1x
24 - 28	RTC	-	Tritium Capacity (grams)	F5.2

LRECL = 28

File: LOCATION.DAT

RCD Posn		Field Name		Format
1 - 3	ILOC	-	Location, Code Number	I 3
4 - 28	LNAME	-	Location Name, Noun	A25
29	GLOC	-	Geographic Location Code	I 1
30			Delimiter ','	1x
31	KSVC	-	Service Code, GAO	I 1
32			Delimiter ','	1x
33 - 35	ALOC	-	Location Code, Alfa Character	A3

LRECL = 35

KSVC =		GLOC =	
1	Air Force	1	Contiguous 48 States
2	Army	2	NonContig. USA & Territories
3	Marine Corps	3	US Ships
4	Navy	4	Outside US Territory

The Analysis Database

The record layout for File EXCHGxx.DAT is shown in figure III.3. This filename was chosen to connote both the nature (exchange actions) and the fiscal year (e.g., EXCHG88) of the file's contents. Dates are presented as a "Day-of-the-Gregorian Calendar". Missing values are represented by a "-1" in the respective data field.

Figure III.3: The Analysis Database

File: EXCHGxx.DAT

RCD Posn	Field NAME		Format	Source
1 - 2	IWT	– DOE Warhead Type, Code Number	I 2	C
3 - 10	WS	– Warhead Serial Number	A8	A,B
11 - 12	IRT	– Reservoir Type, Code Number	I 2	D
13 - 16	LEXP	– Life Expectancy (months)	I 4	B
17 - 19	COEI	– COEI Code (CMP Ending Inv)	A3	B
20 - 22	LOC	– Location Code: Exchange Site	I 3	A
23	KSVCX	– Service Code, DNA	I 1	A
		<==== OLD (Removed) Reservoir ====>		
24 - 31	RRS	– Reservoir Serial Number	A8	A,B
32 - 37	RGDF	– Date Manufactured, DOE	I 6	B
38 - 43	RGDS	– Date Shipped, DOE	I 6	B
44 - 49	RGDI	– Date Installed, DOE	I 6	B
50 - 55	RGDRI	– Date Removed, DOE	I 6	B
56 - 61	RGDD	– Date Deleted, DOE	I 6	B
		– File DNA.DAT Appendage –		
62 - 64	JWT	– DNA Warhead Type, Code Number	I 3	C
65 - 70	RGDR2	– Date Removed, DNA	I 6	A
71 - 76	RGDE2	– Date Expired, DNA	I 6	A
		<==== NEW (Installed) Reservoir ====>		
77 - 84	RS	– Reservoir Serial Number	A8	A,B
85 - 90	GDF	– Date Manufactured, DOE	I 6	B
91 - 96	GDS	– Date Shipped, DOE	I 6	B
97 - 102	GDI1	– Date Installed, DOE	I 6	B
103 - 108	GDR	– Date Removed, DOE	I 6	B
109 - 114	GDD	– Date Deleted, DOE	I 6	B
		– File DNA.DAT Appendage –		
115 - 117	KWT	– DNA Warhead Type, Code Number	I 3	C
118 - 123	GDI2	– Date Installed, DNA	I 6	A
124 - 129	GDE2	– Date Expired, DNA	I 6	A
		<=== Files LOCATION.DAT & WEAPON.DAT Trailer ===>		
130	KSVC	– Service Code	I 1	E
131	GLOC	– Geograhic Location Code	I 1	E
132	KSTRAT	– Strategic / Nonstrategic Code	I 1	C
133 - 137	RTC	– Reservoir Tritium Capacity, grams	F5.2	D
		<==== File DNA.DAT Trailer ====>		
		(Shipment of Removed Reservoir)		
138 - 143	RGDSS	– Date Exchange Site Shipped Reservoir	I 6	A
144 - 149	RGDMS	– Date MFD Shipped to DOE	I 6	A
		(Shipment of Installed Reservoir)		
150 - 155	GDMR	– Date MFD Received from DOE	I 6	A
156 - 161	GDSR	– Date Install Site Received Reservoir	I 6	A

LRECL = 161 — Dates expressed as Day-of-Gregorian Calendar

KSTRAT:
- 1 = Nonstrategic Warhead
- 2 = B61 Warhead, Nonstrategic
- 3 = W80 Warhead Mod0: USAF ALCM, Strategic; Mod1: USN TOMAHAWK SLCM, Nonstrategic
- 4 = Strategic Warhead

Source:
- A = File DNA.DAT
- B = File DOE.DAT
- C = File WEAPON.DAT
- D = File RESERVOIR.DAT
- E = File LOCATION.DAT

Fortran Listing of Impact Program

```
Line#
C***********************************************************************
C       This is a noninteractive PGM for Impact Analysis of           *
C         File EXCHGxx.DAT.   ALSO Provides Exam of Censored Data    *
C***********************************************************************
C*              Program  H3Impact: File= EXCHGxx.DAT                  *
C*      Case Selection:  All Warheads                                 *
C*              Exclude Records w/ Missing Data Fields                *
C*              Exclude Records w/ Negative Time Durations            *
C***********************************************************************
      CHARACTER*20 FNAME1,FNAME2,FNAME3
      CHARACTER*8  WS,RRS,RS
      CHARACTER*3  COEI
      INTEGER      RGDF,RGDS,RGDI,RGDR1,RGDD,RGDR2,RGDE2,
     1             GDF,GDS,GDI1,GDR,GDD,GDI2,GDE2,GLOC,
     2             RGDSS,RGDMS,GDMR,GDSR,
     3             PASS,UNIQUE,SELKEY,NBRERR,XNRA,XUNIQUE,IKEY,
     4             IPA(6), IWA(6), KVAR(4100), MCOUNT(2,100)
      REAL         RMATL(100), SUMA(6,100,5), DEFER(6), WTRATIO(6)
      DATA         KVAR/4100*0/,MCOUNT/200*0/,
     1             RMATL/100*0.0/,SUMA/3000*0.0/,
     2             PASS/-1/,NBRERR/1/,IPRCD/0/,NRA/0/,NRB/0/,IKEY/0/,
     3             IPA/6*0/,IWA/6*0/,XNRA/4100/,XUNIQUE/100/,
     4             WRQMT/0.0/,XRQMT/0.0/
                   DO 2 INDX=1,100
                      DO 1 ICASE=1,6
                         SUMA(ICASE,INDX,4)= 999999.
    1                    SUMA(ICASE,INDX,5)=-999999.
    2              CONTINUE
C
C     DEFINE INPUT FILE AS FNAME1 & OUTPUT SUMMARY AS FNAME2 BELOW
C        IF INTERMEDIATE REPORT ON MISSING/IMPUTED DATA IS DESIRED
C          SET 'IKEY=1' AND DEFINE OUTPUT FILE AS FNAME3,
C           OTHERWISE SET 'IKEY=0'
      IKEY=1
      FNAME1='C:\EXCHGxx.DAT'
      FNAME2='C:\FNAME2.DAT'
      FNAME3='C:\FNAME3.DAT'
      WRITE(*,770)
  770 FORMAT(/15(/),15X,'***** PROGRAM PROCESSING UNDERWAY *****'/,
     1 15X,'               PARDON THE DELAY',9(/))
                     OPEN (2, FILE= FNAME2)
    3                CONTINUE
                     OPEN (1, FILE= FNAME1)
C
C          ****DEFINE INPUT FILE AS DEVICE 1 ABOVE****
C
   10 READ(1,4,END=11) IWT,WS,IRT,LEXP,COEI,LOC,KSVCX,
     1RRS,RGDF,RGDS,RGDI,RGDR1,RGDD,JWT,RGDR2,RGDE2,
     2RS,GDF,GDS,GDI1,GDR,GDD,KWT,GDI2,GDE2,
     3KSVC,GLOC,KSTRAT,RTC,RGDSS,RGDMS,GDMR,GDSR
    4 FORMAT(I2,A8,I2,I4,A3,I3,I1,2(A8,5I6,I3,2I6),3I1,F5.2,4I6)
      IPRCD=IPRCD+1
```

```
C***********************************************************************
C                        START PROGRAM SEGMENT 1                       *
C***********************************************************************
C               SET VARIABLE KFLAG TO DENOTE CONUS-OCONUS CONDITION    *
C                     PER ALBUQUERQUE SUB-OFFICE'S GUIDANCE            *
C                     KFLAG = 1 (CONUS) , = 2 (OCONUS) , = 3 (SHIP )   *
      KFLAG=GLOC
        IF(KFLAG.EQ.4) KFLAG=2
        IF((KFLAG.LT.1).OR.(KFLAG.GT.3)) GO TO 904
C                                                                      *
C               SET VARIABLE JFLAG TO DENOTE SERVICE                   *
C                    JFLAG = 1 (AIR FORCE) , = 2 (ARMY) , = 3 (NAVY)   *
      JFLAG=KSVC
        IF(JFLAG.EQ.3) GO TO 903
        IF(JFLAG.EQ.4) JFLAG=3
        IF((JFLAG.LT.1).OR.(JFLAG.GT.3)) GO TO 903
C                                                                      *
C               SET VARIABLE IFLAG TO DENOTE STRATEGIC/NONSTRATEGIC    *
C                 IFLAG = 1 (NONSTRATEGIC) , = 2 (STRATEGIC    )       *
      IFLAG=1
        IF((KSTRAT.LT.1).OR.(KSTRAT.GT.4)) GO TO 902
        IF((KSTRAT.EQ.3).AND.(JFLAG.EQ.1)) IFLAG=2
        IF(KSTRAT.EQ.4) IFLAG=2
C                                                                      *
C              WHEN REQUIRED, ENTER SELECTION CRITERIA                 *
C                  CURRENT SELECTION = ALL WARHEADS                    *
C example: IF(KFLAG.EQ.1) GO TO 10                                     *
C                                                                      *
C     **** OBTAIN COUNTS & CREATE INDEX VALUE AS KVAR(NRA) ****
      NRA=NRA+1
      IF(NRA.GT.XNRA) GO TO 950
      J= (IRT*1000) + (KFLAG*100) + (JFLAG*10) + IFLAG
          IF(PASS.NE.-1) GO TO 200
          KVAR(NRA)= J
          GO TO 10
C                                                                      *
C                       END PROGRAM SEGMENT 1                          *
C***********************************************************************
   11 CLOSE (1)
      IF(PASS.NE.-1) GO TO 300
         PASS=1
```

```
C**********************************************************************
C                  BEGIN PROGRAM SEGMENT 2                            *
C         SORT ASCENDING, THEN REDUCE TO UNIQUE SET OF VALUES         *
C                                                                     *
          DO 100 I=1,NRA-1
             DO 100 K=I+1,NRA
                IF(KVAR(I).LE.KVAR(K)) GO TO 100
                J=KVAR(I)
                KVAR(I)=KVAR(K)
                KVAR(K)=J
  100     CONTINUE
                J=1
          DO 101 I=2,NRA
                IF(KVAR(J).EQ.KVAR(I)) GO TO 101
                J=J+1
                KVAR(J)=KVAR(I)
  101     CONTINUE
          UNIQUE=J
         IF(UNIQUE.GT.XUNIQUE) GO TO 905
         IPRCD=0
          NRA=0
          GO TO 3
C                                                                     *
C                   END PROGRAM SEGMENT 2                             *
C**********************************************************************
```

```
C***********************************************************************
C                      BEGIN PROGRAM SEGMENT 3                         *
C             FIND INDEX VALUE, DETERMINE TRITIUM WEIGHT BY INDEX      *
C                AND COMPUTE OVERALL TOTAL TRITIUM REQUIREMENT         *
  200 DO 201 I=1,UNIQUE
         IF(KVAR(I).NE.J) GO TO 201
         INDX=I
         GO TO 202
  201 CONTINUE
         GO TO 900
  202 IX=1
         RMATL(INDX)=RTC
         WRQMT=WRQMT+RTC
C                                                                      *
C             RECORDS USED FOR ANALYSIS MUST HAVE APPROPRIATE          *
C             DATE CONSTRUCTION.  COUNT RECORDS PASSING SCREEN 'NRB'   *
         IF((GDF.LT.1).OR.(GDS.LT.1)) GO TO 203
         IF(GDI2.LT.1) GO TO 203
         IF(RGDF.LT.1) GO TO 203
         IF(RGDE2.LT.1) GO TO 203
         IF((RGDR2.LT.1).OR.(RGDD.LT.1)) GO TO 203
         IF(RGDR2.LT.RGDF) GO TO 203
         IF(RGDE2.LE.RGDF) GO TO 203
         IF(RGDD.LT.RGDR2) GO TO 203
         IF(GDI2.LE.GDF) GO TO 203
         IF(GDS.LE.GDF) GO TO 203
         IF(GDF.EQ.RGDF) GO TO 203
         IF(RGDMS.LT.1) GO TO 203
         IF((RGDMS.LT.RGDR2).OR.(RGDMS.GT.RGDD)) GO TO 203
         NRB=NRB+1
         GO TO 204
C              COUNT RESERVOIRS BY CATEGORY MCOUNT(IX,INDX),           *
C                WHERE IX = 1 (USED)   = 2 (NOT USED)                  *
C                AND SUM TRITIUM WEIGHT OF 'NOT USED'                  *
  203 IX=2
         XRQMT=XRQMT+RTC
  204 MCOUNT(IX,INDX)= MCOUNT(IX,INDX)+1
         IF(IX.GT.1) GO TO 10
C     *****************************************************************
C     *      LET IPA = PIPELINE DAYS; IWA = OPERATIONAL DAYS;          *
C     *             AND ILA = LIFE EXPECTANCY DAYS                     *
C     *    COMPUTE ACTUAL INTERVALS: AS EVIDENCED BY OLD BOTTLE        *
C     *           IPA(A) = (RGDI-RGDF) + (RGDD-RGDR2)                  *
C     *           IWA(A) = (RGDR2-RGDI)                                *
C     *  COMPUTE BENCHMARK: ACTUAL INTERVALS EVIDENCED BY OLD BOTTLE   *
C     *    BUT WITH NEW INSTALL INTVL.  REMOVAL IS BEFORE RGDE2.       *
      IPA(1) = ( GDI2- GDF) + (RGDD-RGDR2)
      IWA(1) = (RGDR2-RGDF) - ( GDI2- GDF)
C     *  COMPUTE ACTUAL MOD2: NEW INSTALL INTVL w/ REMOVAL AT RGDE2     *
      IPA(2) = ( GDI2- GDF) + (RGDD-RGDR2)
      IWA(2) = (RGDE2-RGDF) - ( GDI2- GDF)
```

```
C     *  TO COMPARE WITH BENCHMARK: WHEN RGDR2.GT.RGDE2, USE RGDR2.  *
       IF(RGDR2.GT.RGDE2) RGDE2=RGDR2
                         I= GDS- GDF
                         J= RGDE2- RGDF
                         K= RGDD-RGDMS
                         KA= GDI2-GDS
                         KB= RGDMS-RGDE2
       SELKEY=0
C     *****************************************************************
C     *  SELECTION KEY TO DETERMINE IMPACT ON OVERALL TRITIUM SUPPLY  *
C     *      WHEN PIPELINE TIMES ARE SELECTIVELY CHANGED FOR A         *
C     *      PARTICULAR SEGMENT OF THE FORCE (e.g. Silo Based ICBMs).  *
C     *          WARHEADS AFFECTED BY THE CHANGE GO TO 206             *
C     *               OTHERWISE CONTINUE IN SEQUENCE                   *
C     *          CURRENT SELECTION: ====>  ALL WARHEADS                *
       IF (IWT.NE.0) SELKEY=1
       IF (SELKEY.EQ.1) GO TO 206
          DO 205 I=2,6
             IPA(I)= IPA(1)
             IWA(I)= IWA(1)
   205    CONTINUE
             GO TO 207
C     *                                                               *
C     *****************************************************************
   206 NRC=NRC+1
C             COMPUTE IMPACT OF GDF-to-GDS + 90/120 & 60/90 SHIPPING RULE
                 IPA(3) = I +90 + 60 + K
                    IF(KFLAG.EQ.2) IPA(3) = I + 120 + 90 + K
                 IWA(3) = J - I -90
                    IF(KFLAG.EQ.2) IWA(3) = J - I -120
C             COMPUTE IMPACT OF GDF-to-GDS + 60/90 & 30/90 SHIPPING RULE
                 IPA(4) = I + 60 + 30 + K
                    IF(KFLAG.EQ.2) IPA(4) = I + 90 + 90 + K
                 IWA(4) = J - I - 60
                    IF(KFLAG.EQ.2) IWA(4) = J - I - 90
C             COMPUTE IMPACT OF GDF-to-GDS + 45/75 & 15/45 SHIPPING RULE
                 IPA(5) = I + 45 + 15 + K
                    IF(KFLAG.EQ.2) IPA(5) = I +75 + 45 + K
                 IWA(5) = J - I - 45
                    IF(KFLAG.EQ.2) IWA(5) = J - I - 75
C             COMPUTE IMPACT OF ZERO DOD PIPELINE & CURRENT DOE PIPELINE
                 IPA(6) = 30 + 30
                 IWA(6) = J - 30
   207        CONTINUE
```

```
Line#
C*********************************************************************
        DO 208 ICASE=1,6
           X= IPA(ICASE)
           Y= IWA(ICASE)
           Z=X/Y
           IF(Z.LT.0.0) Z=0.0
           SUMA(ICASE,INDX,1)= SUMA(ICASE,INDX,1)+Z
           SUMA(ICASE,INDX,2)= SUMA(ICASE,INDX,2)+Z*Z
           SUMA(ICASE,INDX,3)= SUMA(ICASE,INDX,3)+1.0
           SUMA(ICASE,INDX,4)= MIN(SUMA(ICASE,INDX,4),Z)
           SUMA(ICASE,INDX,5)= MAX(SUMA(ICASE,INDX,5),Z)
    208 CONTINUE
        GO TO 10
C                                                                    *
C                     END PROGRAM SEGMENT 3                          *
C*********************************************************************
C*********************************************************************
C                    BEGIN PROGRAM SEGMENT 4                         *
C            COMPUTE AVERAGE FOR INDX= SUMA(ICASE,INDX,1)            *
    300 CONTINUE
        IF(IKEY.EQ.0) GO TO 305
        OPEN (3, FILE= FNAME3)
        WRITE(3,301)
    301 FORMAT(27X,'MISSING OBSERVATIONS REPORT'/)
        WRITE(3,411) FNAME1,IPRCD,NRA,NRB
        WRITE(3,303)
    303 FORMAT(26X,'** PIPELINE TO WARHEAD RATIO **'/1X,'IRT GLOC ',
       1'KSVC KSTRAT CASE',2X,'MEAN     STD.DEV    MIN.     MAX.',
       2'   OBS. MISS.OBS. TOTAL'/)
    305 DO 352 INDX=1,UNIQUE
           DO 352 ICASE=1,6
             IF(SUMA(ICASE,INDX,3))901,352,311
    311        XS = SUMA(ICASE,INDX,1)
               XSS= SUMA(ICASE,INDX,2)
               XN = SUMA(ICASE,INDX,3)
               AVG= XS/XN
               SUMA(ICASE,INDX,1)=AVG
             IF(IKEY.EQ.0) GO TO 352
               STD= 0.0
C                    LET STD.DEV EQUAL 0.0 WHEN 'N=1' AND
C                    VARIANCE IS LESS THAN 1.0E-10 OF THE 'AVG'
C                    THUS AVOIDING DIVIDE CHECK/ROUNDING LEADING
C                    TO RUN-TIME ERRORS IN SQRT( ) COMPUTATION.
               IF(XN-1.0)901,315,312
    312           Z=((XN*XSS)-(XS*XS))/(XN*(XN-1.0))
                  IF(AVG.GT.(Z*1.0E+10)) GO TO 315
                  STD= SQRT(Z)
    315        CONTINUE
```

```
C                            BREAKOUT INDEX NUMBERS
                    SUMA(ICASE,INDX,2)=STD
                    N=XN
                    J=KVAR(INDX)
                    IRT=J/1000
                    J=MOD(J,1000)
                    KFLAG=J/100
                    J=MOD(J,100)
                    JFLAG=J/10
                    IFLAG=MOD(J,10)
                    J=MCOUNT(2,INDX)
                    M=N+J
                    IF(ICASE.NE.1) GO TO 350
                  WRITE(3,340) IRT,KFLAG,JFLAG,IFLAG,ICASE,AVG,STD,
     1              SUMA(ICASE,INDX,4),SUMA(ICASE,INDX,5),N,J,M
  340               FORMAT(1X,I3,I4,I5,2I6,4F8.5,I5,I7,I8)
                    GO TO 352
  350             WRITE(3,351) ICASE, AVG,STD,
     1              SUMA(ICASE,INDX,4),SUMA(ICASE,INDX,5)
  351               FORMAT(19X,I6,4F8.5)
  352 CONTINUE
        IF(IKEY.EQ.0) GO TO 380
      CLOSE (3)
C                 THEN CALCULATE WEIGHTED AVG FOR ALL BOTTLES                  *
  380 DO 384 ICASE=1,6
          XS=0.0
          XSS=0.0
          DO 383 INDX=1,UNIQUE
             N= MCOUNT(1,INDX) + MCOUNT(2,INDX)
             XN= N
             XN= XN * RMATL(INDX)
             XS= XS + (XN * SUMA(ICASE,INDX,1))
             XSS= XSS + XN
  383     CONTINUE
          WTRATIO(ICASE)= (XS/XSS)
  384 CONTINUE
C                                                                              *
C                            END PROGRAM SEGMENT 4                             *
C******************************************************************************
```

```
C************************************************************************
C              NOW READY TO PRINT FINAL LISTING                           *
C                                                                         *
       WRITE(2,410)
   410 FORMAT(31X,'SUMMARY REPORT'/)
       WRITE(2,411) FNAME1,IPRCD,NRA,NRB
   411 FORMAT(6X,'**** PROGRAM H3IMPACT:  FILE= ',A20,
      1'RCDS I/P =',I5,' ****'//,22X,'SELECTION CRITERIA: ',
      2' ALL FY19xx WEAPONS '/30X,
      3'RCDS SELECTED =',I6/
      424X,'RCDS PASSING DATE SCREENS =',I6/)
       WRITE(2,412)
   412 FORMAT(55X,'MATERIAL REQUIREMENTS'/61X,'PROPORTION'/5X,
      1' CASE',46X,'PIPELINE to WARHEAD'/)
       WRITE(2,413) (WTRATIO(ICASE), ICASE=1,6)
   413 FORMAT(5X,' BENCHMARK:'/8x,
      1 '1   Using GDI2-GDF & Removal at RGDR2        ',F13.5,' : 1'//
      2 5X,' EXCHANGE ON EXPIRATION DATE:'/8X,
      3 '2  Using GDI2-GDF & Removal at Max(RGDR2, RGDE2)',F9.5,
      4 ' : 1'//,5X,' SHIPPING RULES:'/8X,'3  GDF-to-GDS + 90/120',
      5 ' & 60/90 SHIPPING Rule',F13.5,' : 1'/8X,
      6 '4    ...          60/90  & 30/90 SHIPPING Rule',F13.5,' : 1'/8X,

      7 '5    ...    15/30/15 & 45/30/45 SHIPPING Rule',F13.5,' : 1'//,
      8 5X,' MAXIMUM DEFERRAL:'/8X,
      9 '6  ASSUMING ZERO DOD PIPELINE                 ',F13.5,' : 1')
       DO 420 ICASE=2,6
   420 DEFER(ICASE)=12.3232 *((LOG(1.+WTRATIO(1))
      1-LOG(1.+WTRATIO(ICASE)))/LOG(2.0))
       WRITE(2,425) (DEFER(ICASE), ICASE=2,6)
   425 FORMAT(///,25X,'    DEFERRAL IN WEAPON CUTS'/22X,
      1 'VIS-A-VIS  BENCHMARK  (CASE #1)   -----   YEARS'/5X,' CASE'//,

      2 5X,' EXCHANGE ON EXPIRATION DATE:'/8X,
      3 '2  Using GDI2-GDF & Removal at Max(RGDR2, RGDE2)',F13.5//,
      4 5X,' SHIPPING RULES:'/8X,
      5 '3  GDF-to-GDS + 90/120 & 60/90 SHIPPING Rule',F17.5/8X,
      6 '4    ...          60/90  & 30/90 SHIPPING Rule',F17.5/8X,
      7 '5    ...    15/30/15 & 45/30/45 SHIPPING Rule',F17.5//,
      8 5X,' MAXIMUM DEFERRAL:'/8X,
      9 '6  ASSUMING ZERO DOD PIPELINE                 ',F17.5/)
       wrqmt=wrqmt * 0.001
       xrqmt=xrqmt * 0.001
       WRITE(2,430) WRQMT,XRQMT
   430 FORMAT(//5X,' =====>      IN-WARHEAD MATERIAL DEMAND =',F9.5,
      1' Kg'/12X,'(INCLUDES',F9.5,' Kg IN RCDS FAILING DATE SCREENS)')
       GO TO 995
```

```
C***********************************************************************
C                 OUTPUT ERROR NOTIFICATION MESSAGES                   *
C       ERROR CODE = 1 --Exceeds Array Dimension NRA(4100)             *
C                    2 --Exceeds Array Dimension UNIQUE(100)           *
C                    3 --Exceeds Range KFLAG                           *
C                    4 --Exceeds Range JFLAG                           *
C                    5 --Exceeds Range IFLAG                           *
C                    6 --Negative Value in SUMA(I,J,3) Do 352 Loop     *
C                    7 --INDEX Value not matched in Do 201 Loop        *
  900 NBRERR= NBRERR +1
  901 NBRERR= NBRERR +1
  902 NBRERR= NBRERR +1
  903 NBRERR= NBRERR +1
  904 NBRERR= NBRERR +1
  905 NBRERR= NBRERR +1
  950 WRITE(2,951) NBRERR
  951 FORMAT(5X,'PROGRAM INTERRUPT:  ERROR CODE =',I3)
C********************END ERROR CODE PROCESSING**********************
  995 WRITE(*,996) FNAME1,FNAME2
  996 FORMAT(///15X,'>>>>>>>> PROCESSING COMPLETED <<<<<<<<<<',14(/),
     1 10X,'PROGRAM H3IMPACT'//12X,'INPUT FILE WAS ',A20//12X,
     2 'OUTPUT TEXT FILES:'/14X,'PGM RESULTS SUMMARY = ',A20)
  997 IF(IKEY.NE.0) WRITE(*,998) FNAME3
  998 FORMAT(14X,' MISSING/IMPUTED DATA = ',A20)
  999 CONTINUE
      END
```

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