NUCLEAR WEAPONS LATENCY

A Dissertation

by

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Submitted to the Office of Graduate and Professional Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

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August 2014

Major Subject: Nuclear Engineering

ABSTRACT

A novel nuclear weapons proliferation assessment method has been developed to determine a state's Nuclear Weapons Latency, the expected time to be taken by a non-nuclear weapons state to develop a conventionally deliverable nuclear weapon given the state's position on a path toward or away from a nuclear weapon and accounting for the state's motivations and intentions. Potential proliferation time is taken as a representation of the latent proliferation capacity of a non-nuclear weapons state. An assessment of proliferation time is critical to crafting an effective policy response within a useful time frame. Current proliferation assessments either neglect proliferation time or are static case-specific assessments frequently built on restricted information and opaque assumptions.

The Nuclear Weapons Latency computational tool has been developed to determine a state's Nuclear Weapons Latency and embodies a stochastic Petri net proliferation simulation. The tool makes only three simple assumptions: a decision to proliferate has been made, the proliferation pathway network is known, and the associated pathway activity times are estimable. Beyond the quantification of a state's latency, the tool provides a transparent, efficient, adaptable, and highly repeatable platform which allows for extensive sensitivity analysis to better inform the nonproliferation discussion and policy decisions.

Functionality of the tool was verified and inherent sensitivities determined through historical analysis with the U.S. case of proliferation in the Manhattan Project.

Network and operational parameters were found that drove expected Latencies high while others increased the Latency distribution variance. Further confidence was built with historical analyses of the Pakistani and South African cases of proliferation. These verifications were done in lieu of experimental validation which is impossible for future event simulations like the Latency tool. Analysis revealed that while A.Q. Khan altered the Pakistani proliferation pathway, his impact on proliferation time may have been minimal.

A Multi-Attribute Utility Analysis (MAUA) function was implemented for proliferation pathway selection. This function might increase the accuracy of the most-likely Latency estimate in certain cases. However, use of MAUA for adversary modeling also significantly increased the number of assumptions necessary.

A Latency investigation of South Korean nuclear fuel cycle facility development, a current nonproliferation policy concern, demonstrates how Nuclear Weapons Latency can help characterize the proliferation risk of different policy options for decision makers. Analysis showed that development of any one of pyroprocessing, PUREX, or especially commercial uranium enrichment technologies reduces South Korean Latency. This risk characterization ability through policy option sensitivity enables the Latency tool to help fill a void of useful proliferation risk information provided by technical assessments to policy makers identified by the 2013 National Academies study *Improving the Assessment of Proliferation Risk of Nuclear Fuel Cycles*.

DEDICATION

This dissertation is dedicated to Deacon for his devotion to maintaining my sanity throughout this lengthy ordeal and (almost) always being at the door when I returned home, no matter the hour.

ACKNOWLEDGEMENTS

I thank my committee chair, Dr. William S. Charlton, for his guidance and patience. I also thank my committee members, Dr. Boyle, Dr. Hermann, and especially Dr. Wortman for their invaluable insights throughout the course of this research.

The deepest gratitude and thanks go to my friends and family. Katie and Grant, there are no finer friends in the world than the friends the two of you have been to me. Finally, thanks to my mother and father for their unending support and love.

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I. INTRODUCTION

I.A. Motivation

The proliferation of nuclear weapons is one of the major threats to the US and international security today.[1] Substantial attention has also been given to the concept of eliminating all nuclear weapons.[2,3,4] The (potential) nuclear threats of North Korea and Iran regularly grab headlines.[5,6] In 2009, President Obama gave a marquee foreign policy speech vowing to address proliferation concerns and pursue full nuclear disarmament.[7] However, in order to best address nuclear weapons proliferation and prepare for a world without them, one must fully understand the dynamics of proliferation. Paramount among the characteristics of such proliferation are the time (or "latency") and pathway that a state takes to develop its nuclear weapons given its motivations, intentions, and underlying latent capacities.[8,9,10,11]

Nuclear Weapons Latency is defined as "The expected time to be taken by a non-nuclear weapons state to develop a conventionally deliverable nuclear weapon given the state's position on a path toward or away from a nuclear weapon and accounting for the state's motivations and intentions".[12,13] A conventionally deliverable weapon is defined as a weapon deliverable by airdrop, missile, or artillery systems. Proliferation pathways refer to the particular choices, steps, and methods that a state pursues in order to develop a nuclear weapon. In order to deepen the understanding of the dynamics of nuclear weapons proliferation, it is necessary to create a systematic methodology to quantify Nuclear Weapons Latency.

Fig. 1 depicts a graphical representation of Nuclear Weapons Latency. Three general proliferation pathways are shown as linked nodes. The nodes represent sequential levels of development necessary for successful proliferation. Time is indicated on the horizontal axis to illustrate that the required proliferation time is dependent on the path taken.

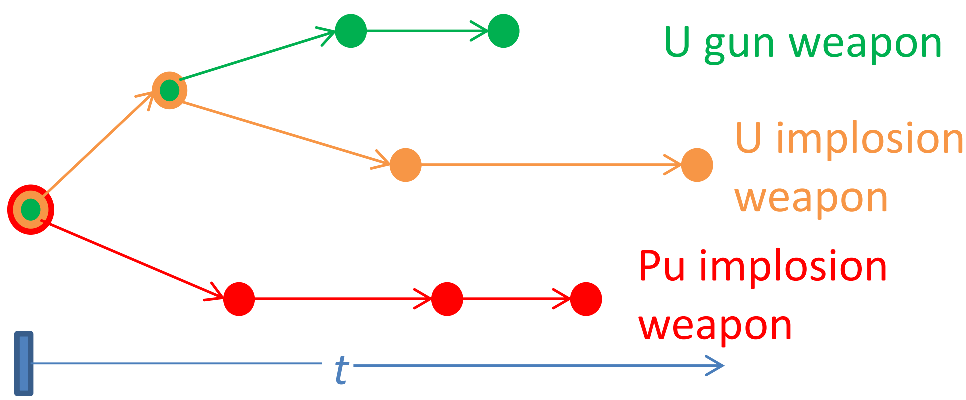


Fig. 1. Graphical Nuclear Weapons Latency representation.

I.B. Objective

The objective of this research is to develop a computational tool to determine a state's Nuclear Weapons Latency given its current condition including available resources and motivational environment. Nuclear Weapons Latency is characterized by an expected time to proliferate and the associated proliferation pathway. Nuclear Weapons Latency is not a prediction of proliferation; such predictions are perilous.[14] Nuclear Weapons Latency answers the question: if a decision to proliferate has already been made how long is it expected to take and what path should the state be expected to follow?

The research objective is met by the developed Nuclear Weapons Latency tool presented in this dissertation. The tool makes only three simple assumptions: 1) that a proliferation decision has been made, 2) that the network of potential proliferation pathways available to the proliferator is known, and 3) that proliferation network activity times may be reasonably estimated. The first assumption is necessary to limit the scope of the problem to what is tractable. A lack of a clear decision in favor of nuclear weapons development can only slow proliferation. Therefore the only consequence of this assumption being incorrect is that proliferation times may be underestimated. Expecting proliferation sooner than it might actually occur is a safe and conservative approximation. The other two assumptions are entirely testable. Tool simulations may be run *ad infinitum,* varying the network and activity time assumptions to quantify their impact. The Latency tool thus provides a transparent platform to perform repeatable studies using well defined and variable assumptions that allow for complete sensitivity analysis of the results. In this manner intuition building by independent users without requiring intensive expert efforts is possible.

I.C. Previous Work

The quantification of Nuclear Weapons Latency as defined above is a type of proliferation assessment which focuses on time and the proliferation pathway. Attempts at assessing proliferation were being made before the first nuclear weapon was even constructed.[15] Modern technical proliferation assessments can be divided into three categories: broad methodologies focused on assessing the likelihood of proliferation and in some cases predicting proliferation which may be applied to any case, proliferation pathway analysis, and specific case based assessments which apply expert analysis. Closely related to proliferation assessments are proliferation resistance methodologies, and these will also be catalogued.

I.C.1. Proliferation Assessments

The seminal work among broad based quantitative assessments is *The Dynamics of Nuclear Proliferation* by Meyers.[9] Meyers developed a technical model to characterize a state's latent capacity for nuclear weapons and then tested three theories of proliferation against historical proliferation cases given the data of the technical model. Meyers found support for proliferation as a result of some external or internal motivator and no support for the theory of technical inertia or the null hypothesis.

Other theoretical proliferation assessments attempted to correlate the impact of various factors and indicators to proliferation decisions or levels of progress towards a nuclear weapons capability. Singh & Way developed correlates of proliferation based on technological, external, and internal determinants and further deconstructed proliferation into three stages: explore, pursue, and acquire.[16] They concluded that proliferation is generally a result of an appropriate economic development level mixed with an externally threatening environment. This analysis was further developed and expanded to include more pertinent nuclear capabilities and agreements by Li, Yim, and McNelis.[17] A study by Jo & Gartzke reinforced prior conclusions that proliferation occurred when there was a combination of determinants from both categories of opportunity and willingness.[18] Kroenig and Fuhrmann respectively assess the impact of foreign assistance to nuclear proliferation.[19,20] A unique proliferation assessment was presented by Jacque E.C. Hymans which concluded that the psychological disposition and associated perceptions of the political leader of the proliferant state has as much, if not more, to do with the decision to proliferate as any other indicator.[21] Taken together these works constitute a rigorous analysis of the drivers for nuclear proliferation. However, largely missing from them is any treatment of how such proliferation may occur.

More recent proliferation assessments have focused on proliferation pathway analysis. Ford developed a tool that could be used to assess the most likely path a state or sub-state actor would follow to acquire the Special Nuclear Material (SNM) required for a nuclear weapon.[22] Freeman implemented a Bayesian network to predict the most likely path to a nuclear weapon based on available resources, proliferant motivations, and existing evidence.[23] The Bayes net allows for the model to be updated as new evidence becomes available. Freeman's Bayesian network was expanded and refined to assess the impact of foreign assistance and technology acquisition by Mella.[24] The pathway assessment added by these methods was useful but left untreated the time associated with proliferation pathway progression.

Further pathway analysis work has been done from an International Atomic Energy Agency (IAEA) safeguards perspective. Listner *et al*. determine the most preferred diversion pathway for a state given a specific set of resources and technologies in order to more appropriately allocate IAEA safeguarding resources.[25] This methodology employs software to solve a shortest path algorithm with path length characterized with different criteria. Analysis has also been done to apply game theory to Listner's model to evaluate adversary strategies in response to pathway based application of safeguards.[26] In a similar vein, Murphy *et al.* propose a structure for IAEA resource allocation based on pathway analysis coupled with available technology, resources, and state behavior.[27] These methods are really assessments of proliferation pathway attractiveness to a proliferator. While this approach may meet IAEA needs, the methods are not a complete assessment of how proliferation might occur.

Proliferation assessments based on specific cases have frequently been done. These assessments are regularly done by intelligence agencies. Examples of proliferation assessments produced by intelligence agencies include any one of the multiple U.S. National Intelligence Estimates which have assessed the Iranian nuclear weapons program.[28] Other analyses that make use of entirely open source information are completed by think tanks, such as David Albright's Institute for Science and

International Security (ISIS) which produces regular reports on the capabilities of Iran and other suspected and known proliferators.[29] Harney *et al.* analyzed a hypothetical case of proliferation from a systems approach using the critical path method to estimate the time required for proliferation given certain assumptions.[30] Brown *et al.* explore optimal methods for interdicting the proliferation analyzed in Harney *et al.*[31] These specific case studies, while usually thorough, are static and require substantial expert effort to create and update.

Proliferation resistance methodologies attempt to assess the proliferation risk of specific nuclear materials, technologies, systems, or fuel cycles. Proliferation resistance is determined relative to other similar nuclear materials, technologies, systems, or fuel cycles, possibly as part of a holistic evaluation of a particular state given the state's current status. Proliferation resistance methodologies can be divided into two general categories: those employing barrier analysis and those using quantitative risk assessment methods. The barrier analysis methods include the Technological Opportunities to increase the Proliferation resistance of global civilian nuclear power Systems (TOPS) method, the Japan Atomic Energy Agency (JAEA) method, the Simplified Approach for Proliferation Resistance Assessment (SAPRA), the Texas A&M University (TAMU) Multi-Attribute Utility Analysis (MAUA) method, and the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) method.[32,33,34,35,36,37,38,39,40] Elements of the SAPRA method were incorporated into the TAMU MAUA. The SAPRA method itself is an extension of the JAEA method, which in turn is an extension of the TOPS method. Quantitative risk analysis based techniques include Proliferation

Resistance and Physical Protection (PR&PP), Risk Informed Proliferation Analysis (RIPA), and the BNL Markovian method.[41,42,43,44] All of these techniques except the BNL method rely on expert elicitation; though RIPA was developed such that the elicitation involved could be applied to different scenarios. While useful from a technology and facilities perspective, these methods assess proliferation resistance as opposed to state proliferation.

While there has been much work done in the area of proliferation assessments, it is clear that a computational tool to determine a state's Nuclear Weapons Latency represents a novel and significant advancement for this field. The traditional predictive proliferation assessments do not address how proliferation will occur. More recent assessments have investigated the likelihood of various pathways but have not addressed the time required by a proliferant to field a deliverable weapon. Case-based assessments, both hypothetical and real, do characterize both the pathway and time associated with proliferation. However, these studies are the product of a concerted effort by specific experts using a specific set of assumptions and information which may not be known or fully understood to those not involved. Further, National Intelligence Estimates and similar studies are produced in a classified environment. Such studies may be updated but not without concerted expert effort. These factors limit the availability, reproducibility, and applicability of their results. It is clear that despite the substantial contributions of previous assessments more work is needed. Table I notes ideal characteristics possessed by the various proliferation assessment methods.

TABLE I

Ideal Proliferation Assessment Characteristics

Proliferation Assessment types	Proliferation Theory	Pathway Analysis	Specific/ Case-based	Latency
Proliferation Likelihood	Yes	No	Yes	No
Pathway Likelihood	No	Yes	Yes	Yes
Proliferation Time	No	No	Yes	Yes
Transparent Assumptions	Yes	Yes	Some	Yes
Robust Uncertainty & Sensitivity Analysis	Some	Yes	Some	Yes
Easily Reproducible & Widely Applicable	Yes	Yes	No	Yes

Though the Latency method treats the actual proliferation decision as an assumption, it does bring distinct advantages. Policy makers and analysts need a reliable method that can promptly provide limits on the window of opportunity they have to influence proliferation and pinpoint the pathway aspects that can be influenced to generate the greatest increase in latency time. This method should also be available in both classified and unclassified settings, use transparent assumptions which can be easily adjusted for sensitivity analysis, and be usable by non-experts to generate valid results. The Nuclear Weapons Latency tool satisfies these needs.

I.D. Overview

This dissertation discusses the probabilistic simulation methodology used by the Nuclear Weapons Latency tool as well as the associated testing and a current application of the latency tool. The latency tool itself, with the necessary probability modeling theory, is described in Section II. Sections III-VI report latency tool verification, sensitivity testing, and historical analysis with the US, Pakistani, and South African proliferation cases. Sections VII-VIII discuss the application of multi-attribute utility theory to the latency tool for proliferation pathway selection. Section IX presents a current latency analysis which investigates the proposed fuel cycle facility development by the Republic of Korea. The dissertation is then concluded in Section X.

II. NUCLEAR WEAPONS LATENCY TOOL

The Nuclear Weapons Latency tool determines a state's Nuclear Weapons Latency by simulating state proliferation through a Petri Net model with the option of using Multi-Attribute Utility Analysis (MAUA) for proliferation pathway selection.[45,46] The problem confronting a decided state proliferator is essentially the well-known Resource-Constrained Scheduling Problem (RCSP).[47] Large scale projects like nuclear weapons development rarely go as planned, and simulations of a proliferator's progress are best represented with a stochastic probability model. Generalized Stochastic Petri Nets (GSPNs) have served well as both an RCSP solution method and dynamic probability models.[48] Petri Nets are highly flexible and also reduce the potential for intractable growth of the probabilistic state-space associated with other probability modeling techniques which could be problematic given the numerous options for proliferation and desired modeling detail. This section describes Petri Nets and their application in the Nuclear Weapons Latency tool along with inputs and outputs from the tool. A discussion of MAUA and its application is left to Section 0.

II.A. Petri Net Theory

Petri Nets are a simple yet powerful simulation technique for modeling complex systems.[49,50,51] Petri Nets are directed bi-partite graphs consisting of *places* and *transitions* represented by circles and bars respectively. Directional arcs connect places to transitions and transitions to places. Any number of places may connect to a single transition and vice versa. However, places cannot connect directly to other places and transitions cannot connect directly to other transitions. Dots located within the places are called *tokens*. The location of these tokens within the network places is known as the *marking* and represents the state or evolution of a Petri Net simulation. Tokens may move from an upstream place to a downstream place as the simulation evolves when the transition between the two places fires. Before firing, a transition must first be enabled. A transition is enabled when all places immediately preceding the transition accumulate the number of tokens corresponding to the weight of the arc connecting that place to the subsequent transition. When a transition fires, it removes tokens from all its immediately preceding places and adds tokens to all the places immediately downstream from the transition. The amount of tokens removed from and added to each place corresponds to the weights of the arcs connecting the places and transition. Fig. 2 depicts the firing of Transition 4 and the associated transfer of tokens. Note in Fig. 2 that Transition 2 is not enabled and cannot fire because the arc weight from Place 2 to Transition 2 is equal to 2 tokens.

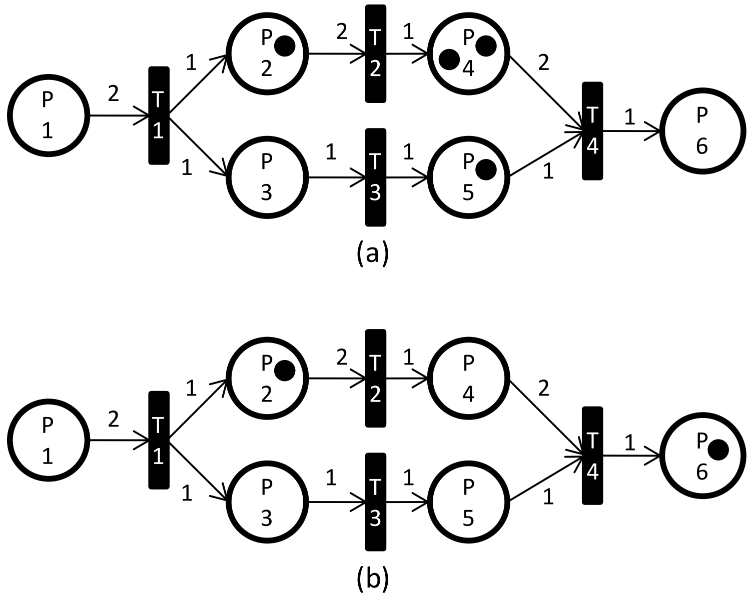


Fig. 2. Simple Petri Net (a) prior to firing of Transition 4, (b) after Transition 4 fires

Inhibitor arcs can add a further degree of control to a Petri Net.[50,51] Inhibitor arcs are connected from places to transitions. When the amount of tokens in place is greater than or equal to the weight of a connected inhibitor arc, the associated transition is blocked from firing even if the current marking would otherwise enable the transition. Fig. 3 shows the net of Fig. 2 with an inhibitor arc added from place 5 to transition 2. In Fig. 3a transition 2 is inhibited from firing as there is one token in place 5. Once transition 4 fires and removes the token from place 5 in Fig. 3b, transition 2 is free to fire again.

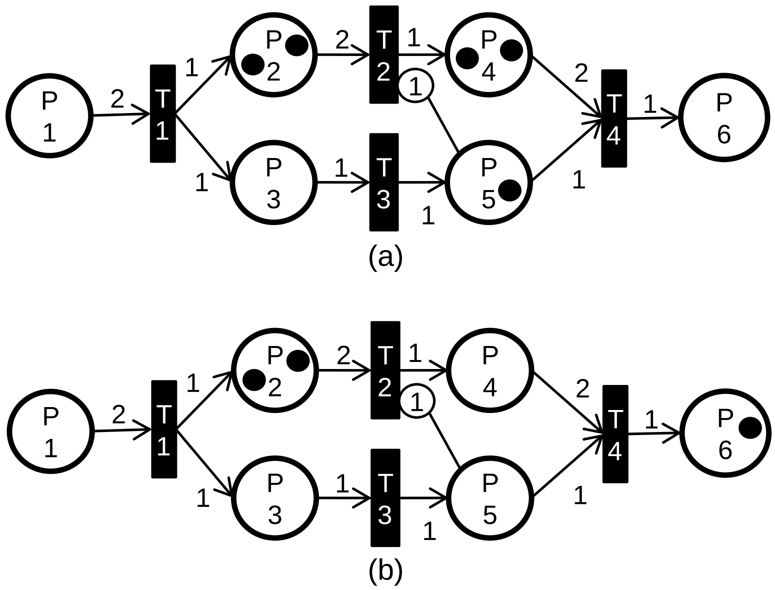


Fig. 3. Simple Petri Net demonstrating an inhibitor arc with (a) transition 2 inhibited and (b) transition 2 uninhibited

The mathematical representation of Petri Nets is straightforward.[49,50,51] A Petri Net is defined as the 6-tuple

$$PN = \{P, T, D^-, D^+, H, M_0\} \tag{1}$$

where

$P = \{p_1, p_2, \ldots, p_r\}$ *is the set of r places*;

$T = \{t_1, t_2, \ldots t_s\}$ *is the set of s transitions*, $T \cap P = \emptyset$;

$D^- \subset (P \times T)$ *is the set of transition input arcs*;

$D^+ \subset (T \times P)$ *is the set of transition output arcs*;

$H \subset (P \times T)$ *is the set of inhibition arcs*;

$M: P \to \mathbb{N}$ *is the marking which lists the number of tokens in each place with initial marking* M_0.

Petri Nets are functionally represented through matrices. The input, output, and inhibition matrices D^-, D^+, and $H$are all $s \times r$ matrices. The matrix element d_{ij}^- is equal to the arc weight connecting place p_j to transition t_i. The element d_{ij}^+ is equal to the weight of the arc connecting transition t_i to place p_j. The element h_{ij} of inhibition matrix $H$is equal to the weight of the inhibitor arc connecting place p_j to transition t_i. The incidence matrix is then $D = D^+ - D^-$. For example, the PN of Fig. 3 is represented as

$$D^- = \begin{bmatrix} 2 & 0 & 0 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 2 & 1 & 0 \end{bmatrix}, \quad (2)$$

$$D^+ = \begin{bmatrix} 0 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}, \quad (3)$$

$$H = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}, \text{ and} \quad (4)$$

$$D = \begin{bmatrix} -2 & 1 & 1 & 0 & 0 & 0 \\ 0 & -2 & 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 & 1 & 0 \\ 0 & 0 & 0 & -2 & -1 & 1 \end{bmatrix}. \quad (5)$$

The marking in Fig. 3a is $M_a = [0\ 2\ 0\ 2\ 1\ 0]$. If $\vec{e_j}$ is an r-dimensional row vector with all elements equal to zero except element $j = 1$, then transition j is enabled to fire when

$$M \geq \vec{e_j} D^-. \quad (6)$$

Further, for transition j to be enabled it must not be inhibited as

$$M < \vec{e_j} H \text{ if } \vec{e_j} H > 0. \quad (7)$$

When transition j fires the new marking becomes

$$M' = M + \vec{e_j} D \quad (8)$$

for all transitions j to be fired at that moment. Thus the marking of Fig. 3b after transition 4 fires is

$$M_b = M_a + [0\ 0\ 0 - 2 - 1\ 1] = [0\ 2\ 0\ 0\ 0\ 1].$$

A PN simulation may end when the marking reaches some desired state as $M \geq M_{desired}$.

Timed Petri Nets require a specific amount of time to pass before the movement of tokens may occur.[52,53] Time in Petri nets may be linked to either the transitions, places, arcs of the net, or the tokens. For this research transitions are associated with proliferation activities that may occur. As such, time is associated with the transitions. Once a transition is enabled, the transition time begins counting. Only once the time is complete is the transition fired. The Latency net developed is a stochastic timed PN, as the activity times are randomly sampled from user-defined probability density functions (pdfs) each time any transition is enabled. This methodology allows for the dynamic fluctuation of activity times as they may be realized in undefined future events.

II.B. Main Petri Net Function

The Latency tool implements a stochastic timed Petri Net using the MATLAB programming language.[54] The primary activity of the Petri Net loop is the maintenance of three arrays: the marking M, a list of enabled transitions ET (which is reset to zero after each time step), and a list of timing transitions TT (the remaining times before previously enabled transitions may fire). At the beginning of each simulation iteration, M is checked and enabled transitions are noted in ET. ET is then checked for transition conflicts and conflicted transitions are de-enabled in random fashion. Activity times are sampled for the remaining enabled transitions and stored in TT. Simulation time is advanced by subtracting the time step TS from TT at the end of each iteration. Transition j is fired when $-TS < TT_j \leq 0$. The elements of TT are initially set to $-TS$ and reset to this value after firing to prevent extraneous transition firing. When the marking is greater than or equal to the user defined deliverable nuclear weapon marking, M_{DNW}, the iteration is complete. Fig. 4 symbolically illustrates the conceptual flow of the Latency Petri Net and maintenance of the three arrays.

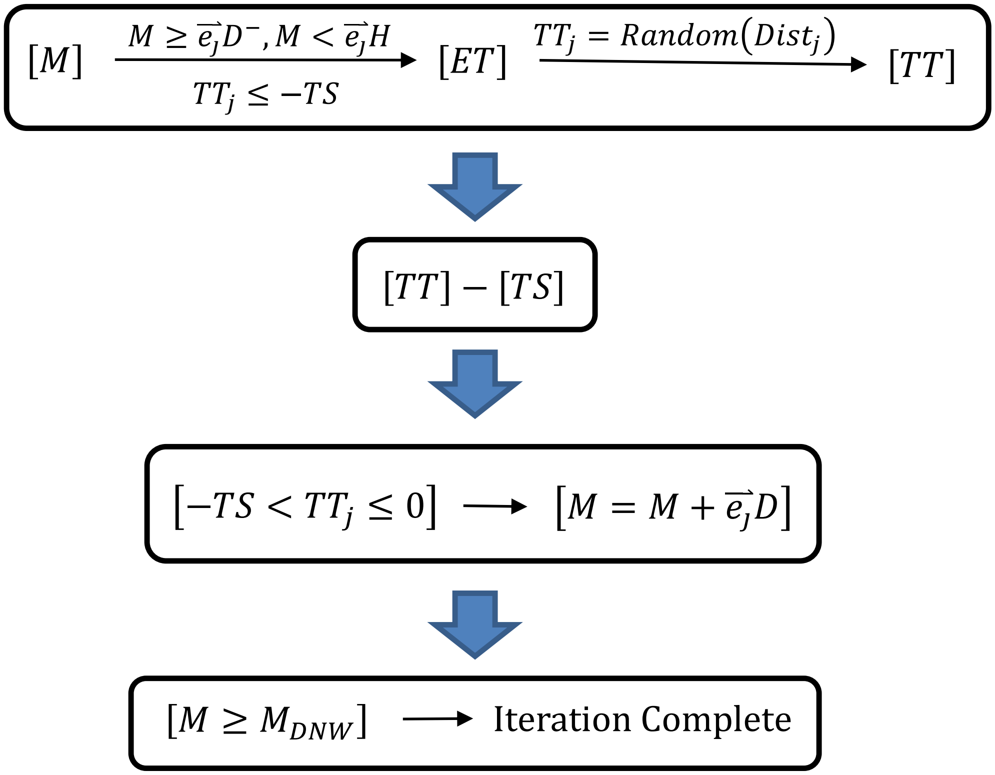


Fig. 4. Conceptual flow of Latency tool Petri Net simulation.

Fig. 5 describes the overall flow of the Latency tool. The proliferation network available to the proliferator is defined by the transition input, output, and inhibit (and incidence) matrices. However, there are normally multiple independent paths within the full proliferation network from which the proliferator may select a preferred path. These independent paths, defined by the transitions which must fire to complete them, are also input by the user. The Latency tool has a built in sub function to generate all possible combinations of the independent paths allowing the simulation to choose from a complete range of proliferation pathways through the independent paths defined by the user. Without detailed insight of the motivations and intentions of the proliferator, path selection is done randomly at intervals specified by the user. Transitions not on the selected path are permanently blocked from being enabled unless those transitions are part of a path selected later in the simulation. Other required inputs are the transition activity time pdfs and associated parameters as well as the initial marking and the deliverable nuclear weapon marking. At the time of this publishing, the Latency tool is capable of sampling from uniform pdfs and log normal pdfs. Other pdfs can easily be added.

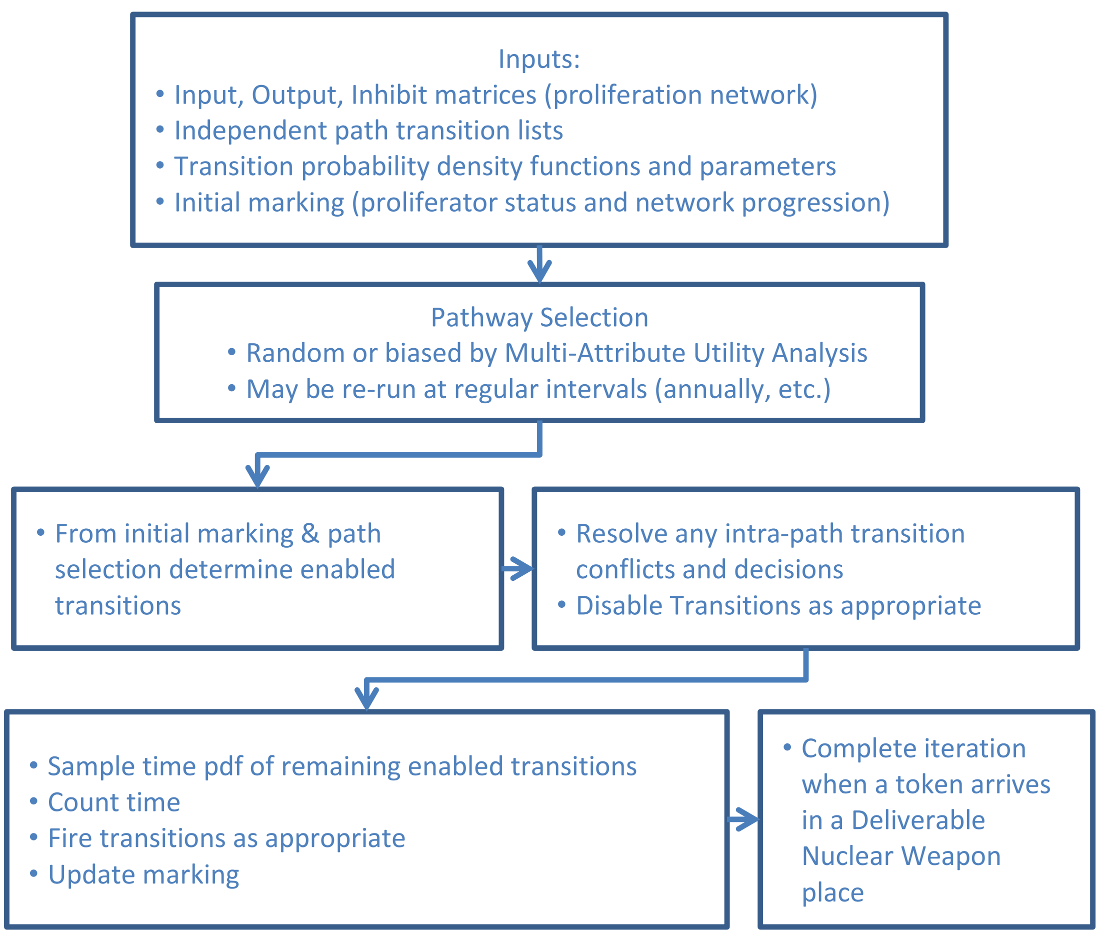


Fig. 5. Overall flow of Latency Tool.

The Latency tool required several other features to facilitate its operation. It is possible for intra-path conflicts to occur where two or more transitions are enabled by the same tokens in upstream places even though there are not enough tokens for all the transitions to fire. A check for intra-path conflicts is done after the enabled transitions are determined. When conflicts are found a sub-function randomly disables one of the conflicted transitions, rechecks for remaining conflicts, and repeats the process until there are no remaining conflicts. The remaining enabled transitions will then receive sampled activity times and progress accordingly.

A fast-forwarding algorithm was applied which drastically reduced run time. Instead of advancing the simulation time by one time step for each loop iteration, simulation time was advanced immediately to either the next time a transition would fire or the next time of a pathway selection. This required the inclusion of a separate array to track the progression of simulation time. The savings in run time were well worth the effort. It should be noted that computation time savings from the fast-forwarding algorithm may be lost when using short activity times for transitions that repeated often during network progression.

A moderately detailed pseudo-code is provided in Fig. 6 below. This pseudo-code algorithm itself resides within a loop over the number of desired simulation iterations. As individual simulations may take hours to days, a batch calling file was also developed.

```
M = M_0
TT = −TS
Time = 0
For i=1:Max simulation time
        ET = 0
        if time ∈ pathway selection interval
                randomly select path
        end
        M_dummy = M − e(TT_j)D^− ∀ TT_j > 0  % remove tokens reserved for timing transitions
        For all j transitions
                If M ≥ e_j H & TT_j > 0    % a timing transition is now inhibited
                        M_dummy = M + e(TT_j)D^− ∀ TT_j > 0    % release reserved tokens
                Else if M < e_j H & TT_j ≤ −TS
                        ET_j = 1
                end
        End
        Check ET for and resolve intrapath conflicts
        For all j transitions
                If ETj = 1
                        TT_j = random(dist_j)
                end
        End
        Clockadvance = min(time to next transition fire, time to next path selection)
        TT = TT − Clockadvance
        Time = Time + Clockadvance
        if −TS < TT_j ≤ 0
                M = M + e_j D
        End
        If M ≥ M_DNW
                Iteration Latency = Time
        End
End
```

Fig. 6. Latency tool Petri Net pseudo-code

II.C. Batch File

The batch file allows multiple cases to be queued to run with multiple variations of each case. The input parameters that must be defined or input to the batch file are listed in Table II. The batch file allows the user to vary most of the inputs of Table II between individual simulations within a single batch call. Beyond those inputs previously defined are the path selection method and frequency bin size. The path selection method may be set to a value of one, two, or three indicating random selection, path MAUA weighted probability selection, or maximum path MAUA selection respectively. The frequency bin size is used by the Latency tool to tally iteration latency times for subsequent frequency plotting. As noted in Table II, the source for the PN definition is a MS Excel file. The batch file imports those arrays as specified by the user with Excel file names, worksheet names, and cell ranges.

TABLE II

Inputs for Latency Tool Required in Batch File

Source	MS Excel input file	Defined in batch file
Input array or variable	D^-	# of iterations
	D^+	Time step
	Transition pdf type & parameters	Path selection interval
	M_0	Path selection method
	M_{DNW}	Frequency bin size

II.D. MS Visio & MS Excel Input File Generation

The network defining arrays are stored conveniently in an MS Excel file which itself is generated from a graphic PN created in MS Visio. A PN is built in Visio using boxes as transitions, circles as places, rounded rectangles to store arc weights, diamonds to store inhibitor arc weights, and directional connectors between the objects. A basic Visio PN is given in Fig. 7. The token flows between places and transitions, both weights and connections, are clearly depicted through the use of Visio. The information contained in this PN is extracted into an Excel workbook via a macro utilizing the "vsoshape.ConnectedShapes" command. The user must specify a name for the Excel file in the macro. If the named Excel file does not exist in the associated directory the macro will create a new file. If the file does exist the macro will append the PN data to the existing file. In this manner separate pathways developed in different Visio sheets may be layered into a single PN. Transitions should not be repeated in separate Visio sheets when layering, though places may be repeated in separate sheets or even the same sheet to eliminate excessive arc overlap.

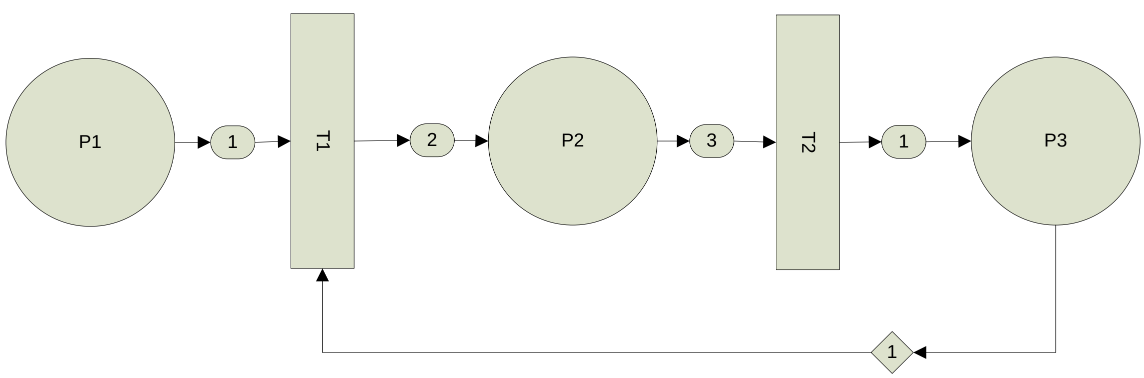
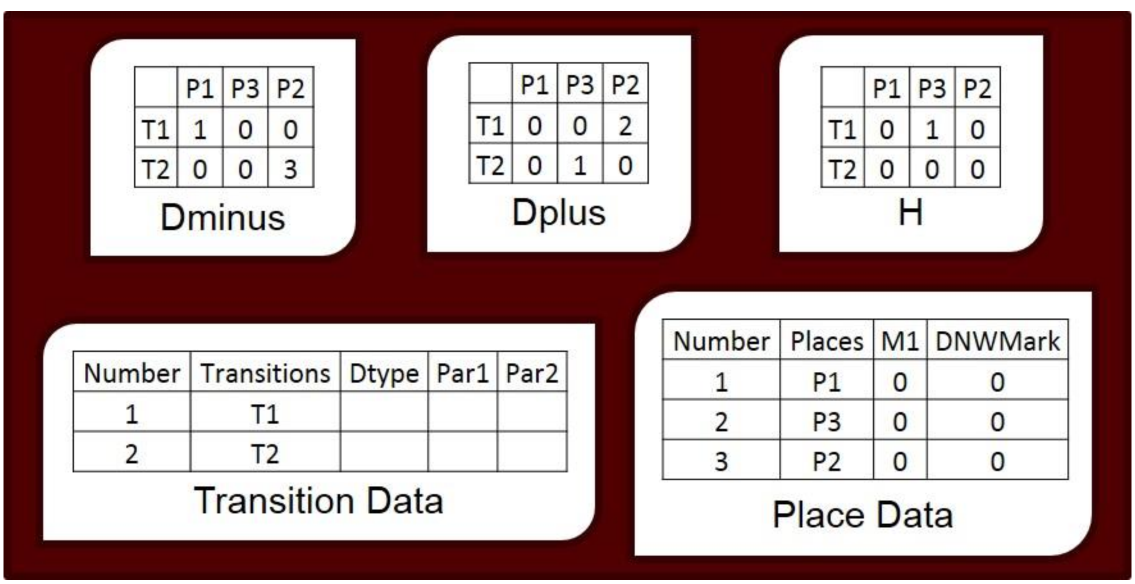


Fig. 7. Basic Visio Petri net.

The Visio macro creates an Excel workbook with the PN parameters stored in separate sheets. The sheets are labeled ‘Dminus’, ‘Dplus’, ‘H’, ‘Transition Data’, and ‘Place Data’. Fig. 8 depicts the workbook and worksheets created from the PN of Fig. 7. The input, output, and inhibition matrices are complete with all information in the original graphical PN (NOTE: the matrices and relations are still correct even if the macro does not order the transitions and places according to name). The user is left to specify the transition pdf type and parameters as well as the marking data in the remaining two sheets. Table III shows the transitions and necessary specifications available at the time of publication. As stated previously the ranges for these worksheets along with the file name are specified in the batch file for cases to be run. Upon completion of each simulation a comprehensive output file is generated.



	P1	P3	P2
T1	1	0	0
T2	0	0	3

Dminus

	P1	P3	P2
T1	0	0	2
T2	0	1	0

Dplus

	P1	P3	P2
T1	0	1	0
T2	0	0	0

H

Number	Transitions	Dtype	Par1	Par2
1	T1			
2	T2			

Transition Data

Number	Places	M1	DNWMark
1	P1	0	0
2	P3	0	0
3	P2	0	0

Place Data

Fig. 8. Excel worksheets generated by Visio macro from the PN of Fig. 7.

TABLE III

Probability Density Function Sampling Input Options

Transition pdf	Dtype	Par1	Par2
Uniform	1	Lower Bound	Upper Bound
LogNormal	2	Mu	Sigma

II.E. Output File

The outputs from the Latency tool are listed in multiple tables contained in the output file. The first set of tables refers to Latency times determined through the simulation. The column headings (transposed to conserve space) of the first three output tables are listed in Table IV. Discussing the Latency tables in reverse order; the 'Raw Latency' is an array of all the Latency times determined for each iteration of the simulation. Listed with each iteration time are the 'FinishChoicePath' and the 'ComboChoicePath'. The 'FinishChoicePath' is the last path chosen or selected before reaching a deliverable nuclear weapon marking and completing the iteration. During the iteration there may be multiple different paths selected. The 'ComboChoicePath' is the path that contains all of the paths selected during that iteration. It should be noted that the actual proliferation path realized during an iteration may be different than both the finishing choice path and combination choice path. The realized path is simply all the transitions that fired during an iteration. The 'All Paths Latency' table reports the mean or expected value, mean standard deviation, minimum, and mode of all the iteration latency times and paths. The ‘Latency’ table lists for each path the number of times a path was completed, the probability that the path was selected, the path latency time mode, the path latency time mean or expected value, and path latency time mean standard deviation. This data is listed for both the finishing choice path and combination choice path. Additionally, the total number of times a path is selected divided by the total number of selections for the entire simulation is given.

TABLE IV

Column Headings of Output Tables with Latency Time Information

Output table 1	**Output table 2**	**Output table 3**
Latency	All Paths Latency	Raw Latency
#timesF	Expected/Mean	LatencyTime
FPProb	STD	FinishChoicePath
FPMode	Min	ComboChoicePath
FPMean	Mode	
FPMSTD		
#timesC		
CPProb		
CPMode		
CPMean		
CPMSTD		
#timesChosen/Choices		

Following those output tables, simulation iteration completion data is recorded in two separate elements. The “Number unfinished iterations” is reported first and counts how many, if any, simulation iterations do not finish. The “unfinished iterations array” follows and is a row vector the length of the number of iterations. Each array entry corresponds to a simulation iteration and has a zero if the iteration finished or a one if the iteration did not finish.

The next two output tables report transition firing data. The "Number of Times Fired" output table comes first in the output and lists the number of times each transition fires for each iteration. Table V shows that the "Number of Times Fired" output table is a total number of transitions *T* by total number of iterations *I* matrix with a row corresponding to each transition *t* of the model network and column corresponding to each iteration *i* of the simulation. Each "Number of Times Fired" entry *(t,i)* equals the number of times transition *t* fired during iteration *i*. The "First Firing Time" output table is also a *T x I* matrix and is demonstrated in Table VI. In the "First Firing Time" output table entry *(t,i)* is equal to time in days from the beginning of the simulation at which transition *t* first fires during iteration *i*. This information is useful for network diagnostics as well as analyzing proliferation progression.

TABLE V

Description of "Number of Times Fired" Output Table

<table>
<tr><th></th><th>Column for iteration # 1</th><th>Column for iteration # 2</th><th>(continued columns for all I iterations)</th></tr>
<tr><td>Row for transition #1</td><td colspan="3" rowspan="3">Output table entry (t,i) = # of times transition t fired during iteration i where t ∈ T transitions and i ∈ I iterations</td></tr>
<tr><td>Row for transition #2</td></tr>
<tr><td>(continued rows for all T transitions)</td></tr>
</table>

TABLE VI

Description of “First Firing Time” Output Table

	Column for iteration # 1	**Column for iteration # 2**	**(continued columns for all *I* iterations)**
Row for transition #1	Output table entry *(t,i)* = Time [days] when transition *t* of iteration *i* first fired where $t \in T$ transitions and $i \in I$ iterations		
Row for transitions #2			
(continued rows for all *T* transitions)			

Pathway selection data is stored in the next set of tables. One ‘All Path Data’ table exists for each simulation iteration. Table VII explains the content of the “All Path Data” table for a single iteration. The first column of Table VII describes the data that appears in the “All Path Data” table. The second column of Table VII shows the actual text or data that is displayed in the “All Path Data” table. The first row of the “All Path Data” output table is a table heading corresponding to the simulation iteration number. The second row is a list of column headings. The third and all subsequent rows of the “All Path Data” output table relate the data for each path selection of the simulation. The first column of the remaining rows in the output table lists the time in days of the pathway selection. The second column lists the path selected. The remaining columns display the utility value determined through MAUA for each path (which is discussed more in Section 0). If path selection is being done randomly, the utility values per path will be replaced simply by a repetition of the number of the path selected.

TABLE VII

Demonstration of "All Path Data" Table for 1 Iteration

	Actual 'Text' or Data displayed in output table				
Table Heading	'All Path Data' # [iteration]				
Heading shown for Columns	'TimeStep PathSelected Utility-Per-Path'				
Table Values (rows repeated for each path selection of the iteration)	Time [d] when path selection occurs	# of path selected	utility value calculated for path 1	utility value calculated for path 2	(additional columns for utility values of remaining paths)

The "MAvgMaxMinSum" table relates the marking statistical data average, maximum, minimum, and sum of the number of tokens in each place during the entire simulation. Table VIII explains the values given in this output table. The first two rows of Table VIII indicate that for each simulation iteration there are four columns in the "MAvgMaxMinSum" output table. The second row of Table VIII shows that for each iteration the quantities listed per iteration time step per place are the average amount of tokens, the maximum number of tokens, the minimum number of tokens, and the sum of all tokens during that iteration. The first column of Table VIII shows that each row of the "MAvgMaxMinSum" table corresponds to the places of the model network. Thus the "MAvgMaxMinSum" output table is a total places P x J matrix where J is equal four times the total iterations I. In this manner four columns of statistical marking data for each place are given for each simulation iteration.

TABLE VIII

Demonstration of Values in "MAvgMaxMinSum" Output Table

	Columns for Iteration #1				**Columns for Iteration #2**				**Etc.**
Quantity per iteration time step	**Average # of tokens**	**Maximum # of tokens**	**Minimum # of tokens**	**Sum of all tokens**	**Average # of tokens**	**Maximum # of tokens**	**Minimum # of tokens**	**Sum of all tokens**	**Etc.**
Place #1	Output table entry *(p,j)* = quantity for place *p* of iteration # = *j/4* rounded up to the nearest integer where $p \in P$ places, $j \in J$, $i \in I$ iterations, and $J = 4I$								
Place #2									
Etc.									

The remainder of the output file is an echo of the input followed by the Latency time frequency data. Optionally, the entire marking for all iterations may be output and will appear at the end of the output file (this should be done only when absolutely necessary, as both writing and opening an output file with the full marking is time intensive).

III. CODE VERIFICATION AND HISTORICAL ANALYSIS WITH U.S. CASE

Before using any newly developed computational tool it is necessary to verify and possibly validate its function when applicable.[55] Verification is done to ensure that the tool functions as designed and expected. This is accomplished by providing the tool with simple inputs for which the expected results are obvious. Experimental validation requires matching tool outputs to results of actual experiments. The experiment for the Latency tool is the future. The results of the future are by definition, and will always be, unknown. As such, it is impossible to experimentally validate the Latency tool. This does not detract from the Latency tool's value to build intuition, test sensitivities, and inform decision makers as will be demonstrated.

In the absence of true experimental validation, historical case analysis is done to build confidence in the verification. It should be noted that while history provides a useful guide to and may impact the future, future cases of proliferation (and the future in general) are new and unique experiments which may vary from history unexpectedly.[56] The best known case of nuclear weapons proliferation is the U.S. Manhattan Project. This case is used as an initial historical analysis in order to verify code function and test the inherent sensitivities of the Latency tool.[57]

III.A. U.S. Network

For verification, the U.S. Manhattan Project is broken into four cases of materials production which were modeled as Petri Nets and analyzed. Petri Nets can determine passage time to any point in the network for any amount of tokens so analysis can be done on portions of a single historical case of nuclear proliferation. The four cases are

1) Liquid thermal diffusion uranium enrichment in the S-50 facility,
2) Gaseous diffusion uranium enrichment in the K-25 facility,
3) Electromagnetic isotope separation uranium enrichment in the Y-12 facility, and
4) Plutonium production at the W facility at Hanford (along with its pilot X program at the Clinton site).[58]

The full combined case of U.S. proliferation is also included in the analysis, which added a weaponization layer involving weapons and delivery system design and production (which involved retrofitting existing B-29 bombers). The characteristics of each case are given in Table IX which lists by column the network material production model, the general activities represented by the models, and the target Latency quantity desired for simulation completion. Since the completion goal for these partial proliferation cases was not a single deliverable nuclear weapon, substitute Latency quantities, established from historical references and given in Table IX, were used as simulation endpoints. Fig. 9 shows the complete Pu production Petri Net with an inset zoom. A historical timeline of U.S. proliferation is given in Appendix A. Full network Petri net matrices and data for the S-50, K-25, Y-12, W&X, weaponization, and the full U.S. case are given in Appendices B, C, D, E, F, and G respectively.

TABLE IX

U.S. Case Latency Network Characteristics

Network Model	Activities	Transitions	Places	Latency quantity
Liquid Thermal Diffusion S-50	R&D; LTD facility: Lab Scale, Pilot Scale, Full Scale	29	11	20420 kg 0.85wt% U-235[A]
Gaseous Diffusion K-25	R&D; Barrier Plant: Pilot Scale, Full Scale; Full Scale GD Plant	21	22	210 kg 0.7wt% U-235[B]
Electromagnetic Isotope Separation Y-12	R&D; Lab Scale; Alpha Track Facility, Beta Track Facility	21	18	66 kg 80wt% U-235[C]
Plutonium Production W (Hanford) & X (Clinton)	Graphite Reactor: Lab Scale, Pilot Scale, Full Scale; Separations Plant: Pilot Scale, Full Scale; Graphite Production; Fuel Slug Canning	59	55	19 kg Pu[D]
US Full	All including a design & weaponization layer	160	133	1 Deliverable nuclear weapon (HEU or PU)

[A]S-50 production through July 1945[59], [B]Derived from [C] the approximated Little Boy uranium content[60,61], [D]approximated plutonium content of 3 Pu cores finished July, 1 1945.[60,61]

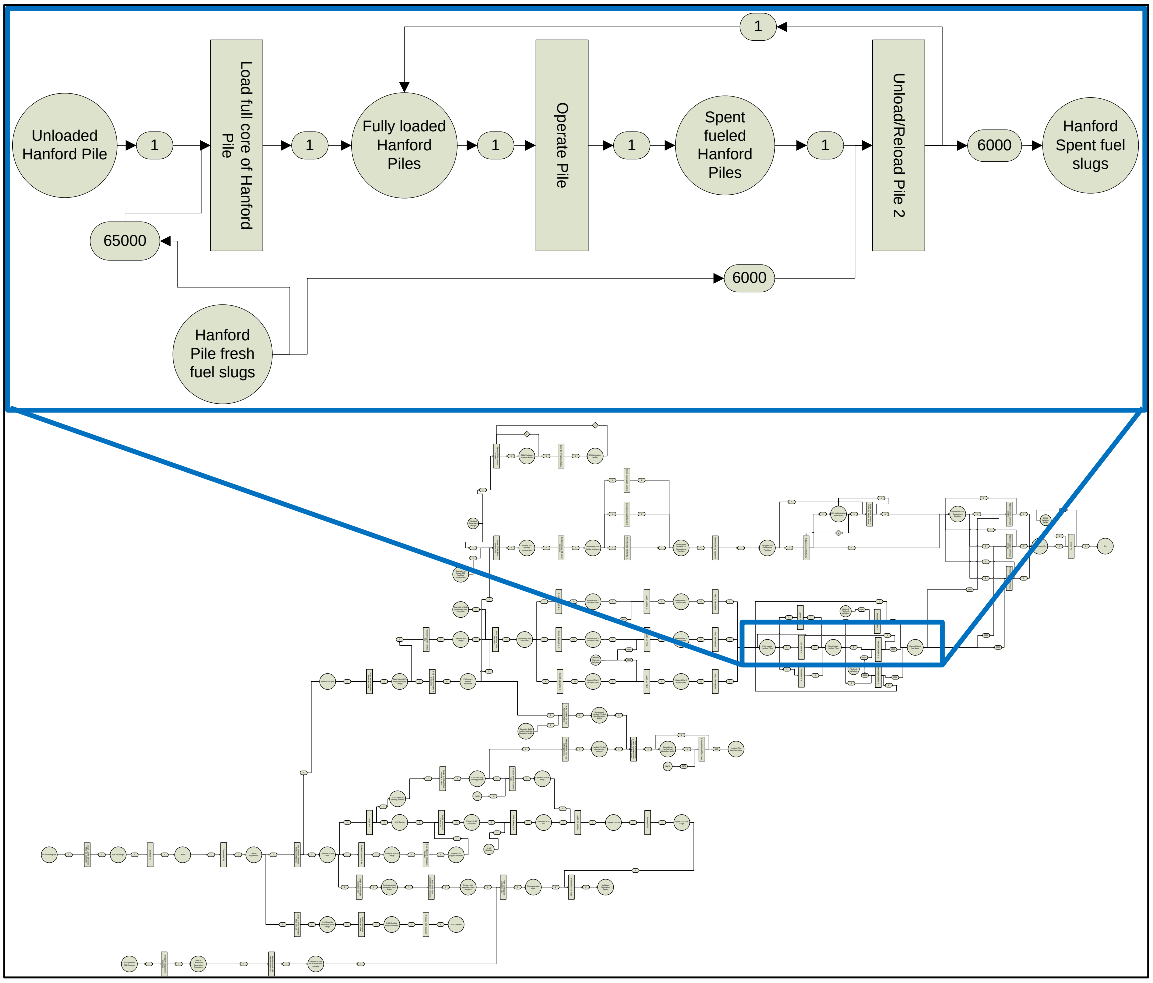


Fig. 9. Complete US Pu production Latency PN with zoom inset.

III.B. Verification with Discrete and Stochastic Simulations

Verification of the Petri Net Latency simulation occurred in two steps. First activity durations were derived from history for the corresponding transitions of the developed Petri Nets. These discrete values were then used as constant transition firing times in the Latency simulations. The resultant Latency time produced for each case with constant transition firing times is taken to be the 'Latency standard'.

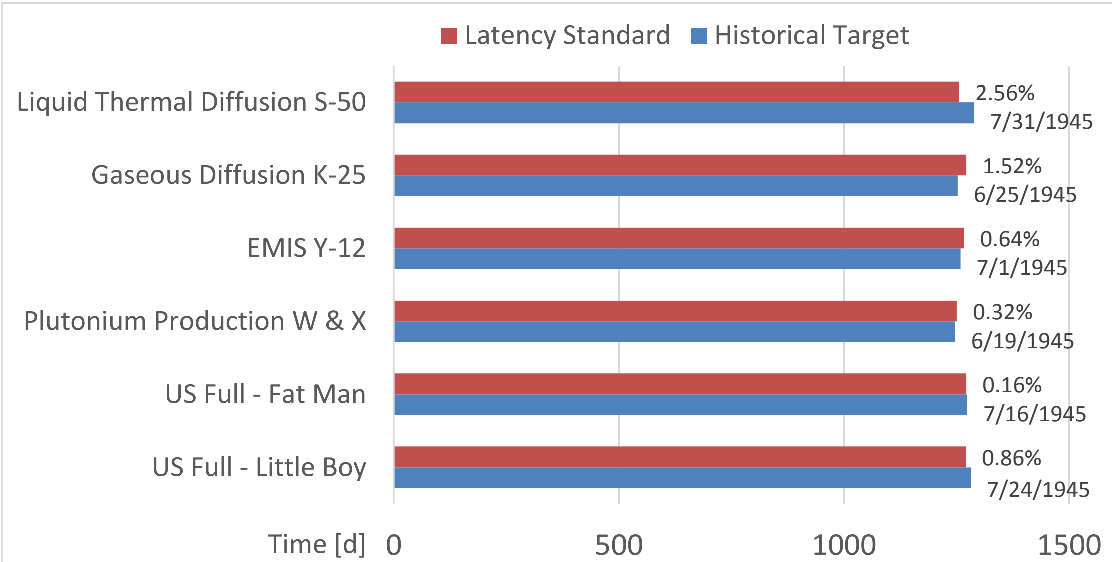


Fig. 10. US Network pathway historical times compared with Latency standard. Listed to the right the bar graphs are the percent difference between the Latency Standard and the historical target as well as the actual historical date for the endpoint.

Fig. 10 shows historical target dates along with the percent difference of the associated Latency standard time. Dates are taken or derived from references given for corresponding Table IX quantities. The U.S. decision for proliferation is assumed to be 1/19/1942 when Roosevelt approved the 3rd National Academies Study on the subject.[58] The Little Boy completion date was assumed to be when HEU fabrication was complete as the rest of the Little Boy bomb weapon had already been finished. [58] The Fatman completion date was assumed to be at the successful Trinity test since the Pu pit and explosive lenses required for implosion were already fabricated. [58] The Latency Standard times very closely agree with the actual historical targets. This was expected since historically accurate details for the individual steps were inserted and then aggregated by the Petri Net simulation to determine the completion date. This is a useful verification test that demonstrates that when given accurate inputs, the tool will produce accurate outputs. The network models and transition times could be further refined to precisely replicate the historical times, but this is not necessary.

Discrete transition times were replaced with uniform pdfs with bounds 50% above and below the historically derived activity time to complete the verification. Each simulation used 1000 iterations. Each iteration in a simulation produces a Latency time. Frequency distributions of single iteration Latency times will subsequently be referred to as ‘Latency distributions.’ The single valued Nuclear Weapons Latency results for a simulation of importance are the expected value or mean and minimum of the Latency distribution. These values are referred to as the expected Latency (time) and the minimum Latency (time).

Fig. 11a-d illustrate the resulting Latency distributions using uniform transition time pdfs for the S-50, K-25, Y-12, and W&X material production cases respectively. The shape of the Latency distributions resulting from the use of uniform transition time pdfs consistently appears to be Gaussian. Both the historical and Latency standard times of each material production case fall within the associated Latency distribution. However, it is also apparent that all the Latency distributions of Fig. 11 are shifted to the right of the reference times. This shift results in the associated Expected Latency times being about 200 days higher than the reference times. This discrepancy was unexpected but can be explained by the activity time pdf bound and time step precision. This precision sensitivity is discussed in Section IV.A.

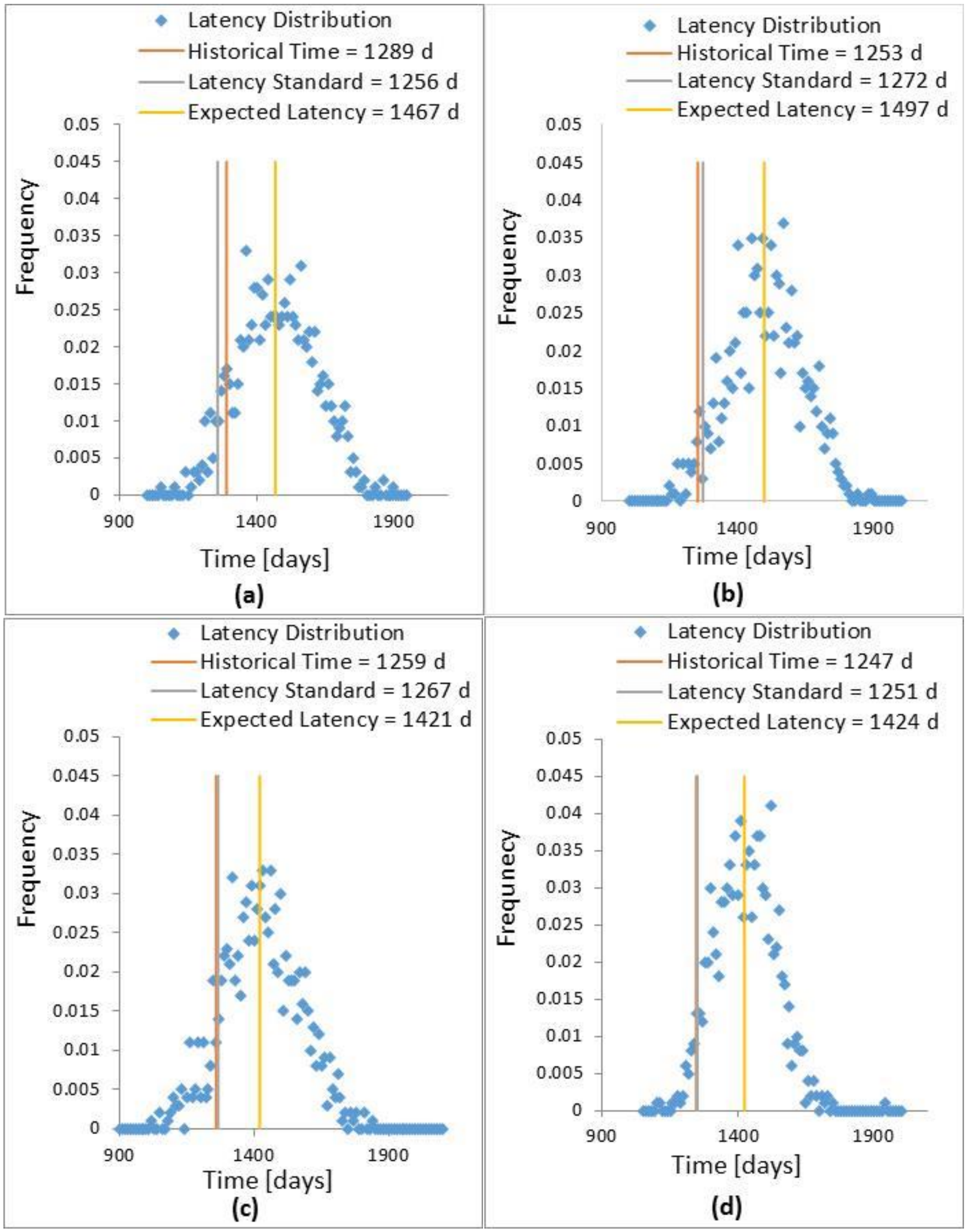


Fig. 11. Latency distributions from simulations using uniform transition time probability density functions with bounds +/- 50% of the reference times with historical and Latency Standard times shown for the US materials production subcases (a) S-50, (b) K-25, (c) Y-12, (d) W & X.

For the simulation of the full U.S. case, all material production cases were combined with a weaponization (WP) layer. The combinations of these components resulted in seven optional paths through the U.S. proliferation network: (1) S-50, K-25, and WP; (2) Y-12 and WP; (3) S-50, K-25, Y-12, and WP; (4) W&X and WP; (5) S-50, K-25, W&X, and WP; (6) Y-12, W&X, and WP; (7) S-50, K-25, Y-12, W&X, and WP. Historically, S-50 never produced any uranium above slightly enriched and was used only as a feed for either Y-12 or K-25.[58] Further K-25 used only the S-50 product as a feed until after the war.[58] Thus those two material production options do not appear independent of each other as an isolated path for producing an HEU weapon.

Fig. 12 shows the Latency distribution for the full U.S. case. Fig. 12a shows a single distribution containing the Latency results for all paths, whereas Fig. 12b shows Latency distributions for the seven different paths. Connecting lines are added in Fig. 12b so the reader can better see the underlying Latency distributions per path. Historical completion times for Little Boy and Fatman, Latency Standard times for each path, and the Expected Latency time including all paths are shown with the Latency distributions of Fig. 12. Fig. 12 illustrates the same effects from Fig. 11: the Latency distributions resulting from uniform pdf transition times are mostly Gaussian, the reference times fall within the Latency distributions, and the Latency distributions and Expected values are shifted above the reference times.

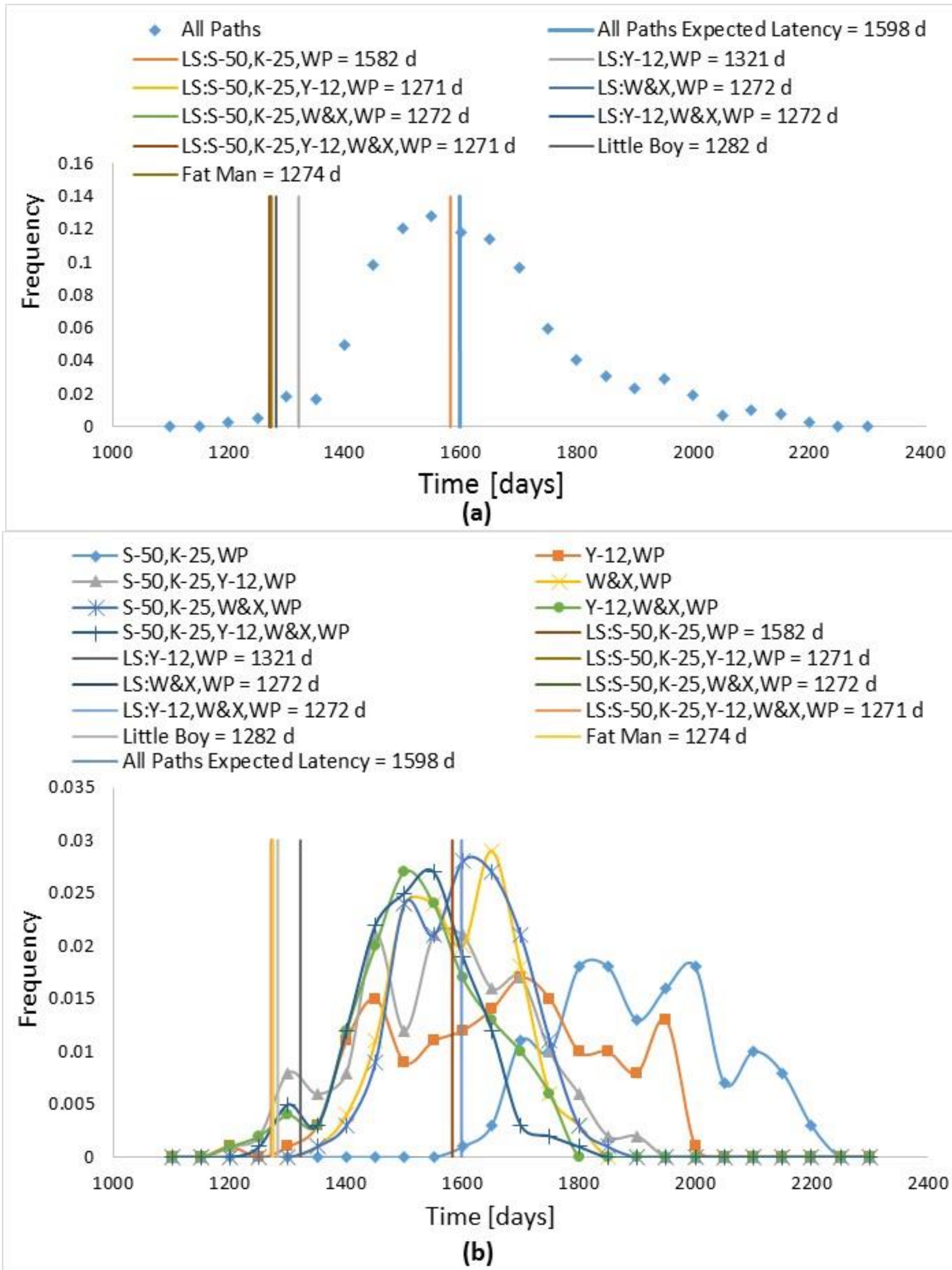


Fig. 12. Latency distributions for the full US case compared with historical time, pathway Latency Standard (LS) time, and the expected Latency time from all paths for (a) all paths and (b) individual paths with lines added for clarity.[1]

[1] Some of the path Latency Standards are obscured in Fig. 12 because they are of equal time.

Together the results of Fig. 10, Fig. 11, and Fig. 12 verify the function of the Latency tool. When given accurate, discrete transition times for an appropriate model, the Latency tool gives accurate results. When transition times are sampled stochastically from pdfs based on accurate reference times the Latency tool will simulate results which contain the accurate result. The Expected Latencies shown in Fig. 11 and Fig. 12 do not agree well with the reference times, which would be preferred. However, Section IV.A will resolve this issue and demonstrate that with proper input and time step precision, the Latency tool with an appropriate model and inputs will generate Expected Latencies that agree well with historic data.

IV. SENSITIVITY ANALYSIS WITH US CASE

In this chapter, sensitivity analysis is used to demonstrate implicit sensitivities and biases inherent within the Latency tool and its operation. Beyond the initial proliferation decision, the Latency tool makes only two other assumptions: the structure and paths of proliferation pathway network available to the proliferator and the activity time pdfs associated with the transitions. This section will explore sensitivities to both as well as operational inputs such as the iteration timestep and path selection interval. Discussion focuses on Latency distributions and both the expected Latency and minimum Latency times, as these values will be of prime interest to decision makers.

IV.A. Input Precision Sensitivity: Transition Bounds and Timestep

The shift of the Latency distributions to the right of the latency standard in the verification Fig. 11 and Fig. 12 above can be explained by a bias resulting from the precision in the transition bounds and tool operation timestep. It was initially decided that using uniform pdf bounds with precision less than 1 day would be impractical for approximating multi-year activities, and the input bounds were rounded up to the nearest day. Further it was also judged impractical to operate the tool such that it would track time steps of less than one day. The impact of these assumptions was tested by varying the precision of the input transition bounds and allowing a time step of less than 1 day.

The results of the input transition bound and timestep precision sensitivity analysis for the S-50 subcase are shown in Fig. 13. Fig. 13a contains the Latency distributions and Expected Latency times determined for S-50 while varying the time step from 1 day, 0.5 day, to 0.1 day while rounding the transition time bounds to the nearest day and leaving the bounds unrounded. In Fig. 13a the rounded bound, 1 day timestep Latency distribution and associated Expected Latency time are the farthest to the right. Moving from right to left in Fig. 13a, the next Expected Latency time is for the rounded bound, 0.5 day timestep simulation. This is followed by the Expected Latency times of the rounded bound, 0.1 day timestep simulation and the unrounded bound, 1 day timestep simulation which are nearly the same. The unrounded bound, 0.5 day Expected Latency is next followed by the historical time. The unrounded bound, 0.1 day timestep Expected Latency is last and agrees very well with the Latency Standard. The Latency distributions shift left with the associated Expected Latency times as bound and timestep precision is increased.

Fig. 13b illustrates the response of the Expected Latency times as expressed by percent difference with the Latency Standard for S-50. Here the percent difference of the Expected Latency times with the Latency Standard is plotted as a function of timestep for both the rounded and unrounded bound simulations. The specific difference in days and percent is listed in Fig. 13b as labels on the data points. Fig. 13b shows that by increasing the precision of the bounds and timestep the difference between the Expected Latency and Latency can be reduced about 200 days or 15%.

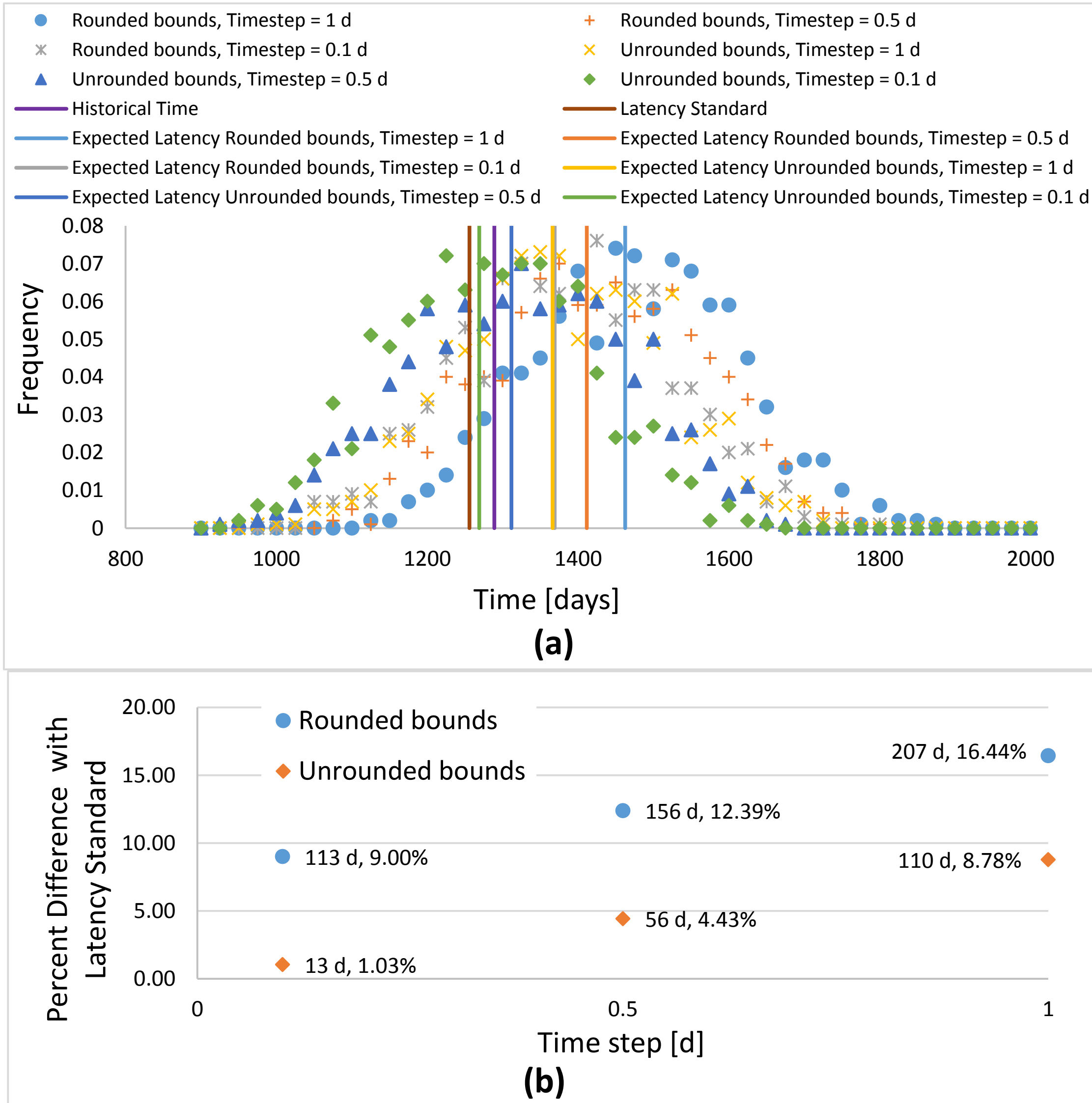


Fig. 13. Sensitivity to bound and timestep precision for the S-50 subcase showing (a) Latency distributions and Expected Latency times compared to the Latency Standard and historical time and (b) Expected Latency percent difference with the Latency Standard as a function of timestep for rounded and unrounded uniform probability density function bound simulations.

Fig. 13 demonstrates that the precision of the inputs and timestep can bias the resulting Latency distributions and expected times high. Fig. 13a shows how the Gaussian Latency distributions and Expected Latencies converge towards the Latency

Standard times as the bound and timestep precision is increased. Fig. 13b shows the improved accuracy of the Expected Latencies expressed as percent difference with the Latency Standard with increasing precision. It is clear from the analysis that both input precision and timestep size can bias Latency results high. Simply rounding those parameters to the nearest day can be expected to increase Latency as much as 15%.

IV.B. Network Sensitivities

A complete understanding of the network sensitivities is necessary, as the network definition is entirely user dependent. It is critical to know if certain network aspects are preferred to others or if and how specific aspects bias results. The analysis described here investigates the three types of network sensitivities: network structures in series and parallel, network detail and resolution, and available network pathways.

IV.B.1. Network Structure

The analysis begins by examining network structures. As explained in previous sections, Petri nets are simply transitions (bars) and places (circles) connected by directed arcs. The arcs indicate the direction of token flows through the network (and proliferation progress). Different paths, sub-paths, or flows can run in series or parallel to each other. This section explores whether there is an impact of this network flow structuring beginning with flows in series.

Fig. 14 illustrates how one transition with a large activity time is split into smaller transitions in series with the same total activity time. Fig. 14a depicts a Petri Net flow with one transition T1. Fig. 14b modifies this flow by splitting T1 into two transitions T1a and T1b separated by the new place P3. T1a and T1b both are half the time of transition T1. Fig. 14c repeats the process and splits T1a and T1b into T1c, T1d, T1e, and T1f respectively. T1c, T1d, T1e, and T1f are all half the time of T1a or T1b and a quarter the time of T1.

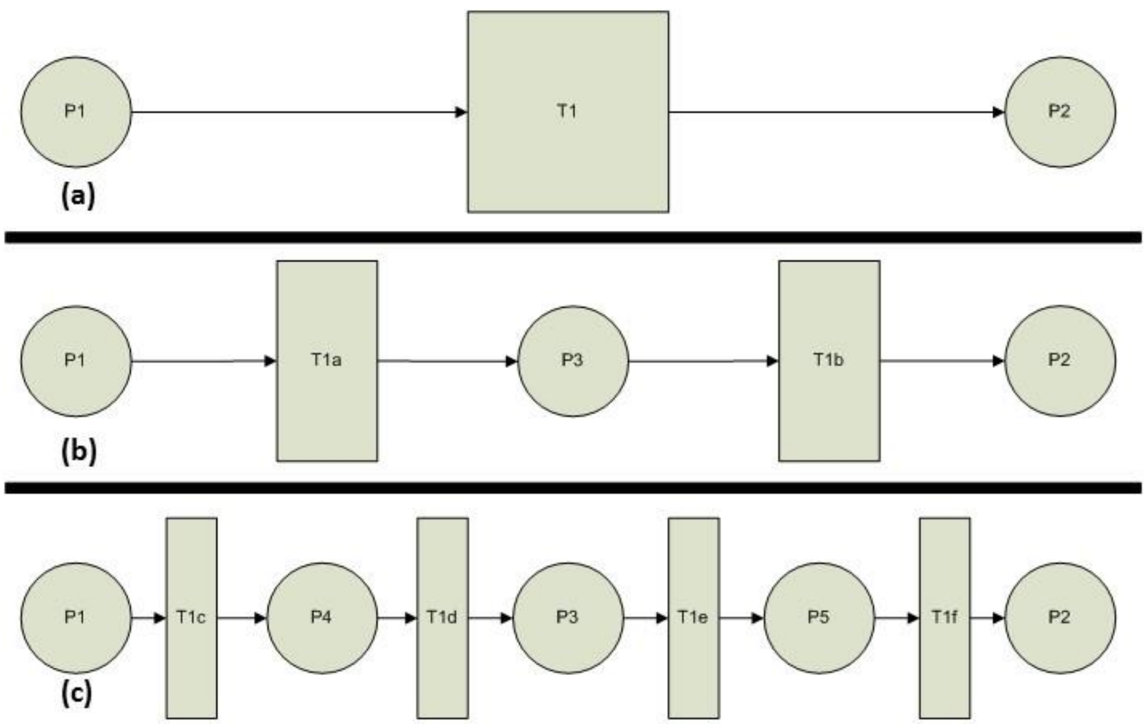


Fig. 14. The expansion of one transition into a series of transitions. A simple Petri net with (a) 1 transition T1, (b) T1 replaced by two transitions in series, T1a and T1b, both half as long as T1, and (c) T1a and T1b each replaced by two transitions in series: T1c, T1d, T1e, and T1f respectively each half as long as T1a and T1b or one quarter as long as T1.

Without using the Latency tool, a simple computational experiment may be conducted to simulate the impact of increasing the number of transitions in series depicted in Fig. 14. This experiment uniformly samples a random number from 0 to 1 for each transition in the flow under consideration and scales that random number by the appropriate transition time. The time of interest is the total time from each transition in the flow being considered. In this experiment, the original activity time is 100 days, the number of transitions in a flow is varied from 1-1000, and each flow is simulated with 1000 iterations.

The results are shown in the Fig. 15 below. Fig. 15a shows the mean time from each flow simulation as a function of the number of transitions in a flow. Since the average random number choice is 0.5 and each flow simulation consists of 1000 iterations, a mean transition time of 50 days is expected regardless of whether the flow consists of one large transition or 1000 small transitions.

Fig. 15b shows the standard deviation of each iteration per simulation as a function of the number of transitions in a flow. As the number of transitions in a flow increase so does the amount of random numbers sampled. Since the random numbers are all being sampled from the same 0 to 1 uniform pdf, it is expected that the standard deviation will decrease as the number of transitions in the flow increases. The experiment is in essence averaging a set of random numbers from 0-1. The increase in transitions simply increases the amount of random numbers to be sampled and averaged. The more numbers that are sampled the closer the average will get to the mean for each simulation iteration. Fig. 15b confirms that the standard deviation vanishes with increasing transitions in series.

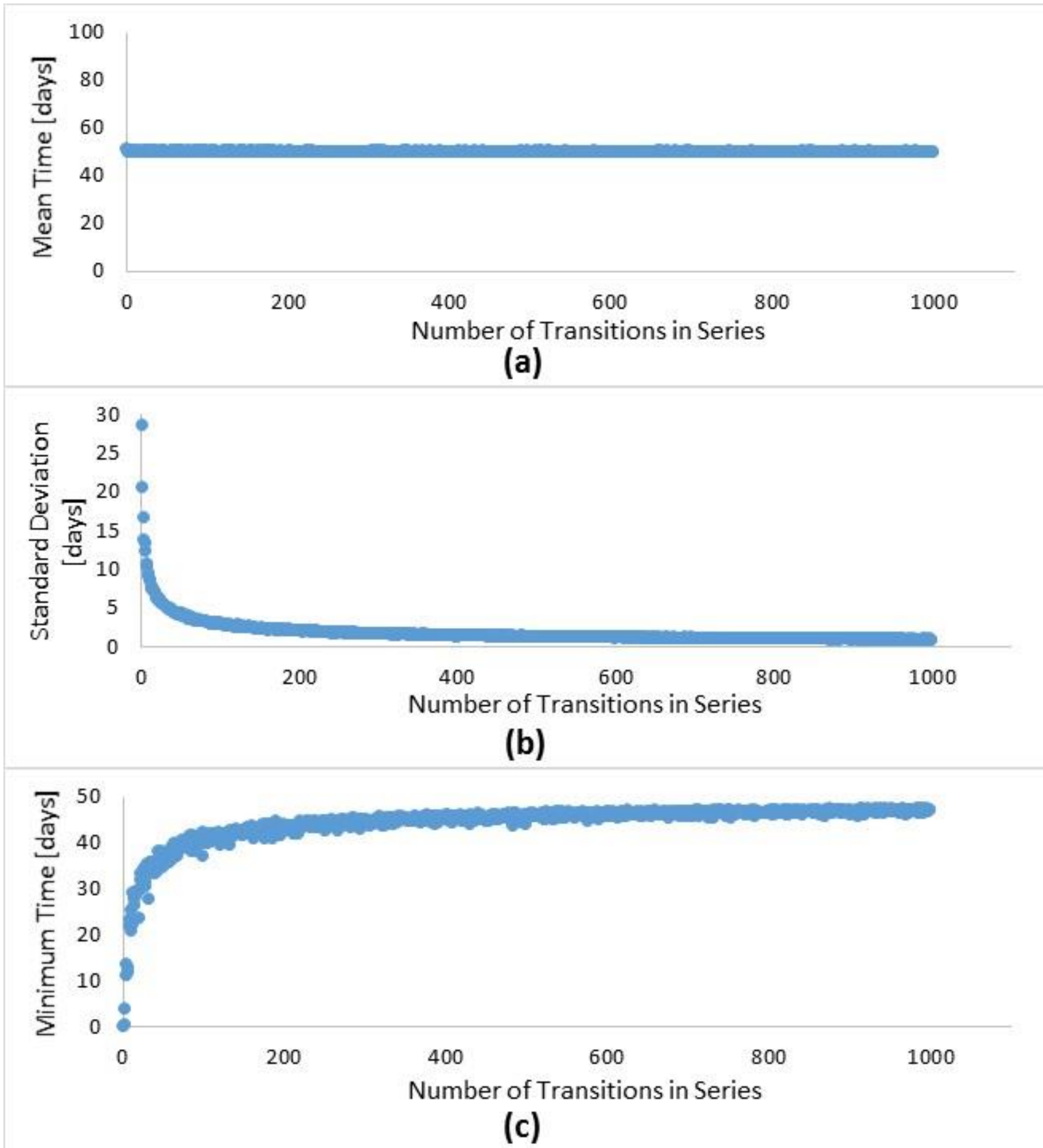


Fig. 15. Results of the computational experiment to determine the sensitivity to the number of transitions for Petri net simulation (a) mean time, (b) standard deviation, and (c) minimum time.

Fig. 15(c) plots the minimum time as a function the number of transitions in series. It is expected that if the standard deviation is reduced with increasing number of transitions that the minimum should converge to the mean. Fig. 15(c) confirms this expectation.

A similar experiment is done to investigate the impact of parallel flows and is illustrated in Fig. 16. Fig. 16a contains a simple two transition, T1 and T2, flow with three places, P1, P2 and P3. In Fig. 16b transition T1 and place P2 were split into two parallel, replicate transition-place pairs: T1a and P2a, and T1b and P2b. T1, T1a, and T1b all represent equal amounts of time. In this manner the amount of transitions in parallel can be increased for an investigation into the impact of network parallelism.

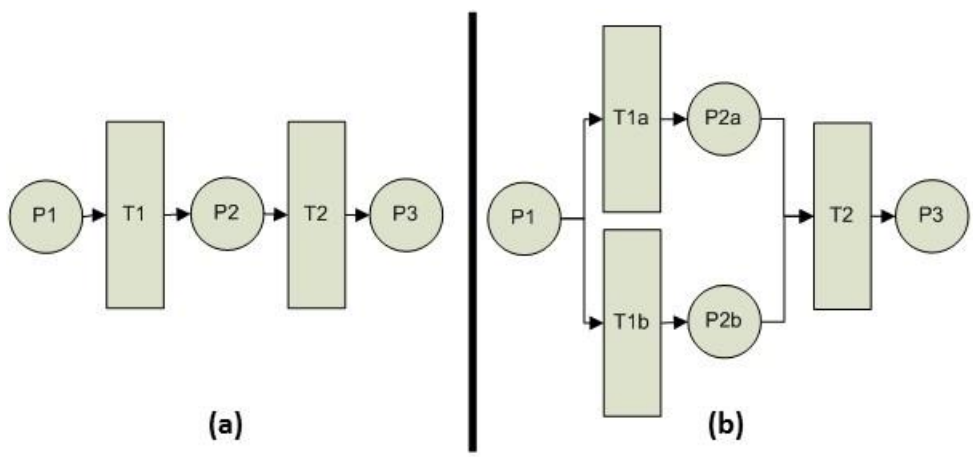


Fig. 16. Expansion of one transition into multiple transitions in parallel.

A computational experiment simulates increasing parallel transitions as described in Fig. 16. For this exercise the time added by the final transition, T2 in Fig. 16, to complete the flow is neglected since its impact is known and focus is on the time to enable the final transition. Enabling the final transition requires all parallel transitions to fire. Thus the time to enable the final transition is equal to the longest parallel transition time sampled. The experiment is then to find the maximum time of all the transitions in parallel while varying the number of transitions in parallel. It is assumed there are enough tokens in the place preceding the parallel transitions (place P1 in Fig. 16) to enable them all simultaneously. All parallel transition times are uniformly distributed from 0 to 1 day with an average firing time of 0.5 days. Thus, the shortest possible time for any transition to fire is 0 days and the longest is 1.0 day. For the experiment each the number of parallel transitions was varied from 1 to 100 and each flow simulation consisted of 1000 iterations.

The simulation iteration time is the maximum of all the transitions in parallel. Thus as the number of times the random number is uniformly sampled from 0 to 1 days. increases so too does the chances of getting a number closer to 1 day. As such it is expected for this experiment that the simulation iteration time will converge to 1 day.

The results of the parallel transition computational experiment are shown in Fig. 17. Fig. 17a-c plot the simulation iteration mean time, standard deviation, and minimum time respectively as a function of the number of transitions in parallel. The plots show that both the mean and minimum times converge to 1 day and the variance vanishes. This confirms the expectation that as the number of transitions in parallel increases the simulation iteration time approaches 1 day.

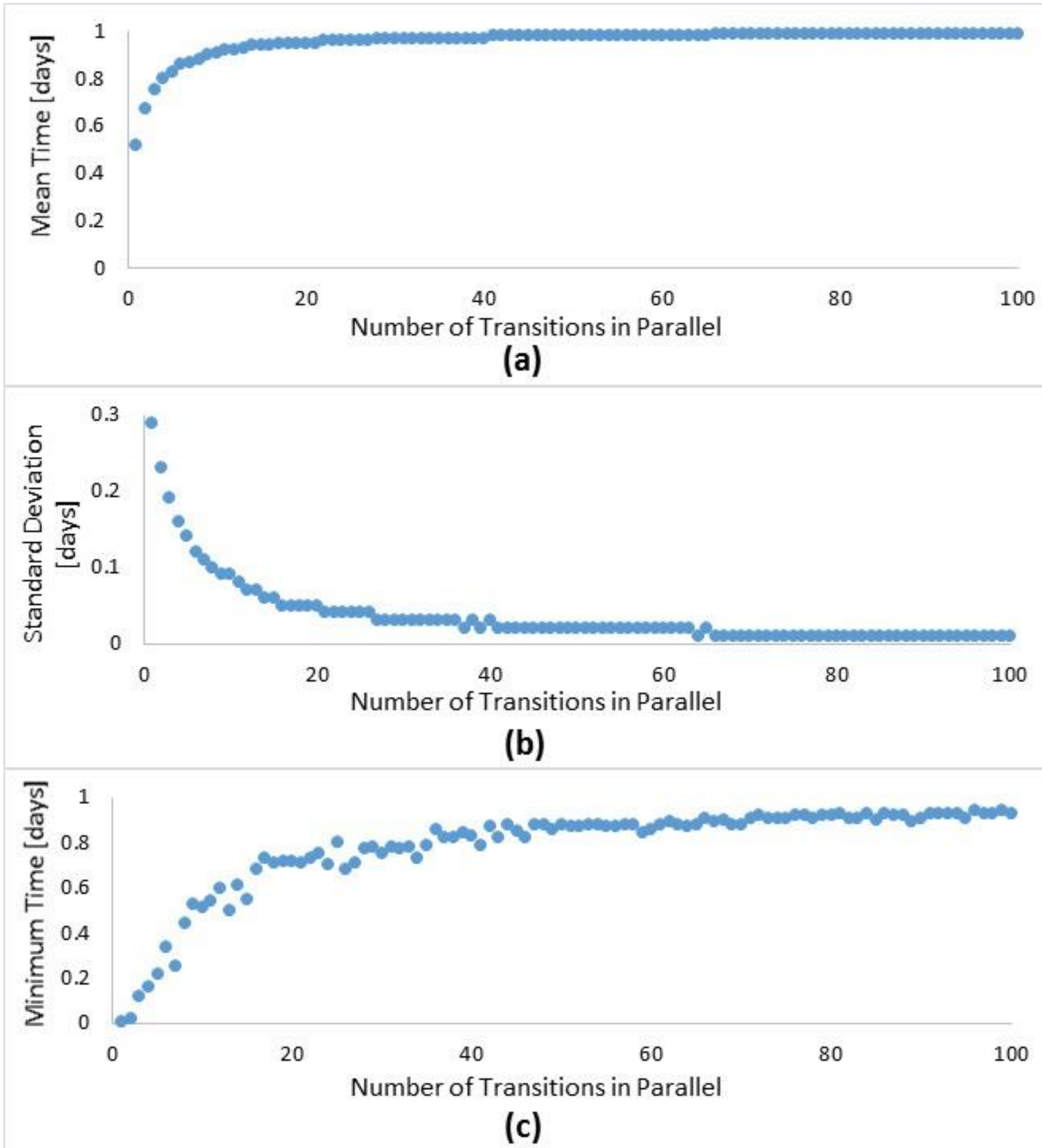


Fig. 17. Parallel experiment (a) mean time, (b) mean std., and (c) minimum time.

Several conclusions can be drawn from the series parallel experiment results shown in Fig. 15 and Fig. 17. The introduction of multiple transitions in series into a network will cause a reduction in variance from the expected value and an increase in minimum time relative to another network modeling the same case with fewer transitions in series. The mean or expected time is unaffected by the number of transitions in series. Extensive network parallelism will bias Latencies high relative to a network with less parallelism modeling the same process.

The amount of series and parallel flows used in model networks depends on Latency tool user needs. In some cases a high degree of parallelism may be a more appropriate representation of reality compared to a network with less parallelism. But these network structure sensitivities must be accounted for when making comparisons and judgments of Latency results.

IV.B.2. Network Resolution or Size

To assess the impact of network resolution or size, reductions were made to each US sub-case. The original US network was an attempt to capture all significant historical events and milestones in the weapons development program. The utility of that effort can be tested by reducing the network, combining various transitions and eliminating the places between them, and comparing results. Reductions were made in two levels. Some sub-cases experienced greater reductions than others. Transition reductions were made only where they would not impact the existing flow of the network. This limited some of the amount of transitions which could be eliminated in some networks. Complete Petri Net matrices defining all these networks and reductions for S-50, K-25, Y-12, W&X, weaponization, and the Full U.S. case are given in Appendices B, C, D, E, F, and G respectively.

Fig. 18 shows a comparison of the total transitions in each of the different resolution levels for each case. The three levels of network resolution are referred to as detailed, medium, and coarse. The detailed resolution corresponds to the largest networks for each case and the coarse resolution corresponds to the smallest network. The specific number of transitions in each network is listed as data labels.

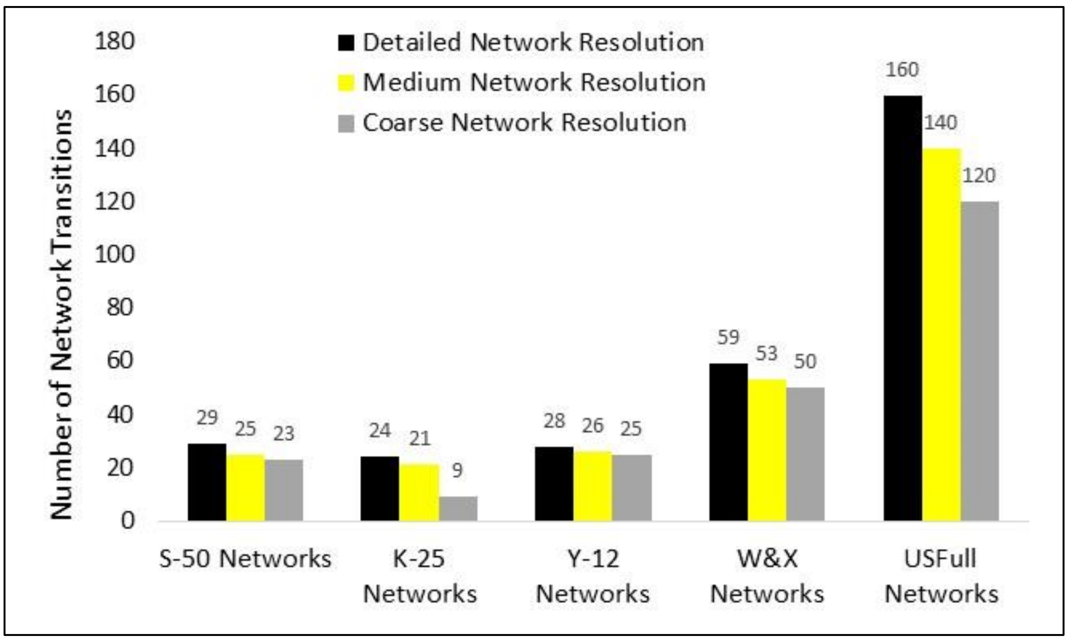


Fig. 18. Comparison of the number of network transitions for different levels of resolution for each case with the total number of transitions given as data labels.

Fig. 19 illustrates the impact of network resolution on the expected value. The S-50 expected Latency times were all about the same at 1463 d, 1470 d, and 1465 d for the detailed, medium, and coarse networks respectively. For K-25 the detailed and medium networks had very similar expected Latencies of 1425 d, and 1432 d. The coarse resolution K-25 network had a much lower expected Latency of 1307 d. The Y-12 networks experienced slight increases in expected Latency time from 1374 d, 1393 d, to 1399 d as network resolution decreased. For the W&X network the expected Latencies for the detailed and coarse networks were both 1616 d while the medium network expected Latency time was just 1 day lower at 1615 d. The U.S.Full case expected Latency times were 1598 d, 1614 d, and 1611 d for the detailed, medium, and coarse resolution networks respectively.

In general the expected Latency time varied less than 25 days or 1-2%. This close agreement is good as regardless of the resolution the networks are modeling the same case with the same overall time. The Y-12 case expected values appear to be inversely proportional to network resolution, though this variation is well within the standard deviation (shown in Fig. 22 below). The lone outlier is the K-25 case.

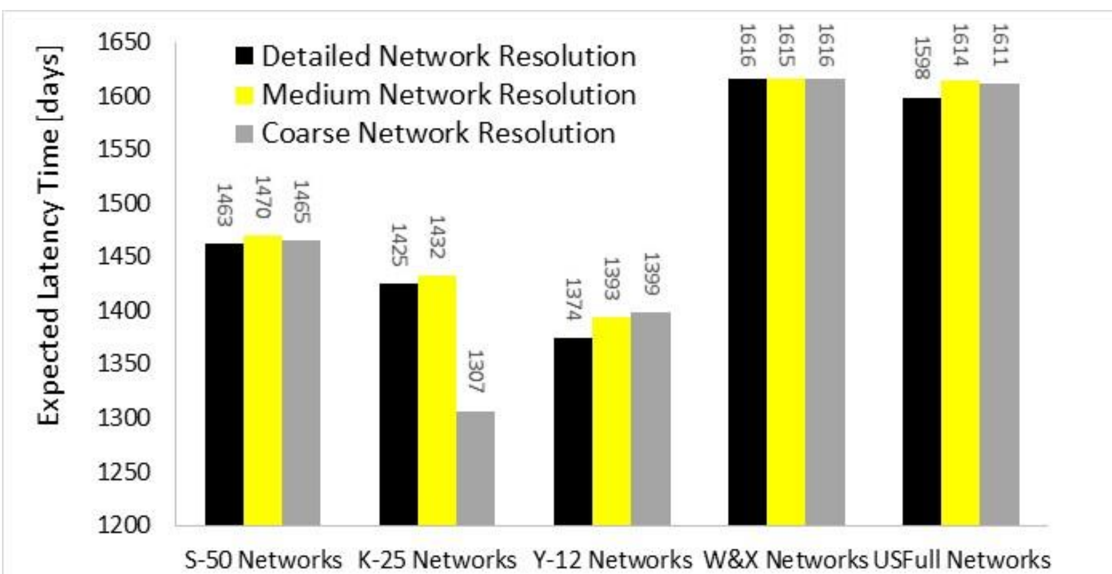


Fig. 19. Expected Latency time [days] for U.S. case cases while varying the level of network resolution.

Two potential explanations for variation in the the K-25 expected Latency with network resolution exist. The first may be that the detailed and medium resolution Latency times are artificially inflated by input rounding and a 1 day timestep as seen before. K-25 expected Latencies with increased precision are compared in Fig. 20. Fig. 20 shows that expected Latencies from the simulations with unrounded bounds and 0.1 day timesteps decreased by 20-31 days relative to the same network simulation results with the original rounded bounds and 1 day timestep. However, the expected Latency for the coarse resolution network is still about 113 days lower than the detailed and medium resolution networks. Thus it is concluded that this variation is not due to a precision bias.

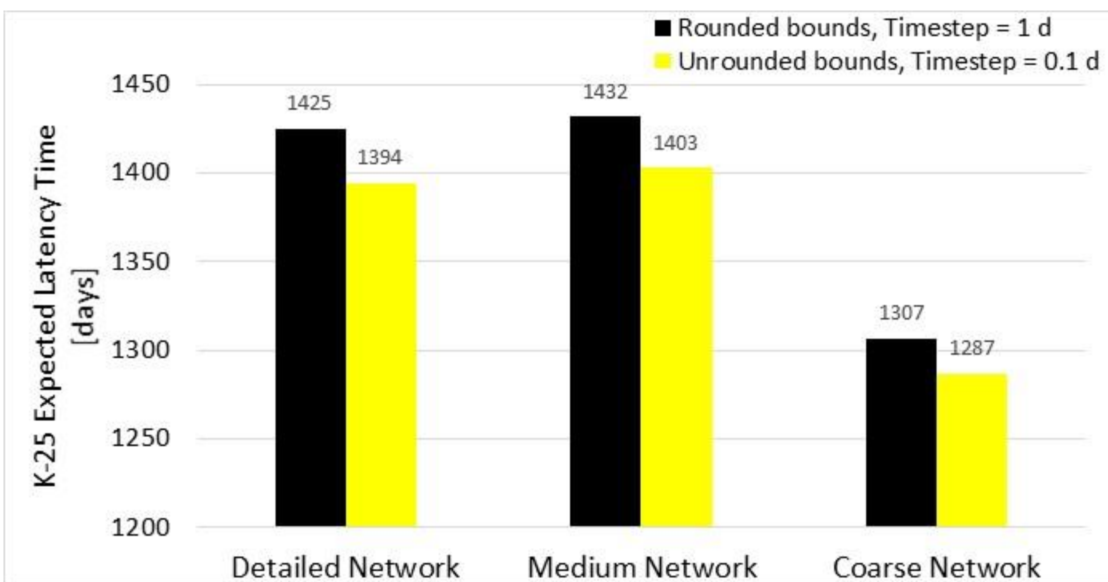


Fig. 20. K-25 expected Latency time [days] for three levels of network resolution while varying the rounding of uniform transition time probability density function bounds and the simulation timestep from 1 day to 0.1 days.

The other factor shown to bias expected Latencies high is network parallelism. The reduced portion of the K-25 network is shown for each of the three resolution levels in Fig. 21 (NOTE: Fig. 21 does not show the entire network which continues to the right). As can be seen there is a high degree of parallelism in the K-25 network which is eliminated in the coarse variation. In Fig. 21a there are essentially 5 parallel paths through that portion of the detailed resolution K-25 network. In Fig. 21b there are again 5 parallel paths through the medium resolution K-25 network. In Fig. 21c there is only one path through the portion of the coarse resolution K-25 network shown. While some of the other networks did have parallel flows, the parallelism was not eliminated during the network reductions as it was for K-25. This was because in the other networks the flows from parallel transitions often mixed into other network flows and any parallel transition elimination would have caused changes to the overall network flow.

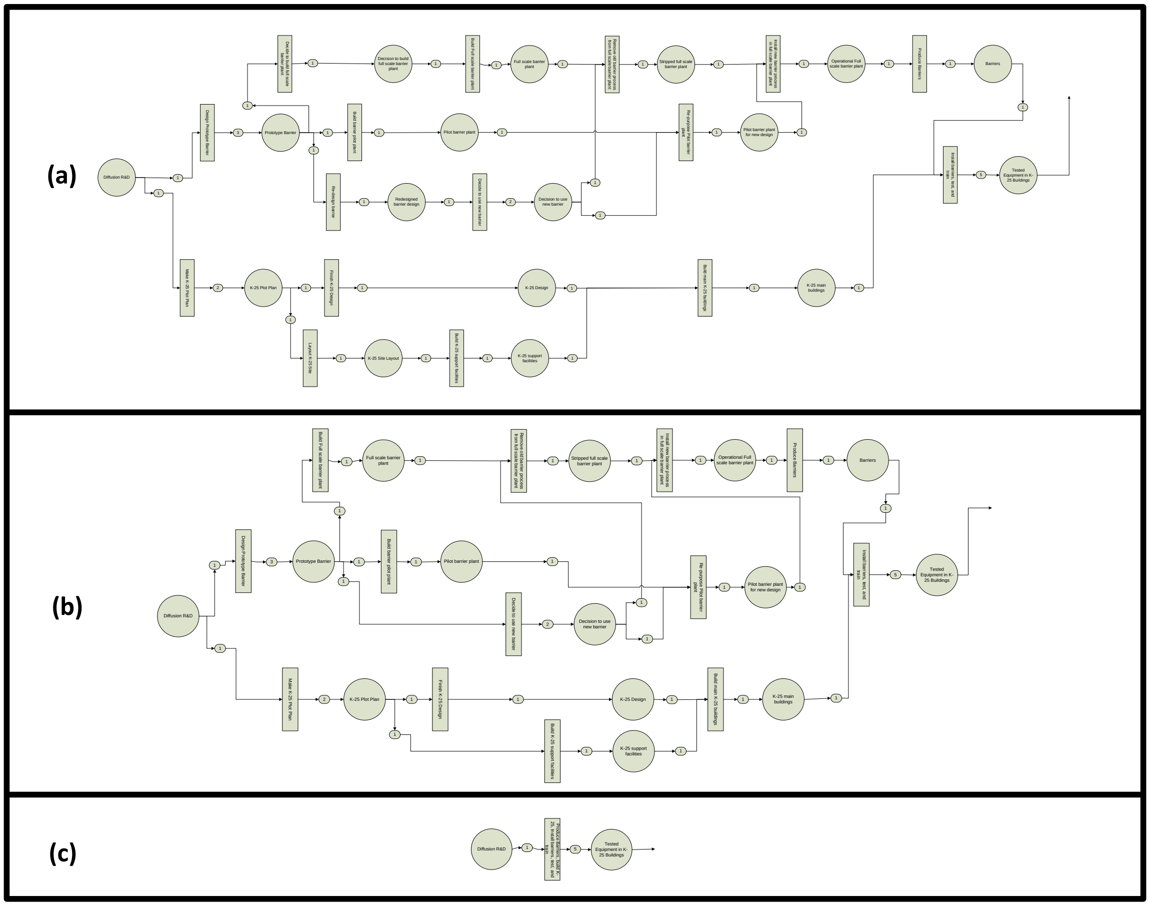


Fig. 21. K-25 networks for (a) detailed, (b) medium, (c) coarse resolution cases.

One might expect that if the parallel flow eliminating reductions had an impact on the K-25 expected Latency that a similar impact should be seen in the U.S. Full case since K-25 is one piece of that network. Within the U.S. Full case though K-25 is itself sometimes a parallel flow to the other cases. So it may be that in the coarse U.S. Full network that flow moves faster through the K-25 portion of the network but at the same speed for the other components of the network and any impact on the final Latency time is negated. Thus it is concluded that elimination of network parallelism is the likely cause of the difference in K-25 expected Latencies.

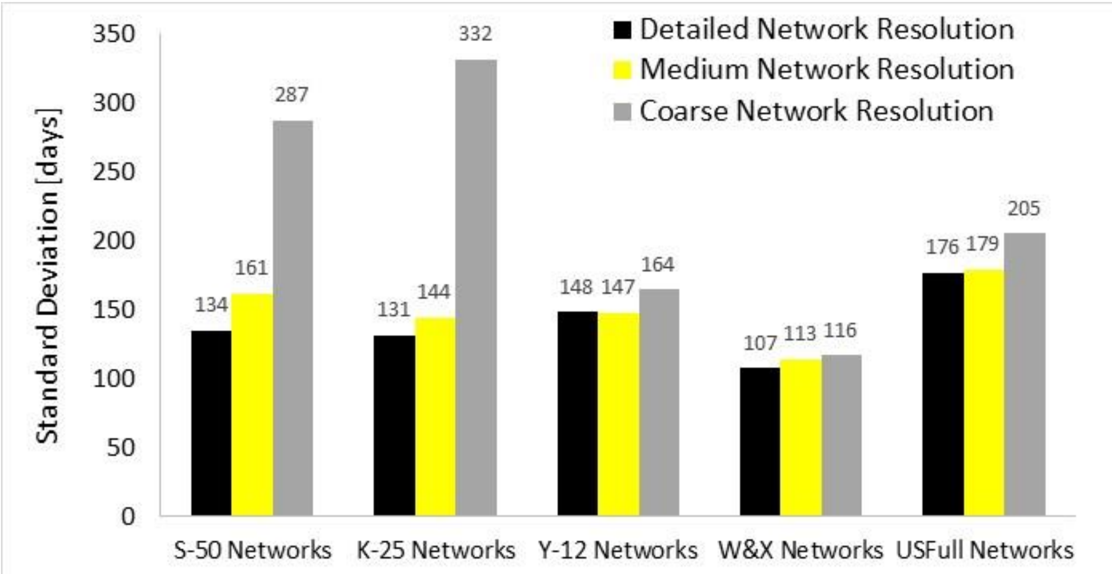


Fig. 22. Standard deviation [days] for the U.S. case networks for detailed, medium, and coarse network resolution.

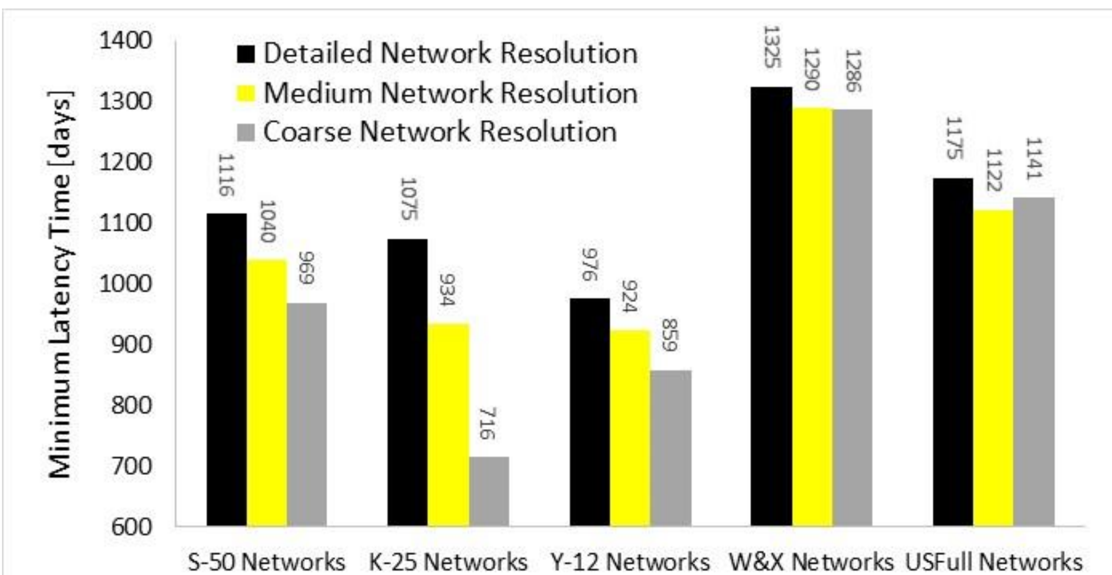


Fig. 23. Minimum Latency time for the U.S. cases for detailed, medium, and coarse network resolution.

The variance of the resulting Latency distributions is inversely proportional to network resolution. An increased variance equates to larger standard deviations and lower minimum latencies as network resolution decreases. These trends are confirmed by the expected Latency standard deviation in Fig. 22 and the minimum Latency time in Fig. 23. In general Fig. 22 shows for each case that Latency time standard deviation increases with decreasing network resolution. Correspondingly, Fig. 23 illustrates that the minimum Latency time generally decreases with network resolution for each case. This is expected and is congruent with the previous discussion of transitions in series. More transitions equates to more pdf samplings which reduces the variance. Fewer pdf samplings of larger time range pdfs leads to greater swings in resultant Latency times.

IV.B.3. Network Pathway Options: Y-12 Feed Enrichment

It is intuitive that any changes to the pathway options available within a network may impact the Latency time. As such, Latency results are sensitive to network pathway options. An example using the Y-12 case to demonstrate this sensitivity is given in Appendix H.

IV.C. Transition Time Probability Density Function Sensitivity

The transition time probability density function sensitivity was examined for two pdf types. Uniform pdfs are used as a simple base case. Uniform pdfs may also be preferred when no other knowledge is available about the actual activity time pdf. Though, it is unlikely that uniform pdfs may be the best representative for all activity times. Activity time pdfs for longer term projects may be expected to have a hard minimum below which completion times are unachievable. The pdf may then experience an exponential-like increase to a forward peaked maximum where activity completion is most likely followed by a fat tail eventually tapering off towards zero. A lognormal pdf exhibits these features and was the second pdf type examined.

The sensitivity analysis applies both uniform and lognormal pdfs to the Y-12 case while varying the bounds and parameters. The bounds used for uniform pdfs are 25%, 50%, and 75% below and above the historical activity time. Lognormal pdfs take the historical activity time as a mean and vary the σ parameter from 0.1, 0.5, to 1.

Fig. 24 shows the resultant Latency distribution profiles from the pdf variation simulations. Fig. 24a illustrates that when using uniform transition time pdfs that the resulting Latency distribution has very Gaussian profile. As the uniform pdf bounds are widened from 25% to 50% to 75% of the reference time Fig. 24a shows that the Latency distributions are broadened.

Fig. 24b depicts the resulting Latency distributions from use of LogNormal transition time pdfs. These Latency distributions retain the lognormal shape of the transition pdfs in contrast those shown in Fig. 24a. Though as in Fig. 24a, when the transition time pdfs are widened by increasing the σ parameter from 0.1, 0.5, and to 1 the resulting Latency distribution is also broadened.

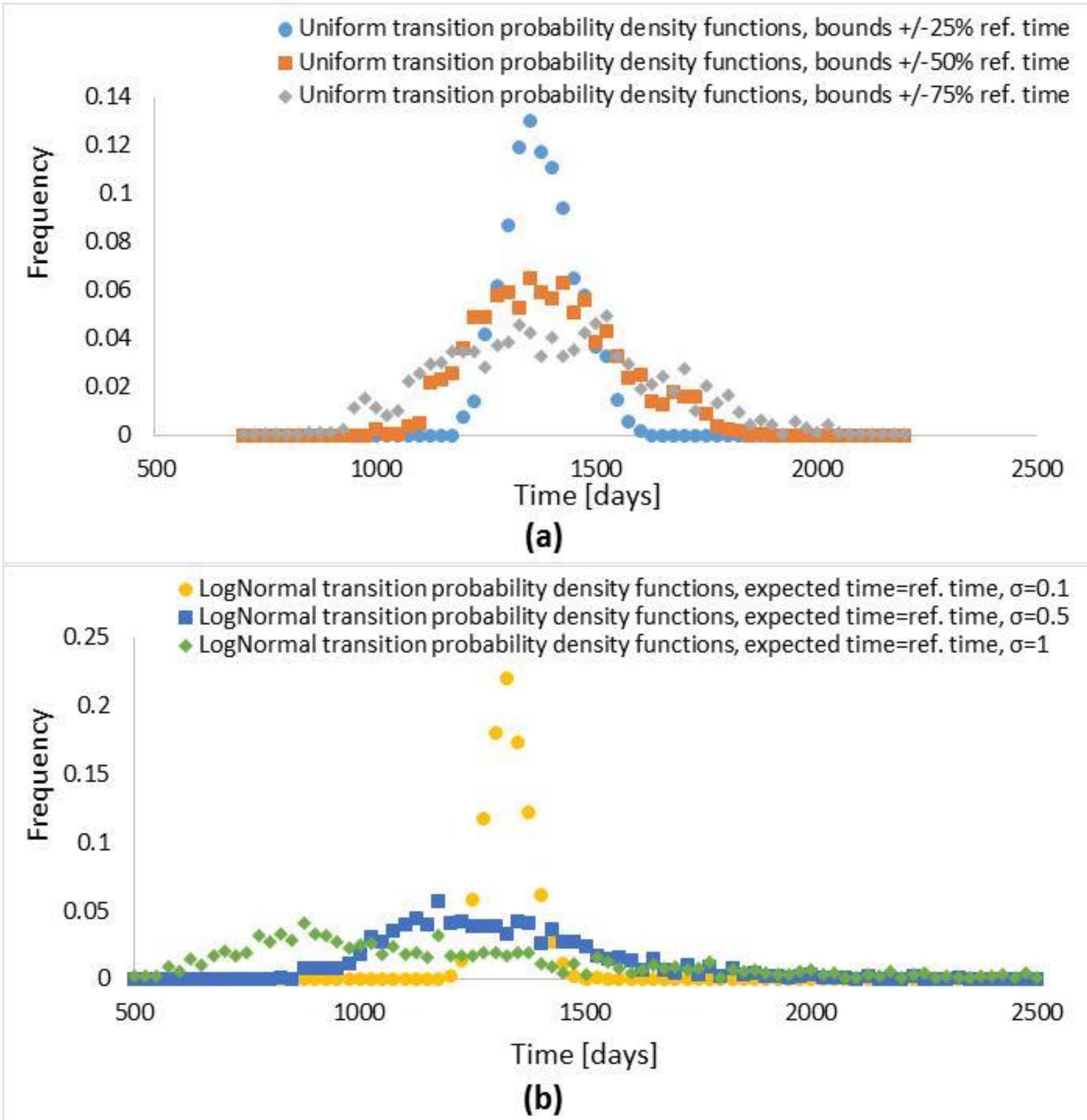


Fig. 24. Y-12 Latency time frequency distributions for simulations with transition activity times using (a) uniform probability density functions with bounds +/- 25%, 50%, and 75 % of the activity reference time and (b) LogNormal probability density functions with the pdf expected time equal to the activity reference time and a σ of 0.1, 0.5, and 1.

Fig. 25a-c shows the expected Latency time, Latency standard deviation, and Latency time minimum respectively for the all the U.S. case transition time pdf variation simulations. In Fig. 25a expected Latencies for S-50 simulations with uniform pdfs are within 6 days. Expected Latencies for S-50 simulations using lognormal pdfs are all within 8 days. S-50 expected Latencies for simulations with uniform pdfs were about 111 days higher than those with lognormal pdfs. Expected Latencies for K-25 simulations with uniform pdfs increase by about 60 days each time the bounds were widened. For K-25 simulations with lognormal pdfs, expected Latencies increased by about 200 days with each σ parameter increase. Y-12 simulations with uniform pdfs had expected Latencies within 23 days. Y-12 simulations with lognormal pdfs and σ equal to 0.1 and 0.5 had expected Latencies within 3 days of each. Y-12 expected Latency using lognormal pdfs with σ equal to 1 increased by 35 days from the previous lognormal simulation. W&X expected Latencies using uniform pdfs increased by about 15 days each time the bounds were widened. The W&X expected Latencies increased by hundreds of days as the σ parameter was increased for simulations with lognormal pdfs. The Full U.S. expected Latencies from simulations using uniform pdfs saw increases of 38 days and 92 days when widening the bounds from 25% of the reference time to 50% and then 75% respectively. The expected Latencies for the U.S. Full case using lognormal pdfs increased 258 days and 367 days when the σ parameter was increased from 0.1 to 0.5 to 1 respectively.

Several general trends can be seen from Fig. 25a. All U.S. case simulation expected Latencies appear to increase when the pdf bounds or σ parameters were increased except for the S-50 case. The S-50 network was entirely serial with no parallelism whereas all the other networks had varying degrees of parallelism. This fact leads to the conclusion that wider range transition activity time pdfs are more sensitive to the network parallelism bias.

The response of the Latency standard deviation to varying transition activity time pdf is shown in Fig. 25b. It was expected that as the transition time pdf ranges were widened that the variance of the resulting Latency distributions should increase. In Fig. 25b the Latency standard deviations for all the uniform pdf simulations increase on average 54 days (ranging from 27 to 79 days) and 65 days (ranging from 49 to 76 days) when increasing the bounds from 25% to 50% of the reference time and again from 50% to 75% of the reference time respectively. The Latency standard deviations for all the lognormal pdf simulations increase on average 223 days (ranging from 184 to 258 days) and 552 days (ranging from 381 to 715 days) when increasing the σ parameter from 0.1 to 0.5 and from 0.5 to 1 respectively. This result confirms the expectation for the Latency standard deviation.

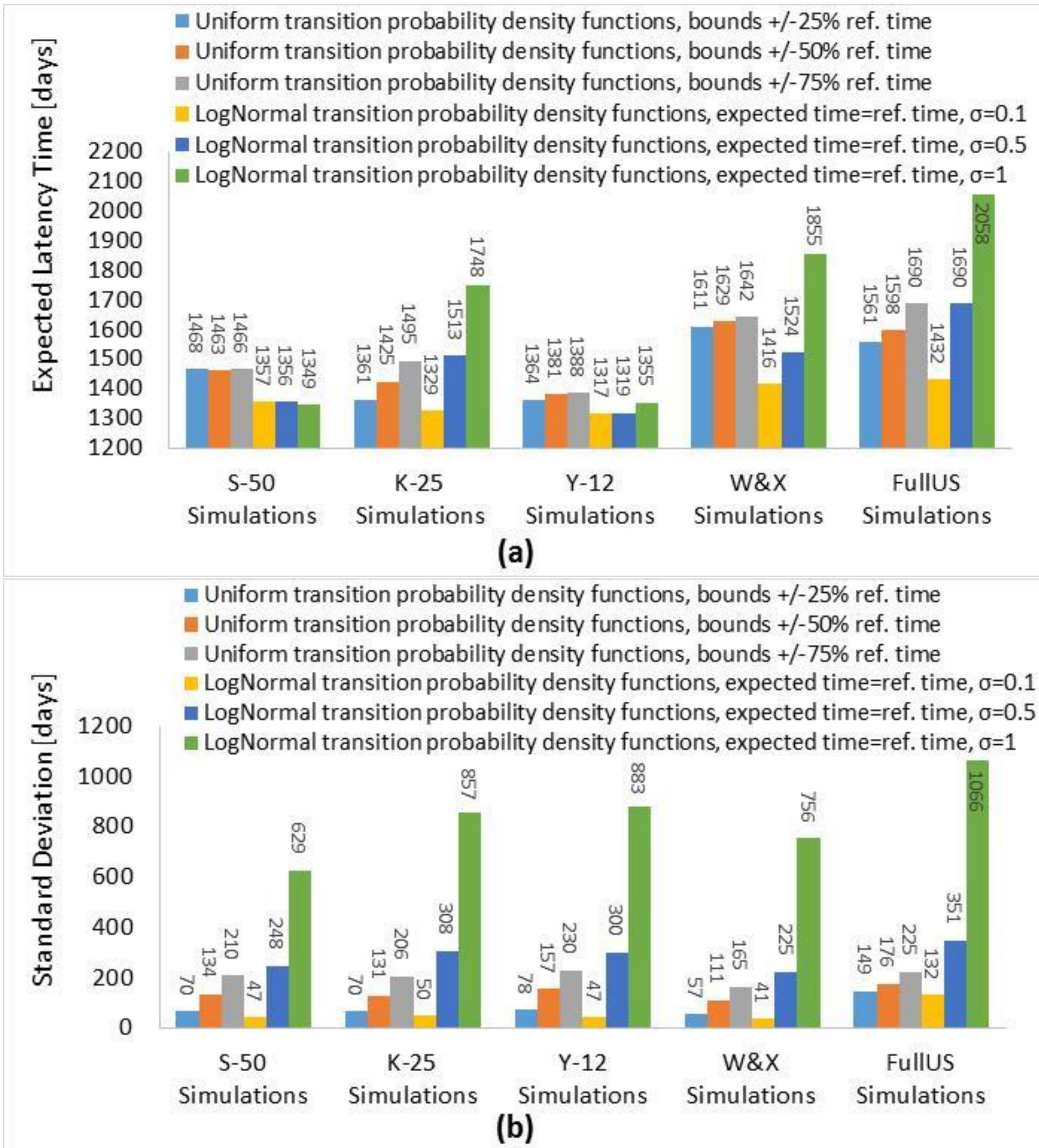


Fig. 25. Impact of transition activity time probability density function variation for U.S. cases on (a) expected Latency time, (b) Latency standard deviation, and (c) minimum Latency time.

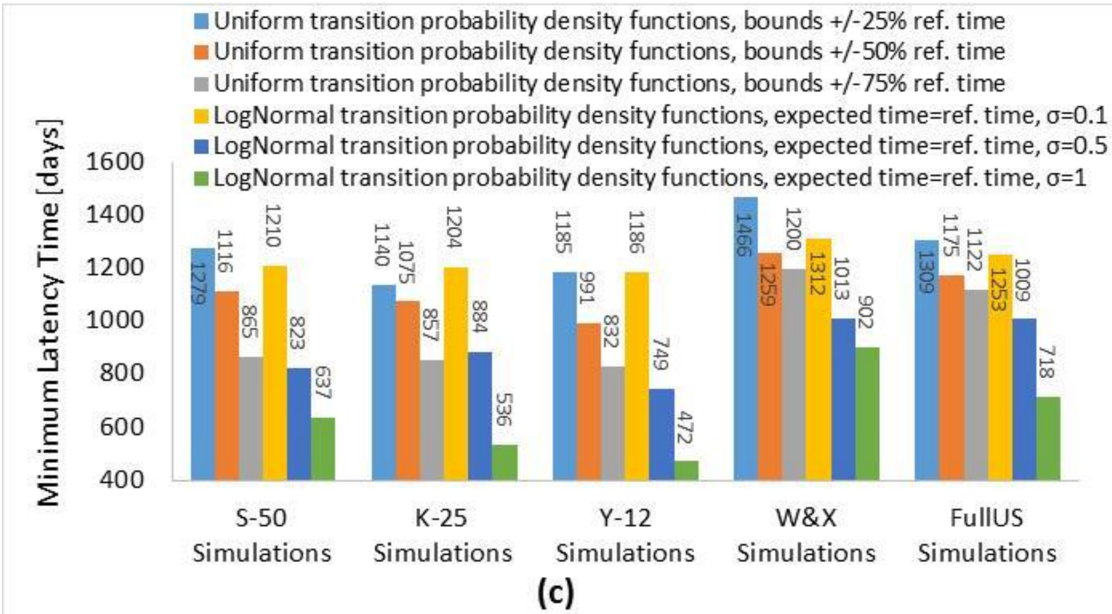


Fig. 25. Continued.

The response of the minimum Latency in Fig. 25c mirrors that of the Latency standard deviation. It was expected that as the underlying pdf variances increase so too does the standard deviation while the minimum reaches greater lows and this is confirmed in Fig. 25c. The minimum Latency in Fig. 25c for all the uniform pdf simulations decreases on average 153 days (ranging from 27 to 79 days) and 148 days (ranging from 53 to 251 days) when increasing the bounds from 25% to 50% of the reference time and again from 50% to 75% of the reference time respectively. The minimum Latency for all the lognormal pdf simulations decreases on average 337 days (ranging from 244 to 437 days) and 243 days (from 111 to 348 days) when increasing the σ parameter from 0.1 to 0.5 and from 0.5 to 1 respectively.

The pdf sensitivity analysis presented here is a useful baseline but should continue to be developed as the Latency tool is used. Other pdfs may be desired and the user should repeat this analysis with any new pdf. Further, this analysis used only one pdf type and parameter for each simulation. Simulations using mixed transition activity time pdfs may have different sensitivities.

IV.D. Path Selection Interval Sensitivity

The frequency of pathway selection during the course of a simulation may also impact the Latency results. The Latency tool allows for random path selection or path selection with the MAUA function. The MAUA application is discussed later, and this analysis focuses on random path selection. Path selection intervals used for the U.S. Full case are 0.5 year, 1 year, 2 years, 5 years, and 10 years (the component cases were not used as those cases had only one path). In the 10 year selection interval all cases finished within just over six years. Thus the ten year selection interval reflects a single path selection at the initiation of a state's nuclear weapons program.

The Latency values for the U.S. Full case resulting from the path selection interval (PSI) variation are shown in Fig. 26. The expected Latency slightly increases by 27 days when the PSI is increased from 0.5 years to 1 year. Then the expected Latency drops successively by 96 days, 298 days, and 63 days as the PSI is further increased.

The Latency standard deviation displays a parabolic shape as a function of path selection interval in Fig. 26. It increases by 108 days then again by 93 days as PSI increases from 0.5 years to 1 year to 2 years respectively. Then Latency standard deviation decreases by 76 days and 258 days as PSI is further increased to 5 years and 10 years.

The minimum Latency times as well as maximum Latency times given on a secondary axis for varying PSI are both shown in Fig. 26 for completeness. The minimum Latencies are within a range of 135 days possibly displaying a decrease as PSI increases. Though, this trend is not clear. The maximum Latency times exhibit a parabolic shape as function of PSI similar to the standard deviation with a range of 3404 days from shortest to the longest maximum Latency.

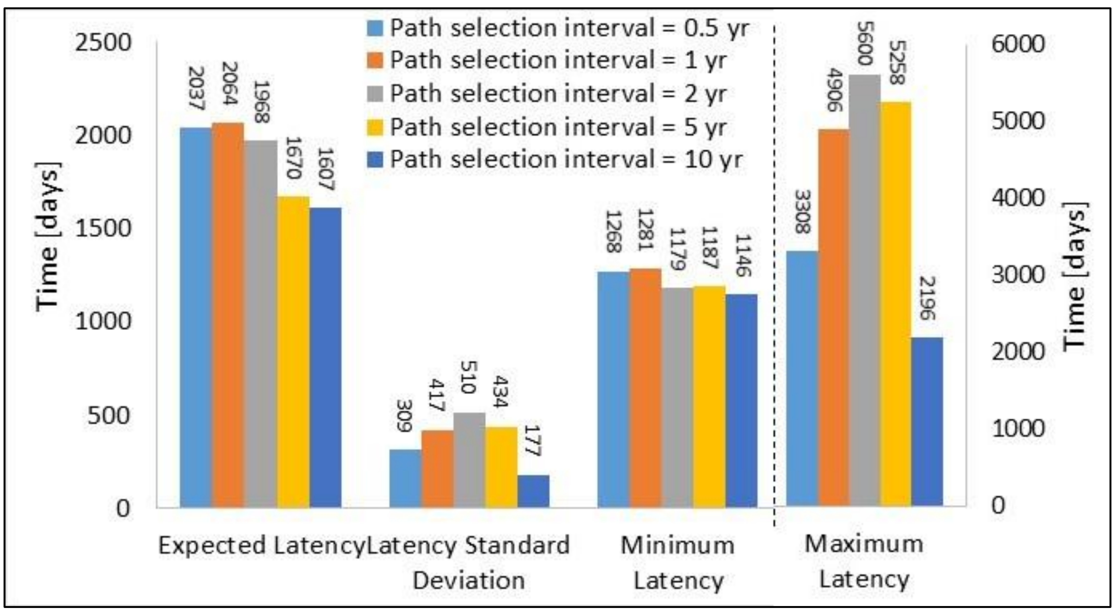


Fig. 26. Impact of path selection interval variation on the U.S. expected Latency, Latency standard deviation, minimum Latency, and maximum Latency (included for completeness).

Three possible trends appear for the Full U.S. case Latency statistics shown in Fig. 26. The first is a clear drop in the statistical values for the longer selection intervals.

This finding agrees with intuition, as a consistent pursuit avoids abandoning previous work and starting a different path anew (or at least further back than the abandoned path). This result is especially true for the short duration U.S. proliferation case.

The remaining two potential trends are alternative interpretations of the same data as the path selection interval decreases. For the standard deviation and maximum, it is clear these values experience a maximum and then decrease as path selection interval decreases. The mean and minimum also appear to experience a maximum before the respective Latency times decrease at the shortest path selection interval, but this final decrease is within the standard deviation and may actually represent an asymptote. Both interpretations may be explained by there being a point where the rate of progress achieved by constantly changing paths becomes no less, and possibly more, than the rate of progression at the path selection interval inflection point which appears to be approximately 1-2 years.

The needs of the analyst or user define Latency modelling requirements. This sensitivity study should provide a baseline for users. It details the features implicit in the tool that influence results and quantifies the impacts. This sensitivity analysis is done to help the user to build better models more appropriately suited to their needs, or as a basis to extending further sensitivity analyses as necessary. Extending the sensitivity analysis may be critical to analyses where the U.S. case does not apply.

V. LATENCY CASE STUDIES: PAKISTAN & SOUTH AFRICA

Additional historical case analysis can provide further confidence in the Nuclear Weapons Latency Tool while adding insight to the cases of proliferation analyzed. Historical case studies of Pakistani and South African proliferation were completed and Latency analyses conducted. The results of the analyses are presented here.

V.A. Pakistan Case Study

Pakistan and its nuclear weapons program have been a constant international security concern since the program began.[62] Thus the program has been well studied; while Pakistan's enduring nuclear rivalry with India and A.Q. Khan based proliferation concerns continue to make Pakistan a useful and interesting historical case analysis for the Latency tool. With the Pakistani case, the Latency tool is also used to assess the impact of (or sensitivity to) the Indian nuclear weapons program and its 1974 peaceful nuclear explosion (PNE).[62]

V.A.1. Pakistan Network

Though its progress was slow, Pakistan developed a robust nuclear weapons complex with mastery of the complete nuclear fuel cycle. This accomplishment translated into a Pakistani Latency network with 8 potential independent pathways which included HEU and Pu weapons, hot and cold tested weapons, and Pu produced in Pakistan's Khushab production reactor or diverted from the safeguarded Karachi Nuclear Power Plant KANUPP. A hot test involves a full nuclear explosion, while a cold test may be identical but conducted with materials such as depleted uranium which will not create a nuclear explosion. Pakistan had delivery systems ready and available in the form of F-16s and Mirage fighter/bombers. The full Pakistani network has 67 transitions and 80 places. Complete lists, network matrices, transition time pdfs, and initial markings are provided in Appendix I.

V.A.2. Latency Analysis of Pakistani Proliferation

The Latency tool was used to simulate Pakistani nuclear weapons proliferation, and the results are compared against historical data. The initial proliferation decision was assumed to be on January 20, 1972 at the Multan conference. [62] The date of achieving a deliverable nuclear weapon is assumed to be at the end of October 1995. This date represents an approximately 180 day weapons manufacturing time after a successful cold testing campaign in May 1995.[62] (The weapons manufacturing time is derived from the South African case study below. The South African gun weapon was simpler than the Pakistani implosion weapon, and South Africa is assumed to be at least as technically competent as Pakistan. So this weapons production time is assumed as a conservative minimum that it would take for Pakistani weapons production.) U.S. political pressure prevented Pakistan from conducting a full hot nuclear test until May

1998, when Pakistan did so as a political response to Indian nuclear tests earlier that month.[62]

Fig. 27 presents the results of discrete transition time simulations with the Pakistani network. Pakistani pathway Latency Standard times are shown, with completion dates, in Fig. 27. The Historical Pakistani proliferation reference time, shown at the top of Fig. 27, is almost perfectly matched by the HEU cold tested implosion weapon path, which was the historically correct path. The cold tested HEU gun path was 707 days shorter than cold tested HEU implosion weapon path. This duration was exactly the difference for implosion and gun weapon design reference times used in the model. Historically, Pakistan initially chose to pursue a Pu weapon which required an implosion design.[62] Pakistan maintained the implosion design choice even after it switched to an HEU path to facilitate incorporation of any future Pu production capability.[62]

The next two paths listed in Fig. 27 are the hot tested HEU weapons paths, both implosion and gun. The Latency Standards for both of these paths were 3316 days shorter than the cold tested HEU implosion Latency Standard. As modeled, the hot tests allow Pakistan to avoid about a 4400 day cold testing phase and produce a weapon as soon as the materials were available. As mentioned previously, Pakistan abstained from a hot test due to pressure from the U.S.[62]

The diversion of spent KANUPP fuel provides another option for a weapon sooner than the historical time. The hot tested KANUPP diversion path could have provided a weapon 2415 days earlier than the historically correct Latency Standard.

However, the cold tested KANUPP diversion path latency standard was the same duration as the historically correct Latency Standard.

The final option for Special Nuclear Material (SNM) was Pu production from the indigenously built Khushab production reactor. The Latency Standard for the hot tested Pu weapon from Khushab (not diverted from KANUPP) was 630 days less than the historically correct path Latency Standard. The Latency Standard for the cold tested Khushab Pu weapon was equal to the historically correct path Latency Standard. This result is surprising because, historically, it took Pakistan much longer to develop Pu weapons than suggested by the Latency Standards of those paths.

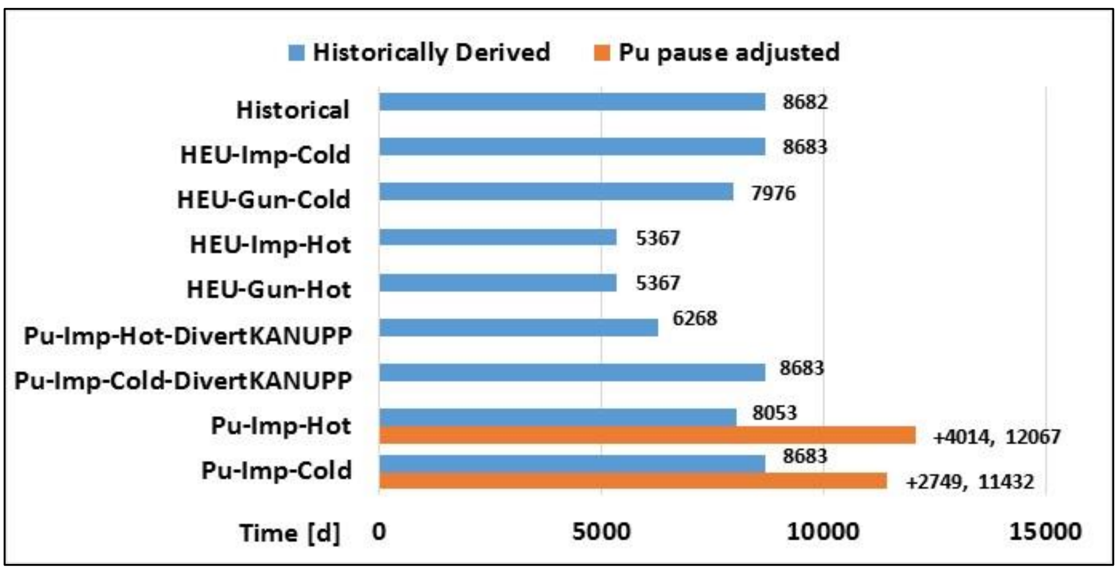


Fig. 27. Pakistani pathway Latency standard times with strict historical activity times and Latency standard time with the Pu production path times adjusted to account for the ~10 year break in Pu production development that occurred when A.Q. Khan brought centrifuge technology to Pakistan.

These historically early Khushab Pu weapon Latency Standards can be explained by the Pakistani pathway shift in response to the centrifuge technology made available by A.Q. Khan. A.Q. Khan, having been motivated by the Indian peaceful nuclear explosion of May 1974, began providing Pakistan with advanced centrifuge design information and technology later that same year.[62] In response, Pakistan invested heavily in a new centrifuge based uranium enrichment path at the expense of the previous Pu production path which was shutdown. Development of Pu production was not restarted until almost ten years later.[62] From this point forward, including the previous development time, Pakistani proliferation through Pu production required the same amount of time. Thus, the Latency tool analysis suggests that A.Q. Khan had little impact on the Latency time for Pakistan; that Pakistan would have acquired a weapon in 1995 with or without the intervention of A.Q. Khan. The only substantial change was whether that weapon was HEU or Pu based (i.e. the pathway chosen). This analysis may neglect possibly necessary technological maturation, which may have occurred in Pakistan during the decade long Pu production pause from 1974 to 1983.

The orange bars in Fig. 27 reproduces the Pu production pause and shows those results for the Khushab produced Pu paths. These results more closely agree with history. The hot testing path actually takes 635 days longer than the cold testing option. For the Pakistani model, this delay is due to the time required to create another bomb's worth of Pu after the hot test. One might expect that Pakistan, or any other state, would wait until at least 2 weapons worth of material were available before conducting any hot test.

V.A.3. Sensitivity to Indian Test (and A.Q. Khan)

The Latency tool provides a simple vehicle to investigate the impact of the 1974 Indian 'peaceful nuclear explosion' by analyzing the hypothetical situation where it does not occur. The Indian PNE directly spurred the Pakistani program, even though Pakistan had already made a positive proliferation decision. The immediately linked events were A.Q. Khan's personal proliferation decision and Bhutto's demand for the establishment of a Pakistani test site.[62] The Pakistani Latency network was constructed such that these event transitions are downstream of the Indian test place. Thus in order for those transitions to fire, the initial marking must include a token in the Indian test place. In the absence of an Indian test, centrifuge development and the decision to build a test site must flow through alternate network transitions which have much longer activity time pdfs. All other transition time pdfs remain the same.

Fig. 28 compares the Latency standard times for the Pakistani network paths with an Indian nuclear test to those without one. Fig. 28 shows the Latency standards with the Indian nuclear test as blue bars and Latency standards without the Indian nuclear test with orange bars. The Latency standard in days is shown for both sets of data. The difference between the Latency standards with and without the test is shown preceding the Latency standards value without the test. The HEU paths are all drastically lengthened, as is expected without the presence of A.Q. Khan. The KANUPP material hot tested weapon is also delayed. This delay is a result of the lengthened time to decide to prepare a nuclear weapons test site. The remaining Pu paths are unaffected.

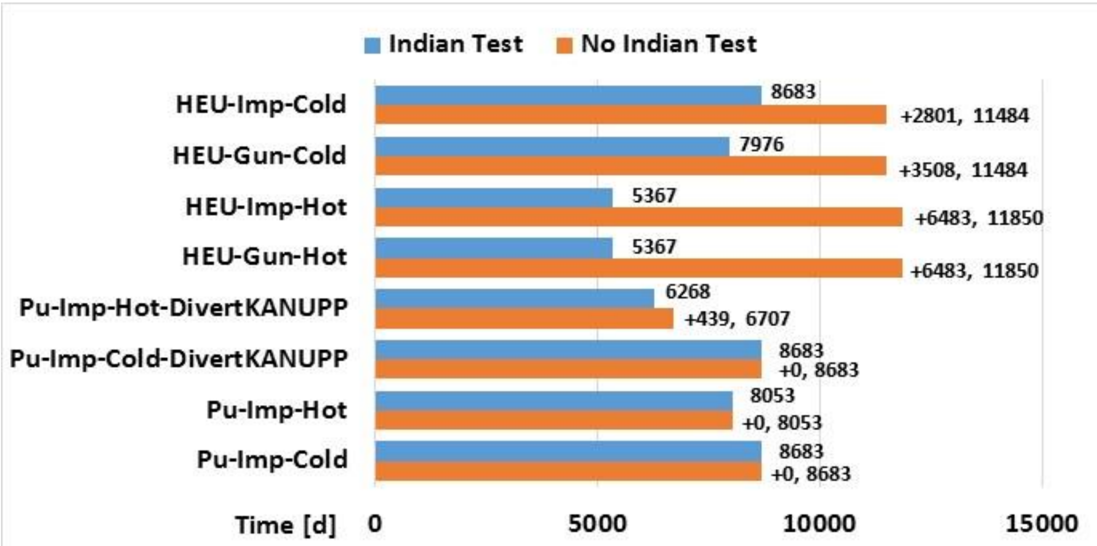


Fig. 28. Pakistani pathway Latency standard times without an Indian nuclear test.

This analysis suggests that the Indian PNE, like A.Q. Khan, also had limited impact on the Pakistani program. The two events, the Indian test and A.Q. Khan's centrifuge espionage, were of course linked. Both events were preceded by the Pakistani proliferation decision.[62] This fact confirms that Pakistani proliferation would likely have occurred without both the Indian PNE and A.Q. Khan's centrifuge espionage. The Latency analysis adds that proliferation may have occurred in the same time. The impact of the Indian PNE and A.Q. Khan appear to have been only to bring centrifuge technology to Pakistan and elsewhere.

A stochastic analysis of the impact of the Indian PNE on Pakistani expected Latency is given in Appendix J. The analysis shows that when considering all paths together, the expected Latency increases when there is no Indian PNE. This increase is a result of the much longer HEU paths shown in Fig. 28. It should be obvious that when averaging all the path Latencies of a simulation, including the longer HEU paths without an Indian PNE, that the expected Latency would be larger than an average of Latencies with the much shorter PNE HEU paths.

V.B. South African Case Study

The South African nuclear weapons proliferation program provides an interesting case for analysis. The case is simple and reasonably well known. While South Africa was and is an economic leader in the region, its resources both financial and human were limited. Further, in some respects, South Africa during the time of its proliferation fits the profile of an aspiring rogue nation challenging the superpower status quo. For these reasons, the South African case may have bearing on proliferation concerns of today.

V.B.1. South African Proliferation Network

South African proliferation was simple and straightforward. The program developed an HEU gun bomb to be delivered with existing aircraft.[63,64] Enriched uranium was provided by an indigenously developed technique. Clear indications existed that South Africa was preparing for a weapons test (either hot or cold) with a fully developed test site.[65] Also, historical evidence demonstrates that South Africa investigated Pu production in nuclear reactors at different times.[66,67] South Africa is assumed to be at least as capable as Pakistan, so the South African Pu pathways are modeled after those in the Pakistani network. The South African Latency model consisted of 46 transitions and 62 places. The proliferation decision date used is March 1971, when the South African Minister of Mines approved an Atomic Energy Board proposal to develop gun, implosion, boosted, and thermonuclear peaceful nuclear explosive designs.[63,65] The data for completion of the first South African deliverable nuclear weapon was assumed to be December 1, 1982.[67] In 1991 South Africa acceded to the Treaty on the Nonproliferation of Nuclear Weapons (NPT) and began a nuclear disarmament process.[67,68] A complete timeline and Petri net data for the South African model is provided in Appendix K.

V.B.2. Latency Analysis of South African Proliferation

Latency standard times for each South African path are generated with discrete transition time simulations, and the results are illustrated in Fig. 29. The Latency tool provides a Latency standard time for the Gun cold path that agrees to within 0.35 % or 15 days of the historical time. Gun cold and hot paths yield the same Latency standard because both paths require subsequent weaponization by the South African weapons producer ARMSCOR. One could argue that if South Africa had continued unabated by foreign powers and conducted a hot test during the summer of 1977, it may have taken longer to weaponize without the external drivers which prompted the decision turn the nuclear explosive project over to ARMSCOR.

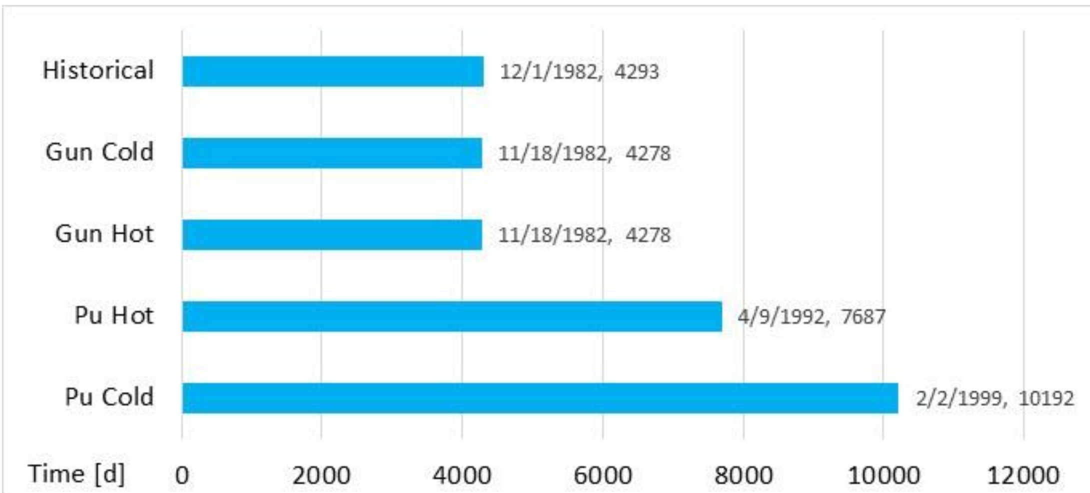


Fig. 29. South African pathway Latency Standard times for the different independent paths of the South African proliferation network.

Both the hot and cold tested Pu weapon paths were much longer than the HEU paths. The hot tested Pu path was 3409 days longer than the HEU path Latency Standard, while the cold tested path was 5914 days longer. South Africa did have two research reactors that were shutdown prior to the 1971 Minister of Mines decision.[64] It was not until 1981 that South Africa restarted development of their Pu production program and after four years of research discontinued the program.[63,67] It was assumed that this additional four year research period would be a necessary precursor to the construction of any potential South African Pu production reactor. This four year research period, in addition to the 12 year Pu production reactor construction adapted from the Pakistani case, accounts for the delay in the hot tested Pu weapon path. The cold testing path required additional time for a cold implosion testing program, also adapted from the Pakistani case history. Both Pu production paths appear that they would have been overtaken by the government's desire to disarm and accept the NPT.

V.C. Conclusion: Pakistan & South Africa Latency Analyses

The Pakistani and South African Latency analyses provide further confidence in the Latency tool while adding useful insight into relevant cases of proliferation. The Pakistani analysis as modeled demonstrated that while the Indian PNE and A.Q. Khan may have impacted the Pakistani proliferation pathway, neither may have impacted Pakistani proliferation time. The South African analysis highlighted the dependence of the HEU paths on ARMSCOR weaponization. The investigation further revealed that South African proliferation may have been overtaken by events had it been shifted onto the Pu production path. Development of such proliferation delaying strategies would be a useful application of the Latency tool.

VI. MODELING VARIATIONS & APPLICATIONS WITH THE PAKISTANI & SOUTH AFRICAN CASES

The Latency analyses of both Pakistan and South Africa highlight the impact of the proliferation pathway choices those countries made on their respective Latency times. The Latency tool controls path selection on a global level by permanently disabling non-pathway transitions as a result of deliberate pathway selection. It is possible though to design networks and operate the Latency tool such that path selection is made at a local level. This section examines some of the modeling features of the Pakistani and South African networks that allow for pathway control internally in addition to tracing South Africa's proliferation evolution with the Latency tool.

VI.A. Internal Pathway Selection by Network Design

With appropriate modeling, pathway control and selection can be built into a network model without needing the global Latency tool pathway selection function. This internal pathway selection control can be implemented by placing multiple transitions on different pathways downstream of a single place representing some form of resources. If the amount of those resources is constrained by limiting the amount of tokens available to the resource place, then the downstream transitions will be in conflict and a choice must be made between them. The Latency tool can then be run by specifying all transitions on a single path so that no global choices are made, allowing the pathway selection to occur organically as the simulation evolves.

VI.A.1. Financial Control & Sensitivity in the Pakistani Network

By modeling the Pakistani network with financial resource control, it is possible to test Pakistani sensitivity to financial resources. Financial constraints limited Pakistan's ability to pursue multiple paths in parallel. Even though global path selection control is built into the Latency tool, pathway decisions can also be forced locally by intentionally using conflicted places: places with multiple transitions immediately downstream. In this manner overarching financial control was added to the Pakistani network and is shown in Fig. 30. The immediately downstream transitions from the 'Nuclear Program Funds' place are 'Develop centrifuge technology indigenously' (this transition is inhibited in the presence of an Indian nuclear test), 'Bhutto approves A.Q. Khan centrifuge program', 'Initiate program to copy Indian CIRUS production reactor', and 'pursue Pu production R&D'. Thus if all these transitions were enabled but there were not enough nuclear program funds (tokens) for them all to fire, a local intra-path choice must be made. As discussed previously the Latency tool does this choosing through a random process.

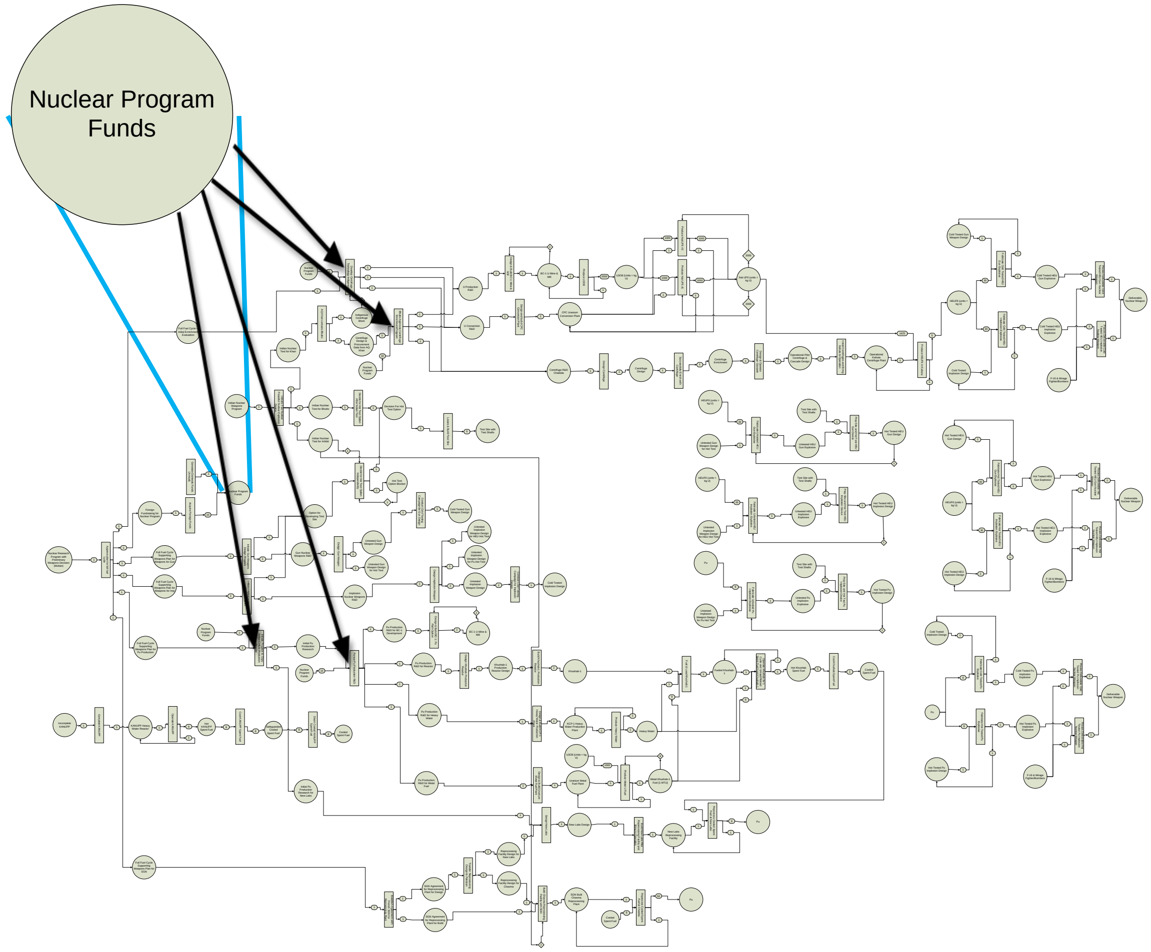


Fig. 30. Overarching financial control of the Pakistani Latency network.

To test the impact of financial resources, simulations were run with the historical constrained Pakistani funds and with excess funds. The simulations assumed an Indian nuclear test and were run for only the combined path of all independent paths such that no transitions (or pathways) were ever permanently disabled by a path selection. In this manner a transition choice was forced only when finances were constrained. 50% bound uniform transition pdfs were used for the simulations. Fig. 31 shows the resulting expected and minimum Latency times for the excess finances and historically limited finances cases. The specific Latency times are listed as data labels and the standard deviation is shown as error bars in Fig. 31.

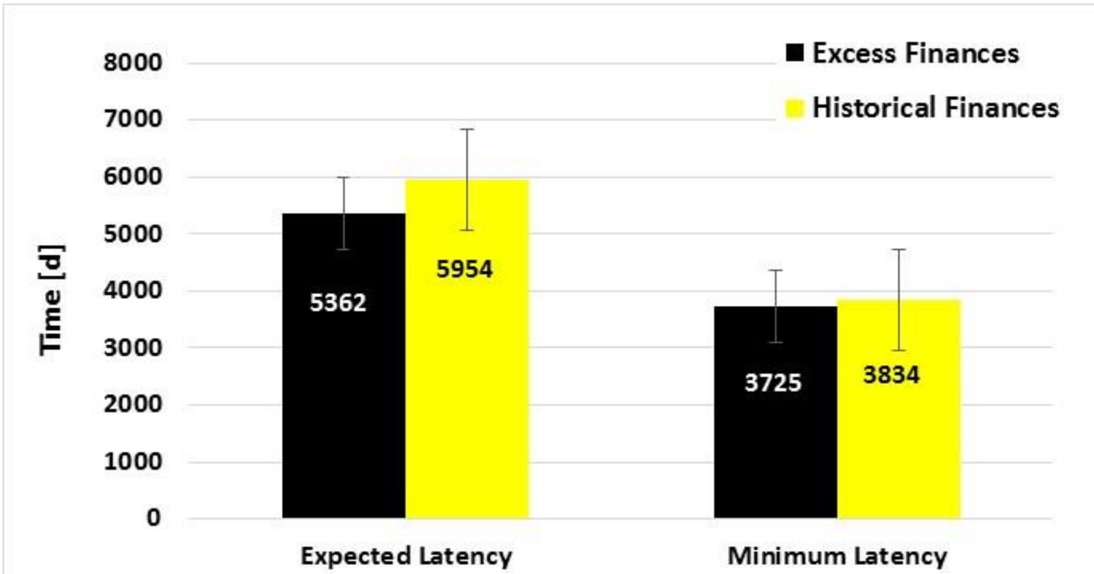


Fig. 31. Impact of financial resources on Pakistani Expected and Minimum Latency times.

The Pakistani financial sensitivity results agree with intuition. The shortest path always gets completed with excess finances instead of forcing the option of a longer path. This constant shortest path completion lowers the expected Latency of the case with excess finances. However, since it is still the same path with the same transition time pdfs in both cases, the minimum Latencies are about the same. This circumstance may not be entirely realistic, as one might expect unlimited funds to decrease activity times. To properly model the situation, it may be necessary to add new transitions with shorter activity time pdfs that require more financial tokens to fire. From that perspective it may be useful in the future to develop "crashing" paths that are identical to the normal path but with shorter transition time pdfs that are more resource intensive.

VI.A.2. Financial & Human Capital Control & Sensitivity in the South African Network

In the same fashion that intra-path financial constraints were placed on the Pakistani network, both financial and personnel constraints were placed on the South African model. Such constraints were experience by the South African program.[63] The results of varying these constraints are shown in Fig. 32 for simulations with 50% uniform transition bounds. Fig. 32 gives the expected and minimum Latencies for the cases varying the amount of funds and personnel available. The expected Latency time and its standard deviation both decrease in the presence of excess resources. This decrease is expected, as in this case the shortest path is always available. The minimum Latencies are basically the same, as again the shortest path is always experienced during the course of the simulation.

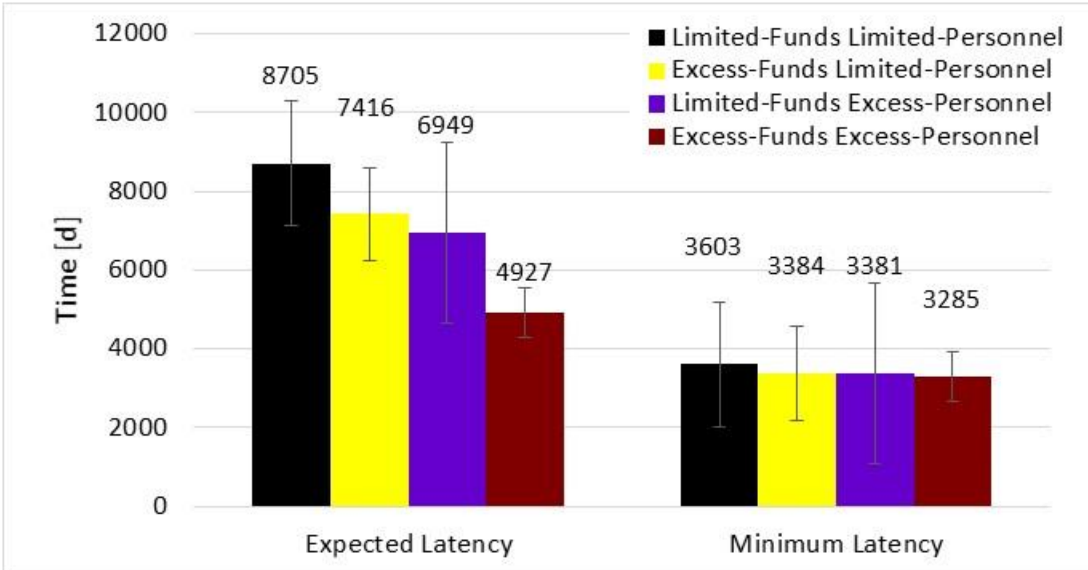


Fig. 32. Impact of financial and personnel constraints on South African Expected and Minimum Latency times.

VI.A.3. Tracing the South African Program Historically

There is some debate surrounding the actual date of the South African proliferation decision, and possible alternative dates have been suggested. After the 1971 Minister of Mines decision, the next cited decision occurred in May 1974 when PM Vorster authorized funding for the development of a device and test site after a successful South African gun type cold test.[63,69,70] In early August 1977, South Africa was discovered to be preparing for a weapons test in the Kalahari Desert. The next possible proliferation decision occurred: "soon after the Kalahari episode, Vorster ordered the AEB to cancel the PNE program, to close down the test site, and to develop a secret nuclear deterrent."[65] This decision is assumed to coincide with the French Foreign Minister's August 22, 1977, announcement of "grave consequences" for South

Africa should they test.[63] This debate presents a useful opportunity for Latency analysis, and simulations are run on the same South African network while varying the initial marking (proliferation network progress). The simulation involved only the historically accurate HEU cold gun path.

Fig. 33 shows the discrete transition time results when using original transition times corresponding to the 1971 proliferation decision and updated transition times corresponding to the 1974 or 1977 transition times, while varying the different initial markings corresponding to the different proliferation decision dates. Initiating simulations at the later start dates meant that some transition activities should have already started but could not. The user must either use the artificially long transition times or update the transition times to reflect the new proliferation progression. As is illustrated, failure to update partially completed transition times after actual proliferation progression could lead to artificially long times.

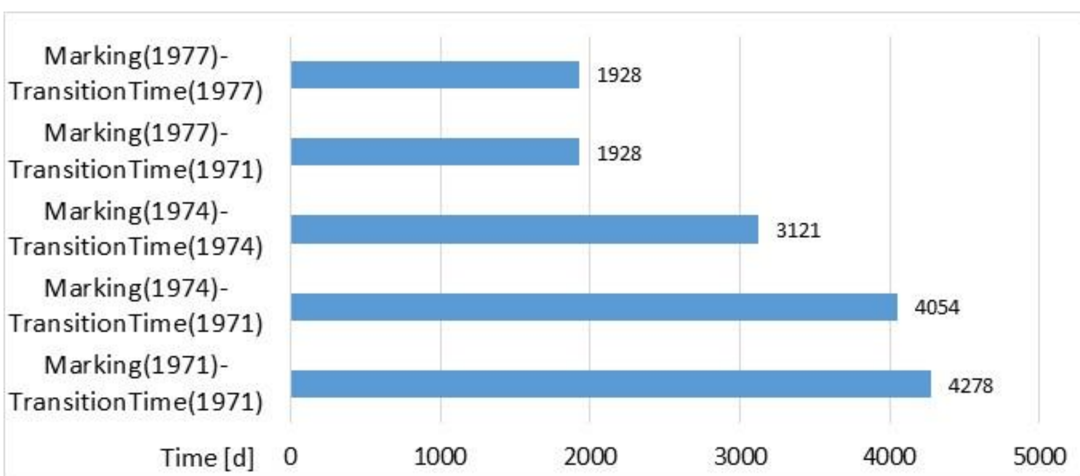


Fig. 33. Impact of initial marking and updated transition times on South African HEU cold tested Latency standard time.

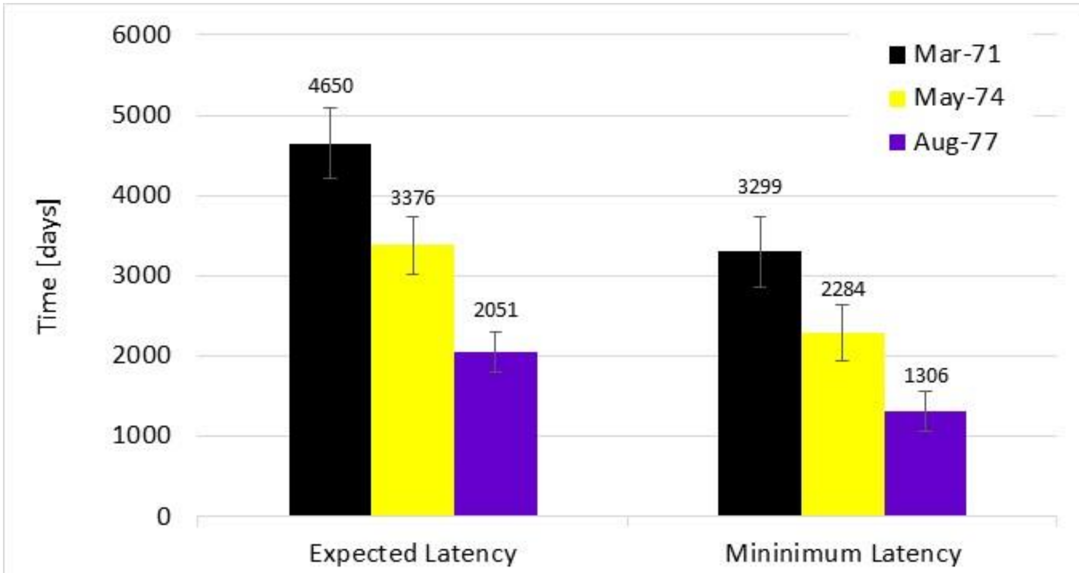


Fig. 34. South African Latency times from varying proliferation decision dates.

Fig. 34 shows the results of stochastic simulations from each proliferation decision date with appropriate transition times. Proliferation assessments tracing the South African program at the time likely showed similar progress as the South African program advanced. The expected and minimum Latency times shown in Fig. 34 are clearly trending down (and eventually reach zero).

The conclusion for a policymaker in the late 1970s is that South Africa was making steady and significant progress toward a deliverable nuclear weapon, and the window to stop South African proliferation was closing. Given the network assumptions, the analysis indicates that in 1977, South Africa could have developed a weapon in as little as ~3.5 years while proliferation was expected in ~5.5 years. It remains debatable whether any timely policy action could have stopped South African proliferation. Regardless, the situation rectified itself when South Africa de-proliferated in the 1990s.[67]

VII. MULTI ATTRIBUTE UTILITY ANALYSIS PATHWAY SELECTION

As seen in the Pakistani case, a state may choose a proliferation pathway based on factors other than the fastest proliferation time. For Latency simulations in the previous sections, the Latency tool selected proliferation pathways during simulations at random. Proliferators are not randomly making pathway choices. Their decisions are based on multiple criteria driven by nuclear weapons program intentions derived from proliferation motivations.[23,71] The previous sections demonstrated that the choice of proliferation pathway taken influences proliferation time and Latency. Thus, a method capable of accurately simulating proliferator pathway decision making during the Latency simulation might improve the expected Latency results generated by the Latency tool. Such a functionality could be built to allow for dynamic path selection response during the stochastic evolution of the Petri net based Latency simulations. Multi-Attribute Utility Analysis (MAUA) is a well-known method for simulating multiple criteria based decision making.[46] An MAUA capability for biasing pathway decisions was built and implemented as an option in the Latency tool.

VII.A. MAUA Theory

MAUA is an extension of Utility theory. [46,72,73] Utility can be thought of as one's happiness or satisfaction with a specific item such as money or an attribute such as color and is defined as

$$U = u(x), \tag{9}$$

where U is the utility value, $u(x)$ is the utility function of x or utility for x, and x is the value of the item considered.[72] When utility values are uncertain expected utility theory may be applied to determine the expected utility

$$E[U(F_a)] = \int u(x) dF_a(x), \tag{10}$$

where $F_a(x)$ is the cumulative probability distribution of item x from the outcome of selection of option a where a is one option of the decision set A.[73] Use of expected utility theory requires preservation of three normative axioms: weak preference ordering (completeness and transitivity), continuity, and independence.

MAUA is a method of aggregating independent utility factors for decision making and will be applied to simulate proliferation pathway decision making by the proliferating state. MAUA is used to rank order pathways based on proliferator preferences for attributes. Assuming the conditions of mutual utility independence and the more restrictive additive independence allows use of the additive form of the Multi-Attribute Utility Equation:

$$U_p = \sum_i k_i u_i\left(x_{i,p}\right), \tag{11}$$

where U_p is the utility of path p, k_i is the normalized weight ascribed to the value of attribute i where $\sum k_i = 1$, u_i is the utility equation of attribute i, and $x_{i,p}$ is the value of attribute i for path p. The utility value is evaluated for all events on path p. Additive independence requires that the preference for values of one attribute is not affected by variation of the values of another attribute. It is believed that additive independence may be safely assumed for the attributes to be discussed. However, it has been shown that even when additive independence fails, the additive utility equation approximates the results of more complex utility equation forms well and thus may still be used with confidence.[74] If it is later proven that additive independence does not hold, a sensitivity analysis may be performed that repeats the decision simulation with a more complex utility equation form.

VII.B. Proliferation Pathway Preference Attribute Development

Attributes influencing proliferator pathway decisions were developed through an historical case analysis and characterized with expert elicitation. All cases of successful nuclear weapons proliferation and some cases of nearly successful proliferation were analyzed. A gap analysis was performed with the case data to determine general attributes that impact proliferation pathway choices. A survey was then prepared to gain expert opinion to determine appropriate weights.

VII.B.1. Attribute Development and Gap Analysis

In order to select the suitable attributes, it is important to understand the function of the attributes within the applied MAUA model. The MAUA model is used to select between different proliferation pathways. Thus, the attributes must represent characteristics that would lead a proliferator to choose one pathway over another. For example, a proliferator may choose to follow one pathway because it may lead to a nuclear weapon faster than another pathway. Another pathway choice may be made because the state has access to a specific proliferation technology. Table X lists potential attributes that may impact proliferator choices. It should be noted that in Table X, concealability and survivability refer to proliferation pathway facilities. This is a large list of potential attributes (15 attributes total). For preservation of MAUA attribute independence relations and overall functionality, it is desirable to use a smaller number of attributes.

TABLE X

Potential Proliferation Pathway Preference Attributes

Number of weapons	Industrial capacity
Delivery method	Technical knowledge
Sustainability	Technical human capital
Reliability	Non-nuclear materials
Time to 1st weapon	Nuclear materials
Concealability	Fissile material production technology availability
Survivability	
Financial resources	other

To confirm the influence and possibly reduce the number of the potential attributes in Table X, an historical gap analysis was performed. The gap analysis examined the historical record of ten known cases of proliferation and several cases of attempted proliferation and is shown in Table XI. Table XI displays a green box where there is strong historical evidence that the corresponding attribute impacted the proliferation decisions of that state in some way. A yellow box indicates that the attribute may have impacted the state's decisions, but the available evidence is not conclusive. The columns of Table XI correspond to the different potential attributes, and each row is for a different case of successful or nearly successful proliferation. Table XI shows that each of the attributes impacted the decisions of at least one proliferator. Further, the decisions of all states have been impacted by at least one attribute.

The results of the gap analysis are explored in greater detail in Fig. 35 and Fig. 36. Fig. 35 shows the number of impacting attributes for the different proliferation cases studied. In Fig. 35 the vertical axis corresponds to the total number of attributes that affected proliferation pathway choices of proliferation cases which are listed by country with proliferation program dates on the horizontal axis. Specific attribute total numbers are listed as data labels on Fig. 35. The proliferation cases are loosely grouped into three categories: successful proliferation by global powers, successful proliferation by regional powers and aspirants, and nearly successful proliferation (Note: these groupings were based on the proliferating country at the time of the proliferation program).

TABLE XI

Historical Gap Analysis for Potential Proliferation Pathway Preference Attributes

(Notes in the table refer to source reference and page numbers)[2]

	US	USSR	UK	FRA	PRC	ISR	IND	RSA	PAK	DPRK	IRQ	BRA	ARG	LBY	IRN
Number of Weapons	A	A								B					
Delivery method											86, p11				
Sustainability							82, p121								
Reliability	75, p55							63, p43	76, p342						
Time to 1st weapon	75, p53								84,p2 8-29		86, p11				
Conceal-ability					76, p139	81, p110		63, p40-45		76, p522, 530	76, p336, 351	90, p14	69, p47		76, p512
Survivability		76, p66			76, p139	81, p109					76, p336				76, p512
Financial Resources			78, p3-4	79, p40							87, p344	90, p14			
Industrial Capacity							82, p136								
Technical Knowledge		77, p104	78, p3-4	76,p 198	80, p105	81, p29	76, p222	63,p39	76, p330	76, p332	87, p318	90, p6		91,p 5,28	93
Technical Human Capital					80, p105	81, p29	82, p83		76, p330		88, p22	90, p12		91, p6	
Non-Nuclear Materials			78, p3-4						76, p330	85, p14	87, p343	90, p4			
Nuclear Materials				79, p41			82, p84					90, p14	69, p47		
Fissile Material Production Technology Availability					80, p105	81, p29	82, p90-93		76,p 328-330	76, p530	89, p35-36	90, p14		91, p5	93
Other	58, p551				80, p118		83. p174	63, p41	62, p230	76,p525,5 57	76, p321	90, p6		92	

[2]A-Size of initial U.S. and Soviet facilities are judged indicative of the desire for a large number of weapons altering the path. B-Size of DPRK 50 MWe and 200 MWe reactors are judged indicative of the desire for a large number of weapons altering the path.

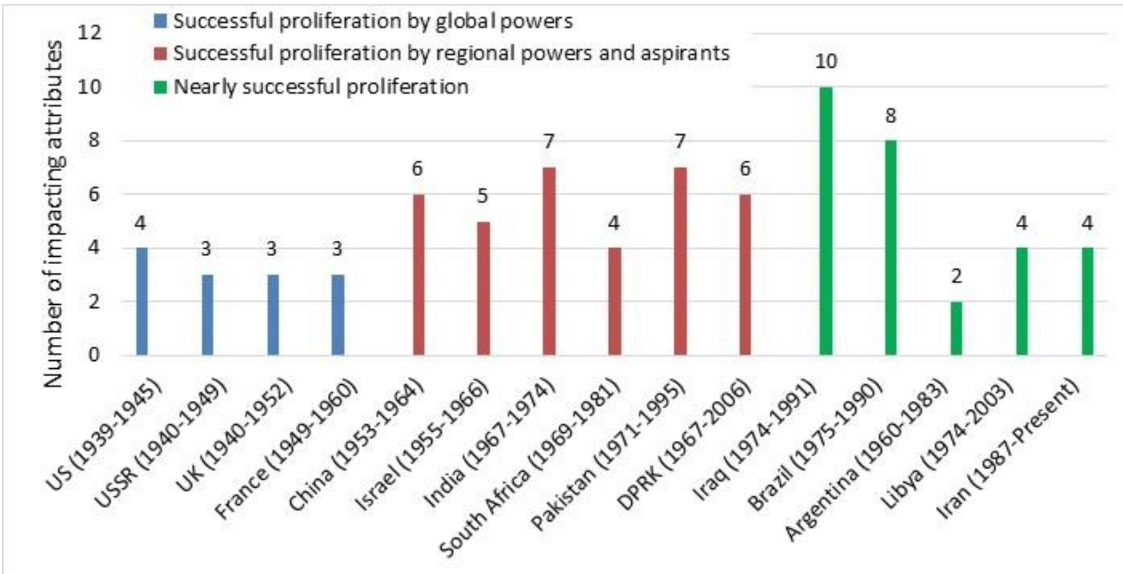


Fig. 35. Impacting attribute totals for historical cases of successful proliferation and near successful proliferation.

A few conclusions may be drawn from Fig. 35. It appears that proliferation by the global powers was generally less impacted by potential pathway attributes than proliferation by regional powers or aspirants. This may be a result of varying levels of capabilities and resources between the two groups. Nearly successful cases of proliferation display a broad range of impacting pathway attribute totals. Some cases proceeded farther than others and at least one case has not yet concluded. So the breadth of results may be expected.

Fig. 36 examines the gap analysis results by attribute. The vertical axis in both Fig. 36a and b is the total number of cases impacted by each potential attribute in Fig. 36a and by the attribute group category in Fig. 36b. The number of weapons, delivery method, and reliability attributes were grouped together as deterrent goals. The time to first weapon, survivability, and concealability were grouped as program goals. Financial resources, industrial capacity, technical knowledge, technical human capital, non-nuclear materials, and nuclear materials were grouped as resources. Fissile material production technology availability was labeled as a more specific program resource. The number of times a potential attribute or attribute group, as a percentage of the total number of times all attributes impact proliferation, was listed on Fig. 36 as data labels with the associated attribute or attribute group.

The results shown in Fig. 36 carry several implications. In Fig. 36a, technical knowledge stands out as the single attribute that affected the most nuclear weapons programs with 13 cases impacted. This result is followed by fissile material production technology availability and the other category, impacting 9 cases of proliferation. Concealability and technical human capital also stand out with 8 and 7 cases impacted respectively. This result suggests that states may bias their pathway selection on specific knowledge (possibly contained by specific persons) or technology, such as centrifuges, that may be immediately available and/or easily concealed. Fig. 36(b) also reveals that resources have shaped programs more often than goals. The significance of the 'other' category, which impacted at least 9 cases of proliferation, suggests that while there are some general factors that influence pathway decisions, very often decisions may be made on factors unique to that particular proliferator. Since it was impossible to characterize, 'other' was dropped from attribute consideration.

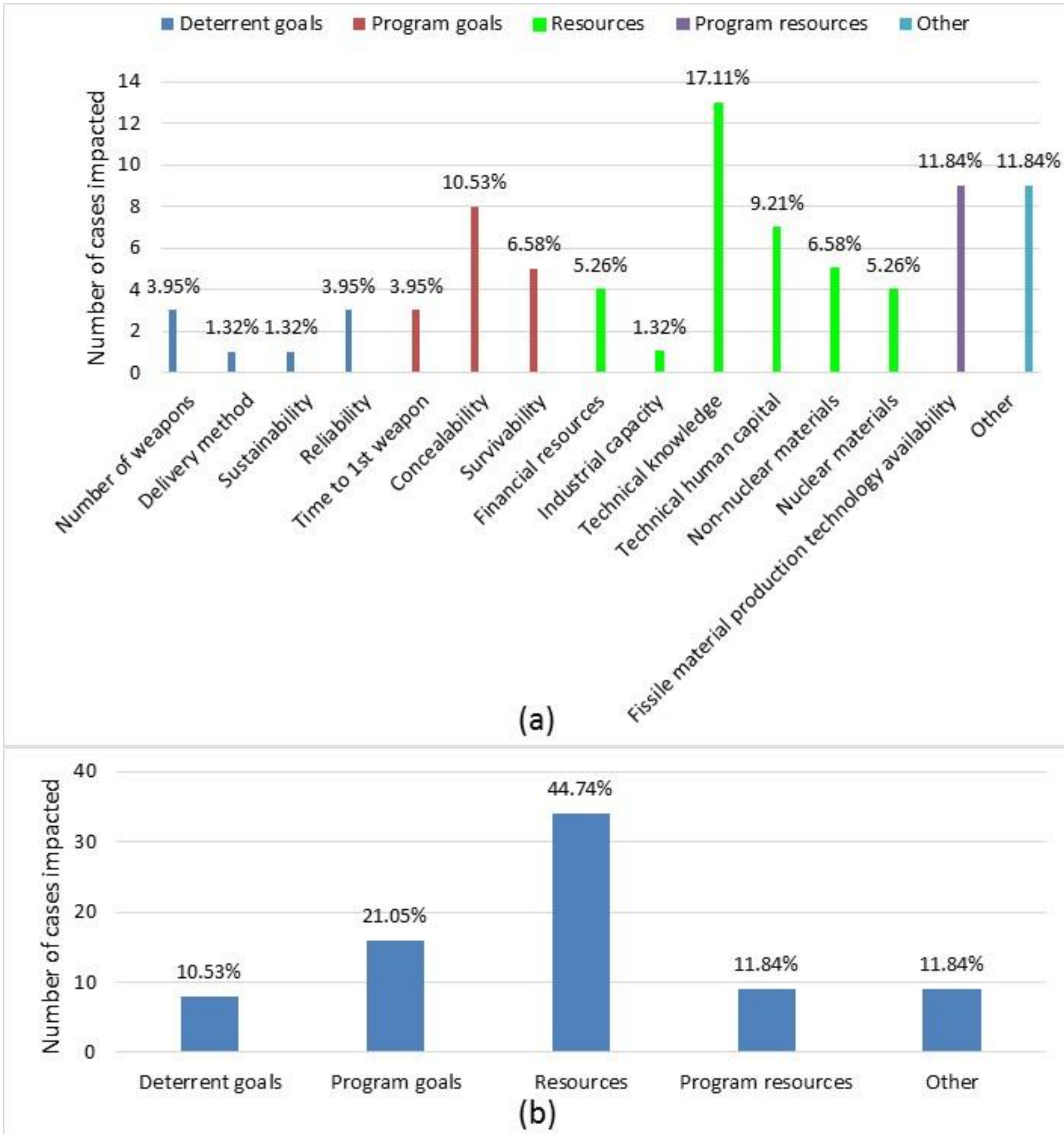


Fig. 36. Proliferation pathway attribute gap analysis results showing the total number of historical proliferation cases impacted by a) each potential attribute and b) each attribute group category.

The gap analysis confirmed the impact of the proposed proliferation pathway attributes. However, the use of fifteen attributes could have compromised the initial additive independence assumption while making the overall analysis cumbersome. To reduce the number of attributes, it was assumed that a state will make pathway decisions based on goals and the likelihood of achieving success for those goal-driven pathways. The resources of a state determine those likelihoods of success. This assumption reduced the list of attributes by half.

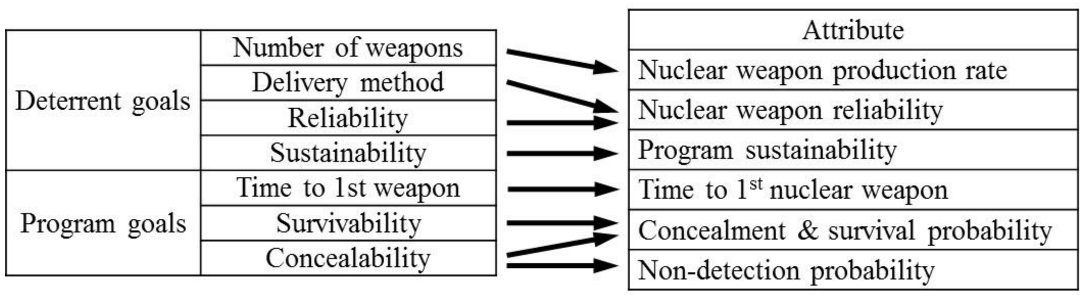


Fig. 37. Proliferation pathway attribute mapping from the goal attributes of the gap analysis.

Fig. 37 shows a mapping of the reduced goal attribute list to the final simplified attribute list. The nuclear weapons production rate is used as a representative metric for the final deterrent size goal. Nuclear weapon reliability refers to both reliable delivery and reliable explosive function at the intended target. Program sustainability refers to the ability to sustain the weapons producing program of the selected pathway after the first weapon has been produced. Concealment and survival probabilities are combined due to lack of complete independence. However, to allow for a focus on the application of safeguards, non-detection probability of materials diversion is drawn out from the more general concealability. Independence from concealment and survival probability is maintained by noting that not declaring a facility to the IAEA for safeguards application is different than concealing a facility from international detection. Table XII gives complete attribute definitions.

TABLE XII

Proliferation Pathway Attribute Definitions

Attribute	Definition
Time to 1st Nuclear Weapon	Time required to acquire the first deliverable weapon on a particular pathway
Nuclear Weapons Production Rate	Annual nuclear weapons production rate expected from a particular pathway (a metric related to the total number of weapons or deterrent size desired by the proliferator)
Concealment & Survival Probability	The probability of undeclared facilities of a particular pathway being concealed from foreign detection or of facilities of a particular pathway surviving conventional foreign attack
Non-Detection Probability	The combined probability of failing to detect the diversion of a significant quantity of nuclear material to a nuclear weapons program from the facilities of a particular pathway. The non-detection probability of an undeclared facility is 100%.
Nuclear Weapon Reliability	The probability of the nuclear weapon produced by a particular path to detonate on target at the designated yield. This accounts for expected adversary countermeasures.[3]
Program Sustainability	The ability of the state to independently maintain and supply the weapon producing program (and weapons) of a particular pathway after the 1st weapon is produced

[3] This is similar to the weapons reliability measures discussed in Appendix F of the ref. 94 the *Nuclear Matters Handbook*.

VII.B.2. Nuclear Weapons Proliferation Pathway Utility Attribute Weighting Survey

The Nuclear Weapons Proliferation Pathway Utility Attribute Weighting Survey (NWPPUAWS) was developed as an efficient method to obtain expert opinion on appropriate attribute weights.[95] Expert elicitation is a frequently used technique when the actual decision makers are unavailable or the appropriate weights are not known *a priori*.[96,97,98] The survey was administered online. The method of the survey was to find when a user is indifferent between two options with varying values of two attributes and all other attribute values being equal.

VII.B.2.a. NWPPUAWS Description

Specifically, the survey operates in the following manner. The survey begins by presenting the user two options comparing the values of two attributes. The first option contains the best value of the first attribute and the worst value of the second attribute, while the second option contains the worst value of the first attribute and the best value of the second attribute. Based on the user preference of the two options, the worst value of the non-preferred option is made incrementally better until the user is indifferent between the two options. The values of the attributes at the indifference point are logged, and the user is presented with two new options.

The ranges of attributes used in the survey are listed in Table XIII. The first column of Table XIII notes each attribute. Next the table gives the range of attribute values considered from the worst value in the second column to the best value in the third column. The units of the values for each attribute are given in the last column of Table XIII.

TABLE XIII

Attribute Ranges Used in NWPPUAWS

Attribute	Range		Units
	Worst	Best	
Time to 1st Nuclear Weapon	20	1	Years
Nuclear Weapons Production Rate	5	50	Weapons/ year
Concealment & Survival Probability	20	80	% C&S Probability
Non-Detection Probability	20	80	% Non-Detection Probability
Nuclear Weapon Reliability	20	80	% Reliability
Program Sustainability	20	80	% Sustainability

The survey response is illustrated in Fig. 38 and Fig. 39. The user is initially presented with the comparison of Fig. 38. Assuming the user prefers option 1, the survey responds by adjusting option 2 as shown in Fig. 39. The survey proceeds in this manner until the user is indifferent. At this point the survey presents a new comparison involving different attributes. Based on the attribute values at indifference, ratios of the attributes may be derived which lead to values of the attribute weights.

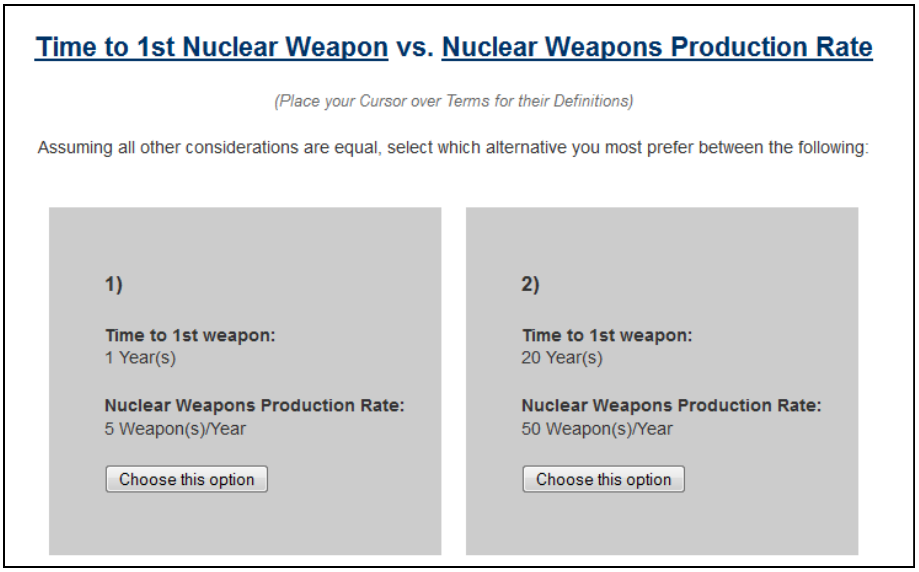


Fig. 38. Initial comparison presented to the user by the NWPPUAWS.

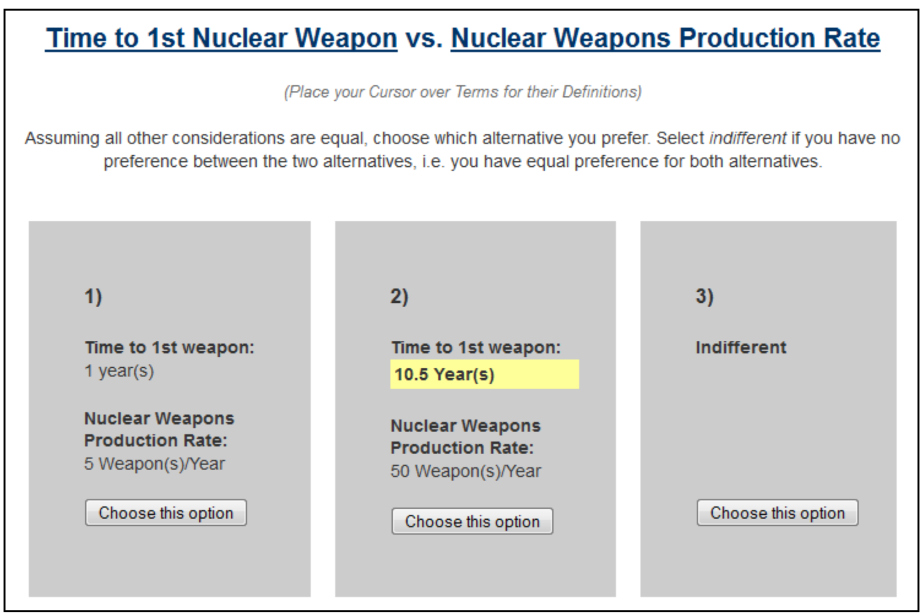


Fig. 39. NWPPUAWS response to selection of option (1) during the initial comparison.

For this survey each attribute is compared in options with the first attribute, time to first nuclear weapon. This was done for two reasons. It was expected that time is always a critical factor (if not the most important factor), and time is a readily quantifiable attribute that is likely easier to understand for users than some of the other attributes. It should also be noted that linear utility functions were assumed for each attribute when determining the attribute weights from the indifference point attribute values.

VII.B.2.b. NWPPUAWS Results

The NWPPUAWS participation was specifically solicited from known experts in addition to being available to the public. These experts were broken into groups based on their expertise shown in Table XIV and given an anonymous code to track their survey results as a group. Additional information requested included education level: professional degree, undergraduate degree, or high school; employment sector: academic, government, industry, or other; and professional discipline: technical, social science, or other. Obviously it was possible that respondents may not report any or all supplemental information including the group code given to the solicited experts. Solicited experts were also divided between two provided country profiles which were denoted in their given code:

- Regional Power – characterized as facing a persistent, elevated (though not immediate) threat from an adversary with an overwhelming military advantage. A regional power may be able to project power beyond its own region and may have global economic impact. A regional power can generally resist all but unanimous foreign non-military pressure, unless the pressure comes directly from a superpower patron to which the regional power is economically and/or strategically bound. A regional power has ample though not unlimited resources available for proliferation.

- Regional Aspirant – characterized as facing a persistent, elevated (though not immediate) threat from an adversary with an overwhelming military advantage. A regional aspirant may be able to project power within its own region though it is not the dominant regional power. It can resist significant foreign non-military pressure, though its response to such pressure may depend on the support or ambivalence of specific permanent members of the UNSC. The resources of a regional aspirant may be limited but such resources are adequate to proliferate.

TABLE XIV

Solicited Expert Groups and Participation

Group	**Proliferation Experts**	**Intelligence Analysts**	**Technical Nuclear Experts**	**Nuclear Policy Experts**
Solicited	31	11	10	22
Responded	8	4	4	4
Response Rate [%]	25.81	36.36	40.00	18.18
Total Expert Participants	20			
Group	**Texas A&M University Students***			
	Undergraduate Nuclear Engineering	**Masters Nuclear Engineering**	**PhD Nuclear Engineering**	**Masters Gov't & Policy Students**
Solicited	4	18	8	7
Responded	2	14	8	2
Response Rate [%]	50.00	77.78	100.00	28.57
Total Student Participants	26		Total Survey Participants**	57

*All student participants are associated with the Nuclear Science & Security Policy Institute through research activities or coursework. **Includes additional participants who either did not report a group code or were not directly solicited.

Table XV shows the mean attribute weights with associated standard deviations determined from the responses of all participants. The first column of Table XV identifies the attribute by name. The second and third columns relate the associated mean and standard deviation respectively for each attribute. The Time to First Weapon (TTFW) was clearly the most preferred attribute, while the Nuclear Weapons Production Rate (NWPR) was the least preferred. The remaining attributes were similarly preferred, with possibly a slight preference for concealment & survival probability (C&S) and non-detection probability (NDP) over reliability (Rel) and sustainability (Sus), but such distinction may not be justified given the standard deviations. Numerical data for all the mean attribute weights and corresponding standard deviations in all possible grouping breakdowns are given in Appendix L in Table L.1. Specific illustrative plots of the data for selected attributes and groupings are discussed below.

TABLE XV

Mean Attribute Weights and Standard Deviations from All Survey Participants

Attribute	**Mean**	**Standard deviation**
W(TTFW)	0.3	0.27
W(NWPR)	0.05	0.06
W(C&S)	0.18	0.15
W(NDP)	0.18	0.13
W(Rel)	0.15	0.13
W(Sus)	0.14	0.12

Fig. 40 and Fig. 41 illustrate the combined results with more detail than Table XV. Fig. 40a relates the resultant attribute weights derived from all survey responses with the attribute as the vertical axis. Fig. 40b relates the same data excluding the student results. The data for each attribute is plotted in the order of weight(TTFW), weight(NWPR), weight(C&S), weight(NDP), weight(Rel), and weight(Sus) with the associated mean following each attribute data set. The standard deviation for each attribute data set is shown as error bars on the associated mean.

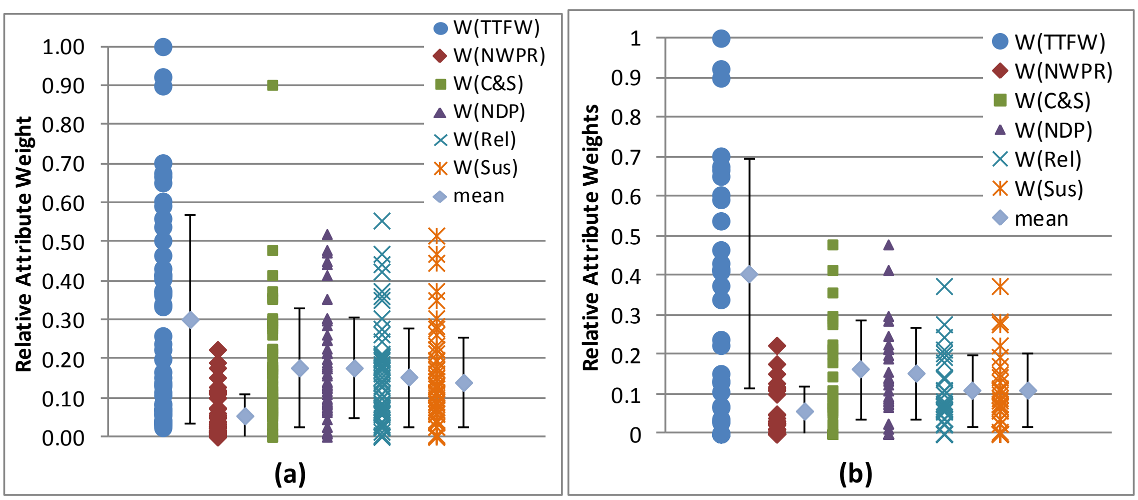


Fig. 40. Preferences for each attribute from (a) all survey results (b) survey results excluding student responses.

Fig. 41 plots the frequency on the vertical axis as function of attribute weight for each attribute. Again, all data is included in Fig. 41a while Fig. 41b excludes the student results.

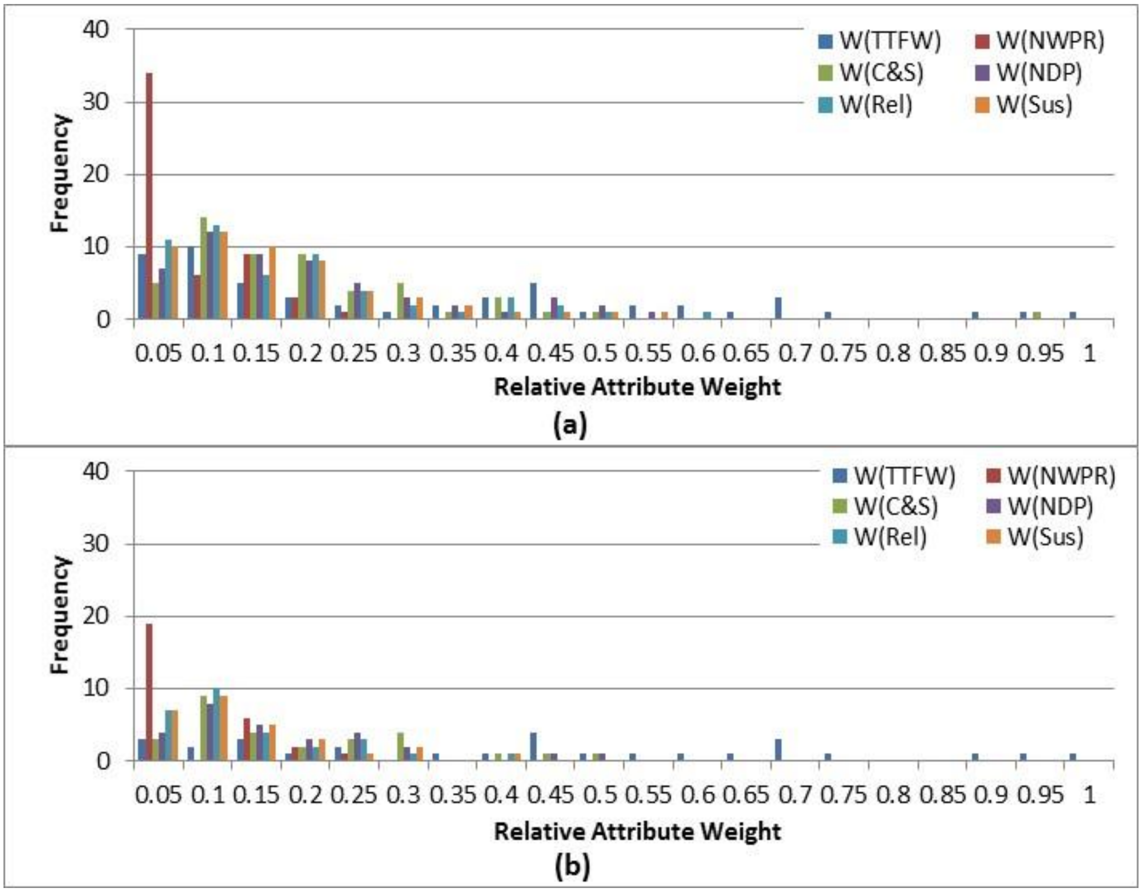
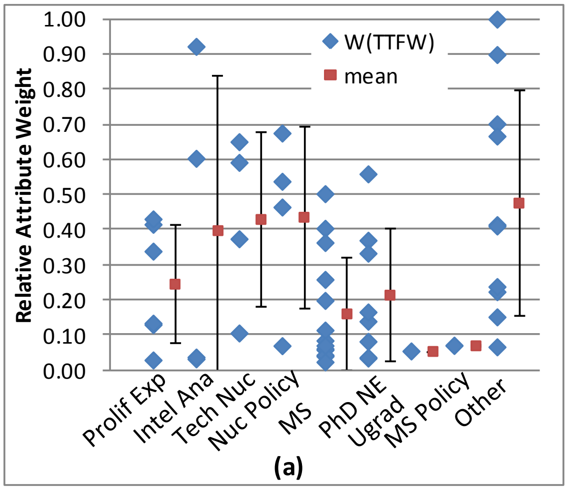


Fig. 41. Frequency of relative attribute weights derived from (a) all survey results and (b) survey results excluding students.

Fig. 40 and Fig. 41 present interesting expert insight. The preference for TTFW appears to have a bimodal (or perhaps trimodal) distribution with peaks at approximately 0.1 and 0.45 (and possibly 0.7) with a long tail extending to a weight of 1. NWPR also appears to be bimodal even in its lack of preference. One group has a very strong distaste for NWPR giving it a weight below 0.05 and the other mode prefers it in almost Gaussian fashion about a peak weight of 0.15. The preference for C&S, NDP, Rel, and

Sus all appear to be a single distribution with a peak around 0.1 and long tail above ~0.20.

Fig. 40b and Fig. 41b also reveal the influence of the surveyed students as a group. From the shifts in distributions and means, it is clear the students had less preference for TTFW than the other participants and greater preference for the fuzzier probabilistic attributes than the other participants. It was expected that the more easily quantifiable attributes would be preferred over the probabilistic attributes. Thus a lack of student group bias towards TTFW was somewhat surprising. As is shown in Table N.1, the students actually prefer all attributes about the same except NWPR, which they prefer less than the others. The removal of the students also reveals a gap in the preference for NWPR by the professionals, emphasizing the bimodality between those that find a modest value in NWPR and those who find it totally irrelevant. Further, some bimodality may exist for the professionals in their preference for C&S, NDP, Rel, and Sus. Secondary peaks may exist at 0.25 for NDP and Rel and at 0.3 for C&S and Sus.



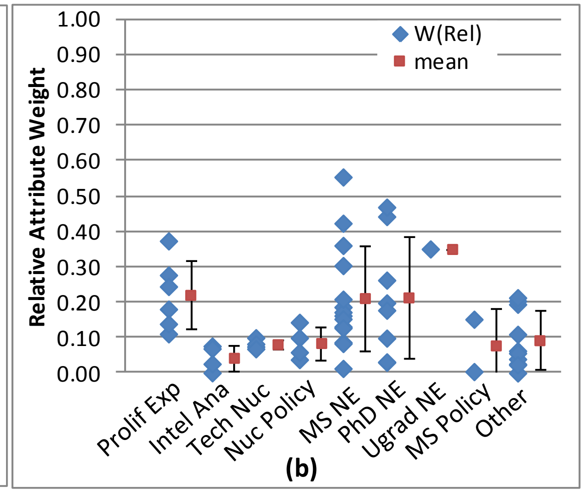


Fig. 42. Attribute weights per expert group for (a) TTFW and (b) Rel.

Fig. 42 shows the attribute weights by group for TTFW and Rel. The vertical axis charts the relative attribute weight, and each expert group is listed on the horizontal axis in the order of proliferation experts, intelligence analysts, technical nuclear experts, nuclear policy experts, Master's nuclear engineering students, Ph.D. nuclear engineering students, undergraduate nuclear engineering students, Master's policy students, and those that did not identify. The associated mean attribute weight with the standard deviation as error bars is shown after each corresponding data set.

As discussed above, the students prefer TTFW less than the other groups and about equally to the probabilistic attributes, such as Rel. All the student results appear to have a bimodal distribution with a tight cluster below ~0.20. This is true for the other attributes as well, indicating that even though all the students do not necessarily think alike there may be a few groups of students that are like minded.

There may also be small groups of like-minded thinkers within the Academia profession as shown in Fig. 43. Fig. 43 depicts the attribute weights for TTFW and NDP from each employment sector shown in the order academia, government, industry and those that did not report. The means of Fig. 43a show that government employees have greater affinity for TTFW than those employed in academia, who seem to prefer other attributes equally to TTFW, such as NDP in Fig. 43b. This finding may indicate a more realistic view of government employees relative to academics. It should be noted though that the students may have also reported themselves working in academia and may thus be responsible for the skew.

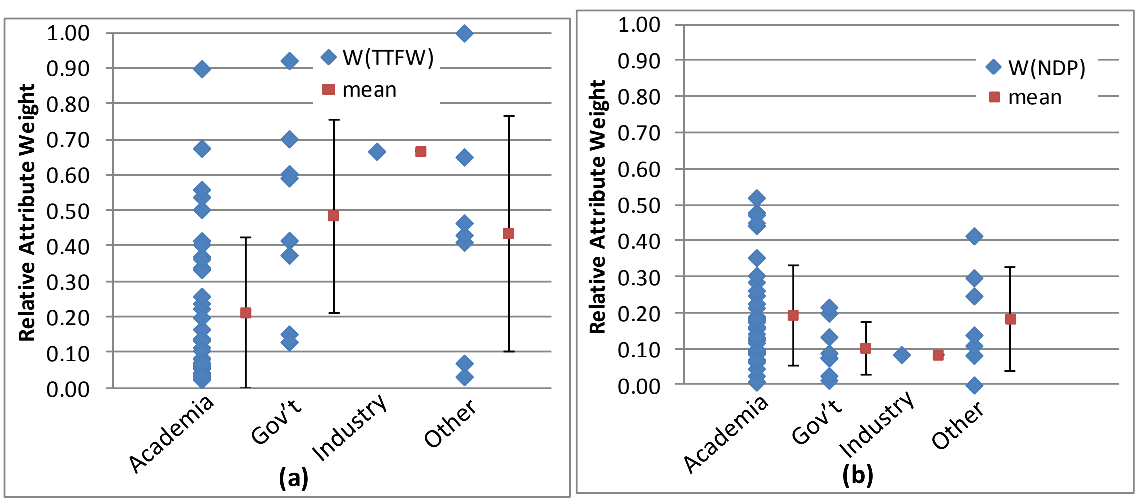


Fig. 43. Attribute weights per employment sector for (a) TTFW and (b) NDP.

Fig. 44 and Fig. 45 depict attribute weights for TTFW and C&S per professional discipline and attribute weights for TTFW and Rel per country profile (regional power or regional aspirant) respectively. Together Fig. 44 and Fig. 45 show that there is generally little difference when dividing between the technical and social scientists or when dividing between regional power or regional aspirant country profiles. The only possible exception is illustrated in Fig. 44b with a higher preference for C&S by social scientists than technical scientists. This result could indicate greater faith of social scientists in the international community's ability to detect nuclear proliferation than technical scientists and thus a greater desire to be able to hide proliferation. Such an explanation is one of many though that could explain a difference that is within a standard deviation from both means. The bimodal distribution of TTFW is clear in both Fig. 44a and Fig. 45a. That there is little difference between the preferences of technical and social scientists and those with different country profiles is somewhat surprising. Perhaps the two professional disciplines think more alike than is commonly believed. The indifference between country profiles means specific countries should not be stereotyped by their profiles.

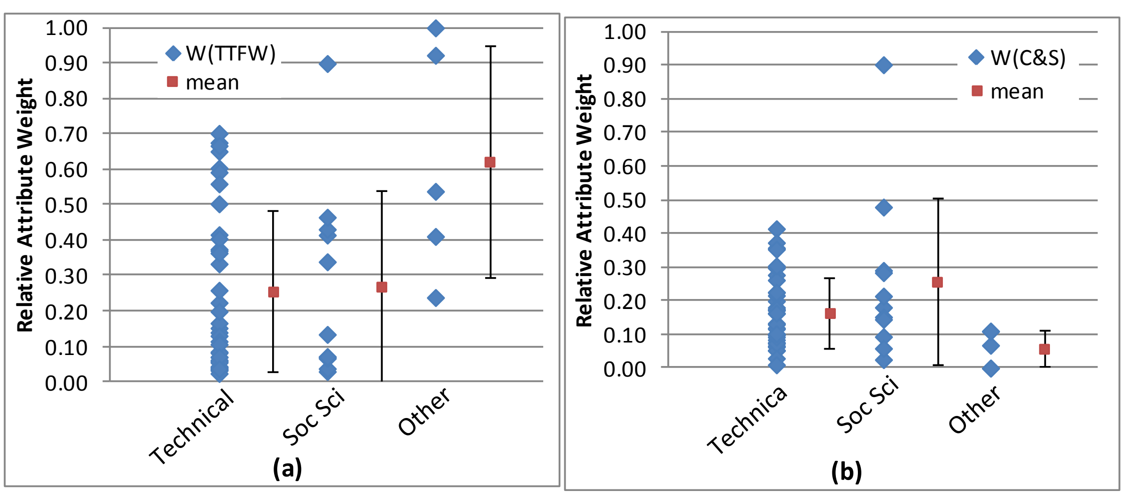


Fig. 44. Attribute weights per professional discipline for (a) TTFW and (b) C&S.

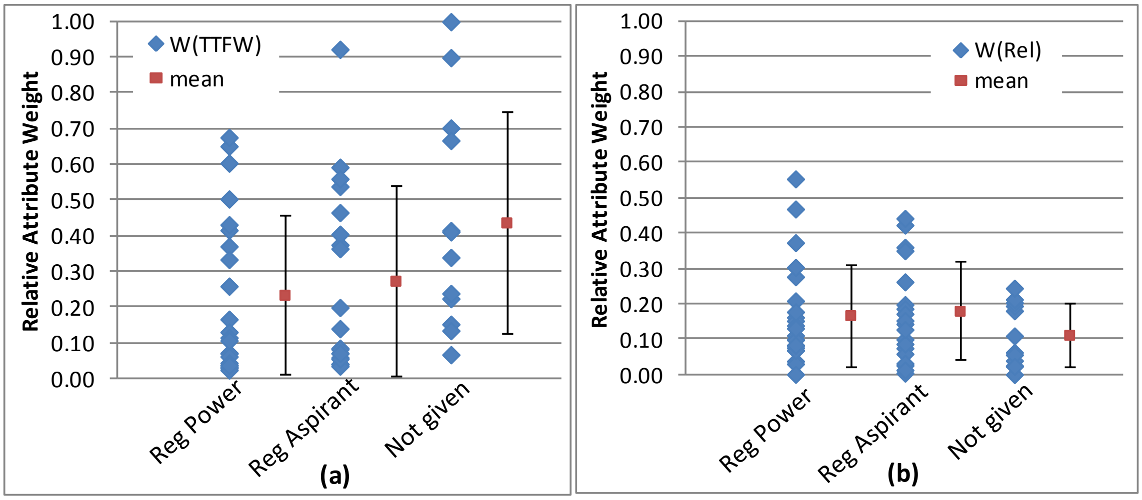


Fig. 45. Attribute weights per country profile for (a) TTFW and (b) Rel.

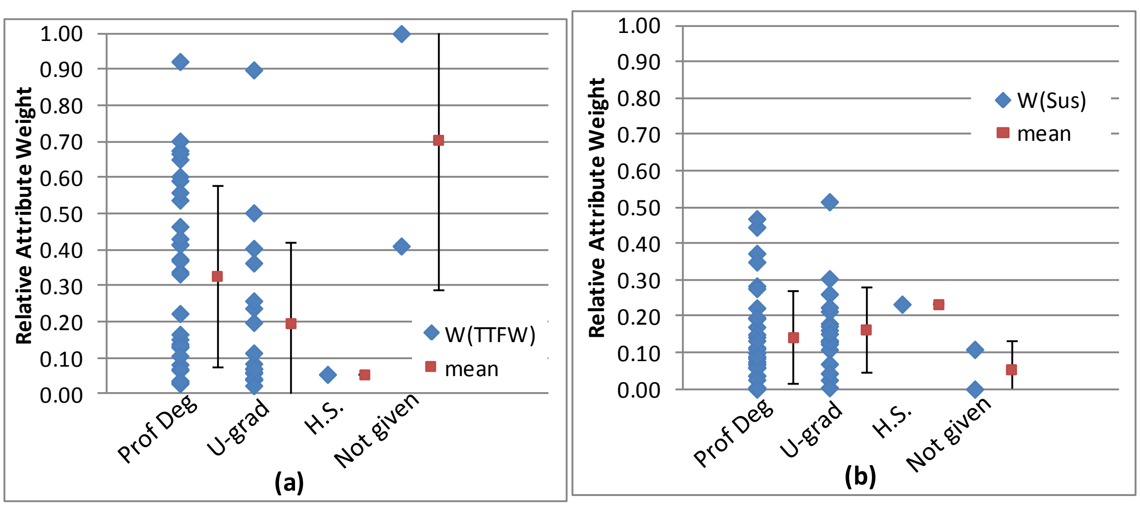


Fig. 46. Attribute weights per education level for (a) TTFW and (b) Sus.

Fig. 46 illustrates the TTFW and Sus attribute weights per education level. Little difference between mean attribute weights exists for different education levels except for

TTFW. It should be noted education level basically separates out the Masters level students, which could explain the lower mean value of the TTFW weight.

VII.B.2.c. NWPPUAWS Conclusions

There were several overarching conclusions that may be drawn from this survey. The focus of the overall Latency project on the time to acquire a first deliverable nuclear weapon was validated by the preference of survey participants for TTFW. The impact of the NSSPI students should not be disregarded. Participation of a more diverse set of students would be useful. The lack of impact of the country profiles was noteworthy. If insights about preferences cannot be gleaned from country profiles, then such insights may only be gained through a deeper understanding of the decision makers governing those states.

This survey may have also had some flaws. At least one participant reported being confused by the survey, and it is possible the results of that participant and others did not reflect their true preferences due to such confusion. It is possible participants that were given a country profile did not actually incorporate the profile into their thinking. The survey did not apply any techniques for judging participants use of the provided data.

The data from four respondents was deemed unusable. Those respondents had at least one attribute they preferred regardless of time. Their results thus weighted time as insignificant compared to at least one other attribute. In one case, time was insignificant to only NWPR. In this case it may be possible to infer that the respondent viewed NWPR as the only significant attribute (i.e. a weight of one) since NWPR dominated TTFW but TTFW was proportional the other attributes. However, this inference is weak without a direct comparison of NWPR to the other attributes, and even if it were true, a NWPR weight of one would clearly have been an outlier given the other participants survey data. In the three other disregarded cases, the respondents weighted time as insignificant to multiple other attributes. In these cases even weak inferences were impossible.

Potential survey changes may alleviate some of the difficulties. Avoiding unusable results may be possible if the ranges of the attributes were extended. For example, a NWPR of 50 weapons/year may not be absolutely preferred if it involved a TTFW of 40 years as opposed to the 20 years that was used. Though, it may be hard for respondents to accurately assess larger ranges than were used. Even if respondents could think in a time frame longer than 20 years it is hard to imagine a government being able to embark on and sustain a research and development project that is expected to last longer than thirty years. Changing the survey so that time is not the only basis for comparison may also help. However, in almost all cases, time was an appropriate basis for comparison, and in most cases time was the best basis for comparison as it was the most important attribute. One other obvious place for improvement is the participants. While all were clearly experts in their fields, none were actual or aspiring proliferators themselves. The responses of nascent or experienced proliferators would be ideal, though obtaining such participation would likely prove elusive. With fully characterized attributes, the proliferation pathway MAUA may now be applied to the Latency tool.

VII.C. Petri Net MAUA Function

MAUA was applied and built as a plug-in function to the existing Latency tool which may be either turned on or off. A different MATLAB sub-function was coded for each of the six proliferation pathway utility attributes. The six attribute sub-functions are called from a higher-level MAU function which aggregates the independent utilities of each path. The MAU function was plugged into the main Petri Net loop of the Latency tool where it can be optionally utilized in place of the random path selection. Each of the six utility sub-functions, the utility aggregation function, and the additional inputs necessary are discussed here in reverse order.

VII.C.1. Additional MAUA Excel Inputs

Four new excel sheets were developed to incorporate the MAUA capability into the latency tool: ‘MAUA Data’, ‘Red-Flow’, ‘Red-CS’, and ‘ProlifData’. The column headings for the input data in the ‘MAUA Data’ Excel sheet are given in Table XVI (transposed to conserve space). The first row of Table XVI, which refers to the first column in the MAUA Data Excel sheet, denotes a row in the Excel sheet for every transition. Transitions that do not require values for any of the MAUA parameters may be left as zero in the Excel sheets.

TABLE XVI

MAUA Data Excel Sheet Column Headings

Transitions
NWPR: Facility Outflow [SQ/yr]
C&S = .25/.5/.75 (Low/Med/High) for Facility Transitions
NDP (IAEA)
R-NeDesign =.25/.5/.75 (Low/Med/High) for weapon transition
R-DS-Range [km]
R-DS-Type
Technical Challenge to Sustain facility [3=Significant,1=Moderate,0=No Challenge]
Sustainability: U or Pu Inflow [kg/yr] (IGNORE USource)
Sus: facility lifetime [yr]

The first three rows of Table XVI (or MAUA Data Excel sheet columns) are self-explanatory. These values are attached to transitions representing either facility construction or facility operation. As long as a single facility does not get marked twice (e.g. for both construction and operation), the computation is indifferent. NWPR utility calculation requires facility outflow in IAEA significant quantities per year.[99] For each facility, C&S needs the user to assign one of the three probability rankings: high (0.75), medium (0.5), low (0.25). This coarse ranking is sufficient for the ordinal, as opposed to cardinal, attribute utility calculation. NDP calculation uses the IAEA non-detection probability for each pathway facility.

The next three rows of Table XVI (or MAUA Data Excel sheet columns) designated 'R-' refer to reliability parameters. 'R-NE' refers to the reliability of the nuclear explosive design and type of testing. Table XVII shows the suggested nuclear explosive (NE) reliabilities as low (0.25), medium (0.5), high (0.75). 'R-DS-Range' is simply the range in km of delivery system attached to single delivery system transition. 'R-DS-Type' is simply a value 1-3 denoting the type of delivery system: 1=Airdrop, 2 = Missile, 3=Artillery.

Table XVII

Suggested Nuclear Explosive Reliabilities

	Reliability rating by test type		
Weapon Type	**None**	**Cold**	**Hot**
Gun	0.5	0.75	0.75
Implosion	0.25	0.5	0.75
Boosted	0.25	0.25	0.75
Thermo-nuclear	0.25	0.25	0.5

The final three rows of Table XVI (or MAUA Data Excel sheet columns) deal with the Sustainability attribute. The first is a measure of how technically challenging a facility is to maintain relative to the capabilities of the state. Technical challenge may be rated as follows with the corresponding value: 3-significant challenge, 1-moderate challenge, and 0-no challenge. The second row is simply the facility inflow in kg U (or Pu). The final row (Excel sheet column) is expected facility lifetime in years.

The Excel sheets 'Red-flow' and 'Red-CS' deal with pathway facility redundancy. Redundancy refers to facilities that repeat the same capability. The two redundancies can be different. The flow itself is measured in units of IAEA significant quantities for use by the NWPR function. This unit of measure is used so that total weapon production may be counted regardless of the weapon material HEU or Pu. As such HEU enrichment and Pu production facilities are flow redundant. This flow redundancy is in contrast to C&S redundancy where a plutonium production facility cannot replace the pathway and material specific capability of an HEU production facility. Of course, the user may have a different interpretation and can define the sheets the same if desired.

Both redundancy sheets have the same format. The input data table is a transition by transition matrix, with transition names listed in the first column and first row of the Excel sheets. If two transitions T_j and T_k are redundant then a value of 1 is placed in both matrix elements (j,k) and (k,j). All other matrix elements are zero.

The 'ProlifData' sheet has one table specifying additional information about the proliferator. The input table is repeated below in Table XVIII. The first column of Table XVIII gives the row headings found in the ProlifData sheet. The second column is a description of the table value for that row. The user may need to update Excel sheet cell references in the Latency tool batch input file depending on how many adversary targets are listed. Additional input parameters specified in the batch file are discussed with the attribute functions for which they apply.

Table XVIII

ProlifData Excel Sheet Table and Values

Row heading	**ProlifData table value description**		
Range To Adversary Targets [km]	RAT1	RAT2	Etc.
Adversary Defense Rank	1=Superior, 2=Comparable, 3=Inferior	--	--
Uranium Data (reserves stocks) [MT]	reserves	stocks	--

VII.C.2. PetriPathMAUA

The independent utilities are aggregated through a separate MAUA function. This function begins by generating an empty $(paths) \times (transitions)$ matrix. This matrix is filled with attribute utility values by iterating through each path calling each attribute utility function. These attribute utilities are normalized among paths by the maximum utility for each attribute from all paths. Pathway utilities are then summed according to Equation (11). At this point, the previous path utility is multiplied by the user defined current path weight as input in the batch file. This approach can help account for any previous choice commitment biases the user feels may exist within the proliferating state. The path may then be selected either with path probabilities weighted by the determined utilities or simply by the maximum utility as specified in the batch file.

VII.C.3. Independent Attribute Utility Determination

Separate MATLAB functions were developed for each of the six pathway attributes. Appropriate utility equations would likely be difficult to elicit from potential proliferators. Therefore the simplest form, linear attribute utility equations, were assumed. All attribute utility equations were positive linear with the exception of TTFW which was negative linear for increasing time. The attribute functions are discussed in order TTFW, NWPR, C&S, NDP, Rel, and Sus.

It is expected that states have sophisticated means of estimating project time, and the TTFW should share this sophistication. The Latency tool already has a sophisticated Petri Net simulation built and this is re-used. Future time is an uncertain value, so expected utility is taken with a Latency time distribution generated by a separate Petri Net sub-function. This TTFW simulation uses the existing transition data set. The user inputs the number of iterations for TTFW simulations in the batch file. To save on computational time, the default is one iteration while taking the mean of the transition time pdfs for time sampling.

An interesting analysis could be done if the TTFW simulation was run with a different transition data set than the main Petri Net. This approach could provide analysis of a situation where a proliferator's expectations are different than reality and would be straightforward to implement with a separate Excel input sheet. One could even imagine a dynamic algorithm where the proliferator's perceived activity time pdfs are updated as the simulation evolves and the proliferator learns. Though, this analysis using different sets of activity times is left for future consideration.

NWPR assesses pathway weapons production capability from the data specified in the Excel 'MAUA Data' sheet. Each path production rate is limited by the minimum facility flow. The NWPR function uses the path minimum as representative of the full path. Any redundant facility flows along a pathway according to the flow redundancy Excel sheet are summed for those facilities. The path with the greatest minimum flow will have the highest NWPR utility.

Pathway C&S and NDP are aggregated in similar fashion. For both, the user has the option of specifying that the path probabilities be determined by the familiar product of facility probabilities or by simply taking the minimum value (zero values listed in the Excel input for transitions are neglected for the calculation). These options simulate the proliferator's choice of deciding between the technically correct result and judging the entire path by its weak point. Additionally, pathway C&S has a third option of being determined by the product augmented for C&S facility redundancy as

$$P_{C\&S}(x_p) = \left[\prod^{i} \left(P_{C\&S}(f_i)\right)\right] \prod^{R} \left[1 - \prod^{r} \left(1 - P_{C\&S}(f_r)\right)\right], \tag{12}$$

where $f_i \in$ of non-redundant facilities, $f_r \in$ of redundant facilities for capability R, $R \in$ of pathway capabilities (such as uranium enrichment) for which facilities with the same redundant capability exist. Use of this C&S calculation method allows the proliferator to prefer pathways that may still function with the detection or loss of a redundant facility. The method for each attribute calculation is specified in the batch file.

Pathway Reliability is determined through a combination of the reliability parameters specified relative to the proliferator adversary parameters. It is possible for one pathway to have different designs, with different levels of testing, and different delivery systems with different ranges. During utility calculation for each path, the Rel function decomposes the path into any unique independent paths. This step keeps the data for different weapons systems separate. Then three component Rel values are determined for each independent path of the current utility calculation path. The first value is the 'NE-Rel' value taken directly from the 'MAUA Data' input sheet. Next a range factor equal to the weapon system delivery range divided by the average range to adversary target, taken from the 'ProlifData' Excel sheet, is determined. The range factor is then coarsened into a high (0.75), medium (0.5), or low (0.25) probability of the weapon system being able to reach the intended target. Lastly, a penetration probability is assigned to the independent path with the weapon system type from the 'MAUA Data' sheet and the adversary air defense rank from the 'ProlifData' sheet according to Table XIX. The adversary air defense rank is a measure of the capability of the adversary air defenses relative to the proliferator's air power. The adversary air defense rank is basically an indication of whether the proliferator can reliably deliver a weapon to an adversary target with its military aircraft, or whether the proliferator needs missile or artillery systems to do so. The maximum product of the three determined reliability parameters for each independent path is taken as the pathway reliability utility.

Table XIX

Adversary Defense Penetration Probability Matrix

Adversary Air Defense Rank		**Reliability rating for proliferator delivery method**		
		Gravity Bomb	**Missile**	**Artillery**
Superior	1	0.25	0.75	0.75
Comparable	2	0.5	0.75	0.75
Inferior	3	0.75	0.75	0.75

Sustainability is a combination of the technical challenge to sustain and facility lifetime parameters relative to uranium reserve data. The function first determines a lifetime facility uranium flow expectancy by multiplying the facility uranium inflow and expected lifetime values from the 'MAUA Data' Excel sheet. It then takes a ratio of the lifetime flow to the sum of the uranium reserves and stocks input in the 'ProlifData' Sheet. The uranium reserve ratio is coarsened into a high (0.75), medium, (0.5), or low (0.25) rating. A technical challenge factor is then determined from the ratio of the sum of the technical challenge ratings for the current path listed in the 'MAUA Data' sheet to the sum of the technical challenge ratings of all facilities from all paths. The sustainability utility is then either the product of uranium flow and technical challenge ratings or the minimum as specified by the user in the batch file. With the MAUA path selection fully developed, the remaining task prior to its use was to verify its function.

VII.D. MAUA Function Verification

Verification of the Latency tool MAUA path selection function proceeded in a straightforward fashion. A simple Latency network was developed with enough pathway variation to test each of the attribute utility functions. All associated MAUA verification network data is given in Appendix M. The network consisted of four pathways detailed in Table XX. The first column of Table XX lists the path number and the second column describes the path features. The overall network consisted of 19 transitions and 19 places. Financial control was added through a funding choice between each of the three possible special nuclear material (SNM) production facilities.

Table XX

MAUA Verification Network Pathways

Path	Path features
1	Cold Tested HEU Gun Gravity Bomb, 1 Enrichment Facility
2	Cold Tested HEU Gun Gravity Bomb, 2 Enrichment Facilities
3	Cold Tested Pu Implosion Missile
4	Hot Tested Pu Implosion Missile

Table XXI ranks the independent pathways for each attribute according to the pathway features as defined in the verification network Excel. The first column of Table XXI lists the attribute and any network or MAUA parameter variations. The remaining columns list the ranking of each path as preferred by the attribute (with parameter variation) listed in the first column.

Table XXI

MAUA Verification Test Path Rankings by Attribute with Parameter Variation

Attribute with parameter variation	**Path rank by attribute with parameter variation**			
	Path 1	**Path 2**	**Path 3**	**Path 4**
TTFW-limited funds	1	1	2	3
TTFW-excess funds	2	1	3	4
NWPR	3	1	2	2
C&S	1	2	3	4
C&S-Redundant	2	1	3	4
NDP	2	3	1	1
Rel-adversary air defense=3, range to adversary target=long	1	1	3	2
Rel-adversary air defense =3, range to adversary target=short	1	1	2	1
Rel-adversary air defense =1, range to adversary target=long	1	1	2	1
Rel-adversary air defense =1, range to adversary target=short	3	3	2	1
Sus-excess uranium	1	2	1	1
Sus-limited uranium	2	3	1	1

The rankings Table XXI were based on the variable features defined for the pathways. The time was shorter to develop and produce HEU than it was for Pu. The SNM production rate of a single HEU enrichment facility was less than that of the Pu production facility which was less than the rate of the two HEU enrichment facilities together. All SNM production facilities were considered flow-redundant while only the enrichment facilities were C&S-redundant. The enrichment facilities individually were assigned a high probability of concealment and survival while the Pu production facility received a medium probability. The hot test of Pu weapon was given a low probability of concealment and survival. The Pu production facility complex was assigned a higher IAEA non-detection probability than the uranium enrichment facilities, which had the same NDP. The nuclear explosive reliability of the hot tested Pu implosion weapon and the cold tested HEU gun weapon were both ranked as high, whereas the cold tested Pu implosion weapon was rated with medium reliability. The missile delivery system was given a shorter range than the gravity bomb delivery system. The Pu production facility was deemed a significant technical challenge to sustain, while the enrichment facilities each were only a moderate challenge. A single enrichment facility had greater Uranium demands than the Pu production facility, while all facilities had a 20 year lifetime.

Other network parameters and definitions were varied during the verification study. The financial resource production rate was varied for cases of limited and excess funds. A lower financial resources production rate forced the proliferator to choose between SNM production facilities. With the higher resources production rate the proliferator was able to build all three simultaneously. The state adversary profile was varied between inferior and superior air defenses (adversary air defense (AAD) = 3 and AAD = 1, respectively) and the range of adversary targets (RAT) from short to long. One final variation included defining national uranium availability in excess or as limited relative to the potential pathway lifetime requirements. Verification can be done by simulating the verification network and sequentially setting each attribute weight equal to one while the others remain zero. If the pathway utility values determined through simulation match the rankings of Table XXI, verification can be confirmed.

Verification is demonstrated by the pathway utility values determined during verification simulation shown in Fig. 47. Fig. 47 gives the normalized utility value on the vertical axis. The simulation preferred attribute (set to 1) and any pertinent simulation parameters are noted along the horizontal axis. Fig. 47 presents utility values for all combination paths based on the independent paths from Table XX.

Fig. 47a shows the desired response that when the amount of available finances was increased, the time of the dual enrichment facility path was shorter than the single enrichment facility path. This was not the case when finances were constrained and parallel construction could not be afforded. Fig. 47a further illustrates the NWPR utility preference for paths with all three SNM production methods.

Fig. 47b displays the C&S and NDP results. Without accounting for redundancy, the single enrichment facility is the least detectable pathway. Further drops in the C&S utility occur for Pu production and hot testing. The dual enrichment facility path obtained a higher utility when pathway redundancy was taken into account. As expected the NDP utility is greatest for pathways with only the Pu production facility.

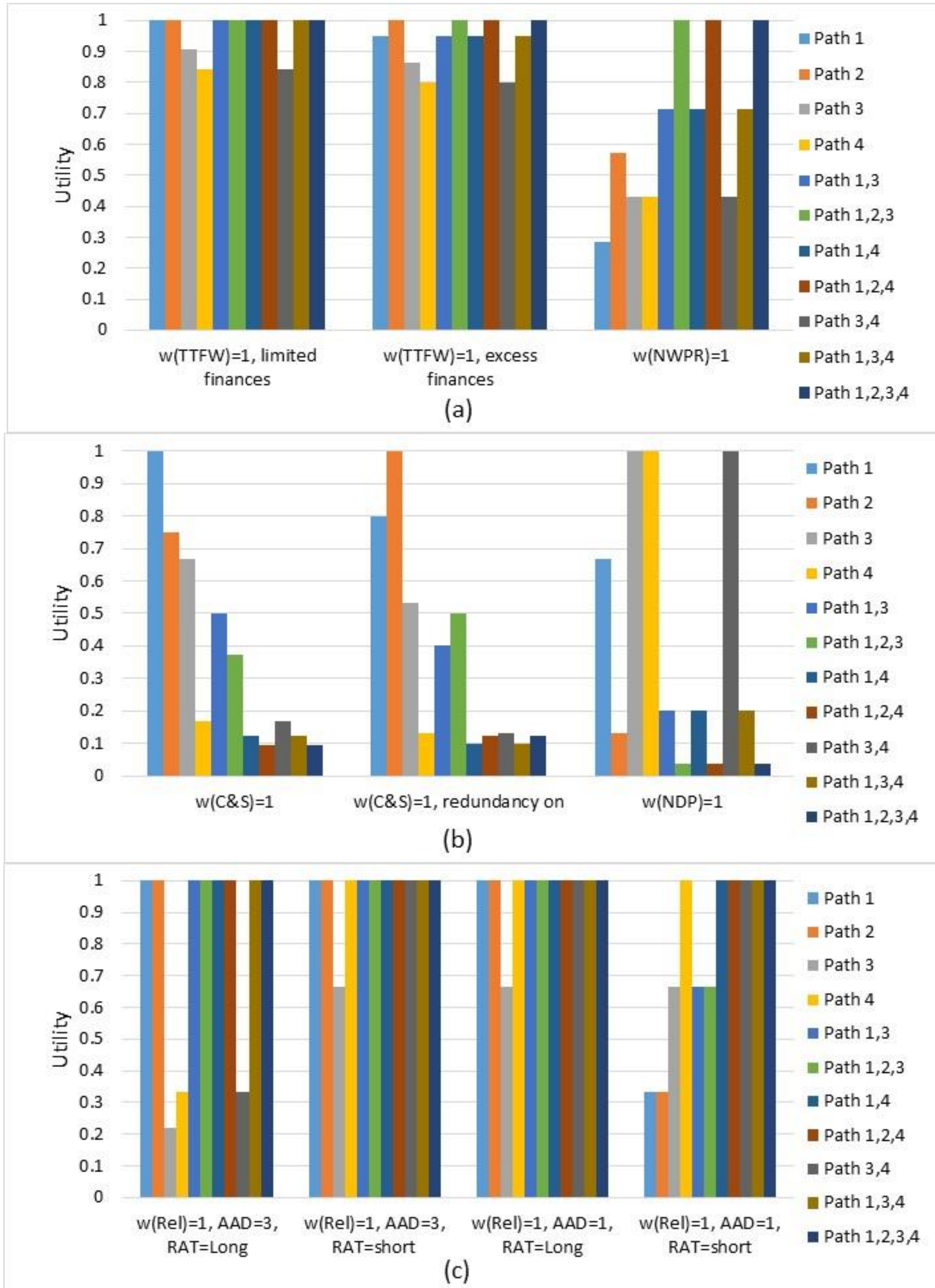


Fig. 47. Verification simulation results for (a) TTFW, (b) C&S and NDP, (c) Rel, (d) Sus.[4]

[4] The astute reader will notice the paths shown do not include all possible combinations of the independent path numbers. This is because combination paths (1,2), (2,3), (2,4), and (2,3,4) are redundant by transition with paths (2), (1,2,3),(1,2,4), and (1,2,3,4) respectively.

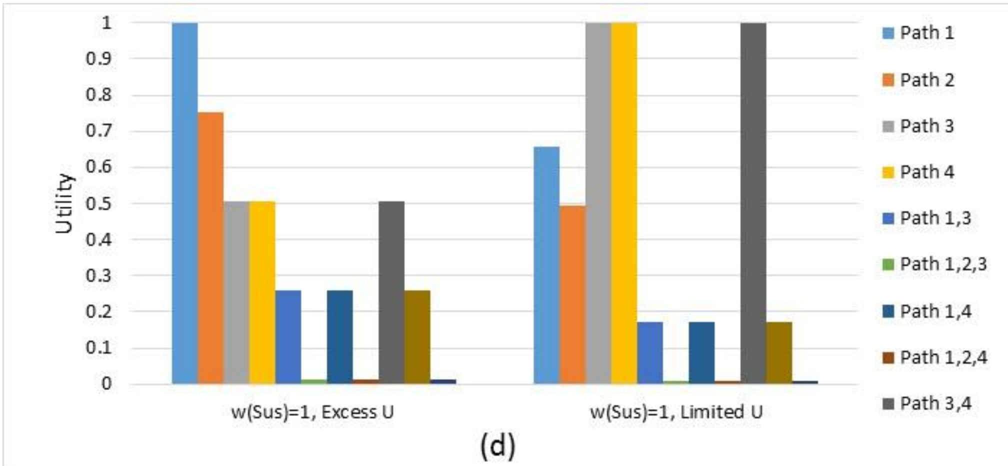


Fig. 47. Continued.

Rel utilities are illustrated in Fig. 47c. When adversary air defense are weak and ranges long, pathways with gravity bomb delivery systems were Rel preferred. When the range was decreased, all pathways were equally good with the exception of the cold tested Pu weapon which had a less reliable nuclear explosive. When adversary air power was superior and ranges long, all paths were equally bad, again with the exception of the cold tested Pu weapon being worse. When ranges were again shortened, the missile system is preferred.

Fig. 47d contains the Sus utility results. When uranium was in excess, the single enrichment facility path was most favorable due to the reduced technical challenge. If uranium was limited though, the more technically challenging Pu paths had greater Sus utility. With the MAUA Latency function verified, it is now possible to assess its utility for Latency determination and characterize the impact of its use.

VIII. MAUA CASE STUDY SENSITIVITIES

MAUA was developed and applied in order to model proliferator pathway decisions to increase the accuracy of the expected Latency time by biasing the potentially more proliferator preferred paths and to additionally generate associated pathway probabilities. To test the impact of the MAUA function, simulations were run while varying path selection interval, the path selection method, and the attribute weights. The variations performed are described in Table XXII. Table XXII lists for each Latency case the path selection intervals, selection methods, and weights used by the simulations. Path selection methods include utility weighted probability selection and selection strictly by the maximum utility, in addition to the original fully random selection. The weights were varied as equally divided between those influencing attributes as determined from the gap analysis for that state, equally divided among all six attributes, or taken as the mean attribute values from the NWPPUAWS. Simulation results were investigated for path selection probability and Latency statistical results.

TABLE XXII

MAUA Simulation Variations

Case	Path selection		Weights
	Interval	Method	
U.S.	1 yr, 5 yr, Once	Random, Weighted Utility probability, Maximum Utility	Gap analysis-equal, all-equal
South Africa	1 yr, 5 yr, Once	Random, Weighted Utility probability, Maximum Utility	Gap analysis-equal, NWPPUAWS
Pakistan	1 yr, 5 yr, Once	Random, Weighted Utility probability	All-equal

VIII.A. Influence on Path Selection

As previously discussed, path probabilities were calculated for two quantities by the Latency tool. One was the combination path probability, which is the path that contains all paths chosen at least once during the simulation iteration. The other was the finishing path probability, which is the path being pursued at the time of path completion. Probabilities are obtained by taking the number of times a combined path or finishing path was tallied divided by the total number of simulation iterations. The cases considered were the same U.S., South African, and Pakistani proliferation programs from before.

VIII.A.1. U.S.

The combination path probabilities for the U.S. case are shown in Fig. 48. Fig. 48 gives the simulation path selection probability for each path for each simulation varying the selection method, weights, and C&S determination method. The maximum utility selection methods have a clear impact. For maximum utility selection with equal attribute weights, path 3, the plutonium path, is preferred. When the attribute weight is equally divided between the TTFW, NWPR, and Rel attributes as identified by the gap analysis, the pathway probability is equal for path 4, which includes all enrichment options, and path 7, which is path 4 with plutonium production added. Path 7 recreates the actual historical path.

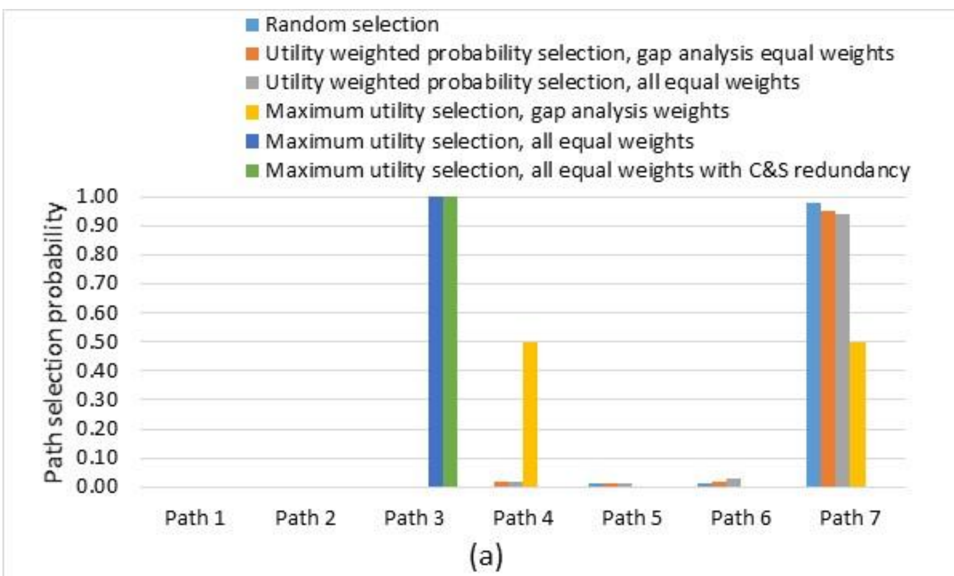


Fig. 48. U.S. combination path probabilities for path selection intervals of (a) 1 year, (b) 5 years, and (c) once during the simulation iteration.

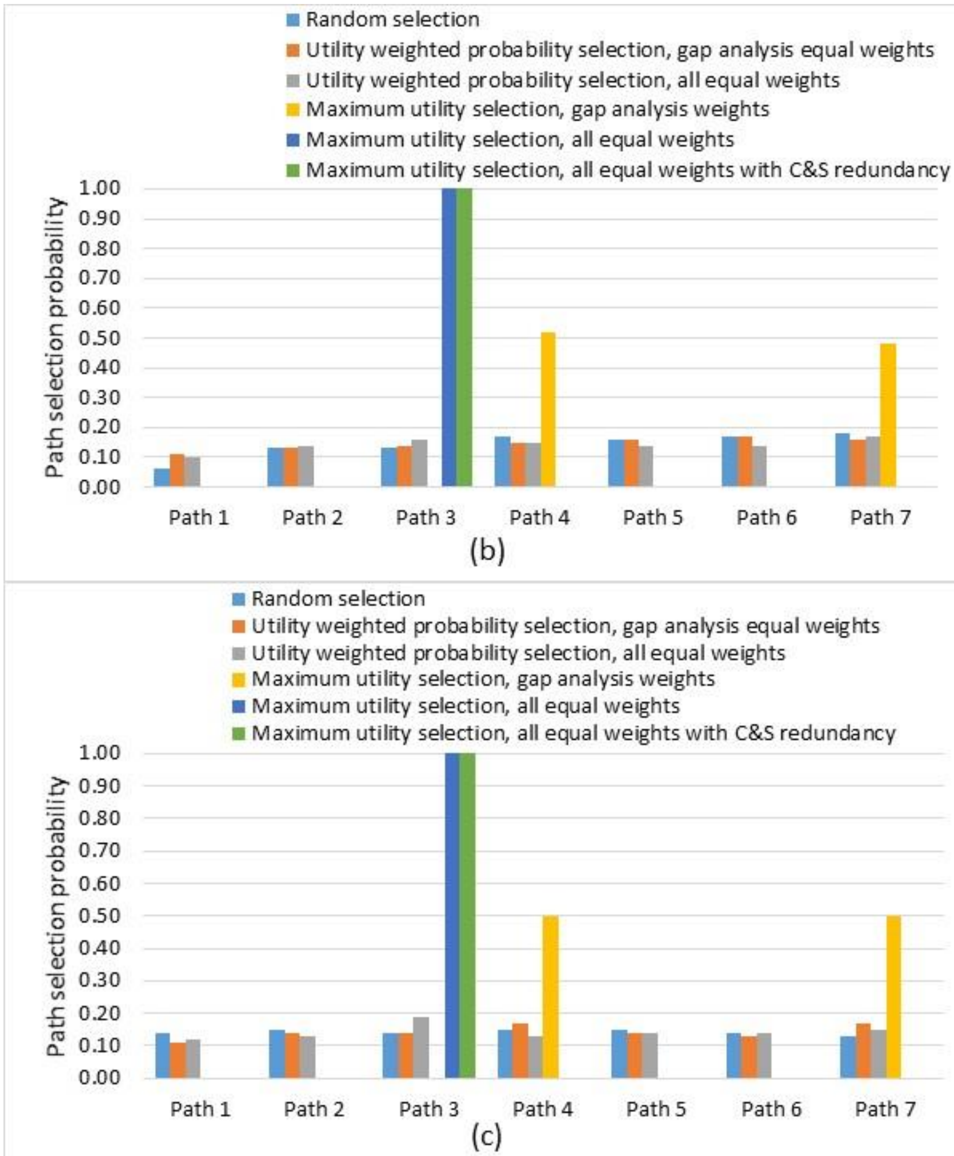


Fig. 48. Continued.

Fig. 48 shows that utility weighted probability selection is not that much different than the original random path selection. For each path selection interval, utility weighted probabilities per path were very close to the random probability. One does notice when progressing through Fig. 48a-c, that for more frequent path selection with essentially random path selection probability, it becomes highly likely that all paths will be selected at least once. This higher likelihood of all paths being selected at shorter path selection intervals results in the increased probability for combination path 7 in Fig. 48a. One explanation for the very random-like selection when using the utility probabilities is that the determined utility values per path were all about equal. This utility invariance was confirmed by extracting the first path selection utility results from the output files shown in Fig. 49. Fig. 49 relates the utility value calculated for each path at the time of the first path selection given for the corresponding weights used.

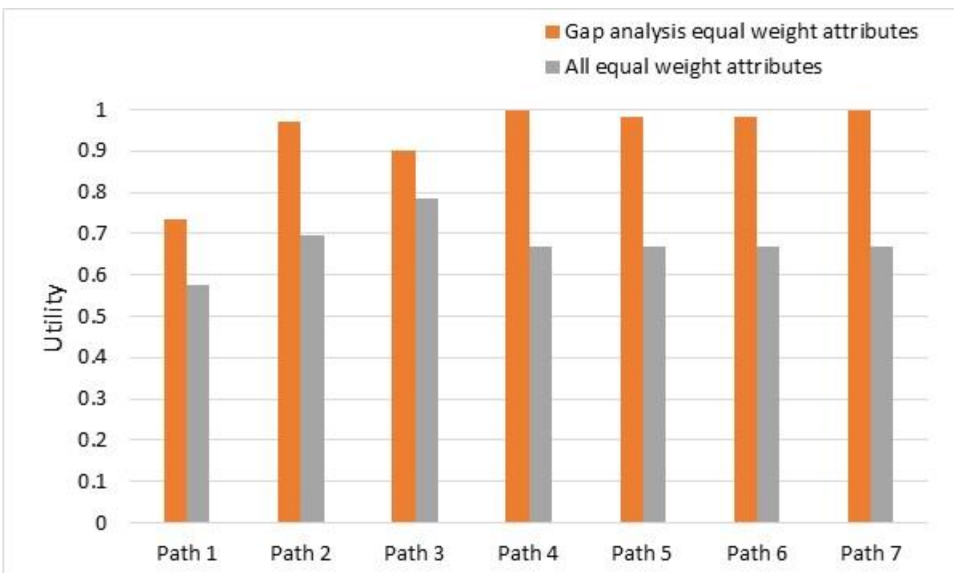


Fig. 49. Initial utility values determined at first path selection for the U.S.

Finishing path probabilities for the U.S. simulation are illustrated in Fig. 50. Fig. 50 shows the resulting finishing path selection probability for each path for each MAUA simulation variation. The same dynamics from Fig. 48 are seen without the path combination effect of Fig. 48a. There may be a slight trend of increasing preference for path 7 in Fig. 50 as the path selection frequency increases. This preference increase could be the result of the slightly higher utility value seen in Fig. 49 for the gap analysis attribute weights. However the potential preference increase with increasing path selection frequency may just be noise.

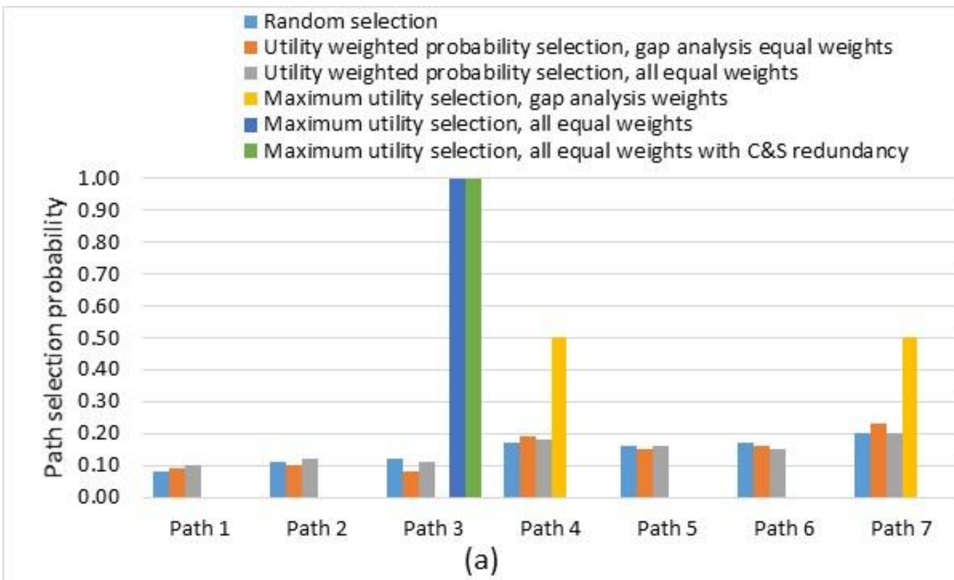


Fig. 50. U.S. finishing path probabilities for path selection intervals of (a) 1 year, (b) 5 years, and (c) once during the simulation iteration.

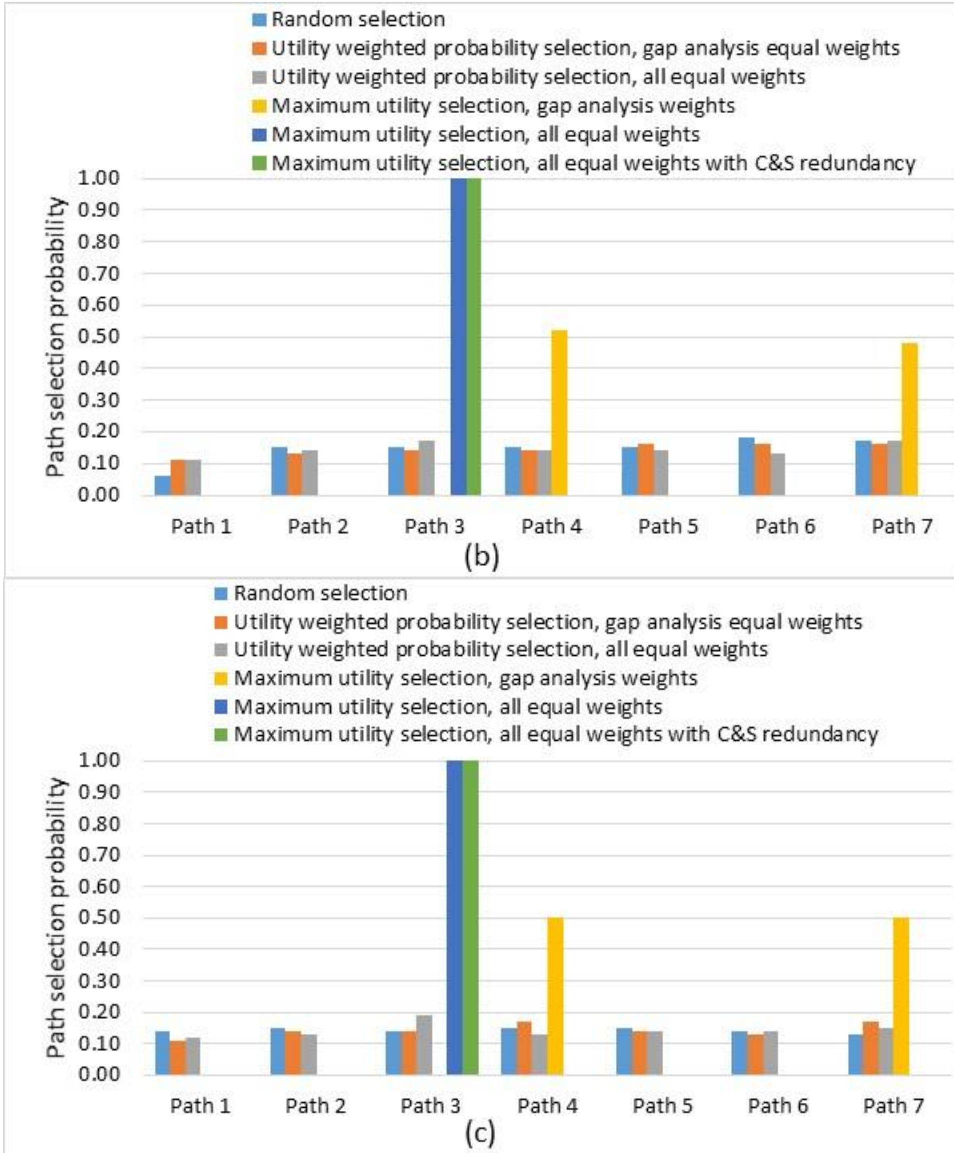


Fig. 50. Continued.

The clear take away from Fig. 48 and Fig. 50 was that use of the maximum utility selection method will clearly influence pathway probability, whereas the influence of the utility weighted probability selection method may be more subtle for the U.S. case. Further, it appears that gap analysis confirmed attributes were suitable for modeling U.S. proliferation pathway selection, whereas the complete attribute set equally weighted was not when using the maximum utility selection method. It should be noted that the U.S. case of proliferation was very quick, shortening the window for the utility weighted probabilities to have an effect.

VIII.A.2. South Africa

The finishing path probabilities for the South African case simulations are shown in Fig. 51. Finishing path probability is illustrated for each path and for each MAUA variation described in Table XXII. Path selection for South Africa was done with mean NWPPUAW Survey attribute weights and for gap analysis attributes with equal weights. The South African gap analysis confirmed attributes were C&S and Rel. Simulations that used the maximum determined utility clearly preferred path 1, which avoided the less concealable hot test and plutonium production infrastructure.

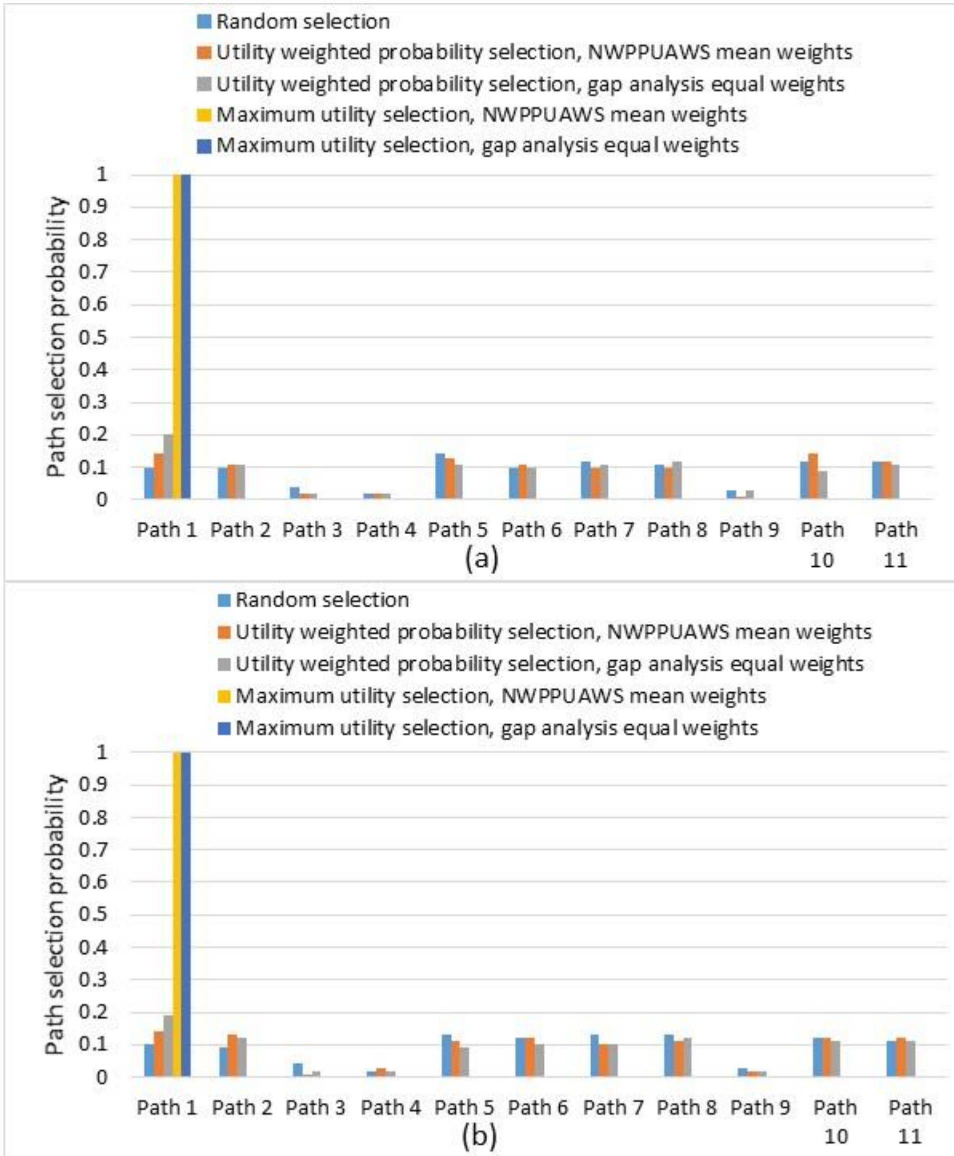


Fig. 51. South Africa finishing path probabilities for path selection intervals of (a) 1 year, (b) 5 years, and (c) once during the simulation iteration.

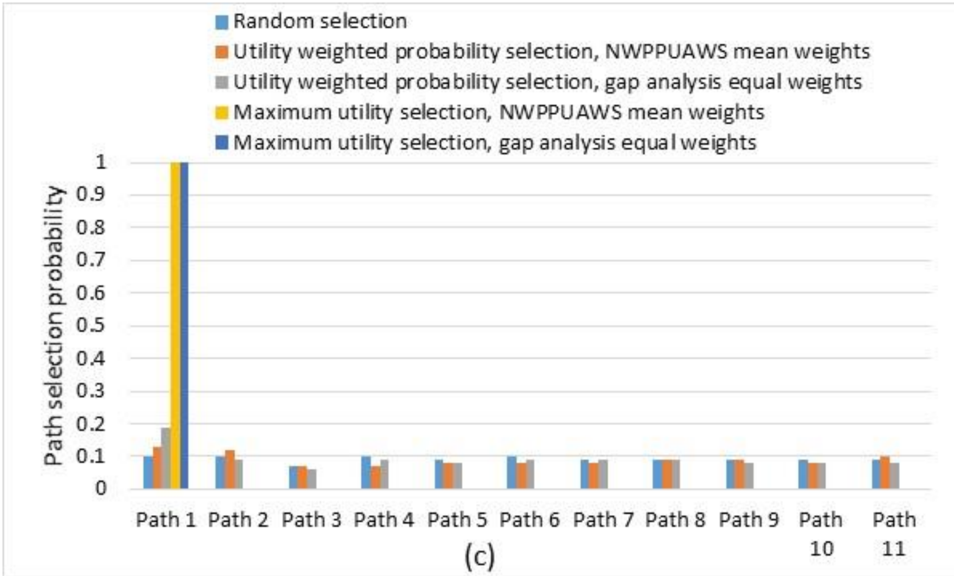


Fig. 51. Continued.

Paths 3, 4, and 9, the paths without any uranium enrichment, appear to lose favor with more path selections. This effect may be a result of slightly lower determined utility for these paths. Fig. 52 shows the determined utility per path for the first simulation path selection for both weight sets used. Fig. 52 demonstrates that aside from the enrichment-only paths 1 and 2, the initial utility values for the remaining paths are about the same and not any lower as previously suspected. The reason for decreased finishing probability is evident though when one considers the South African Latency standards for the plutonium paths are over twice as long (~5000 days) as the standards for the uranium paths. Use of both NWPPUAW Survey and gap analysis confirmed attributes were suitable to model South African proliferation pathway decision making when using the maximum utility selection method.

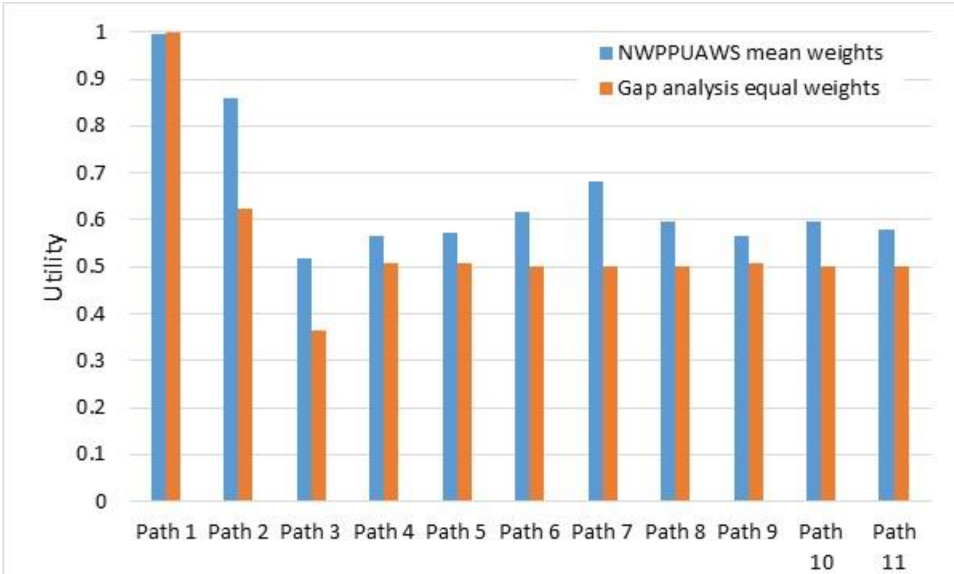


Fig. 52. Initial utility values determined at first path selection for South Africa.

VIII.B. Influence on Latency Statistical Results

If pathway selection becomes more attune with actual proliferator decision making, then the results should provide more accurate Latency results. By avoiding the less preferred paths, the simulation results reflect only variation within the preferred path(s) instead of including the non-preferred paths. Latency statistics for MAUA selection methods are given and compared to those generated with random selection for the U.S., South African, and Pakistani cases.

VIII.B.1. U.S.

Fig. 53 illustrates the impact of path selection method on U.S. Latency time statistics. Fig. 53a depicts the expected Latency for different path selection intervals with Latency Standard times for Little Boy and Fatman added. Fig. 53a shows the expected Latency simulated with selection by maximum utility based on gap analysis attributes is closer to reference results. The maximum utility selection method results, in general, also appear to be invariant to the path selection interval for all the Latency statistical measures. This result is in contrast to the random or weighted probability selection methods where the expected Latency and variance increase with selection interval.

Fig. 53b and c show the Latency standard deviation and minimum Latency time as a result of the path selection interval variation respectively. It indicates that the variance is reduced even in the event of a single path selection. Though in the case of the complete attribute set with equal weights, the results may be converging on the wrong answer. It should also be noted that expected Latency for complete attribute set simulations are longer than the reference values, a risky, non-conservative result.

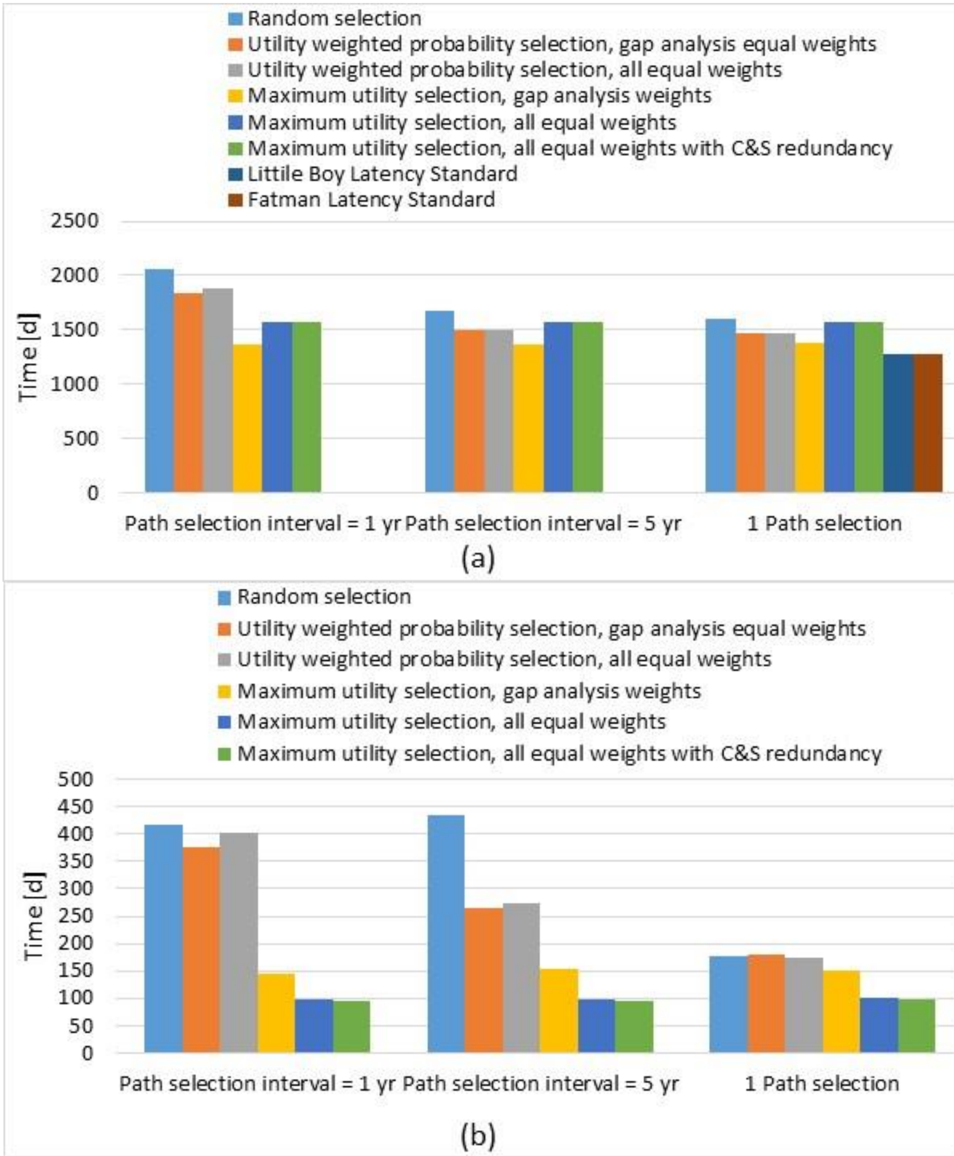


Fig. 53. Impact of path selection method on U.S. (a) expected Latency with historical and Latency standard times added, (b) Latency standard deviation, and (c) minimum Latency.

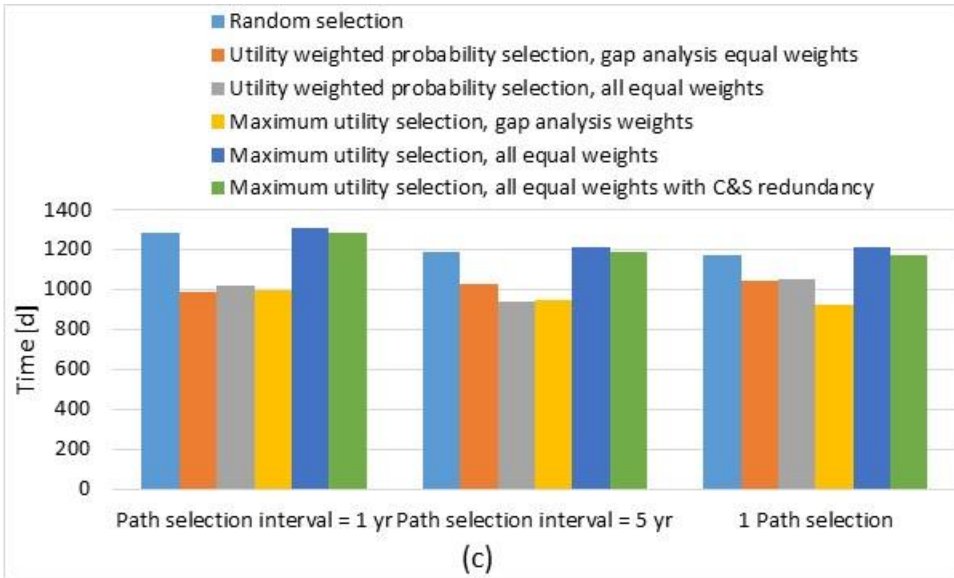


Fig. 53. Continued.

VIII.B.2. South Africa

The South African expected Latency, Latency standard deviation, and minimum Latency, with varying path selection method for stochastic simulations using mean NWPPUAW Survey weights and equal gap analysis derived weights, are depicted in Fig. 54. Previously, Fig. 51 proved that both the attribute sets used adequately modeled the historical path selection. As a result the expected Latency and standard deviation for both maximum utility selection simulations tightened around the reference values. This finding supports use of the maximum utility selection method when attribute values are appropriate.

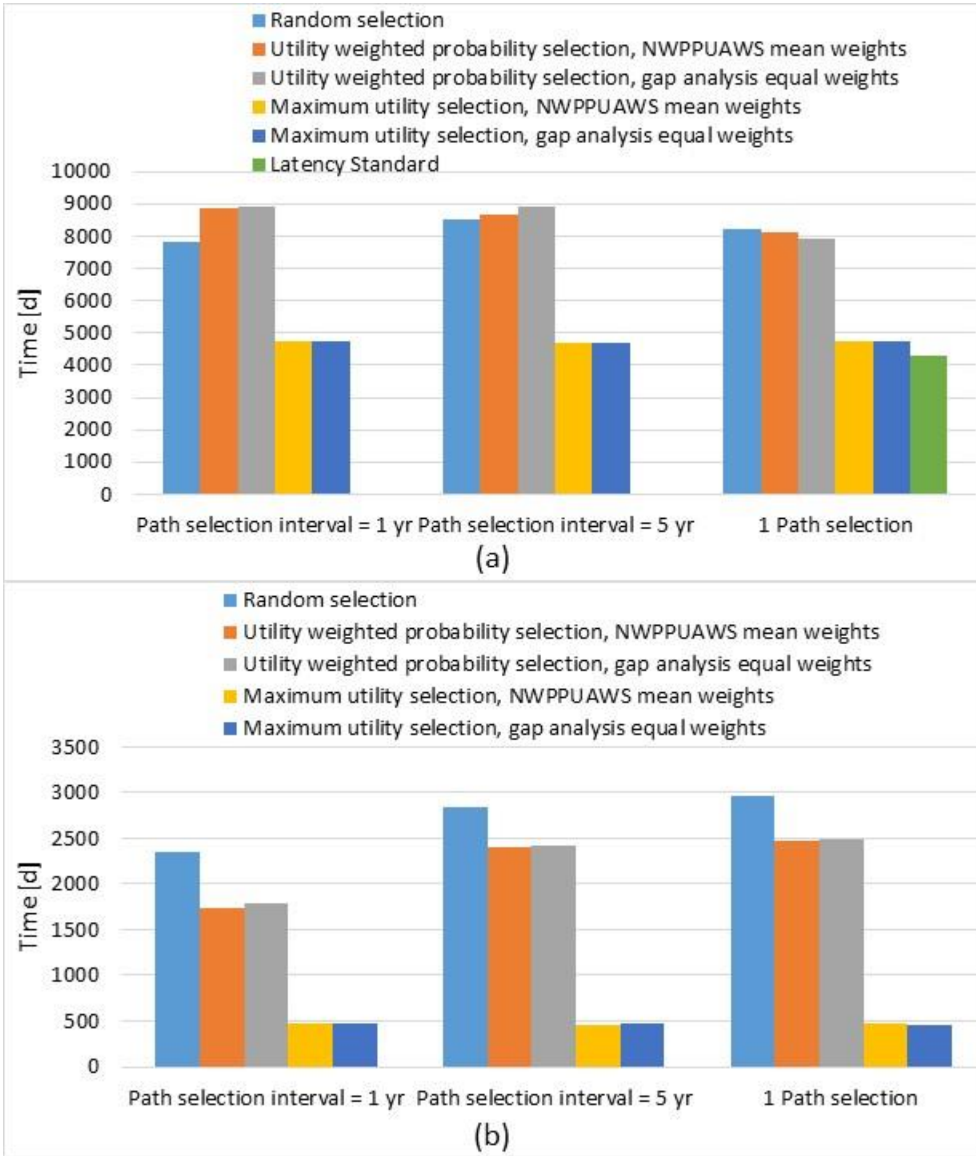


Fig. 54. Impact of path selection method on South African (a) expected Latency with historical and Latency standard times added, (b) Latency standard deviation, and (c) minimum Latency.

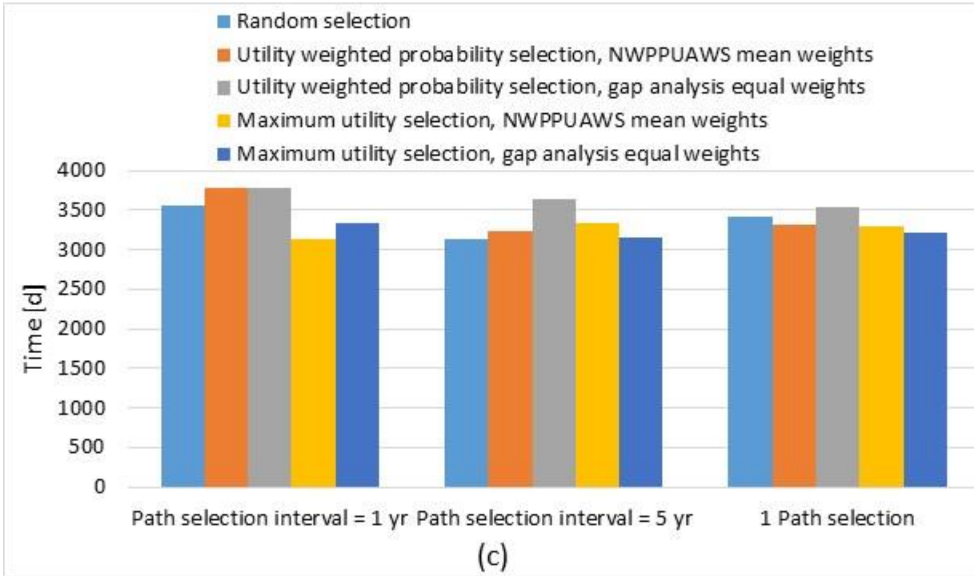


Fig. 54. Continued.

VIII.B.3. Pakistan

Fig. 55 shows the expected Latency, Latency standard deviation, and minimum Latency for the Pakistani case using stochastic simulations with random path selection. Fig. 55 compares the results of a simulation using utility weighted probability path selection to a simulation using the complete set of attributes with equal weights. As expected from the prior analysis, the utility weighted probability selection results vary little from the fully random selection results. The expected Latencies for both are well below the reference values. This result is due to the inclusion of hot testing and safeguarded plutonium diversion paths which were drastically shorter than what actually occurred. Fortunately, underestimating Latency time, the time it takes a state to proliferate, is a conservative error.

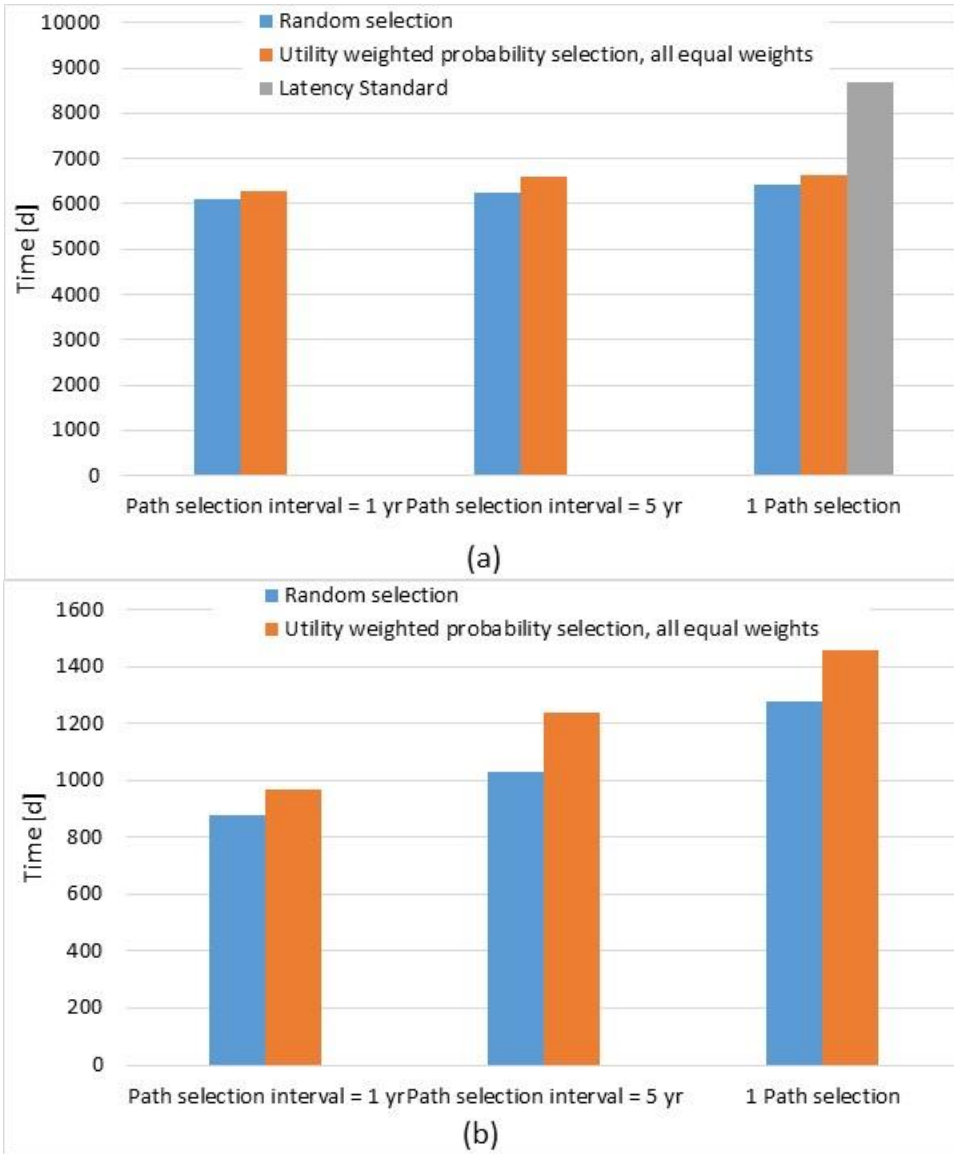


Fig. 55. Impact of path selection with utility weighted probabilities and equal utility attribute weights on Pakistani (a) expected Latency with Latency standard time added, (b) Latency standard deviation, and (c) minimum Latency.

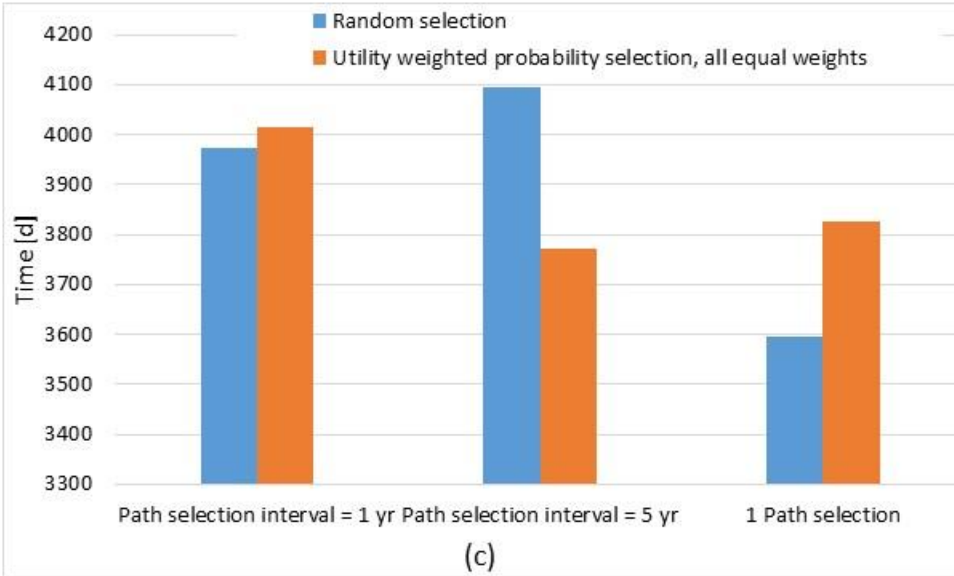


Fig. 55. Continued.

VIII.C. MAUA Analysis Conclusions

The analysis shows advantages and disadvantages of using the MAUA path selection function in the Latency. Expected Latencies and associated variances can be brought closer to reference values when appropriate attributes and weights are used. However, with inappropriate parameters the results may be led astray possibly in a non-conservative fashion. Further the gap analysis showed a high frequency impact of 'other', case-specific non-generalizable factors. This poses a direct challenge to applying MAUA when detailed insights into proliferator decision making is difficult to obtain. Further, people and potentially proliferators frequently make non-utility maximizing decisions.

IX. PRESENT CASE STUDY – ROK FUEL CYCLE DEVELOPMENT

South Korea, also known as the Republic of Korea (ROK), and the U.S. have a long history of nuclear cooperation that currently faces a significant hurdle.[100,101,102] The countries have divergent views on ROK development of nuclear fuel cycle facilities. The ROK is interested in developing spent fuel reprocessing and uranium enrichment capabilities. This development would be contrary to standing U.S. non-proliferation policies which discourage the development of enrichment and reprocessing technologies in states that don't already have them. However, the U.S. and ROK are strong allies with close military and economic ties. Thus, the ROK is seeking a shift in U.S. policy for what it sees as a benefit to ROK social and economic interests. Latency analysis of potential ROK fuel cycle facility options was performed to inform the policy discussion on this issue.

IX.A. ROK-U.S. Nuclear Background

The ROK has a significant and growing domestic nuclear industry that is expanding to include nuclear export.[100,101,102] The ROK currently operates twenty nuclear power reactors supplying 40% of its electricity. With six reactors under construction and orders for four more, the nuclear power energy share is projected to expand to 60% by 2030. The ROK became an international nuclear player when a consortium led by the Korea Electric Power Company won a 2009 bid to supply four nuclear reactors to the United Arab Emirates.

The ROK desire for nuclear fuel cycle facilities rises from both spent nuclear fuel management needs and economic business interests. By 2008, the ROK had already produced 10,083 metric tons of spent fuel. This stockpile may reach 100,000 metric tons by 2100. Current on-site spent fuel storage is set to reach its capacity by 2016, underscoring the need for a permanent long term and likely high capacity spent fuel repository. With a population of 50 million wedged into a country the size of the state of Virginia, finding space for the projected 20 square km repository has proven difficult, especially given the current public resistance. In addition to significantly reducing the repository burden, reprocessing could also play a role in the development of next generation reactor fuels enhancing long-term ROK energy sustainability concerns.

In addition to reprocessing capability, Uranium enrichment could greatly benefit the ROK's economy. The ROK spends over $300 million each year to import enriched fuel for its domestic reactor fleet. Further, the ROK would greatly enhance its nuclear export portfolio by adding fuel cycle services, both enrichment and reprocessing. Having these fuel cycle services would bring the ROK to the same level as its nuclear export competitors, France and Japan, which already possess these capabilities.

The ROK plans to meet its spent nuclear fuel reduction and economic desires by developing pyroprocessing and centrifuge enrichment facilities. Pyroprocessing is a form of spent fuel reprocessing that separates uranium from a combined stream of plutonium, other transuranics, and some fission products. Retaining the other elements with the plutonium is seen as a proliferation resistance increase over the traditional PUREX reprocessing technique which produces completely separated plutonium.[103] The ROK has developed a lab scale pyroprocessing facility, built an inactive pilot demonstration facility, and has plans for both an active pilot demonstration and commercial facilities by 2030.[104,105]

ROK nuclear fuel cycle development currently is constrained by its 123 agreement with the U.S.[102] A 123 agreement refers to section 123 of the U.S. Atomic Energy Act which requires a 123 agreement for U.S. nuclear cooperation with a foreign state. The previous agreement with the ROK, signed in 1973, was extended for 2 years in March 2014, and currently is set to expire in March 2016.[106] This agreement requires specific consent from the U.S. for the ROK to alter or reprocess U.S. origin spent fuel. Almost 60% of current ROK spent fuel is U.S. origin, which would require such consent. The ROK is seeking advanced consent for reprocessing of U.S. origin material in the new agreement. This prospect raises significant non-proliferation concerns for the U.S. given the North Korean nuclear situation, the ROK's spotted non-proliferation track record, and global non-proliferation policy consistency.[100,101,102] The current two-year 123 agreement extension was done specifically to allow more time for policymakers in both countries to resolve their differences of opinion prior to enacting a new agreement.

IX.B. ROK Latency Network

A Latency analysis was performed considering three scenarios of ROK fuel cycle development. Complete ROK network specifications are given in Appendix N. The first fuel cycle facility option considered was a 10 MT/yr pilot pyroprocessing facility as planned by the ROK. Associated network activity time pdfs and network flows were adapted from existing papers and presentations from ROK establishments.[104,105,107,108] An additional plutonium purification step would be required to weaponize the proposed pyroprocessing facility product. Facility requirements for this step would be greatly reduced, as the majority of the uranium and the highly radioactive cesium and strontium fission products have already been removed. Reference activity times for the highly capable ROK to design and construct such a facility were assumed to be one year each. The ROK pyroprocessing facility uranium/transuranic metal product was estimated to contain 4 kg of plutonium. The product was produced from a reprocessing campaign with an estimated reference activity time of 16 days.[104,107] (For this simulation, operation of the facility was maximized assuming constant operation 365 days per year. At this operation rate, expected throughput of the facility became approximately 11.4 MT/yr).

A complete PUREX path was considered as an alternative reprocessing path for the ROK. The PUREX path involved additional PUREX specific research and development, PUREX chemicals acquisition, and a pilot 10 MT/yr PUREX facility analogous to the proposed pilot pyroprocessing facility (to correspond to the maximized flow of the pyroprocessing simulation this facility was also simulated with an expected facility throughput of approximately 11.4 MT/yr assuming constant operation 365 days per year). Given historical PUREX facility development and ROK's level of capability, design and construction of the PUREX facility were estimated at 1 year and 3 years respectively.[109] The plutonium production rate was matched to the pyroprocessing plant such that the facilities considered had equal capacity. Inclusion of the PUREX development path provides a baseline reprocessing option for comparison with the proposed pyroprocessing facility.

Uranium enrichment, desired for primarily economic interests, was considered on a much larger scale. This pathway option was based on the 3000 MTSWU/yr URENCO-USA centrifuge enrichment facility.[110] The proposed enrichment facility was expected as a turn-key import with an assumed 180-day design and nearly four year construction time corresponding to U.S. plant construction.[111] Reconfiguration of the plant from low-enriched uranium to weapons-grade uranium production was assumed to take 60 days. Both uranium and plutonium materials production paths required subsequent weaponization.

Weaponization was based on historical weapon examples using existing ROK delivery systems. The ROK was assumed at least as capable as the U.S. in 1950. The second generation Mark-7 plutonium implosion weapon and Mark-8 HEU gun weapon developed from 1949-1952 and 1950-1951, respectively, were taken as references. Pertinent weapon characteristics for delivery are given in Table XXIII.[112,113] Currently available ROK delivery systems capable of delivering such weapons are F-15 and F-16 aircraft for both plutonium and HEU gravity bombs and Hyunmoo missiles (both ballistic and cruise) for the lighter plutonium explosives.[114,115,116] The plutonium weaponization could occur with or without a 'hot' nuclear test. Validation of the plutonium weapon was assumed to take 180 days with a nuclear test and four times as long with sub-critical testing. Though, the ROK was assumed to stockpile 5 weapons worth of plutonium prior to a full nuclear test.

TABLE XXIII

U.S. Reference Weapons Characteristics

Weapon	**Mk-7**	**Mk-8**
Type	Pu implosion	HEU Gun
Diameter [m]	.775	.368
Length [m]	1.42	3.35
Weight [kg]	498	1488

IX.C. ROK Latency Results

The results of Latency simulations for each fuel cycle facility option for both present undeveloped paths and future developed paths with complete facilities are shown in Fig. 56 and Fig. 57. Fig. 56 shows the expected and minimum Latencies for both the present case of undeveloped fuel cycle facilities and the future case with complete facilities. Fig. 56 gives the specific Latency times as data labels. Fig. 57 depicts the difference in days of the Latencies, both expected and minimum, between the present case of undeveloped fuel cycle facilities and the future case with complete facilities

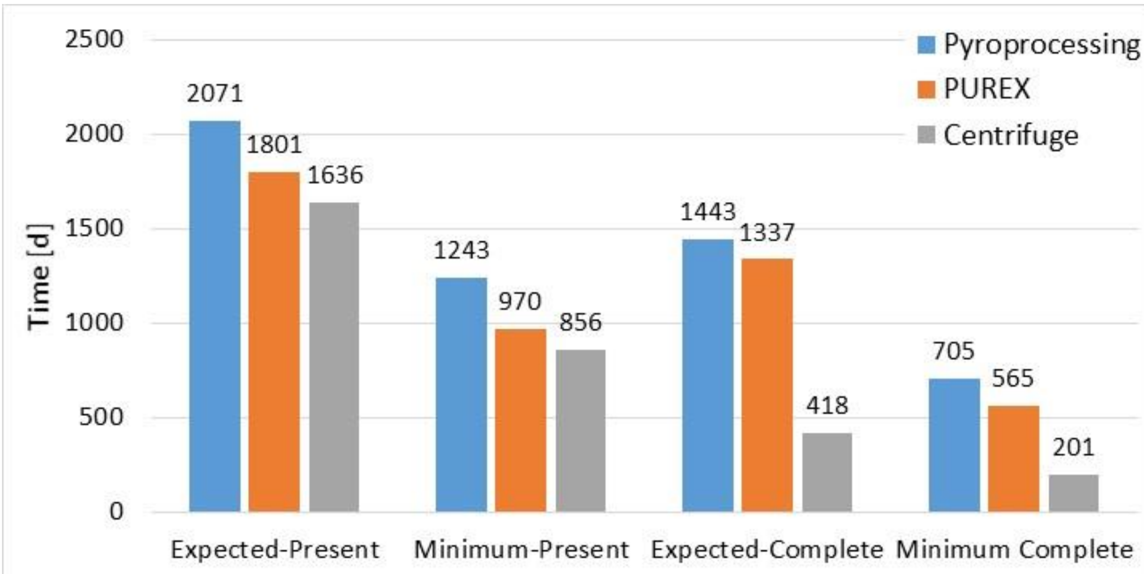


Fig. 56. Expected and minimum Latency times for ROK fuel cycle options both without and with completed facilities.

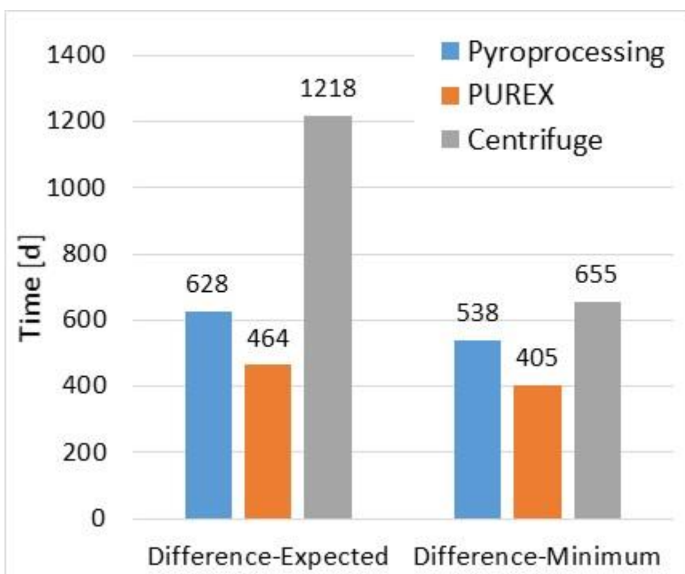


Fig. 57. Difference between present, undeveloped facility and future, complete facilities for the expected and minimum Latencies

The reduction in Latency time with ROK fuel cycle development is clear. The expected Latencies for the fuel cycle facility options descend in order of the pyroprocessing path, the PUREX path, to the uranium enrichment path having the shortest Latency. Further, the expected latency with a complete centrifuge enrichment plant is less than one third of the expected latencies of the other two options. This large difference is a result of the much higher operational capacity of the commercial enrichment facility compared to the pilot reprocessing facilities. Given the analysis assumptions, Fig. 56 shows that Latency is longer for the pyroprocessing path than the PUREX path by 900 days for the present, undeveloped facility case and 473 days longer for the future, complete facility case.

IX.D. ROK Conclusions

Nuclear weapons latency is just one factor for U.S. policy consideration on ROK fuel cycle development. The Latency analysis demonstrates fuel cycle development will reduce the time necessary for potential ROK proliferation should the ROK reconsider its non-proliferation commitment. This increased risk could be offset by the societal benefit of reduced long term spent fuel repository requirements or the economic benefit from enrichment. Given the region, any ROK developments will have to account for the impact on and possible reaction of the Democratic People's Republic of Korea (North

Korea). It is believed that this Latency analysis will better inform and prepare U.S. policy makers for their decision.

X. CONCLUSION

A new computational proliferation assessment methodology has been developed called the Nuclear Weapons Latency tool. Given three basic assumptions, the tool determines a state's nuclear weapons Latency, the expected time to be taken by a non-nuclear weapons state to develop a conventionally deliverable nuclear weapon given the state's position on a path toward or away from a nuclear weapon and accounting for the state's motivations and intentions. Beyond the Latency time result, the tool provides a transparent, efficient, and highly repeatable platform which allows for extensive sensitivity analysis to better inform the nonproliferation discussion.

Sensitivity analysis can determine the impact of varying assumptions, including the nuclear fuel cycle technology available to the potential proliferator. As such, the Latency tool can provide a characterization of proliferation risk due to the acquisition of different technology to policy makers. This enables the Latency tool to help fill a void in quantifying proliferation, identified by the 2013 National Academies study *Improving the Assessment of the Proliferation Risk of Nuclear Fuel Cycles*. The Latency tool also serves as a foundation for future development that may lead to a more complete characterization of proliferation risk to better support nuclear non-proliferation policy making.

X.A. Latency Tool Summation

Three simple assumptions are made by the Latency tool. The first is that a state has made the decision to proliferate. Whether a state will proliferate is a difficult question to answer and is better left to future consideration. The absence of a commitment to a decision in favor of proliferation can serve only to slow proliferation. Thus this assumption is safely conservative, leading to an overestimate of potential proliferator capability or resolve. This result is preferable to underestimating the adversary. The other assumptions made are the proliferation pathway network available to the proliferator and the associated pathway activity time pdfs. Both these assumptions may be tested through sensitivity analysis.

The Latency tool is a stochastic Petri net simulation which has been verified and historically benchmarked. The U.S. case was used for initial verification and to reveal several inherent sensitivities. Large timesteps, rounded pdf bounds, increased network parallelism, and greater network resolution (dividing activities into sub-activities) can drive expected latency times high. Smaller networks with coarse resolution show greater variance. Further, the type of pdfs used to represent activity times and the available network pathways will influence latency results. Given these sensitivities, it is up to the user of the Latency tool to develop the appropriate network model and associated activity times.

Pakistan and South Africa provided interesting proliferation cases for investigation. The Pakistani analysis brought into to question the actual impact of A.Q.

Khan. It is possible that while the Pakistani pathway definitely changed, the actual proliferation time may have been similar had Pakistan simply remained focused on the plutonium path the entire time. The South African analysis demonstrated how Latency time can effectively portray the evolution of a nuclear weapons program towards complete proliferation.

The MAUA pathway selection function may or may not produce increased accuracy in results. MAUA was applied to the Latency tool as a dynamic pathway selection function to determine pathway probabilities and effectively weight certain pathways and proliferation times during the course of a Latency simulation. Using MAUA in this fashion adds three layers of additional assumptions: that the axioms of expected utility are preserved; that attribute independence relations are preserved; and that the attributes, the attribute utility equations, the attribute values, and the associated attribute value uncertainties accurately represent proliferator preferences. If any of these assumptions fail, then the MAUA Latency simulations will produce incorrectly skewed results. For this reason, it is important that the analyst or user fully understand this Latency tool feature before utilizing. Other proliferator modeling methods, like Bayesian analysis, should be studied for this type of adversary modeling.

Regardless, any proliferator decision modeling technique will always run the risk of driving results away from the actual proliferator decisions with inaccurate information and assumptions. Operating the Latency tool with the original random path selection technique, however, will always include the correct result. This fact simply reinforces the utility of the Latency tool for sensitivity analyses, including for path selection methods. For this reason, it may be useful to develop a path weighting algorithm that could be applied in a post-processing step using previous random path selection Latency results. Further, where utility analysis fails in capturing adversary preferences, it shines for evaluating a decision maker's own policy options.

The Latency tool produced clear results for future ROK fuel cycle development. A full scale commercial centrifuge uranium enrichment facility represented a much more significant Latency time reduction than either a pilot PUREX or pilot pyroprocessing facility. However, any ROK fuel cycle facility development would shorten their Nuclear Weapons Latency. Latency is just one factor of several for US policy makers to consider when evaluating options for ROK.

The Nuclear Weapons Latency tool provides clear and expressive results for policy makers. The ROK analysis demonstrates how the Latency tool bounds expected proliferation. The results establish a window of time for policy action should ROK reconsider its non-proliferation commitments both before and after fuel cycle facility development. The Latency results further create a baseline for IAEA safeguards timeliness goals based on the capabilities of the ROK. As expected, the ROK Latency is clearly sensitive to the fuel cycle facilities. As a result any such future facilities should be the focus of US non-proliferation policy in the ROK.

X.B. Future Work

Future development in the area of Nuclear Weapons Latency includes both further development of the Latency tool as well as extension of the application of Latency results and concepts to further characterize nuclear proliferation risk. Computational efficiency of the Latency tool would be improved by fully parallelizing the main Petri net function. Implementation of a parallelized Latency tool on a multi-processor cluster or supercomputer would greatly reduce computation time and enhance the ability of the tool to model greater proliferation detail. It would also be beneficial to convert the Latency tool code from MATLAB to a stand-alone executable. This step would eliminate any dependence on MATLAB for potential users and increase the tools portability. Within the Petri net function of the tool, it may be beneficial to implement a permanent transition priority option for certain transitions over others, in addition to the existing random transition conflict resolution.

Further case studies of both historical and current proliferation are expected. Iranian proliferation activity and nuclear interest elsewhere in the Middle East provide relevant opportunities for analysis in an area of continued strategic importance. Latency analyses can also be applied to analysis of vertical proliferation. The networks simply need to be extended and the simulation ending marking altered. Additionally, the Latency networks considered were highly specific. It may be beneficial to create and analyze more general networks which would have broader application.

X.C. Policymaker Utility for Nuclear Weapons Latency, Nuclear Proliferation Risk, and Nuclear Proliferation Policy Decision Consequences

As opposed to proliferator pathway utility, decision maker utility for Latency time is something that can be readily evaluated. Surveys could be developed and administered to policy makers to develop policy maker utility equations for proliferator latency. Given this data, expected utilities determined for the nuclear weapons latency of different policy options could easily be determined. This approach would serve as a technical support to the intuition of policy makers based on Latency.

An underlying motivation of latency development has been to further characterize proliferation risk. Proliferation risk has been defined as

$$R = \sum_{i=1}^{I} L^i P^i C^i \tag{12}$$

where L^i is the probability that a proliferator may choose to proliferate along path i, P^i is the probability that the adversary will succeed to proliferate along the path i, and C^i is the consequence of adversary proliferation from path i.[117] Latency is a probability of a consequence. Specifically, the cumulative Latency distribution is the conditional probability of the consequence, proliferation in $t \leq T$, given a proliferation decision. From this interpretation, Latency could be directly applied or incorporated into a formulation of proliferation risk R.

If policy makers are choosing between two or more policy options, it may be easier to compare the decision makers' expected utility for consequences of their policy choices, such as Latency, directly. A specific state Latency that results from a policy decision is one of several consequences of policy options that may be of importance to policy makers. Other consequences (some analogous to the previously developed pathway attributes) could include resultant deterrent composition (survivability, production rate, etc.), pathway safeguardability or proliferation resistance, economic benefits, and societal or cultural benefits. It would be possible to characterize the probability of these policy option consequences just as the Latency tool characterized the proliferation time consequence. It is likely that, at least initially, these probabilities should be left conditional on a proliferation decision.

Policy maker utility equations for all of these consequences, including latency, could be developed and aggregated through MAUA. Alternatively all parameter quantities could be converted to U.S. dollars spent on U.S. foreign policy responses or gained from revenues generated. Expanding and incorporating the Latency analysis and utility theory in this fashion could lead to an effective method for evaluating U.S. nuclear nonproliferation policy options based on probability of nuclear proliferation consequences (akin to nuclear proliferation risk).

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APPENDIX A: U.S. MANHATTAN PROJECT TIMELINE DATA

	Begin	End	Time [d]	Notes	Source
General					
Sachs delivers Einstein letter to Roosevelt	10/11/1939				
Roosevelt creates Advisory Committee on Uranium (Dr. Lyman Briggs, director Bureau of Standards, Lt. Col Adamson Army, Commander Hoover, Navy)	10/11/1939				
1st meeting of Advisory Committee on Uranium	10/21/1939				
U committee delivers 1st report	11/1/1939				
1st separation of U235/U238	2/28/1940	2/29/1940	1		
U-235 confirmed responsible for slow neutron fission at columbia cyclotron	3/1/1940				
Vannevar Bush/FDR create National Defense Research Council which absorbs Uranium Committee	6/12/1940				
Bush moves up to head new umbrella agency OSRD, Conant replaces him as head of NDRC	6/28/1941				
Bush recieves draft MAUD committee final report	7/15/1941				
MAUD report officially transmitted to Conant/OSRD	10/3/1941				Rhodes, p377
Bush briefs Roosevelt on MAUD report (and US scientists opinions), Roosevelt directs Bush to "exploring thoroughly" if a bomb could be built	10/9/1941				Rhodes, p377
3rd National Academies Report	11/1/1941				
Roosevelt approves 3rd NAS report, given to him by Bush on 11/27	11/27/1941	1/19/1942	53		Rhodes, p388
Bomb program now Section-1 of OSRD (research involvment of NDRC was over)	12/6/1941				Rhodes, p398
Bush Report to Roosevelt ranks prospects for producing bomb: (1)EMIS, (2)Centrifuge, (3)Diffusion	3/9/1942				Rhodes, p406
Roosevelt replies with support emphasizing time overr money	3/11/1942				Rhodes, p406
Conant decides to pursue all: centrifuge, gdiff, EMIS, graphite, heavy water in the interest of time	5/23/1942				Rhodes, p406

	Begin	End	Time [d]	Notes	Source
Bush/Roosevelt give production responsibilities jointly to Army & OSRD, Colonel James Marshall given responsibility, Marshall creates Manhattan Engineering District	6/27/1942				Rhodes, p412
Bush reports to Sec of War that super is possible	8/29/1942				Rhodes p421
Groves appointed run MED and given full control of project, bomb project consolidated under Army Corp of Engineers	9/17/1942				Rhodes p424
Groves purchases 1250 tons of belgian Uoxide (65%) stored in NY	9/18/1942				Rhodes p427
Groves acquires AAA priority rating from War Production Board	9/19/1942				Rhodes p427
Groves purchases site X in Tennessee, 52,000 acres	9/19/1942				Rhodes p427
Construction begins at Oak Ridge	Jan-43				Rhodes p486
Army accumulates 3700 tons of Uoxide from Congo	Dec-44				Hewlett 291
Army orders 700 tons Uoxide from US producer	Dec-42				Hewlett 291
Army accumulates 400 tons of U oxide from US & Canada	Dec-44				Hewlett 291
Total Army accumulation of almost 6000 tons Uoxide	Dec-44				Hewlett 292
Army has 3 U refineries for U purification	summer 1943				
Instead of more alpha tracks, Groves decides to build a 4th beta plant (higher enr) and a 2nd gas diff plant (more lower enr stages)	3/15/1945				Rhodes 602
Oak Ridge began sending HEU to LA	early 1945				
					52.631579
LTD	Begin	End	Time [d]	Notes	Source
Research	7/1/1940				
Design	7/1/1940	7/1/1941	365		Reed

	Begin	End	Time [d]	Notes	Source
UF6 prod method		10/1/1940	92		
Build mini-Lab Facility (12' columns)	7/1/1940	6/1/1941	335		
Build Lab Facility (36' columns)	6/1/1941	9/1/1942	457		
Build Pilot Plant (14 48' col)	july 1942	11/15/1942	137	Label NRL/Anacostia 48' columns as (full scale) lab facility	
Groves vist NRL	9/21/1942				
Begin Pilot Operation	12/1/1942				
Groves vist NRL/Anacostia	12/10/1942				
Murphree letter to briggs, LTD as feeder for Gdiff idea	1/25/1943				
Build 18 48' LTD col	feb 1943	july 1943	150		
Operate 48' LTD col			1000 days		
column operation intervals (500 hrs = 21 days)			21		Reed 171
Send 236 lbs of slightly enr UF6 to metlab	sept 1943				
Decision to build Phili pilot/small Plant (300 48' col, initially 100)	11/17/1943			Phili plant sent 5000 lbs .86 wt % UF6 to Oak Ridge during war	
Build Phili pilot/small Plant	1/1/1944	7/15/1944	196		
Operate phili pilot plant	7/15/1944	8/1/1945	382	Phili plant operated for another year, but this is end of war operation	
Oppenheimer 'alerts' Groves of LTD work	4/28/1944				
Groves decides to build S-50 plant	6/24/1944				
Build S-50 (break ground) in 21 racks of 102 columns	7/6/1944	10/11/1944	97	Probably begin "build" phase with decision and not ground breaking	
1 rack completed		10/18/1944			
S-50/1 rack operation	10/18/1944	9/9/1945	326	S-50 personell were trained at Phili	
10 racks completed		1/15/1945			
Operate S-50		9/9/1945			
10.5 lbs U @ .85 wt%	10/18/1944	10/31/1944	13		
K-25 starts producing 1.1wt%, so LTD sends all its product to feed K-25 instead of to Alpha I tracks	4/1/1945				Jones 169
12,730 lbs U .85 wt%	6/1/1945	6/30/1945	29		
45000 lbs U .85 wt%	10/18/1944	7/31/1945			
56,500 lbs U .85 wt%	10/18/1944	9/9/1945	326		

	Begin	End	Time [d]	Notes	Source
all 21 racks S-50 enriching	3/15/1945	9/9/1945	178		Rhodes 602, Reed 178
	from Jones 182				
.852 wt% U-235	Production [lbs]	kg	Month		
	10.5	4.762716	October		
	171.8	77.9271056	November		
	20	9.07184	December		
0	765	346.99788	January	there was some production in Jan (Jones 182), value shown is extrapolated down from feb/June	
assume linear ramp up	3158	1432.443536	February		Jones 182
2	5551	2517.889192	March		
3	7944	3603.334848	April		
4	10337	4688.780504	May		
	12,730	5774.22616	June		
390	11,500	5216.308	July		
m	b		August		
2393	765				
sum	52187.3	23671.74178			
sum to july	40687.3	18455.43378			
Gas Diffusion					
Dunning begins research on Gas Diffusion	Nov 1940				Rhodes, p380
Dunning enriched a measurable amount of U w/Gas Diff	Nov 1941				Rhodes, p381
Detailed K-25 plant design estimates		Dec-42			Hewlett p123, says "by the end of 1942, Cohen had completed more detailed calculations"

	Begin	End	Time [d]	Notes	Source
Norris-Adler most promising type of barrier		Dec-42			Hewlett 126
Kellex completed plot plan of K-25		Mar-43			Hewlett p123
Build Barrier production pilot plant	Jan-43	Jul-43	181		Hewlett p127, Rhodes 494
Build full scale barrier production plant	Apr-43	Oct-43	guesstimate on end		Rhodes 494
Survey party arrives to Build coal-fired power plant to run K-25 gas diffusion plant	5/31/1943				Hewlett 130
Ground grading for power plant	6/2/1943				Hewlett 130
Groves cut plans for K-25, limit to production of .50 U-235, eliminate top portion of production cascade, ASSUME this finishes design of K-25	8/13/1943				Hewlett 129
Break ground for main K-25 process buildings	Sep-43				Hewlett 130
New sufficient barrier design finished (kellex)	Oct-43				Hewlett 133
Groves decides to strip old process from barrier production plant and install new kellex barrier production system	1/16/1944				Hewlett 138
Setup a new (and retask old) pilot nickel(kellex) barrier production plants, significant production of kellex barriers from pilot plants began in May	Jan-44	Apr-44	91		Hewlett 139
Convert H&H barrier production plant to kellex/nickel method	Feb-44	Jun-44	121		hewlett 140
Satisfactory barriers start arriving at K-25	Jan-45				Rhodes 601
First stage of K-25 charge with UF6	1/20/1945				Rhodes 602
First operation of units on regular process gas	Feb-45				Jones 168
Case 1 finished		3/24/1945			Jones 169
Case 2 Finished		4/24/1945			USDoI p10???(checkagain)
K-25/Case 1(inferred from source) begins producing 1.1% U-235 which is sent Alpha tracks for further ENR	Apr-45				Jones 169
Cases I&II yielding product @ 1% U-235		5/1/1945			Jones 169

	Begin	End	Time [d]	Notes	Source
Case 3 finished		5/24/1945		Cases 2-4 added at ~ a case per month	
Case 4 Finished		6/24/1945			
Case 5 Finished		7/24/1945			
link full plant cascade		8/15/1945		23%: after full plant cascade went on stream product concentration increased to 23%	Jones 169
K-25 has 100,000 kg SWU/year		End of War 1945			Laughter 5
k-25 delivers product at 30 wt % U-235 to Beta Tracks		Aug-45		DO NOT USE, USE Jones above	DoI p10
K-25=2892 converter stages, ~6 converter stages/cell, cell = basic process unit					Jones 158
482	cells in K-25				
207.4688797	SWU/cell/yr				
Case 1 = 402 Stages	67	cells			Jones 164
assume Case 2 = 4*Case1, Case3=1.5*Case1, Case 4=0.5*Case1					
Plan: Case 1 = .9 wt %, Case 2 = 5 wt %, Case					
Centrifuge					
Urey (isotope separation head for S-1 Ur Com) contracts Westinghouse to build prototype Centrifuge	Oct 1941				Rhodes, p 380
Westinghouse/Beam(UVA) build prototypes		Aug-43			Kemp 2
Urey terminates Centrifuge program after failed testing	12/31/1943				Kemp 2
Zippe leaves USSR with knowledge of working centrifuge design		Jul-56			Kemp3
EMIS					
Lawrence installs 180 degree mass spec in Berkeley 37" cyclotron	Late 1941	12/1/1941			
Lawrence operates initial mass spec to produce 100 ug of U-235	a month later				Rhodes p487
Calutron design	spring 1942	summer 1942	90		Rhodes p488
	Mar-42	Aug-42			
Build 1st alpha race track (5 alpha tracks approved to be built)	2/18/1943	10/25/1943	249		Rhodes p490-491
Groves authorizes 2 beta tracks, beta design finalized & alpha 1 design finalized	3/17/1943				Rhodes p490 , Hewlett 151

	Begin	End	Time [d]	Notes	Source
Groves authorizes 4 more alpha tracks & corresponding beta tracks	Aug-43				Rhodes p491
Complete 2nd alpha race track		1/15/1944			Rhodes p492
Start up Betas 5 & 6	5/22/1944	11/22/1944			Hewlett 299
1st 5 alpha tracks in op & 1st 2 betas in op	Jun-44				Jones 142
2 beta tracks complete	Jul-44				Jones 142
four alpha tracks in operation	Jul-44				Hewlett 167
100g/day of 10% U-235 from alpha tracks	Sep-44				Rhodes 600
Beta Output 40 g/day	Nov-44				Rhodes 601
Beta Output 90 g/day	Dec-44				Rhodes 601
All 9 Alphas & 3 Beta Tracks in production (Betas 4-6 in operation, but not production)	12/15/1944				Hewlett 299
85% of 864 Alpha Tanks => 258 g/day 10% U-235, 36 Beta Tanks => 204 g/day 80 % U-235	Jan-45				Rhodes 601
Training of operators (mostly from unskilled background)	Aug-43				Jones 141
1800 operator trainees		Sep-43			Jones 142
2500 operators necessary for 5 Alpha 1 racetracks					Jones 142
Tennessee Eastman (operating firm) payroll 10,000 employees		early 1944			Jones 142
Tennessee Eastman (operating firm) payroll 25,000 employees		mid-1945			Jones 142
Alpha track shutdown: 88 kgs 84.5 % U-235 from Alpha racetracks (shutdown early sept 1945)		Sep-45			Jones 148
Beta Tracks shutdown: additonal 953 kgs 95% U-235 produced		Dec-45			Jones 148
last 2 beta tracks went into operation in Nov & Dec					Hewlett 625
USE FOR BETA (BELOW)					
Bring Beta 1 into Operation	487				
Bring Beta 2 into Operation	517				
Bring Beta 3 into Operation	731				
Bring Beta 4 into Operation	761				
Bring Beta 5 into Operation	791				
Bring Beta 6 into Operation	821				
Reliable U metal fab Process	1941				Hewlett 209

	Begin	End	Time [d]	Notes	Source
Pu					
Seaborg begins experiments to find Pu	9/1/1940				
Seaborg isolates Pu	2/24/1941				
Seaborg discovers Pu is fissionable with slow neutrons	3/28/1941				
Washington U. begins cyclotron irradiation of 300 lbs of U-nitrate-hexahydrate	6/17/1942	7/27/1942	40		Rhodes, p410
300 lbs of UNH arrive in Chicago for Seaborg	7/27/1942				Rhodes p 413
Chemists under Seaborg isolate pure Pu for first time	8/20/1942				Rhodes p414
Design PhosphateBismuth extraction method, greenewalt picked PhBis on this date		May-43			Gosling 35
Remote operators train at DuPont, Oak Ridge & mokcups at Hanford	Fall 1944				
install process equipment in 221 buildings	Oct-44	Dec-44	61		Rhodes 604
Build 221T	Jan-44	9/15/1944	258		Hewlett 220,221
install eq in 221 T			47		
installation complete, begin testing in 221T		11/1/1944			Hewlett 309
Testing in 221T			55		
Build 221U	Jan-44	Dec-44	335		Hewlett221
Build 221B	Apr-44	Mar-45	334		Hewlett221
Build Concetration Building (224 T,U,B)	Feb-44				Hewlett221
224 T & U Finished		10/8/1944	250		Hewlett222
224 B finished		2/10/1945	375		Hewlett222
1st processing of irradiated slugs at 221-T sept Plant (-pile slugs)	12/26/1944	1/5/1945	10		Rhodes 604/Hewlett 309
221 T & 221 U complete		12/15/1944			Gosling 76
Build Isolation building 231W	4/8/1944	12/20/1944			Hewlett 222
eq installation in isolation building 231 complete		1/20/1945			hewlett 309
1st purified Pu produced at hanford		1/31/1945			hewlett 309
221-T Pu recovery rates improved to 90% from initial runs at 60-70%	feb-1945				rhodes 604
1st small sample of hanford Pu arrives at LA	2/2/1945				hewlett 310
221 B Complete		Spring 1945			Gosling 76

	Begin	End	Time [d]	Notes	Source
enough Pu for trinity & fatman are sent from hanford	6/15/1945				Thayer, 141
Graphite Reactor					
$6K to fermi for graphite	2/1/1940				
Fermi conducts graphite absorption experiments	april 1940				
Fermi's 1st pile, k=.87	Sept 1941				Rhodes, p400
Fermi's 2nd pile,k= .918, Allison Chicago pile k=.94	April 1942				Rhodes, p401
Decision to build experimental pile in Oak Ridge & pilot separation facility	1/15/1943				Hewlett 207
Design experimental pile		4/27/1943	102		Hewlett 208
Engineering council for reactors discusses full scale pile cooling options	June 1942				Rhodes p411
Fermi begins planning full chain reacting pile, CP-1 Chicago Pile 1	may 1942				Rhodes p428
Groves has DuPont take over contract for full scale production	11/11/1942				Rhodes p432
Build CP-1	11/16/1942	12/1/1942	15		Rhodes p433
CP-1 goes critical	12/2/1942				Rhodes p436
Groves decides reactor location can't be at Oak Ridge	12/14/1942				Rhodes p496
Groves buys Hanford site for Pu production	1/21/1943				Rhodes 497
Dupont starts CX on 1st buildings for x-10/Clinton	2/2/1943				Hewlett 207
Design Choice for production plant (water cooled) made, decides for 3 water cooled piles at Hanford, Construction can now begin	2/15/1943				Rhodes 498
decision to build water cooled piles allowed to reduce # of piles to 3 and general Hanford arrangement emerged	3/30/1943				hewlett 215
Build x-10 pilot separation plant	3/7/1943	8/1/1943			Hewlett 208
Begin Stacking Graphite in x-10 building		9/1/1943			Hewlett 208
Build graphite fab plant (x-10)	3/25/1943	5/25/1943	61		Hewlett 208

	Begin	End	Time [d]	Notes	Source
Dupont begins Hanford CX, USE THIS as when design initial hanford fires/build initial hanford is enabled	4/1/1943				hewlett 215
Build x-10 facility pilot reactor	4/27/1943	10/25/1943	181		Hewlett 208/211
Alcoa begins fuel fabrication (slug canning) for x-10, without refined process slug canning is substandard	6/14/1943				Hewlett 209
Refined x-10 slug canning process equipment installed in Alcoa canning plant, x-10 slug canning begins in ernest	10/15/1943				hewlett 210
1st engineering drawings for hanford piles released by dupont		10/4/1943			Hewlett 216
Build Hanford slug production facility 313	5/1/1943	1/1/1944			Hewlett 224
Dupont begins Hanford slug canning research	10/17/1943				Hewlett 223
Build 1st pile 100-B	10/10/1943	9/13/1944	339		Rhodes 499/557, hewlett 216
begin loading slugs into x-10	11/3/1943				hewlett 211
Initial operation of x-10	11/4/1943	Mar-44	118		
pilot separation plant operation (test)	dec 1943	12/30/1943	29	first small sample of Pu sent to chicago for analysis	Hewlett 211
second loading of x-10	3/1/1944				
Transfer all Hanford-pile slug canning research/operations to Hanford	march 1944				Hewlett 225
1st experimental canning operation started at hanford building 313	3/20/1944				hewlett 225
1st true slug canning production line started in 313	5/11/1944				hewlett 226
Build D-pile	Nov-43	Dec-44	396		DOE/RL-97-1047 p2-3.5
Build F-pile	Dec-43	Feb-45	428		DOE/RL-97-1047 p2-3.5
produce 1st core load of pile slugs			125		
Load B-pile	9/13/1944	9/26/1944	13		Rhodes 557
B-pile goes critical/begins operation	9/26/1944	9/29/1944	3		Rhodes 559
Xenon FP poison discovery/redesign of reactors	9/29/1944	10/2/1944	3		Rhodes 559
Dpile goes critical/begins operation	12/17/1944				Rhodes 560
B-pile restarted after redesign	12/28/1944				Rhodes 560
F-pile startup/goes critical	2/25/1945				Thayer 141

	Begin	End	Time [d]	Notes	Source
Weapon Design					
Oppenheimer gathered the "luminaries" together at berkeley	7/1/1942	7/31/1942		summer(july) 1942	Rhodes p415-16
Teller/Bethe state 'super' fusion bomb is possible, begin theoretical work	july 1942				Rhodes p417
Groves Appoints Oppenheimer as head of central weapons design lab	10/15/1942				Rhodes p449
Los Alamos purchased as lab site	11/21/1942				Rhodes p451
Introductory lectures at Los Alamos(sante fe)	Apr-43				Rhodes p460
Most of technical staff had arrived at Los Alamos	mid-april 1943				Rhodes p465
Los Alamos review committee recommends: investigate thermonuclear bomb with secondary priority, subordinate to fission bomb, work on chemical purification of Pu, begin ordnance work immediately before nuclear physics work is complete	5/10/1943				Rhodes p476
Implosion work begins- Neddermeyer	7/4/1943				Rhodes p479
Modifications/retrofit/redesign of B-29 for thin man & fat man	11/29/1943				
Gun-1st gun test shot	9/17/1943				Rhodes p541
Weapon Test planning	Mar-44				Rhodes 571
Implosion lense development	winter 1943-1944				Rhodes 575
Selected initiator design	5/1/1945				Rhodes 580
Experimental implosion agrees with theory	4/11/1945				
Frisch reports U-235 criticality (Dragon) exp results to Oppenheimer, mass of little boy known, assume little boy design complete	4/13/1945				Rhodes 614
iniator design finalized	5/1/1945				Rhodes 580
Pu criticality experiments begin	5/31/1945				Rhodes 654
Core design (Christy gadget)	6/24/1945				Rhodes 654
Fabrication of explosive lenses	Jun-45	7/10/1945	39		Rhodes 655-656
Assembly of Trinity and cold mockup explosives	7/12/1945	7/12/1945	0		Rhodes 658
mating of trinity with core	7/13/1945				Rhodes 659
Creutz cold test	7/14/1945				
Trinity Test	7/16/1945				Rhodes
Delivery					

	Begin	End	Time [d]	Notes	Source
Delivery-Navy Captain William S. Parsons arrives to head Ordnance Division at Los Alamos	Jun-43				Rhodes p477
Delivery-Ramsey (group leader delivery) contacts USAF about delivery with potential bomb specs, learns B-29 is only aircraft that can carry	Jun-43				Rhodes p478
Delivery-scaled flight tests begin with a bomb mockup	8/13/1943				Rhodes p479
1st full dummy (thin man) test drop	3/3/1944				Rhodes 582
Modifications on 17 more B-29	Aug-44				Rhodes 582
Pumpkin/Blockbuster fat man training program	Dec-44	7/1/1945			Rhodes 590
Test					
Site Selection	Mar-44	May-44			Rhodes 652
Site planning & preparation "end of Feb", "bomb physics well in hand by then"	2/28/1945				Rhodes 652
diagnostics check, practice chemical explosion w/hot hanford slugs	5/6/1945	5/7/1945			Rhodes 654
Little boy minus core sent from ABQ	7/14/1945				Rhodes 662
Finish (re)processing metal for part of target and almost all of projectile (U-235)	7/1/1945				hewlett 375
about 50 kgs U-235 reprocessed & cast	7/1/1945				LAMS-266
Finish casting U metal (rings) completing fabrication of Littleboy	7/24/1945				Rhodes 691, hewlett 380
Mass LB = 64.15 kg					Coster-Mullen (Sublette)
Mass Pu FM = 6.2kg (pu gallium alloy, 3 % molar gallium or .8% by weight)					Coster-Mullen (Sublette)
3 pairs of hemispheres fabricated out of delta phas alloys	7/1/1945				LAMS-266 p18

APPENDIX B: U.S. S-50 LIQUID THERMAL DIFFUSION PETRI NET DATA

Detailed

Number	Transitions	Ref Time [d]
1	Operate S-50 Rack 21	1
2	Operate S-50 Rack 20	1
3	Operate S-50 Rack 19	1
4	Operate S-50 Rack 18	1
5	Operate S-50 Rack 17	1
6	Operate S-50 Rack 16	1
7	Operate S-50 Rack 15	1
8	Operate S-50 Rack 14	1
9	Operate S-50 Rack 13	1
10	Operate S-50 Rack 12	1
11	Operate S-50 Rack 11	1
12	Operate S-50 Rack 10	1
13	Operate S-50 Rack 9	1
14	Operate S-50 Rack 8	1
15	Operate S-50 Rack 7	1
16	Operate S-50 Rack 6	1
17	Operate S-50 Rack 5	1
18	Operate S-50 Rack 4	1
19	Operate S-50 Rack 3	1
20	Operate S-50 Rack 2	1
21	Operate S-50 Rack 1	1
22	Build 1 Rack S-50	7
23	Build S-50 Complex	97
24	Decide for S-50	175
25	Build Pilot LTD	196
26	Design Pilot LTD	45
27	Operate Lab LTD	367
28	Build Lab LTD	137
29	Design Lab LTD	163

Number	Places	M1	DNW Mark
1	.85 wt% Enriched U	0	20420
2	Nat U	1.00E+09	0
3	S-50 Racks	0	0
4	S-50 Complex	0	0
5	S-50 Decision	0	0
6	Pilot LTD Design	0	0
7	Pilot LTD	0	0
8	Lab LTD Facility	0	0
9	Tested Lab LTD design	0	0
10	LTD R&D	1	0
11	Lab LTD Design	0	0

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
T1	0	8	1	0	0	0	0	0	0	0	0
T2	0	8	1	0	0	0	0	0	0	0	0
T3	0	8	1	0	0	0	0	0	0	0	0
T4	0	8	1	0	0	0	0	0	0	0	0
T5	0	8	1	0	0	0	0	0	0	0	0
T6	0	8	1	0	0	0	0	0	0	0	0
T7	0	8	1	0	0	0	0	0	0	0	0
T8	0	8	1	0	0	0	0	0	0	0	0
T9	0	8	1	0	0	0	0	0	0	0	0
T10	0	8	1	0	0	0	0	0	0	0	0
T11	0	8	1	0	0	0	0	0	0	0	0
T12	0	8	1	0	0	0	0	0	0	0	0
T13	0	8	1	0	0	0	0	0	0	0	0
T14	0	8	1	0	0	0	0	0	0	0	0
T15	0	8	1	0	0	0	0	0	0	0	0
T16	0	8	1	0	0	0	0	0	0	0	0
T17	0	8	1	0	0	0	0	0	0	0	0
T18	0	8	1	0	0	0	0	0	0	0	0
T19	0	8	1	0	0	0	0	0	0	0	0
T20	0	8	1	0	0	0	0	0	0	0	0
T21	0	8	1	0	0	0	0	0	0	0	0
T22	0	0	0	1	0	0	0	0	0	0	0
T23	0	0	0	0	1	0	0	0	0	0	0
T24	0	0	0	0	0	1	0	0	0	0	0
T25	0	0	0	0	0	1	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	1	0	0
T27	0	0	0	0	0	0	0	1	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	1
T29	0	0	0	0	0	0	0	0	0	1	0

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
T1	5	0	1	0	0	0	0	0	0	0	0
T2	5	0	1	0	0	0	0	0	0	0	0
T3	5	0	1	0	0	0	0	0	0	0	0
T4	5	0	1	0	0	0	0	0	0	0	0
T5	5	0	1	0	0	0	0	0	0	0	0
T6	5	0	1	0	0	0	0	0	0	0	0

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
T7	5	0	1	0	0	0	0	0	0	0	0
T8	5	0	1	0	0	0	0	0	0	0	0
T9	5	0	1	0	0	0	0	0	0	0	0
T10	5	0	1	0	0	0	0	0	0	0	0
T11	5	0	1	0	0	0	0	0	0	0	0
T12	5	0	1	0	0	0	0	0	0	0	0
T13	5	0	1	0	0	0	0	0	0	0	0
T14	5	0	1	0	0	0	0	0	0	0	0
T15	5	0	1	0	0	0	0	0	0	0	0
T16	5	0	1	0	0	0	0	0	0	0	0
T17	5	0	1	0	0	0	0	0	0	0	0
T18	5	0	1	0	0	0	0	0	0	0	0
T19	5	0	1	0	0	0	0	0	0	0	0
T20	5	0	1	0	0	0	0	0	0	0	0
T21	5	0	1	0	0	0	0	0	0	0	0
T22	0	0	1	1	0	0	0	0	0	0	0
T23	0	0	0	1	0	0	0	0	0	0	0
T24	0	0	0	0	1	0	0	0	0	0	0
T25	0	0	0	0	0	0	1	0	0	0	0
T26	0	0	0	0	0	2	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	1	0	0
T28	0	0	0	0	0	0	0	1	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	1

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
T1	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
T13	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	21	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	1	0	0	0	0	0	0
T25	0	0	0	0	0	0	1	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0

Medium

Number	Transitions	Ref Time [d]
1	Operate S-50 Rack 21	1
2	Operate S-50 Rack 20	1
3	Operate S-50 Rack 19	1
4	Operate S-50 Rack 18	1
5	Operate S-50 Rack 17	1
6	Operate S-50 Rack 16	1
7	Operate S-50 Rack 15	1
8	Operate S-50 Rack 14	1
9	Operate S-50 Rack 13	1
10	Operate S-50 Rack 12	1
11	Operate S-50 Rack 11	1
12	Operate S-50 Rack 10	1
13	Operate S-50 Rack 9	1
14	Operate S-50 Rack 8	1
15	Operate S-50 Rack 7	1
16	Operate S-50 Rack 6	1

Number	Transitions	Ref Time [d]
17	Operate S-50 Rack 5	1
18	Operate S-50 Rack 4	1
19	Operate S-50 Rack 3	1
20	Operate S-50 Rack 2	1
21	Operate S-50 Rack 1	1
22	Build 1 Rack S-50	7
23	Build S-50 Complex	272
24	Design Pilot LTD	412
25	Build Lab LTD	300

Number	Places
1	.85 wt% U
2	Nat U
3	S-50 Racks
4	S-50 Complex
5	Pilot LTD Design
6	Lab LTD Facility
7	LTD R&D

D-	P1	P2	P3	P4	P5	P6	P7
T1	0	8	1	0	0	0	0
T2	0	8	1	0	0	0	0
T3	0	8	1	0	0	0	0
T4	0	8	1	0	0	0	0
T5	0	8	1	0	0	0	0
T6	0	8	1	0	0	0	0
T7	0	8	1	0	0	0	0
T8	0	8	1	0	0	0	0
T9	0	8	1	0	0	0	0
T10	0	8	1	0	0	0	0
T11	0	8	1	0	0	0	0
T12	0	8	1	0	0	0	0
T13	0	8	1	0	0	0	0
T14	0	8	1	0	0	0	0
T15	0	8	1	0	0	0	0
T16	0	8	1	0	0	0	0

D-	P1	P2	P3	P4	P5	P6	P7
T17	0	8	1	0	0	0	0
T18	0	8	1	0	0	0	0
T19	0	8	1	0	0	0	0
T20	0	8	1	0	0	0	0
T21	0	8	1	0	0	0	0
T22	0	0	0	1	0	0	0
T23	0	0	0	0	1	0	0
T24	0	0	0	0	0	1	0
T25	0	0	0	0	0	0	1

D+	P1	P2	P3	P4	P5	P6	P7
T1	5	0	1	0	0	0	0
T2	5	0	1	0	0	0	0
T3	5	0	1	0	0	0	0
T4	5	0	1	0	0	0	0
T5	5	0	1	0	0	0	0
T6	5	0	1	0	0	0	0
T7	5	0	1	0	0	0	0
T8	5	0	1	0	0	0	0
T9	5	0	1	0	0	0	0
T10	5	0	1	0	0	0	0
T11	5	0	1	0	0	0	0
T12	5	0	1	0	0	0	0
T13	5	0	1	0	0	0	0
T14	5	0	1	0	0	0	0
T15	5	0	1	0	0	0	0
T16	5	0	1	0	0	0	0
T17	5	0	1	0	0	0	0
T18	5	0	1	0	0	0	0
T19	5	0	1	0	0	0	0
T20	5	0	1	0	0	0	0
T21	5	0	1	0	0	0	0
T22	0	0	1	1	0	0	0
T23	0	0	0	1	0	0	0
T24	0	0	0	0	1	0	0
T25	0	0	0	0	0	1	0

H	P1	P2	P3	P4	P5	P6	P7
T1	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0
T22	0	0	21	0	0	0	0
T23	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0

Coarse

Number	Transitions	Ref Time [d]
1	Operate S-50 Rack 21	1
2	Operate S-50 Rack 20	1
3	Operate S-50 Rack 19	1
4	Operate S-50 Rack 18	1
5	Operate S-50 Rack 17	1
6	Operate S-50 Rack 16	1
7	Operate S-50 Rack 15	1
8	Operate S-50 Rack 14	1

Number	Transitions	Ref Time [d]
9	Operate S-50 Rack 13	1
10	Operate S-50 Rack 12	1
11	Operate S-50 Rack 11	1
12	Operate S-50 Rack 10	1
13	Operate S-50 Rack 9	1
14	Operate S-50 Rack 8	1
15	Operate S-50 Rack 7	1
16	Operate S-50 Rack 6	1
17	Operate S-50 Rack 5	1
18	Operate S-50 Rack 4	1
19	Operate S-50 Rack 3	1
20	Operate S-50 Rack 2	1
21	Operate S-50 Rack 1	1
22	Build 1 Rack S-50	7
23	Build S-50 Complex	984

Number	Places
1	.85 wt% U
2	Nat U
3	S-50 Racks
4	S-50 Complex
5	LTD R&D

D-	P1	P2	P3	P4	P5
T1	0	8	1	0	0
T2	0	8	1	0	0
T3	0	8	1	0	0
T4	0	8	1	0	0
T5	0	8	1	0	0
T6	0	8	1	0	0
T7	0	8	1	0	0
T8	0	8	1	0	0
T9	0	8	1	0	0
T10	0	8	1	0	0
T11	0	8	1	0	0
T12	0	8	1	0	0

D-	P1	P2	P3	P4	P5
T13	0	8	1	0	0
T14	0	8	1	0	0
T15	0	8	1	0	0
T16	0	8	1	0	0
T17	0	8	1	0	0
T18	0	8	1	0	0
T19	0	8	1	0	0
T20	0	8	1	0	0
T21	0	8	1	0	0
T22	0	0	0	1	0
T23	0	0	0	0	1

D+	P1	P2	P3	P4	P5
T1	5	0	1	0	0
T2	5	0	1	0	0
T3	5	0	1	0	0
T4	5	0	1	0	0
T5	5	0	1	0	0
T6	5	0	1	0	0
T7	5	0	1	0	0
T8	5	0	1	0	0
T9	5	0	1	0	0
T10	5	0	1	0	0
T11	5	0	1	0	0
T12	5	0	1	0	0
T13	5	0	1	0	0
T14	5	0	1	0	0
T15	5	0	1	0	0
T16	5	0	1	0	0
T17	5	0	1	0	0
T18	5	0	1	0	0
T19	5	0	1	0	0
T20	5	0	1	0	0
T21	5	0	1	0	0
T22	0	0	1	1	0
T23	0	0	0	1	0

H	P1	P2	P3	P4	P5
T1	0	0	0	0	0
T2	0	0	0	0	0
T3	0	0	0	0	0
T4	0	0	0	0	0
T5	0	0	0	0	0
T6	0	0	0	0	0
T7	0	0	0	0	0
T8	0	0	0	0	0
T9	0	0	0	0	0
T10	0	0	0	0	0
T11	0	0	0	0	0
T12	0	0	0	0	0
T13	0	0	0	0	0
T14	0	0	0	0	0
T15	0	0	0	0	0
T16	0	0	0	0	0
T17	0	0	0	0	0
T18	0	0	0	0	0
T19	0	0	0	0	0
T20	0	0	0	0	0
T21	0	0	0	0	0
T22	0	0	21	0	0
T23	0	0	0	0	0

APPENDIX C: U.S. K-25 GASEOUS DIFFUSION PETRI NET DATA

Detailed

Number	Transitions	Ref Time [d]
1	Operate 5 linked K-25 Units for 80 wt% U-235	1
2	Operate 5 linked K-25 units	1
3	Link 4th & 5th K-25 Units to plant	22
4	Operate 3 linked K-25 units	1
5	Link 3 units of K-25	29
6	Operate 1 K-25 Unit 2	1
7	Operate 1 K-25 Unit 1	1
8	Complete 1 K-25 Unit	31
9	Install barriers, test, and train	51
10	Build K-25 support facilities	91
11	Build main K-25 buildings	488
12	Produce Barriers	214
13	Install new barrier process in full scale barrier plant	61
14	Remove old barrier process from full scale barrier plant	60
15	Decide to use new barrier	123
16	Re-purpose Pilot barrier plant	60
17	Build Full scale barrier plant	206
18	Layout K-25 Site	93
19	Finish K-25 Design	184
20	Re-design barrier	304
21	Build barrier pilot plant	181
22	Decide to build full scale barrier plant	121
23	Make K-25 Plot Plan	406
24	Design Prototype Barrier	316

Number	Places	M1	DNW Mark
1	80 wt% U	0	0
2	Full Plant K-25 Experience	0	0
3	23 wt% U	0	0
4	Operational K-25 Units	0	0
5	# K-25 Units in operation (block 1 unit operation)	0	0
6	Send all .85 wt% U to K-25	0	0
7	Operational linked K-25 Units	0	0

Number	Places	M1	DNW Mark
8	.85 wt% U	1.00E+09	0
9	7 wt% U	0	210
10	1.1wt% U	0	0
11	Tested Equipment in K-25 Buildings	0	0
12	K-25 support facilities	0	0
13	K-25 main buildings	0	0
14	Barriers	0	0
15	Operational Full scale barrier plant	0	0
16	Stripped full scale barrier plant	0	0
17	Decision to use new barrier	0	0
18	Pilot barrier plant for new design	0	0
19	Full scale barrier plant	0	0
20	K-25 Site Layout	0	0
21	K-25 Design	0	0
22	Redesigned barrier design	0	0
23	Pilot barrier plant	0	0
24	Decision to build full scale barrier plant	0	0
25	K-25 Plot Plan	0	0
26	Prototype Barrier	0	0
27	Diffusion R&D	2	0

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
T1	0	140	0	0	0	0	0	126	0	0	0	0	0	0
T2	0	0	0	0	0	0	5	126	0	0	0	0	0	0
T3	0	0	0	2	0	0	1	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	3	126	0	0	0	0	0	0
T5	0	0	0	3	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	1	0	0	0	126	0	0	0	0	0	0
T7	0	0	0	1	0	0	0	126	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	1	1
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27
T1	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	1	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	1	0	0	0	0	0	0
T12	1	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	1	0	1	0	0	0	0	0	0	0	0	0
T14	0	0	1	0	1	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	1	0	0	0	0	0
T16	0	0	1	0	0	0	0	0	1	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	1	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	1	0	0
T19	0	0	0	0	0	0	0	0	0	0	1	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	1	0
T21	0	0	0	0	0	0	0	0	0	0	0	1	0
T22	0	0	0	0	0	0	0	0	0	0	0	1	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	1
T24	0	0	0	0	0	0	0	0	0	0	0	0	1

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
T1	1	140	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	1	3	0	0	0	5	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	3	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	3	0	10	0	0	0	0	0
T5	0	0	0	0	0	0	3	0	0	0	0	0	0	0
T6	0	0	0	1	0	0	0	0	0	86	0	0	0	0
T7	0	0	0	1	0	0	0	0	0	86	0	0	0	0
T8	0	0	0	1	1	1	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	3	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27
T1	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27
T12	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	1	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	1	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	2	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	1	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	1	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	1	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	1	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	1	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	1	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	1	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	2	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	3	0

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	140	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	2	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	3	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	3	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27
T1	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0

Medium

Number	Transitions	Ref Time [d]
1	Operate 5 linked K-25 Units for 80 wt% U-235	1
2	Operate 5 linked K-25 units	1
3	Link 4th & 5th K-25 Units to plant	22
4	Operate 3 linked K-25 units	1

Number	Transitions	Ref Time [d]
5	Link 3 units of K-25	29
6	Operate 1 K-25 Unit 2	1
7	Operate 1 K-25 Unit 1	1
8	Complete 1 K-25 Unit	31
9	Install barriers, test, and train	51
10	Build K-25 support facilities	184
11	Build main K-25 buildings	488
12	Produce Barriers	214
13	Install new barrier process in full scale barrier plant	61
14	Remove old barrier process from full scale barrier plant	60
15	Decide to use new barrier	427
16	Re-purpose Pilot barrier plant	60
17	Build Full scale barrier plant	327
18	Finish K-25 Design	184
19	Build barrier pilot plant	181
20	Make K-25 Plot Plan	406
21	Design Prototype Barrier	316

Number	Places
1	80 wt% U
2	Full Plant K-25 Experience
3	23 wt% U
4	Operational K-25 Units
5	# K-25 Units in operation (block 1 unit operation)
6	Send all .85 wt% U to K-25
7	Operational linked K-25 Units
8	.85 wt% U
9	7 wt% U
10	1.1 wt% U
11	Tested Equipment in K-25 Buildings
12	K-25 support facilities
13	K-25 main buildings
14	Barriers
15	Operational Full scale barrier plant
16	Stripped full scale barrier plant
17	Decision to use new barrier
18	Pilot barrier plant for new design

Number	Places
19	Full scale barrier plant
20	K-25 Design
21	Pilot barrier plant
22	K-25 Plot Plan
23	Prototype Barrier
24	Diffusion R&D

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
T1	0	140	0	0	0	0	0	126	0	0	0	0
T2	0	0	0	0	0	0	5	126	0	0	0	0
T3	0	0	0	2	0	0	1	0	0	0	0	0
T4	0	0	0	0	0	0	3	126	0	0	0	0
T5	0	0	0	3	0	0	0	0	0	0	0	0
T6	0	0	0	1	0	0	0	126	0	0	0	0
T7	0	0	0	1	0	0	0	126	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	1	0
T9	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	1
T12	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0

D-	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24
T1	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0

D-	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24
T6	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0
T9	1	1	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	1	0	0
T11	0	0	0	0	0	0	0	1	0	0	0	0
T12	0	0	1	0	0	0	0	0	0	0	0	0
T13	0	0	0	1	0	1	0	0	0	0	0	0
T14	0	0	0	0	1	0	1	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	1	0
T16	0	0	0	0	1	0	0	0	1	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	1	0
T18	0	0	0	0	0	0	0	0	0	1	0	0
T19	0	0	0	0	0	0	0	0	0	0	1	0
T20	0	0	0	0	0	0	0	0	0	0	0	1
T21	0	0	0	0	0	0	0	0	0	0	0	1

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
T1	1	140	0	0	0	0	0	0	0	0	0	0
T2	0	1	3	0	0	0	5	0	0	0	0	0
T3	0	0	0	0	0	0	3	0	0	0	0	0
T4	0	0	0	0	0	0	3	0	10	0	0	0
T5	0	0	0	0	0	0	3	0	0	0	0	0
T6	0	0	0	1	0	0	0	0	0	86	0	0
T7	0	0	0	1	0	0	0	0	0	86	0	0
T8	0	0	0	1	1	1	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	3	0
T10	0	0	0	0	0	0	0	0	0	0	0	1
T11	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
T20	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0

D+	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24
T1	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0
T11	1	0	0	0	0	0	0	0	0	0	0	0
T12	0	1	0	0	0	0	0	0	0	0	0	0
T13	0	0	1	0	0	0	0	0	0	0	0	0
T14	0	0	0	1	0	0	0	0	0	0	0	0
T15	0	0	0	0	2	0	0	0	0	0	0	0
T16	0	0	0	0	0	1	0	0	0	0	0	0
T17	0	0	0	0	0	0	1	0	0	0	0	0
T18	0	0	0	0	0	0	0	1	0	0	0	0
T19	0	0	0	0	0	0	0	0	1	0	0	0
T20	0	0	0	0	0	0	0	0	0	2	0	0
T21	0	0	0	0	0	0	0	0	0	0	3	0

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
T1	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	140	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	2	0	0	5	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	3	0	0	0	0	0	0	0
T7	0	0	0	0	3	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
T10	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0

H	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24
T1	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0
T11	1	0	0	0	0	0	0	0	0	0	0	0
T12	0	1	0	0	0	0	0	0	0	0	0	0
T13	0	0	1	0	0	0	0	0	0	0	0	0
T14	0	0	0	1	0	0	0	0	0	0	0	0
T15	0	0	0	0	2	0	0	0	0	0	0	0
T16	0	0	0	0	0	1	0	0	0	0	0	0
T17	0	0	0	0	0	0	1	0	0	0	0	0
T18	0	0	0	0	0	0	0	1	0	0	0	0
T19	0	0	0	0	0	0	0	0	1	0	0	0
T20	0	0	0	0	0	0	0	0	0	2	0	0
T21	0	0	0	0	0	0	0	0	0	0	3	0

Coarse

Number	Transitions	Ref Time [d]
1	Operate 5 linked K-25 Units for 80 wt% U-235	1
2	Operate 5 linked K-25 units	1
3	Link 4th & 5th K-25 Units to plant	22
4	Operate 3 linked K-25 units	1
5	Link 3 units of K-25	29
6	Operate 1 K-25 Unit 2	1
7	Operate 1 K-25 Unit 1	1
8	Complete 1 K-25 Unit	31
9	Produce Barriers, build K-25, Install barriers, test, and train	1129

Number	Places
1	80 wt% U
2	Full Plant K-25 Experience
3	23 wt% U
4	Operational K-25 Units
5	# K-25 Units in operation (block 1 unit operation)
6	Send all .85 wt% U to K-25
7	Operational linked K-25 Units
8	.85 wt% U
9	7 wt% U
10	1.1 wt% U
11	Tested Equipment in K-25 Buildings
12	Diffusion R&D

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
T1	0	140	0	0	0	0	0	126	0	0	0	0
T2	0	0	0	0	0	0	5	126	0	0	0	0
T3	0	0	0	2	0	0	1	0	0	0	0	0
T4	0	0	0	0	0	0	3	126	0	0	0	0
T5	0	0	0	3	0	0	0	0	0	0	0	0
T6	0	0	0	1	0	0	0	126	0	0	0	0
T7	0	0	0	1	0	0	0	126	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	1	0
T9	0	0	0	0	0	0	0	0	0	0	0	1

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
T1	1	140	0	0	0	0	0	0	0	0	0	0
T2	0	1	3	0	0	0	5	0	0	0	0	0
T3	0	0	0	0	0	0	3	0	0	0	0	0
T4	0	0	0	0	0	0	3	0	10	0	0	0
T5	0	0	0	0	0	0	3	0	0	0	0	0
T6	0	0	0	1	0	0	0	0	0	86	0	0
T7	0	0	0	1	0	0	0	0	0	86	0	0
T8	0	0	0	1	1	1	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	3	0

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
T1	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	140	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	2	0	0	5	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	3	0	0	0	0	0	0	0
T7	0	0	0	0	3	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX D: U.S. Y-12 EMIS PETRI NET DATA

Detailed: Note Transitions 1-6 and Places 1, 2, 3, 5, 7, and 9 do not occur in the full network as they represent available products from other US materials production streams.

Number	Transitions	Ref Time [d]
1	Operate Linked K-25	1
2	Enable Linked K-25	1238
3	Operate K-25	1
4	Enable K-25	1168
5	Operate S-50	1
6	Enable S-50	1092
7	Operate Beta 6	5
8	Operate Beta 5	5
9	Operate Beta 4	5
10	Operate Beta 3	5
11	Complete Beta 6	821
12	Complete Beta 5	791
13	Complete Beta 4	761
14	Complete Beta 3	731
15	Build Lab Scale EMIS	41
16	Design Calutron	153
17	Operate Beta 2	5
18	Operate Beta 1	5
19	Operate 9 Alphas on 7wt% U	1
20	Operate 9 Alphas on .85wt% U	1
21	Operate 9 Alphas on Nat U	1
22	Complete Beta 2	517
23	Complete Beta 1	487
24	Operate 9 Alphas on 1.1wt% U	1
25	Design Beta	169
26	Build & Test 9 Alphas	652
27	Decide to Build Beta	27
28	Design Alpha	201

Number	Places	M1	DNW Mark
1	Linked K-25 Work	1	0
2	K-25 Work	1	0
3	S-50 Work	1	0
4	7 wt% U	0	0
5	Linked K-25 Enabled	0	0
6	1.1 wt% U	0	0
7	K-25 Enabled	0	0
8	.85 wt% U	0	0
9	S-50 Enabled	0	0
10	Send all .85 wt% U to K-25	0	0
11	EMIS R&D	1	0
12	Lab Scale EMIS	0	0
13	80 wt% U	0	66
14	Nat U	1.00E+09	0
15	Operational Betas	0	0
16	10 wt% U	0	0
17	Beta Design	0	0
18	9 Operational Alphas	0	0
19	Decision to build Beta	0	0
20	Alpha Design	0	0
21	Calutron Design	0	0

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
T1	0	0	0	0	1	0	0	0	0	0	0
T2	1	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	1	0	0	0	0
T4	0	1	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	1	0	0
T6	0	0	1	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
T15	0	0	0	0	0	0	0	0	0	0	1
T16	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	27	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	27	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	27	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0

D-	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21
T1	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	1	8	0	0	0	0	0
T8	0	0	0	1	8	0	0	0	0	0
T9	0	0	0	1	8	0	0	0	0	0
T10	0	0	0	1	8	0	0	0	0	0
T11	0	0	0	0	0	1	0	0	0	0
T12	0	0	0	0	0	1	0	0	0	0
T13	0	0	0	0	0	1	0	0	0	0
T14	0	0	0	0	0	1	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0
T16	1	0	0	0	0	0	0	0	0	0
T17	0	0	0	1	8	0	0	0	0	0
T18	0	0	0	1	8	0	0	0	0	0
T19	0	0	0	0	0	0	1	0	0	0
T20	0	0	0	0	0	0	1	0	0	0
T21	0	0	27	0	0	0	1	0	0	0

D-	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21
T22	0	0	0	0	0	1	0	0	0	0
T23	0	0	0	0	0	1	0	0	0	0
T24	0	0	0	0	0	0	1	0	0	0
T25	0	0	0	0	0	0	0	1	0	0
T26	0	0	0	0	0	0	0	0	1	0
T27	0	0	0	0	0	0	0	0	1	0
T28	0	0	0	0	0	0	0	0	0	1

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
T1	0	0	0	10	1	0	0	0	0	0	0
T2	0	0	0	0	1	0	0	0	0	0	0
T3	0	0	0	0	0	85	1	0	0	0	0
T4	0	0	0	0	0	0	1	0	0	1	0
T5	0	0	0	0	0	0	0	105	1	0	0
T6	0	0	0	0	0	0	0	0	1	0	0
T7	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0

D+	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21
T1	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0
T7	0	1	0	1	0	0	0	0	0	0
T8	0	1	0	1	0	0	0	0	0	0
T9	0	1	0	1	0	0	0	0	0	0
T10	0	1	0	1	0	0	0	0	0	0
T11	0	0	0	1	0	0	0	0	0	0
T12	0	0	0	1	0	0	0	0	0	0
T13	0	0	0	1	0	0	0	0	0	0
T14	0	0	0	1	0	0	0	0	0	0
T15	1	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	1
T17	0	1	0	1	0	0	0	0	0	0
T18	0	1	0	1	0	0	0	0	0	0
T19	0	0	0	0	11	0	1	0	0	0
T20	0	0	0	0	2	0	1	0	0	0
T21	0	0	0	0	2	0	1	0	0	0
T22	0	0	0	1	0	0	0	0	0	0
T23	0	0	0	1	0	0	0	0	0	0
T24	0	0	0	0	3	0	1	0	0	0
T25	0	0	0	0	0	6	0	0	0	0
T26	0	0	0	0	0	0	1	0	0	0
T27	0	0	0	0	0	0	0	1	0	0
T28	0	0	0	0	0	0	0	0	2	0

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
T1	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
T6	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	27	0	27	0	0	0	1	0
T21	0	0	0	27	0	27	0	27	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	27	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0

H	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21
T1	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	5	0	0	0	0	0	0

H	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21
T13	0	0	0	4	0	0	0	0	0	0
T14	0	0	0	3	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	2	0	0	0	0	0	0
T23	0	0	0	1	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0

Medium

Number	Transitions	Ref Time
1	Operate Linked K-25	1
2	Enable Linked K-25	1238
3	Operate K-25	1
4	Enable K-25	1168
5	Operate S-50	1
6	Enable S-50	1092
7	Operate Beta 6	5
8	Operate Beta 5	5
9	Operate Beta 4	5
10	Operate Beta 3	5
11	Complete Beta 6	821
12	Complete Beta 5	791
13	Complete Beta 4	761
14	Complete Beta 3	731
15	Design Calutron	194
16	Operate Beta 2	5
17	Operate Beta 1	5

Number	Transitions	Ref Time
18	Operate 9 Alphas on 7wt% U	1
19	Operate 9 Alphas on .85wt% U	1
20	Operate 9 Alphas on Nat U	1
21	Complete Beta 2	517
22	Complete Beta 1	487
23	Operate 9 Alphas on 1.1wt% U	1
24	Design Beta	196
25	Build & Test 9 Alphas	652
26	Design Alpha	201

Number	Places
1	Linked K-25 Work
2	K-25 Work
3	S-50 Work
4	7 wt% U
5	Linked K-25 Enabled
6	1.1 wt% U
7	K-25 Enabled
8	.85 wt% U
9	S-50 Enabled
10	Send all .85 wt% U to K-25
11	EMIS R&D
12	80 wt% U
13	Nat U
14	Operational Betas
15	10 wt% U
16	Beta Design
17	9 Operational Alphas
18	Alpha Design
19	Calutron Design

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19
T1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19
T5	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T6	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	0	0	0	0
T18	0	0	0	27	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T19	0	0	0	0	0	0	0	27	0	0	0	0	0	0	0	0	1	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	27	0	0	0	1	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T23	0	0	0	0	0	27	0	0	0	0	0	0	0	0	0	0	1	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19
T1	0	0	0	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	85	1	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	105	1	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T16	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	1	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19
T19	0	0	0	27	0	27	0	0	0	1	0	0	0	0	0	0	0	0	0
T20	0	0	0	27	0	27	0	27	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T23	0	0	0	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Coarse

Number	Transitions	Ref Time [d]
1	Operate Linked K-25	1
2	Enable Linked K-25	1238
3	Operate K-25	1
4	Enable K-25	1168
5	Operate S-50	1
6	Enable S-50	1092
7	Operate Beta 6	5
8	Operate Beta 5	5
9	Operate Beta 4	5
10	Operate Beta 3	5
11	Complete Beta 6	821
12	Complete Beta 5	791
13	Complete Beta 4	761
14	Complete Beta 3	731
15	Operate Beta 2	5
16	Operate Beta 1	5
17	Operate 9 Alphas on 7wt% U	1
18	Operate 9 Alphas on .85wt% U	1
19	Operate 9 Alphas on Nat U	1
20	Complete Beta 2	517
21	Complete Beta 1	487
22	Operate 9 Alphas on 1.1wt% U	1
23	Design Beta	196
24	Build & Test 9 Alphas	652
25	Design Alpha	395

Number	Places
1	Linked K-25 Work
2	K-25 Work
3	S-50 Work
4	7 wt% U
5	Linked K-25 Enabled
6	1.1 wt% U
7	K-25 Enabled
8	.85 wt% U
9	S-50 Enabled
10	Send all .85 wt% U to K-25
11	EMIS R&D
12	80 wt% U
13	Nat U
14	Operational Betas
15	10 wt% U
16	Beta Design
17	9 Operational Alphas
18	Alpha Design

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18
T1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T6	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	0	0	0

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	0	0	0
T17	0	0	0	27	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T18	0	0	0	0	0	0	0	27	0	0	0	0	0	0	0	0	1	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	27	0	0	0	1	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T22	0	0	0	0	0	27	0	0	0	0	0	0	0	0	0	0	1	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T25	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18
T1	0	0	0	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	85	1	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	105	1	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	1	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	27	0	27	0	0	0	1	0	0	0	0	0	0	0	0
T19	0	0	0	27	0	27	0	27	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T22	0	0	0	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX E: U.S. W & X PU PRODUCTION PETRI NET DATA

Detailed

Number	Transitions	Ref Time [d]
1	Isolate Pu	5
2	Reprocess spent fuel in 221 facility 3	15
3	Reprocess spent fuel in 221 facility 2	15
4	Reprocess spent fuel in 221 facility 1	15
5	Initiate normal process in 221 facility without testing	1
6	Test process in 221 facility	55
7	Install 221 facility equipment	47
8	Finish building 221 facility 3	179
9	Finish building 221 facility 1	179
10	Finish building 221 facility 2	179
11	Build preliminary 221 facility structures	90
12	Build 231 W isolation facility	287
13	Design 231 W isolation process	100
14	Initiate 221 facilities construction	1
15	Unload/Reload Pile 3	1
16	Unload/Reload Pile 2	1
17	Unload/Reload Pile 1	1
18	Operate Pile 3	21
19	Operate Pile 2	21
20	Operate Pile 1	21
21	Pile 3 is fully loaded	1
22	Pile 2 is fully loaded	1
23	Pile 1 is fully loaded	1
24	Load 1 unit Pile 3	1
25	Load 1 unit Pile 2	1
26	Load 1 unit Pile 1	1
27	Finish Building Pile 3	393
28	Finish Building Pile 2	393
29	Finish Building Pile 1	393
30	Produce Hanford fuel slugs	1
31	Install & Test canning process equipment in fuel slug fabrication facility	52
32	Design Hanford Fuel slug canning process	157
33	Build Hanford fuel slug fabrication facility	245
34	Build Preliminary Pile Structures	30

Number	Transitions	Ref Time [d]
35	Finalize Design for Hanford Pile	192
36	Operate X-10	31
37	Load X-10 with fuel	1
38	Produce canned X-10 fuel slugs	19
39	Finish Building X-10	54
40	Design X-10 Fuel Slug canning process	171
41	Build Primary X-10 Structures	127
42	Reprocess X-10 Slugs	25
43	Build Preliminary Hanford Structures	30
44	Decide to use Ph-Bi separation process	69
45	Finish building pilot separation plant	78
46	Build primary pilot separation plant structures	69
47	Design preliminary pilot separation plant	45
48	Design Basic Hanford Pu Production Plant	70
49	Design X-10	96
50	Build Clinton/X-10 Support Facilities	84
51	Produce X-10 Graphite	99
52	Design Clinton/X-10 site	12
53	Build X-10 Graphite Production Plant	61
54	Design Graphite Production Plant for X-10	101
55	Site Selection for Pilot & Production facilities	38
56	Operate Lab Rx	12
57	Build Lab Rx	15
58	Design Pu Separation processes	412
59	Design Lab Rx & Develop Materials Capability	301

Number	Places	M1	DNW Mark
1	Desired # of Build Preliminary Pile Structures	3	0
2	Desired # Build Hanford fuel slug fabrication facility	1	0
3	Hanford Pile fresh fuel slugs	0	0
4	Desired # of Initiate 221 facilities construction	1	0
5	Nat U	1.00E+09	0
6	Pu	0	19
7	231W isolation facility	0	0
8	Reprocessed Pu	0	0
9	221 facility testing experience	0	0
10	Operational 221 Separations Facilities	0	0

Number	Places	M1	DNW Mark
11	Equipped 221 Separations Facilities	0	0
12	Unequipped untested 221 Separations Facilities	0	0
13	Preliminary 221 facility structures	0	0
14	231W Isolation process design	0	0
15	Validated Separation Design	0	0
16	Initiated 221 facilities construction	0	0
17	Hanford Spent fuel slugs	0	0
18	Spent fueled Hanford Piles	0	0
19	Fully loaded Hanford Piles	0	0
20	Hanford Pile 3 loaded units	0	0
21	Hanford Pile 1 loaded units	0	0
22	Hanford Pile 2 loaded units	0	0
23	Hanford Pile 3 unloaded units	0	0
24	Hanford Pile 1 unloaded units	0	0
25	Hanford Pile 2 unloaded units	0	0
26	Operational Hanford fuel fabrication facility	0	0
27	Unequipped Hanford Pile fuel slug fabrication facility	0	0
28	Hanford Pile fuel slug canning process	0	0
29	Preliminary Pile Structures	0	0
30	Hanford Pile Design	0	0
31	Spent X-10 Fuel Slugs	0	0
32	Loaded X-10 Rx	0	0
33	Canned X-10 fuel slugs	0	0
34	X-10 Fuel Slug canning process	0	0
35	X-10 Graphite	0	0
36	Primary X-10 Structures	0	0
37	X-10 Design to canning process	0	0
38	X-10 Design	0	0
39	Unloaded X-10 Rx	0	0
40	Preliminary Hanford Structures	0	0
41	Decision to use Ph-Bi separation process	0	0
42	Basic Hanford Pu Production Plant Design	0	0
43	Pilot separation plant	0	0
44	Primary pilot separation plant structure	0	0
45	Preliminary pilot separation plant design	0	0
46	Clinton/X-10 Support Facilities	0	0
47	X-10 Graphite Production Plant	0	0
48	Clinton/X-10 Site Design	0	0

Number	Places	M1	DNW Mark
49	X-10 Graphite Production Plant Design	0	0
50	Lab Rx Experience	0	0
51	Clinton/X-10 Site Plan	0	0
52	Hanford site plan	0	0
53	Lab Rx	0	0
54	PhBi & Lanthanum Separation Processes	0	0
55	Pu Separation R&D Program	1	0
56	Lab Rx Design	0	0
57	Rx R&D Program	1	0

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T14	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
T15	0	0	6000	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	6000	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	6000	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	3692	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	3692	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	3692	0	0	0	0	0	0	0	0	0	0	0	0

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	2475	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	6000	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T3	0	6000	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	6000	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	18	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	18	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T30	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T36	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0
T38	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T42	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P46	P47	P48	P49	P50	P51	P52	P53	P54	P55	P56	P57
T1	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0

D-	P46	P47	P48	P49	P50	P51	P52	P53	P54	P55	P56	P57
T31	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0
T41	1	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	1	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	1	0	0	0	0	0	0
T48	0	0	0	0	0	0	1	0	0	0	0	0
T49	0	0	0	0	0	1	0	0	0	0	0	0
T50	0	0	1	0	0	0	0	0	0	0	0	0
T51	0	1	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	1	0	0	0	0	0	0
T53	0	0	0	1	0	0	0	0	0	0	0	0
T54	0	0	0	0	1	0	0	0	0	0	0	0
T55	0	0	0	0	1	0	0	0	0	0	0	0
T56	0	0	0	0	0	0	0	1	0	0	0	0
T57	0	0	0	0	0	0	0	0	0	0	1	0
T58	0	0	0	0	0	0	0	0	0	1	0	0
T59	0	0	0	0	0	0	0	0	0	0	0	1

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
T3	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
T4	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T7	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T12	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	850	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	6000	0	1	0	0	0	0	0	0	0	0	0	0	0
T16	0	6000	0	1	0	0	0	0	0	0	0	0	0	0	0
T17	0	6000	0	1	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0

D+	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T21	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	18	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	18	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	18	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T40	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T48	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
T49	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P46	P47	P48	P49	P50	P51	P52	P53	P54	P55	P56	P57
T1	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0

D+	P46	P47	P48	P49	P50	P51	P52	P53	P54	P55	P56	P57
T11	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0

D+	P46	P47	P48	P49	P50	P51	P52	P53	P54	P55	P56	P57
T49	0	0	0	0	0	0	0	0	0	0	0	0
T50	1	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	1	0	0	0	0	0	0	0	0	0
T53	0	1	0	0	0	0	0	0	0	0	0	0
T54	0	0	0	1	0	0	0	0	0	0	0	0
T55	0	0	0	0	0	3	1	0	0	0	0	0
T56	0	0	0	0	2	0	0	0	0	0	0	0
T57	0	0	0	0	0	0	0	1	0	0	0	0
T58	0	0	0	0	0	0	0	0	1	0	0	0
T59	0	0	0	0	0	0	0	0	0	0	1	0

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P46	P47	P48	P49	P50	P51	P52	P53	P54	P55	P56	P57
T1	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0

H	P46	P47	P48	P49	P50	P51	P52	P53	P54	P55	P56	P57
T29	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0
T54	0	0	0	0	0	0	0	0	0	0	0	0
T55	0	0	0	0	0	0	0	0	0	0	0	0
T56	0	0	0	0	0	0	0	0	0	0	0	0
T57	0	0	0	0	0	0	0	0	0	0	0	0
T58	0	0	0	0	0	0	0	0	0	0	0	0
T59	0	0	0	0	0	0	0	0	0	0	0	0

Medium

Number	Transitions	Ref Time [d]
1	Isolate Pu	5
2	Reprocess spent fuel in 221 facility 3	15
3	Reprocess spent fuel in 221 facility 2	15
4	Reprocess spent fuel in 221 facility 1	15
5	Initiate normal process in 221 facility without testing	1
6	Test process in 221 facility	55
7	Install 221 facility equipment	47
8	Finish building 221 facility 3	179
9	Finish building 221 facility 1	179
10	Finish building 221 facility 2	179
11	Build preliminary 221 facility structures	90
12	Build 231 W isolation facility	287
13	Design 231 W isolation process	100
14	Initiate 221 facilities construction	1
15	Unload/Reload Pile 3	1
16	Unload/Reload Pile 2	1
17	Unload/Reload Pile 1	1
18	Operate Pile 3	21
19	Operate Pile 2	21
20	Operate Pile 1	21
21	Pile 3 is fully loaded	1
22	Pile 2 is fully loaded	1
23	Pile 1 is fully loaded	1
24	Load 1 unit Pile 3	1
25	Load 1 unit Pile 2	1
26	Load 1 unit Pile 1	1
27	Finish Building Pile 3	393
28	Finish Building Pile 2	393
29	Finish Building Pile 1	393
30	Produce Hanford fuel slugs	1
31	Install & Test canning process equipment in fuel slug fabrication facility	52
32	Design Hanford Fuel slug canning process	157
33	Build Hanford fuel slug fabrication facility	245
34	Build Preliminary Pile Structures	30
35	Finalize Design for Hanford Pile	192
36	Operate X-10	32

Number	Transitions	Ref Time [d]
37	Produce canned X-10 fuel slugs	19
38	Finish Building X-10	54
39	Design X-10 Fuel Slug canning process	171
40	Build Primary X-10 Structures	127
41	Reprocess X-10 Slugs	25
42	Build Preliminary Hanford Structures	30
43	Decide to use Ph-Bi separation process	481
44	Finish building pilot separation plant	78
45	Build primary pilot separation plant structures	114
46	Design Basic Hanford Pu Production Plant	70
47	Design X-10	96
48	Build Clinton/X-10 Support Facilities	96
49	Produce X-10 Graphite	99
50	Build X-10 Graphite Production Plant	162
51	Site Selection for Pilot & Production facilities	38
52	Operate Lab Rx	12
53	Build Lab Rx	316

Number	Places	M1	DNW Mark
1	Desired # of Build Preliminary Pile Structures	3	0
2	Desired # Build Hanford fuel slug fabrication facility	1	0
3	Hanford Pile fresh fuel slugs	0	0
4	Desired # of Initiate 221 facilities construction	1	0
5	Nat U	1.00E+09	0
6	Pu	0	19
7	231W isolation facility	0	0
8	Reprocessed Pu	0	0
9	221 facility testing experience	0	0
10	Operational 221 Separations Facilities	0	0
11	Equipped 221 Separations Facilities	0	0
12	Unequipped untested 221 Separations Facilities	0	0
13	Preliminary 221 facility structures	0	0
14	231W Isolation process design	0	0
15	Validated Separation Design	0	0
16	Initiated 221 facilities construction	0	0
17	Hanford Spent fuel slugs	0	0
18	Spent fueled Hanford Piles	0	0

Number	Places	M1	DNW Mark
19	Fully loaded Hanford Piles	0	0
20	Hanford Pile 3 loaded units	0	0
21	Hanford Pile 1 loaded units	0	0
22	Hanford Pile 2 loaded units	0	0
23	Hanford Pile 3 unloaded units	0	0
24	Hanford Pile 1 unloaded units	0	0
25	Hanford Pile 2 unloaded units	0	0
26	Operational Hanford fuel fabrication facility	0	0
27	Unequipped Hanford Pile fuel slug fabrication facility	0	0
28	Hanford Pile fuel slug canning process	0	0
29	Preliminary Pile Structures	0	0
30	Hanford Pile Design	0	0
31	Spent X-10 Fuel Slugs	0	0
32	Canned X-10 fuel slugs	0	0
33	X-10 Fuel Slug canning process	0	0
34	X-10 Graphite	0	0
35	Primary X-10 Structures	0	0
36	X-10 Design to canning process	0	0
37	X-10 Design	0	0
38	Unloaded X-10 Rx	0	0
39	Preliminary Hanford Structures	0	0
40	Decision to use Ph-Bi separation process	0	0
41	Basic Hanford Pu Production Plant Design	0	0
42	Pilot separation plant	0	0
43	Primary pilot separation plant structure	0	0
44	Clinton/X-10 Support Facilities	0	0
45	X-10 Graphite Production Plant	0	0
46	Lab Rx Experience	0	0
47	Clinton/X-10 Site Plan	0	0
48	Hanford site plan	0	0
49	Lab Rx	0	0
50	Pu Separation R&D Program	1	0
51	Rx R&D Program	1	0

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T14	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
T15	0	0	6000	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	6000	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	6000	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	3692	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	3692	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	3692	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	2475	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	6000	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	6000	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	6000	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	18	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	18	0	0	0	0	0	0	0	0

D-	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T23	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T30	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T36	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
T37	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
T41	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0

D-	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P46	P47	P48	P49	P50	P51
T1	0	0	0	0	0	0
T2	0	0	0	0	0	0
T3	0	0	0	0	0	0
T4	0	0	0	0	0	0
T5	0	0	0	0	0	0
T6	0	0	0	0	0	0
T7	0	0	0	0	0	0
T8	0	0	0	0	0	0
T9	0	0	0	0	0	0
T10	0	0	0	0	0	0
T11	0	0	0	0	0	0
T12	0	0	0	0	0	0
T13	0	0	0	0	0	0
T14	0	0	0	0	0	0
T15	0	0	0	0	0	0
T16	0	0	0	0	0	0
T17	0	0	0	0	0	0
T18	0	0	0	0	0	0
T19	0	0	0	0	0	0
T20	0	0	0	0	0	0
T21	0	0	0	0	0	0
T22	0	0	0	0	0	0
T23	0	0	0	0	0	0
T24	0	0	0	0	0	0

D-	P46	P47	P48	P49	P50	P51
T25	0	0	0	0	0	0
T26	0	0	0	0	0	0
T27	0	0	0	0	0	0
T28	0	0	0	0	0	0
T29	0	0	0	0	0	0
T30	0	0	0	0	0	0
T31	0	0	0	0	0	0
T32	0	0	0	0	0	0
T33	0	0	0	0	0	0
T34	0	0	0	0	0	0
T35	0	0	0	0	0	0
T36	0	0	0	0	0	0
T37	0	0	0	0	0	0
T38	0	0	0	0	0	0
T39	0	0	0	0	0	0
T40	0	0	0	0	0	0
T41	0	0	0	0	0	0
T42	0	0	0	0	0	0
T43	0	0	0	0	1	0
T44	0	0	0	0	0	0
T45	0	1	0	0	0	0
T46	0	0	1	0	0	0
T47	0	1	0	0	0	0
T48	0	1	0	0	0	0
T49	0	0	0	0	0	0
T50	1	0	0	0	0	0
T51	1	0	0	0	0	0
T52	0	0	0	1	0	0
T53	0	0	0	0	0	1

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
T3	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
T4	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T7	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T12	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	850	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	6000	0	1	0	0	0	0	0	0	0	0	0	0	0
T16	0	6000	0	1	0	0	0	0	0	0	0	0	0	0	0
T17	0	6000	0	1	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0

D+	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T27	0	0	0	0	0	0	0	18	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	18	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	18	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T39	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T46	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0

D+	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T47	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T49	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P46	P47	P48	P49	P50	P51
T1	0	0	0	0	0	0
T2	0	0	0	0	0	0
T3	0	0	0	0	0	0
T4	0	0	0	0	0	0
T5	0	0	0	0	0	0
T6	0	0	0	0	0	0
T7	0	0	0	0	0	0
T8	0	0	0	0	0	0
T9	0	0	0	0	0	0
T10	0	0	0	0	0	0
T11	0	0	0	0	0	0
T12	0	0	0	0	0	0
T13	0	0	0	0	0	0
T14	0	0	0	0	0	0
T15	0	0	0	0	0	0
T16	0	0	0	0	0	0
T17	0	0	0	0	0	0
T18	0	0	0	0	0	0
T19	0	0	0	0	0	0
T20	0	0	0	0	0	0
T21	0	0	0	0	0	0
T22	0	0	0	0	0	0
T23	0	0	0	0	0	0
T24	0	0	0	0	0	0
T25	0	0	0	0	0	0
T26	0	0	0	0	0	0
T27	0	0	0	0	0	0
T28	0	0	0	0	0	0

D+	P46	P47	P48	P49	P50	P51
T29	0	0	0	0	0	0
T30	0	0	0	0	0	0
T31	0	0	0	0	0	0
T32	0	0	0	0	0	0
T33	0	0	0	0	0	0
T34	0	0	0	0	0	0
T35	0	0	0	0	0	0
T36	0	0	0	0	0	0
T37	0	0	0	0	0	0
T38	0	0	0	0	0	0
T39	0	0	0	0	0	0
T40	0	0	0	0	0	0
T41	0	0	0	0	0	0
T42	0	0	0	0	0	0
T43	0	0	0	0	0	0
T44	0	0	0	0	0	0
T45	0	0	0	0	0	0
T46	0	0	0	0	0	0
T47	0	0	0	0	0	0
T48	0	0	0	0	0	0
T49	0	0	0	0	0	0
T50	0	0	0	0	0	0
T51	0	3	1	0	0	0
T52	2	0	0	0	0	0
T53	0	0	0	1	0	0

Coarse

Number	Transitions	Ref Time [d]
1	Isolate Pu	5
2	Reprocess spent fuel in 221 facility 3	15
3	Reprocess spent fuel in 221 facility 2	15
4	Reprocess spent fuel in 221 facility 1	15
5	Initiate normal process in 221 facility without testing	1
6	Test process in 221 facility	55
7	Install 221 facility equipment	47
8	Finish building 221 facility 3	179

Number	Transitions	Ref Time [d]
9	Finish building 221 facility 1	179
10	Finish building 221 facility 2	179
11	Build preliminary 221 facility structures	90
12	Build 231 W isolation facility	287
13	Design 231 W isolation process	100
14	Initiate 221 facilities construction	1
15	Unload/Reload Pile 3	1
16	Unload/Reload Pile 2	1
17	Unload/Reload Pile 1	1
18	Operate Pile 3	21
19	Operate Pile 2	21
20	Operate Pile 1	21
21	Pile 3 is fully loaded	1
22	Pile 2 is fully loaded	1
23	Pile 1 is fully loaded	1
24	Load 1 unit Pile 3	1
25	Load 1 unit Pile 2	1
26	Load 1 unit Pile 1	1
27	Finish Building Pile 3	393
28	Finish Building Pile 2	393
29	Finish Building Pile 1	393
30	Produce Hanford fuel slugs	1
31	Install & Test canning process equipment in fuel slug fabrication facility	52
32	Design Hanford Fuel slug canning process	157
33	Build Hanford fuel slug fabrication facility	245
34	Build Preliminary Pile Structures	30
35	Finalize Design for Hanford Pile	262
36	Operate X-10	32
37	Produce canned X-10 fuel slugs	19
38	Finish Building X-10	54
39	Design X-10 Fuel Slug canning process	171
40	Build Primary X-10 Structures	127
41	Reprocess X-10 Slugs	25
42	Build Preliminary Hanford Structures	100
43	Decide to use Ph-Bi separation process	481
44	Finish building pilot separation plant	78
45	Build primary pilot separation plant structures	114
46	Design X-10	96

Number	Transitions	Ref Time [d]
47	Build Clinton/X-10 Support Facilities	96
48	Produce X-10 Graphite	261
49	Site Selection for Pilot & Production facilities	38
50	Operate Lab Rx	328

Number	Places	M1	DNW Mark
1	Desired # of Build Preliminary Pile Structures	3	0
2	Desired # Build Hanford fuel slug fabrication facility	1	0
3	Hanford Pile fresh fuel slugs	0	0
4	Desired # of Initiate 221 facilities construction	1	0
5	Nat U	1.00E+09	0
6	Pu	0	19
7	231W isolation facility	0	0
8	Reprocessed Pu	0	0
9	221 facility testing experience	0	0
10	Operational 221 Separations Facilities	0	0
11	Equipped 221 Separations Facilities	0	0
12	Unequipped untested 221 Separations Facilities	0	0
13	Preliminary 221 facility structures	0	0
14	231W Isolation process design	0	0
15	Validated Separation Design	0	0
16	Initiated 221 facilities construction	0	0
17	Hanford Spent fuel slugs	0	0
18	Spent fueled Hanford Piles	0	0
19	Fully loaded Hanford Piles	0	0
20	Hanford Pile 3 loaded units	0	0
21	Hanford Pile 1 loaded units	0	0
22	Hanford Pile 2 loaded units	0	0
23	Hanford Pile 3 unloaded units	0	0
24	Hanford Pile 1 unloaded units	0	0
25	Hanford Pile 2 unloaded units	0	0
26	Operational Hanford fuel fabrication facility	0	0
27	Unequipped Hanford Pile fuel slug fabrication facility	0	0
28	Hanford Pile fuel slug canning process	0	0
29	Preliminary Pile Structures	0	0
30	Hanford Pile Design	0	0
31	Spent X-10 Fuel Slugs	0	0

Number	Places	M1	DNW Mark
32	Canned X-10 fuel slugs	0	0
33	X-10 Fuel Slug canning process	0	0
34	X-10 Graphite	0	0
35	Primary X-10 Structures	0	0
36	X-10 Design to canning process	0	0
37	X-10 Design	0	0
38	Unloaded X-10 Rx	0	0
39	Preliminary Hanford Structures	0	0
40	Decision to use Ph-Bi separation process	0	0
41	Pilot separation plant	0	0
42	Primary pilot separation plant structure	0	0
43	Clinton/X-10 Support Facilities	0	0
44	Lab Rx Experience	0	0
45	Clinton/X-10 Site Plan	0	0
46	Hanford site plan	0	0
47	Pu Separation R&D Program	1	0
48	Rx R&D Program	1	0

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T14	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
T15	0	0	6000	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	6000	0	0	0	0	0	0	0	0	0	0	0	0

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T17	0	0	6000	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	3692	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	3692	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	3692	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	2475	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T2	0	6000	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	6000	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	6000	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	18	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	18	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T30	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40
T1	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	1	0
T15	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0

D-	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40
T25	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0
T32	0	0	1	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	1	0
T34	0	0	0	0	0	0	0	0	1	0
T35	0	0	0	0	0	0	0	0	0	0
T36	0	1	0	0	0	0	0	1	0	0
T37	0	0	1	0	0	0	0	0	0	0
T38	0	0	0	1	1	0	0	0	0	0
T39	0	0	0	0	0	1	0	0	0	0
T40	0	0	0	0	0	0	1	0	0	0
T41	1	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	1
T45	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0

D-	P41	P42	P43	P44	P45	P46	P47	P48
T1	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0

D-	P41	P42	P43	P44	P45	P46	P47	P48
T10	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	1	0	0
T36	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0
T40	0	0	1	0	0	0	0	0
T41	1	0	0	0	0	0	0	0
T42	0	0	0	0	0	1	0	0
T43	0	0	0	0	0	0	1	0
T44	0	1	0	0	0	0	0	0
T45	0	0	0	0	1	0	0	0
T46	0	0	0	0	1	0	0	0
T47	0	0	0	0	1	0	0	0

D-	P41	P42	P43	P44	P45	P46	P47	P48
T48	0	0	0	1	0	0	0	0
T49	0	0	0	1	0	0	0	0
T50	0	0	0	0	0	0	0	1

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
T3	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
T4	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T12	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	850	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	6000	0	1	0	0	0	0	0	0	0	0	0	0	0
T16	0	6000	0	1	0	0	0	0	0	0	0	0	0	0	0
T17	0	6000	0	1	0	0	0	0	0	0	0	0	0	0	0

D+	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T18	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	18	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	18	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	18	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40
T1	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0

D+	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40
T3	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0
T36	1	0	0	0	0	0	0	0	0	0
T37	0	1	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	1	0	0
T39	0	0	2	0	0	0	0	0	0	0
T40	0	0	0	0	1	0	0	0	0	0

D+	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40
T41	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	5	0
T43	0	0	0	0	0	0	0	0	0	1
T44	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	1	1	0	0	0
T47	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	1	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0

D+	P41	P42	P43	P44	P45	P46	P47	P48
T1	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0

D+	P41	P42	P43	P44	P45	P46	P47	P48
T26	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0
T44	1	0	0	0	0	0	0	0
T45	0	1	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0
T47	0	0	1	0	0	0	0	0
T48	0	0	0	0	0	0	0	0
T49	0	0	0	0	3	2	0	0
T50	0	0	0	2	0	0	0	0

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40
T1	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0

H	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40
T19	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0

H	P41	P42	P43	P44	P45	P46	P47	P48
T1	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0

H	P41	P42	P43	P44	P45	P46	P47	P48
T4	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0

H	P41	P42	P43	P44	P45	P46	P47	P48
T42	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0

APPENDIX F: U.S. WEAPONIZATION PETRI NET DATA

Detailed

Number	Transitions	Ref Time [d]
1	Decide to research weapon design theory	163
2	Design Initiator	722
3	Deliver HEU to LA	2
4	Delivery Pu to LA	2
5	Possess Deliverable Pu Implosion Weapon	1
6	Possess Deliverable Gun Weapon	1
7	Make Core Mockup	1
8	Process & fabricate Pu Pit	4
9	Cold Test	1
10	Fabricate Explosive Lenses	39
11	Conduct Implosion Device Test	2
12	Conduct Mock Test	1
13	Prepare Nuclear Weapon Test Site	67
14	Select a Test Site	61
15	Decide to Test Implosion Explosive	296
16	Test & Train with Delivery systems	212
17	Process & Fabricate HEU Gun Pit Component	2
18	Retrofit bombers & bomb system	571
19	Design Gun Explosive	704
20	Complete Lens/mold design	753
21	Complete Implosion explosive design	54
22	Create Preliminary Design	660
23	Decision to split Gun and Implosion R&D	170
24	LA Site Selection	37
25	Gather luminaries	30
26	Groves Decision to appoint Oppenheimer	76

Number	Places
1	Decision to build a nuclear weapon
2	Initiator Design
3	Preliminary Design to Test Site
4	80wt% U
5	Pu

Number	Places
6	Desired Number of Implosion Mockups
7	Deliverable Pu Implosion Weapon
8	Deliverable HEU Gun Weapon
9	Cold Tested Design
10	Implosion Core Mockup
11	Pu Core
12	Hanford Pu
13	Pu Core Design
14	Explosive lenses
15	Explosive lens mold/design
16	Tested Implosion Device Design
17	Mock Tested & Prepared Nuclear Weapon Test Site
18	Prepared Nuclear Weapon Test Site
19	Nuclear Weapon Test Site
20	Decision for a Test
21	Tested & Trained Delivery systems
22	Retrofitted bombers & bomb system
23	Little Boy HEU Pit Components
24	HEU
25	Gun Explosive Design
26	Delivery System R&D
27	Gun R&D
28	Preliminary Design
29	Implosion R&D
30	Centralized Weapons R&D
31	Decision for theoretical weapons research
32	Oppenheimer running Weapons R&D
33	Weapons R&D program

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17
T1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17
T8	0	0	0	0	0	0	0	0	0	0	0	6	1	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T11	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	1
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30	P31	P32	P33
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	1	0	22	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T16	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0

D-	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30	P31	P32	P33
T17	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T5	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
T6	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
T9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
T11	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
T22	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30	P31	P32	P33
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
T18	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	1	1	0	4	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30	P31	P32	P33
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30	P31	P32	P33
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Medium

Number	Transitions	Ref Time [d]
1	Design Initiator	722
2	Deliver HEU to LA	2
3	Delivery Pu to LA	2
4	Possess Deliverable Pu Implosion Weapon	0
5	Possess Deliverable Gun Weapon	0
6	Make Core Mockup	1
7	Process & fabricate Pu Pit	4
8	Cold Test	1
9	Fabricate Explosive Lenses	792
10	Conduct Implosion Device Test	2
11	Conduct Mock Test	1
12	Prepare Nuclear Weapon Test Site	67
13	Select a Test Site	357
14	Test & Train with Delivery systems	783
15	Process & Fabricate HEU Gun Pit Component	2
16	Design Gun Explosive	704
17	Complete Implosion explosive design	54
18	Create Preliminary Design	660
19	Decide to split Gun and Implosion R&D	170

Number	Transitions	Ref Time [d]
20	LA Site Selection	113
21	Gather luminaries	193

Number	Places
1	Decision to build a nuclear weapon
2	Initiator Design
3	Preliminary Design to Test Site
4	80 wt% U
5	Pu
6	Desired Number of Implosion Mockups
7	Deliverable Pu Implosion Weapon
8	Deliverable HEU Gun Weapon
9	Cold Tested Design
10	Implosion Core Mockup
11	Pu Core
12	Hanford Pu
13	Pu Core Design
14	Explosive lenses
15	Tested Implosion Device Design
16	Mock Tested & Prepared Nuclear Weapon Test Site
17	Prepared Nuclear Weapon Test Site
18	Nuclear Weapon Test Site
19	Tested & Trained Delivery systems
20	Little Boy HEU Pit Components
21	HEU
22	Gun Explosive Design
23	Delivery System R&D
24	Gun R&D
25	Preliminary Design
26	Implosion R&D
27	Centralized Weapons R&D
28	Weapons R&D program

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	1	0	0	0	0	0	0	0	0	0	0

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
T3	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	1	0	0	1
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	1	0	0	0	0	0	0	1	0
T7	0	0	0	0	0	0	0	0	0	0	0	6	1	0
T8	0	0	0	0	0	0	0	0	0	1	0	0	0	1
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	1	0	1	0	0	1
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	1	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28
T1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	1	0	0	0	1	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	1	22	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T10	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T14	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T15	0	0	0	0	0	0	3	1	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	1	0	0	0	0

D-	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28
T17	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
T1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T4	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	1	0	1	0
T8	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	3
T10	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	2	0
T18	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	1	0	0	0	1	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	1	1	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	2	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	1	0	1	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T19	0	0	0	0	0	0	0	0	1	1	0	4	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	1

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Coarse

Number	Transitions	Ref Time [d]
1	Design Initiator	722
2	Deliver HEU to LA	2
3	Delivery Pu to LA	2
4	Possess Deliverable Pu Implosion Weapon	0
5	Possess Deliverable Gun Weapon	0
6	Make Core Mockup	1
7	Process & fabricate Pu Pit	4
8	Cold Test	1

Number	Transitions	Ref Time [d]
9	Design & Fabricate Explosive Lenses	792
10	Conduct Implosion Device Test	2
11	Conduct Mock Test	1
12	Prepare Nuclear Weapon Test Site	67
13	Decide to test & Select a Test Site	357
14	Retrofit DS & Test & Train with Delivery systems	783
15	Process & Fabricate HEU Gun Pit Component	2
16	Design Gun Explosive	704
17	Complete Implosion explosive design	54
18	Create Preliminary Design	660
19	Create LA & Decide to split Gun and Implosion R&D	476

Number	Places
1	Decision to build a nuclear weapon
2	Initiator Design
3	Preliminary Design to Test Site
4	80 wt% U
5	Pu
6	Desired Number of Implosion Mockups
7	Deliverable Pu Implosion Weapon
8	Deliverable HEU Gun Weapon
9	Cold Tested Design
10	Implosion Core Mockup
11	Pu Core
12	Hanford Pu
13	Pu Core Design
14	Explosive lenses
15	Tested Implosion Device Design
16	Mock Tested & Prepared Nuclear Weapon Test Site
17	Prepared Nuclear Weapon Test Site
18	Nuclear Weapon Test Site
19	Tested & Trained Delivery systems
20	Little Boy HEU Pit Components
21	HEU
22	Gun Explosive Design
23	Delivery System R&D
24	Gun R&D

Number	Places
25	Preliminary Design
26	Implosion R&D

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	1	0	0	1
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	1	0	0	0	0	0	0	1	0
T7	0	0	0	0	0	0	0	0	0	0	0	6	1	0
T8	0	0	0	0	0	0	0	0	0	1	0	0	0	1
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	1	0	1	0	0	1
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	1	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26
T1	0	0	0	0	0	0	0	0	0	0	0	1
T2	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0
T4	1	0	0	0	1	0	0	0	0	0	0	0
T5	0	0	0	0	1	22	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	1
T10	0	1	0	0	0	0	0	0	0	0	0	0
T11	0	0	1	0	0	0	0	0	0	0	0	0

D-	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26
T12	0	0	0	1	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	1
T14	0	0	0	0	0	0	0	0	1	0	0	0
T15	0	0	0	0	0	0	3	1	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	1	0	0
T17	0	0	0	0	0	0	0	0	0	0	1	0
T18	0	0	0	0	0	0	0	0	0	0	0	1
T19	0	0	0	0	0	0	0	0	0	0	0	0

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
T1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T4	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	1	0	1	0
T8	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	3
T10	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	2	0
T18	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26
T1	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	1	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0
T4	1	0	0	0	1	0	0	0	0	0	0	0
T5	0	0	0	0	1	0	0	0	0	0	0	0

D+	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26
T6	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0
T10	1	1	0	0	0	0	0	0	0	0	0	0
T11	0	1	0	0	0	0	0	0	0	0	0	0
T12	0	0	1	0	0	0	0	0	0	0	0	0
T13	0	0	0	1	0	0	0	0	0	0	0	0
T14	0	0	0	0	2	0	0	0	0	0	0	0
T15	0	0	0	0	0	1	0	1	0	0	0	0
T16	0	0	0	0	0	0	0	1	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	1	0
T19	0	0	0	0	0	0	0	0	1	1	0	4

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26
T1	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0
T10	1	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX G: FULL U.S. PETRI NET DATA

Detailed

Number	Transitions	Ref Time [d]
1	Operate S-50 Rack 21	1
2	Operate S-50 Rack 20	1
3	Operate S-50 Rack 19	1
4	Operate S-50 Rack 18	1
5	Operate S-50 Rack 17	1
6	Operate S-50 Rack 16	1
7	Operate S-50 Rack 15	1
8	Operate S-50 Rack 14	1
9	Operate S-50 Rack 13	1
10	Operate S-50 Rack 12	1
11	Operate S-50 Rack 11	1
12	Operate S-50 Rack 10	1
13	Operate S-50 Rack 9	1
14	Operate S-50 Rack 8	1
15	Operate S-50 Rack 7	1
16	Operate S-50 Rack 6	1
17	Operate S-50 Rack 5	1
18	Operate S-50 Rack 4	1
19	Operate S-50 Rack 3	1
20	Operate S-50 Rack 2	1
21	Operate S-50 Rack 1	1
22	Build 1 Rack S-50	7
23	Build S-50 Complex	97
24	Decide for S-50	175
25	Build Pilot LTD	196
26	Design Pilot LTD	45
27	Operate Lab LTD	367
28	Build Lab LTD	137
29	Design Lab LTD	163
30	Operate 5 linked K-25 Units for 80 wt% U-235	1
31	Operate 5 linked K-25 units	1
32	Link 4th & 5th K-25 Units to plant	22
33	Operate 3 linked K-25 units	1
34	Link 3 units of K-25	29

Number	Transitions	Ref Time [d]
35	Operate 1 K-25 Unit 2	1
36	Operate 1 K-25 Unit 1	1
37	Complete 1 K-25 Unit	31
38	Install barriers, test, and train	51
39	Build K-25 support facilities	91
40	Build main K-25 buildings	488
41	Produce Barriers	214
42	Install new barrier process in full scale barrier plant	61
43	Remove old barrier process from full scale barrier plant	60
44	Decide to use new barrier	123
45	Re-purpose Pilot barrier plant	60
46	Build Full scale barrier plant	206
47	Layout K-25 Site	93
48	Finish K-25 Design	184
49	Re-design barrier	304
50	Build barrier pilot plant	181
51	Decide to build full scale barrier plant	121
52	Make K-25 Plot Plan	406
53	Design Prototype Barrier	316
54	Operate Beta 6	5
55	Operate Beta 5	5
56	Operate Beta 4	5
57	Operate Beta 3	5
58	Complete Beta 6	821
59	Complete Beta 5	791
60	Complete Beta 4	761
61	Complete Beta 3	731
62	Build Lab Scale EMIS	41
63	Design Calutron	153
64	Operate Beta 2	5
65	Operate Beta 1	5
66	Operate 9 Alphas on 7wt% U	1
67	Operate 9 Alphas on .85wt% U	1
68	Operate 9 Alphas on Nat U	1
69	Complete Beta 2	517
70	Complete Beta 1	487
71	Operate 9 Alphas on 1.1wt% U	1
72	Design Beta	169

Number	Transitions	Ref Time [d]
73	Build & Test 9 Alphas	652
74	Decide to Build Beta	27
75	Design Alpha	201
76	Isolate Pu	5
77	Reprocess spent fuel in 221 facility 3	15
78	Reprocess spent fuel in 221 facility 2	15
79	Reprocess spent fuel in 221 facility 1	15
80	Initiate normal process in 221 facility without testing	1
81	Test process in 221 facility	55
82	Install 221 facility equipment	47
83	Finish building 221 facility 3	179
84	Finish building 221 facility 1	179
85	Finish building 221 facility 2	179
86	Build preliminary 221 facility structures	90
87	Build 231 W isolation facility	287
88	Design 231 W isolation process	100
89	Initiate 221 facilities construction	1
90	Unload/Reload Pile 3	1
91	Unload/Reload Pile 2	1
92	Unload/Reload Pile 1	1
93	Operate Pile 3	21
94	Operate Pile 2	21
95	Operate Pile 1	21
96	Pile 3 is fully loaded	1
97	Pile 2 is fully loaded	1
98	Pile 1 is fully loaded	1
99	Load 1 unit Pile 3	1
100	Load 1 unit Pile 2	1
101	Load 1 unit Pile 1	1
102	Finish Building Pile 3	393
103	Finish Building Pile 2	393
104	Finish Building Pile 1	393
105	Produce Hanford fuel slugs	1
106	Install & Test canning process equipment in fuel slug fabrication facility	52
107	Design Hanford Fuel slug canning process	157
108	Build Hanford fuel slug fabrication facility	245
109	Build Preliminary Pile Structures	30
110	Finalize Design for Hanford Pile	192

Number	Transitions	Ref Time [d]
111	Operate X-10	31
112	Load X-10 with fuel	1
113	Produce canned X-10 fuel slugs	19
114	Finish Building X-10	54
115	**Design X-10 Fuel Slug canning process**	171
116	Build Primary X-10 Structures	127
117	Reprocess X-10 Slugs	25
118	Build Preliminary Hanford Structures	30
119	Decide to use Ph-Bi separation process	69
120	Finish building pilot separation plant	78
121	Build primary pilot separation plant structures	69
122	Design preliminary pilot separation plant	45
123	Design Basic Hanford Pu Production Plant	70
124	Design X-10	96
125	Build Clinton/X-10 Support Facilities	84
126	Produce X-10 Graphite	99
127	Design Clinton/X-10 site	12
128	Build X-10 Graphite Production Plant	61
129	Design Graphite Production Plant for X-10	101
130	Site Selection for Pilot & Production facilities	38
131	Operate Lab Rx	12
132	Build Lab Rx	15
133	Design Pu Separation processes	412
134	Design Lab Rx & Develop Materials Capability	301
135	Decide to research weapon design theory	163
136	Design Initiator	722
137	Deliver HEU to LA	2
138	Delivery Pu to LA	2
139	Possess Deliverable Pu Implosion Weapon	0
140	Possess Deliverable Gun Weapon	0
141	Make Core Mockup	1
142	Process & fabricate Pu Pit	4
143	Cold Test	1
144	Fabricate Explosive Lenses	39
145	Conduct Implosion Device Test	2
146	Conduct Mock Test	1
147	Prepare Nuclear Weapon Test Site	67
148	Select a Test Site	61

Number	Transitions	Ref Time [d]
149	Decide to Test Implosion Explosive	296
150	Test & Train with Delivery systems	212
151	Process & Fabricate HEU Gun Pit Component	2
152	Retrofit bombers & bomb system	571
153	Design Gun Explosive	704
154	Complete Lens/mold design	753
155	Complete Implosion explosive design	54
156	Create Preliminary Design	660
157	Decide to split Gun and Implosion R&D	170
158	LA Site Selection	37
159	Gather luminaries	30
160	Groves Decision to appoint Oppenheimer	76

Sub-Net	T-begin	T-end	Path
LTD (S-50)	1	29	1
Gas Diffusion (K-25)	30	53	1
EMIS (Y-12)	54	75	2
Hanford (W & X)	76	134	3
Weaponization	135	160	1,2,3

Number	Places	M1	DNW Mark
1	.85 wt% U	0	0
2	Nat U	1.00E+09	0
3	S-50 Racks	0	0
4	S-50 Complex	0	0
5	S-50 Decision	0	0
6	Pilot LTD Design	0	0
7	Pilot LTD	0	0
8	Lab LTD Facility	0	0
9	Tested Lab LTD design	0	0
10	LTD R&D	1	0
11	Lab LTD Design	0	0
12	80 wt% U	0	0
13	Full Plant K-25 Experience	0	0
14	23 wt% U	0	0
15	Operational K-25 Units	0	0

Number	Places	M1	DNW Mark
16	# K-25 Units in operation (block 1 unit operation)	0	0
17	Send all .85 wt% U to K-25	0	0
18	Operational linked K-25 Units	0	0
19	7 wt% U	0	0
20	1.1 wt% U	0	0
21	Tested Equipment in K-25 Buildings	0	0
22	K-25 support facilities	0	0
23	K-25 main buildings	0	0
24	Barriers	0	0
25	Operational Full scale barrier plant	0	0
26	Stripped full scale barrier plant	0	0
27	Decision to use new barrier	0	0
28	Pilot barrier plant for new design	0	0
29	Full scale barrier plant	0	0
30	K-25 Site Layout	0	0
31	K-25 Design	0	0
32	Redesigned barrier design	0	0
33	Pilot barrier plant	0	0
34	Decision to build full scale barrier plant	0	0
35	K-25 Plot Plan	0	0
36	Prototype Barrier	0	0
37	Diffusion R&D	2	0
38	EMIS R&D	1	0
39	Lab Scale EMIS	0	0
40	Operational Betas	0	0
41	10 wt% U	0	0
42	Beta Design	0	0
43	9 Operational Alphas	0	0
44	Decision to build Beta	0	0
45	Alpha Design	0	0
46	Calutron Design	0	0
47	Desired # of Build Preliminary Pile Structures	3	0
48	Desired # Build Hanford fuel slug fabrication facility	1	0
49	Hanford Pile fresh fuel slugs	0	0
50	Desired # of Initiate 221 facilities construction	1	0
51	Pu	0	0
52	231W isolation facility	0	0
53	Reprocessed Pu	0	0

Number	Places	M1	DNW Mark
54	221 facility testing experience	0	0
55	Operational 221 Separations Facilities	0	0
56	Equipped 221 Separations Facilities	0	0
57	Unequipped untested 221 Separations Facilities	0	0
58	Preliminary 221 facility structures	0	0
59	231W Isolation process design	0	0
60	Validated Separation Design	0	0
61	Initiated 221 facilities construction	0	0
62	Hanford Spent fuel slugs	0	0
63	Spent fueled Hanford Piles	0	0
64	Fully loaded Hanford Piles	0	0
65	Hanford Pile 3 loaded units	0	0
66	Hanford Pile 1 loaded units	0	0
67	Hanford Pile 2 loaded units	0	0
68	Hanford Pile 3 unloaded units	0	0
69	Hanford Pile 1 unloaded units	0	0
70	Hanford Pile 2 unloaded units	0	0
71	Operational Hanford fuel fabrication facility	0	0
72	Unequipped Hanford Pile fuel slug fabrication facility	0	0
73	Hanford Pile fuel slug canning process	0	0
74	Preliminary Pile Structures	0	0
75	Hanford Pile Design	0	0
76	Spent X-10 Fuel Slugs	0	0
77	Loaded X-10 Rx	0	0
78	Canned X-10 fuel slugs	0	0
79	X-10 Fuel Slug canning process	0	0
80	X-10 Graphite	0	0
81	Primary X-10 Structures	0	0
82	X-10 Design to canning process	0	0
83	X-10 Design	0	0
84	Unloaded X-10 Rx	0	0
85	Preliminary Hanford Structures	0	0
86	Decision to use Ph-Bi separation process	0	0
87	Basic Hanford Pu Production Plant Design	0	0
88	Pilot separation plant	0	0
89	Primary pilot separation plant structure	0	0
90	Preliminary pilot separation plant design	0	0
91	Clinton/X-10 Support Facilities	0	0

Number	Places	M1	DNW Mark
92	X-10 Graphite Production Plant	0	0
93	Clinton/X-10 Site Design	0	0
94	X-10 Graphite Production Plant Design	0	0
95	Lab Rx Experience	0	0
96	Clinton/X-10 Site Plan	0	0
97	Hanford site plan	0	0
98	Lab Rx	0	0
99	PhBi & Lanthanum Separation Processes	0	0
100	Pu Separation R&D Program	1	0
101	Lab Rx Design	0	0
102	Rx R&D Program	1	0
103	Decision to build a nuclear weapon	1	0
104	Initiator Design	0	0
105	Preliminary Design to Test Site	0	0
106	Desired Number of Implosion Mockups	1	0
107	Deliverable Pu Implosion Weapon	0	1
108	Deliverable HEU Gun Weapon	0	1
109	Cold Tested Design	0	0
110	Implosion Core Mockup	0	0
111	Pu Core	0	0
112	Hanford Pu	0	0
113	Pu Core Design	0	0
114	Explosive lenses	0	0
115	Explosive lens mold/design	0	0
116	Tested Implosion Device Design	0	0
117	Mock Tested & Prepared Nuclear Weapon Test Site	0	0
118	Prepared Nuclear Weapon Test Site	0	0
119	Nuclear Weapon Test Site	0	0
120	Decision for a Test	0	0
121	Tested & Trained Delivery systems	0	0
122	Retrofitted bombers & bomb system	0	0
123	Little Boy HEU Pit Components	0	0
124	HEU	0	0
125	Gun Explosive Design	0	0
126	Delivery System R&D	0	0
127	Gun R&D	0	0
128	Preliminary Design	0	0
129	Implosion R&D	0	0

Number	Places	M1	DNW Mark
130	Centralized Weapons R&D	0	0
131	Decision for theoretical weapons research	0	0
132	Oppenheimer running Weapons R&D	0	0
133	Weapons R&D program	0	0

D-, D+, H for full US case for each resolution level can be assembled from preceding component data.

U1	NWPR: Facility Outflow [SQ/yr]
U2	C&S [.25/.5/.75 (Low/Med/High) for Facility Transitions
U3	NDP (IAEA)
U4	R-NeDesign =.25/.5/.75 (Low/Med/High) for weapon transition
U5	R-DS-Range
U6	R-DS-Type
U7	Technical Challenge to Sustain facility [3=Significant,1=Moderate,0=No Challenge]
U8	Sustainability: U Inflow [kg/yr] (IGNORE USource)
U9	Sus: facility lifetime

Udata	U1	U2	U3	U4	U5	U6	U7	U8	U9
T1	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0

Udata	U1	U2	U3	U4	U5	U6	U7	U8	U9
T15	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0
T23	102.2	0.25	0	0	0	0	0	61320	2
T24	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0
T30	2.92	0	0	0	0	0	0	45990	20
T31	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0
T40	0	0.25	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0

Udata	U1	U2	U3	U4	U5	U6	U7	U8	U9
T53	0	0	0	0	0	0	0	0	0
T54	0	0	0	0	0	0	0	0	0
T55	0	0	0	0	0	0	0	0	0
T56	0	0	0	0	0	0	0	0	0
T57	0	0	0	0	0	0	0	0	0
T58	0	0	0	0	0	0	0	0	0
T59	0	0	0	0	0	0	0	0	0
T60	0	0	0	0	0	0	0	0	0
T61	0	0	0	0	0	0	0	0	0
T62	0	0	0	0	0	0	0	0	0
T63	0	0	0	0	0	0	0	0	0
T64	0	0	0	0	0	0	0	0	0
T65	17.52	0	0	0	0	0	0	3504	20
T66	10.71	0	0	0	0	0	0	9855	20
T67	0	0	0	0	0	0	0	0	0
T68	0	0	0	0	0	0	0	0	0
T69	0	0	0	0	0	0	0	0	0
T70	0	0.25	0	0	0	0	0	0	0
T71	0	0	0	0	0	0	0	0	0
T72	0	0	0	0	0	0	0	0	0
T73	0	0.25	0	0	0	0	0	0	0
T74	0	0	0	0	0	0	0	0	0
T75	0	0	0	0	0	0	0	0	0
T76	9.125	0	0	0	0	0	0	0	0
T77	0	0	0	0	0	0	0	0	0
T78	0	0	0	0	0	0	0	0	0
T79	0	0	0	0	0	0	0	0	0
T80	0	0	0	0	0	0	0	0	0
T81	0	0	0	0	0	0	0	0	0
T82	0	0	0	0	0	0	0	0	0
T83	0	0	0	0	0	0	0	0	0
T84	0	0	0	0	0	0	0	0	0
T85	0	0	0	0	0	0	0	0	0
T86	0	0	0	0	0	0	0	0	0
T87	0	0	0	0	0	0	0	0	0
T88	0	0	0	0	0	0	0	0	0
T89	0	0	0	0	0	0	0	0	0
T90	0	0	0	0	0	0	0	0	0

Udata	U1	U2	U3	U4	U5	U6	U7	U8	U9
T91	0	0	0	0	0	0	0	0	0
T92	0	0	0	0	0	0	0	0	0
T93	0	0	0	0	0	0	0	0	0
T94	0	0	0	0	0	0	0	0	0
T95	6.22	0	0	0	0	0	0	869540	20
T96	0	0	0	0	0	0	0	0	0
T97	0	0	0	0	0	0	0	0	0
T98	0	0	0	0	0	0	0	0	0
T99	0	0	0	0	0	0	0	0	0
T100	0	0	0	0	0	0	0	0	0
T101	0	0	0	0	0	0	0	0	0
T102	0	0	0	0	0	0	0	0	0
T103	0	0	0	0	0	0	0	0	0
T104	0	0.25	0	0	0	0	0	0	0
T105	90.34	0	0	0	0	0	0	903356	20
T106	0	0	0	0	0	0	0	0	0
T107	0	0	0	0	0	0	0	0	0
T108	0	0	0	0	0	0	0	0	0
T109	0	0	0	0	0	0	0	0	0
T110	0	0	0	0	0	0	0	0	0
T111	0	0	0	0	0	0	0	0	0
T112	0	0	0	0	0	0	0	0	0
T113	0	0	0	0	0	0	0	0	0
T114	0	0	0	0	0	0	0	0	0
T115	0	0	0	0	0	0	0	0	0
T116	0	0	0	0	0	0	0	0	0
T117	0	0	0	0	0	0	0	0	0
T118	0	0	0	0	0	0	0	0	0
T119	0	0	0	0	0	0	0	0	0
T120	0	0	0	0	0	0	0	0	0
T121	0	0	0	0	0	0	0	0	0
T122	0	0	0	0	0	0	0	0	0
T123	0	0	0	0	0	0	0	0	0
T124	0	0	0	0	0	0	0	0	0
T125	0	0	0	0	0	0	0	0	0
T126	0	0	0	0	0	0	0	0	0
T127	0	0	0	0	0	0	0	0	0
T128	0	0	0	0	0	0	0	0	0

Udata	U1	U2	U3	U4	U5	U6	U7	U8	U9
T129	0	0	0	0	0	0	0	0	0
T130	0	0	0	0	0	0	0	0	0
T131	0	0	0	0	0	0	0	0	0
T132	0	0	0	0	0	0	0	0	0
T133	0	0	0	0	0	0	0	0	0
T134	0	0	0	0	0	0	0	0	0
T135	0	0	0	0	0	0	0	0	0
T136	0	0	0	0	0	0	0	0	0
T137	0	0	0	0	0	0	0	0	0
T138	0	0	0	0	0	0	0	0	0
T139	0	0	0	0	0	0	0	0	0
T140	0	0	0	0	0	0	0	0	0
T141	0	0	0	0	0	0	0	0	0
T142	91.25	0	0	0	0	0	0	0	0
T143	0	0	0	0	0	0	0	0	0
T144	0	0	0	0	0	0	0	0	0
T145	0	0	0	0.75	0	0	0	0	0
T146	0	0	0	0	0	0	0	0	0
T147	0	0	0	0	0	0	0	0	0
T148	0	0	0	0	0	0	0	0	0
T149	0	0	0	0	0	0	0	0	0
T150	0	0	0	0	0	0	0	0	0
T151	8.3	0	0	0	0	0	0	0	0
T152	0	0	0	0	5230	1	0	0	0
T153	0	0	0	0.75	0	0	0	0	0
T154	0	0	0	0	0	0	0	0	0
T155	0	0	0	0	0	0	0	0	0
T156	0	0	0	0	0	0	0	0	0
T157	0	0	0	0	0	0	0	0	0
T158	0	0	0	0	0	0	0	0	0
T159	0	0	0	0	0	0	0	0	0
T160	0	0	0	0	0	0	0	0	0

RF	T30	T65	T95
T30	0	1	1
T65	1	0	1
T95	1	1	0

Zero entries are omitted to conserve space.

RCS	T30	T65
T30	0	1
T65	1	0

Prolifdata

Range To Adversary Targets [km]	2368	2521	2531
Adversary Defense Rank	3		
Uranium Data (reserves stocks) [MT]	1.00E+09	6.00E+06	

APPENDIX H: NETWORK PATHWAY SENSITIVITY: Y-12 FEED VARIATION

Network pathway sensitivity is tested using the Y-12 enrichment sub-case. The network pathway was altered by varying the enrichment of the available uranium feed to Y-12. During the Manhattan Project Y-12 experienced feeds of natural U, 0.85 wt. %, 1.1 wt. %, and 7 wt. % U-235 as S-50 and K-25 (in different functional levels) came online. The resulting Latency distribution and Latency statistics are shown in Fig. 58 and Fig. 59 respectively. Varying the availability of these feeds between simulations effectively eliminates S-50 and K-25 or adds a fully functional K-25 to start.

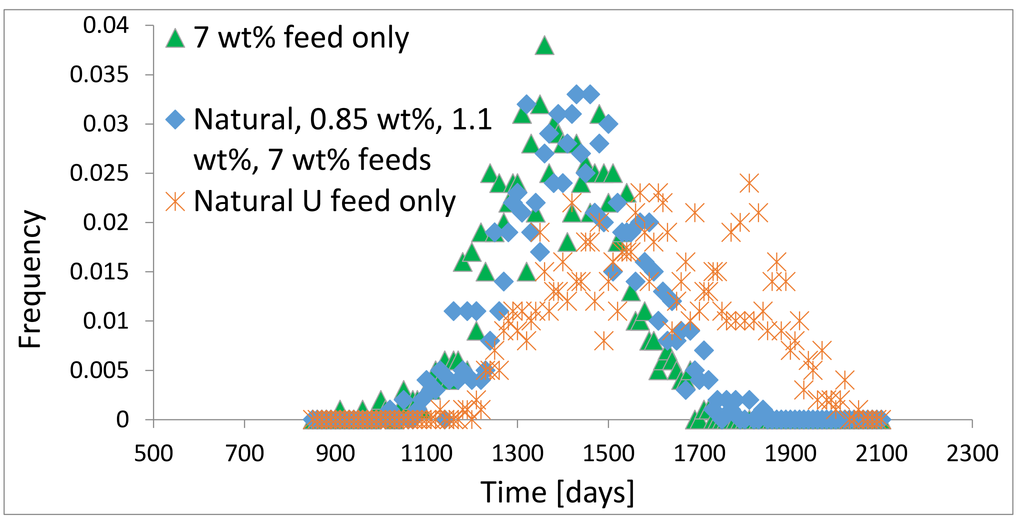

Fig. 58. Impact of pathway variation on Y-12 Latency distribution.

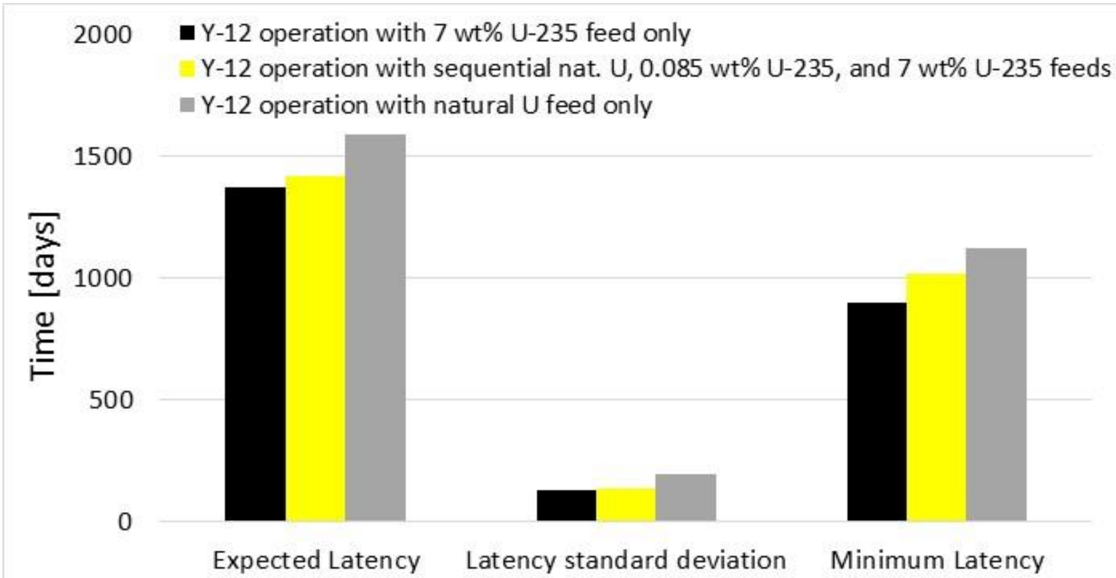

Fig. 59. Impact of pathway variation on Y-12 Latency time statistics.

The results may show a marginal decrease in expected value from the historically accurate feed schedule consisting of natural, 0.85 wt. %, 1.1 wt. %, and 7 wt. % U-235 feeds and using the 7 wt. % U-235 feed the whole time. But both Fig. 58 and Fig. 59 shows a clear drop off in performance when using only natural U feed. This corresponds to a higher expected and minimum Latencies while the Latency distribution is shifted and spread to the right. This may indicate that the difference for Y-12 was greater going from natural feed to .85 wt. % & 1.1 wt. % feeds than it was going from the latter to 7 wt. % feed. It should be noted that when developing the models average production rates based on final production quantities were used instead of theoretically engineered values due to the combination of limited production numbers and the knowledge that theoretical efficiency was rarely if ever achieved during the Manhattan Project.

APPENDIX I: PAKISTAN TIMELINE AND PETRI NET DATA

Date	Event	Source
1970	pilot plant built for uranium ore concentration. 10,000 lbs/day capacity	
1/20/1972	Multan Conference, Bhutto charges scientists with developing nuclear weapons, puts Munir Khan in charge of PAEC	Khan p85
3/20/1972	"2 months after the scientific conference at Multan". Bhutto approves PAEC chair Munir Khan's plan for pursuit of complete nuclear fuel cycle to support building bomb	Khan p104
11/28/1972	Bhutto inaugurates KANUPP	
1972	Pakistan has initial talks with French SSGN for a reprocessing plant	Khan p130
Mar-73	Initial contract for basic design of reprocessing plant signed	Khan p131
Oct-73	IAEA report on Pakistan nuclear energy needs	Khan p131
1973	Pakistan initiates PAKNUR project to replicate India's CIRUS Pu production rx. Project is shelved 1 year later due to insufficient funds. It is later restarted as Khushab.	Khan p192
5/18/1974	Indian PNE Test	Khan p117
6/15/1974	Bhutto meets with Defense Committee of Cabinet. "First formal institutional meeting to conclude that the only viable option for Pakistan was to develop a nuclear deterrent capability… the nuclear program had officially shifted from merely acquiring a nculear capability to decisively pursuing weapons."	Khan p121-122
7/6/1974	Bhutto writes letter to PM Ghandi suggesting no assurance can secure Pakistan's security after Indian Nuclear test	Khan p119
summer 1974	summer of 1974 Bhutto directed PAEC to start search for nucelar test site	Khan p182
9/17/1974	AQ Khan sends second letter to Bhutto about centrifuge enrichment	Khan p140
Sep-74	Chagai site selected for Pakistan's nuclear testing. Search lasted 10 days (I think)	Khan p118
10/18/1974	signed contract for detailed design of reprocessing plant and construction with SGN	Khan 131
10/1/1974	"October 1974" PAEC launches project 706 to develop centrifuge U enrichment	Khan p142
1974	Pakistan "shelved" Pu production project do to lack of funds	Khan p192
12/1/1974	"December 1974" Bhutto gives interview and discloses that Iran and Arab countries had given Pakistan some $450 million in loans. Assume loans came in sometime before, use AQ Khan 2nd Letter date	Khan p112
2/15/1975	Bhutto approves loans for centrifuge [project 706 p143] plant and uranium mine at Baghalchor in Dera Ghazi Kan (BC01) and the Chemical Proudction Complec (CPC) in DG Khan Some funding also sent to Wah Group (theoretical physics team working on nuclear weapons design) (??)	Khan p112
12/1/1975	"December 1975" AQ Khan leaves Holland	Khan p147
1975-76	PAEC began work on Chemical Production Complex (CPC) (conversion facility: UO2 for KANUPP and UF6) current production estimated at 200 tons UF6/yr	Khan p116

Date	Event	Source
2/1/1976	"first months of 1976" indigenous centrifuge production R&D begins	Khan p153
Feb-76	IAEA aproved french sale of reprocessing plant to pakistan	khan p 131
Apr-76	"April 1976" AQ Khan formally joins enrichment project	Khan p147
12/1/1976	"December 1976" Canada cuts off all supplies: nuclear fue, heavy water, spare parts, and technical support for KANUPP	
Jun-76	"June 1976" first experimental centrifuges began to be tested	Khan p153
7/17/1976	AZ Khan placed in charge of Project 706 (enrichment)	Khan p150
1976	Special Development works created under Chief of Army Staff, that would prepare test site	Khan p118
12/1/1977	"late 1977" Pakistan had developed P-1 centrifuge	Khan p154
1977	"end of 1977" Pkaistan was confident machines at Sihala pilot plant would operate effectively	Khan p154
6/4/1978	"At the Sihala plant … a centrifuge machine succeeded in separating U-235 from U-238"	Khan p 155
8/1/1978	"by August 1978"SGN had transferred 95% of all the detailed engineering designs and drawings for building the reprocessing plant to PAEC	Khan p132
1978	Pakistan succeeds in enrichment	Khan p150
Late 1970s	Pakistan acquired 110-150 tons of yellowcake from Niger	Khan p114
1978-1980	Pakistan acquries 450 tons of unsafeguarded yellowcake from Niger via Libya	Khan p114
2/1/1979	"February 1979" Sihala successfully running 54 machine test cascade	Khan p156
1980	Nuclear Test sites complete 2 to 3 horizontal and vertical shft tunnels	Khan p183
1980	CPC UF6 production problems solved	Khan p152
1980	by 1980 the Kundian Nuclear Fuel Complex, the Baghalchur-1 facility (BC-1) and CPC were ready and producting sufficient amounts of high purity yellow cake (BC-1), UF6, U metal, UO2 (CPC), and nuclear fuel for KANUPP (from KNFC)	Khan p 116
1980	Belgonuclearire builds 13 MT heavy water fcility in Multan. Not big enough to supply Khushab.	Khan 201
1980	BC-1 begins full production (previous was just experimental) averaging 23 MTU per year	Mian Fissile Material Production in Pakistan p 81
1980	Pakistan began construction on New Labs	IISS, Nuclear Black Markets: Pakistan, A.Q. Khan and the Rise of Proliferation Networks (2007) via NTI
1981	"by 1981" Outer ring of Kahuta plant complete and centrifuge halls prepared for installment of centrifuges	Khan p156
9/1/1981	"September 1981" earthquak destorys 4000 operating centrifuges at Kahuta	khan p156
1981	after earthquake Lt. Gen Navi goes to China, recieveds ~50 kg HEU and the CHIC-4 weapon design	khan p157
1982	New Labs cold reprocessing experiments	Khan p200
3/11/1983	First successful Pakistani Cold Test (was also first cold test)	Khan p185
1983	Pakistan restarts its Pu production program. President Zia-ul-Haq decision was clearly affected by fears of successful Israel strike at Osirak and massive destruction of centrifuges at Kahuta from an earthquake, both in 1981	Khan p196

Date	Event	Source
1983	New Labs believed they were redy to begin reprocessing (did not yet)	Khan p199
1985	KRL produces enough WGHEU for 1 nuclear device	Khan p159
1987	New Labs hot tests occurred, New Labs preprared to reprocess fuel	Khan p200
1987	Construction fo Khushab Chemical Plant-1 (KCP-1) heavy water production plant begins	Khan p201
1988	Between 1988 and 1995 PAF & PAEC (NDC) conducted several cold test simulations of Air drop bombs	Khan p186
1992	China transfers M-11 Missiles to Pakistan, these took "years" to re-engineer to make them nuclear capable [Khan p240]	Khan p238
May-95	PAEC gets desired cold test air drop results	Khan p186
May-95	R&D begins on solid fuel missile system (as result of positive cold test above)	Khan p186
1995	by summer of 1995 Pakistan had a nuclear device deliverable by figheter aircraft	Khan p186
4/1/1998	"April of 1998" Pakistan began operating Khushab-1	albright/ISIS
5/11/1998	India Tests Nuclear Explosives	Khan p269
5/16/1998	Pakistan decided to respond with its own nuclear tests	Khan p278
5/19/1998	massive logistical operation began to tranport the men, equipment and devices to the Chagai site	khan p279
5/28/1998	Pakistan tests nuclear explosives at Chagai	khan p280

Number	Transitions	Ref Time [d]
1	Divert Cooled KANUPP Spent Fuel	0
2	Complete KANUPP	313
3	Cool Khushab Spent Fuel	200
4	Reprocess Cooled Spent Fuel at Chasma	21
5	Operate KANUPP	365
6	Cool KANUPP Spent Fuel	200
7	Design & Build BC-1: Pu Path Option	881
8	Fabricate Untested Pu Implosion Explosive	180
9	Fabricate Untested HEU Implosion Explosive	180
10	Fabricate Untested HEU Gun Explosive	180
11	Generate Domestic Funds (Annual)	365
12	Develop Centrifuge Technology Indigenously	7300
13	Posses Deliverable Cold Tested Pu Implosion Nuclear Weapon	0
14	Fabricate Hot Tested Pu Explosive	180
15	Fabricate Cold Tested Pu Explosive	180
16	Posses Deliverable Hot Tested Pu Implosion Nuclear Weapon	0

Number	Transitions	Ref Time [d]
17	Produce U3O8	30
18	Pursue Pu Production R&D	0
19	Design & Build Uranium Metal Fuel Plant	3285
20	Design & Build KCP-1 Heavy Water Production Plant	4745
21	Produce Metal U Fuel	30
22	Produce Heavy Water	365
23	Operate Khushab for 1 Cycle and Unload/Reload Spent Fuel from Khushab-1	365
24	Fuel & Load Khushab-1	30
25	Posses Deliverable Hot Tested HEU Gun Nuclear Weapon	0
26	Fabricate Hot Tested HEU Implosion Explosive	180
27	Fabricate Hot Tested HEU Gun Explosive	180
28	Posses Deliverable Hot Tested HEU Implosion Nuclear Weapon	0
29	Prep Site and Hot Test HEU Implosion Device	12
30	Prep Site and Hot Test HEU Gun Device	12
31	Prep Site and Hot Test Pu Implosion Device	12
32	Posses Deliverable Cold Tested HEU Gun Nuclear Weapon	0
33	Fabricate Cold Tested HEU Implosion Explosive	180
34	Fabricate Cold Tested HEU Gun Explosive	180
35	Initiate Gun Weapons Design Program	256
36	Approve plan for full fuel cycle	60
37	Design Implosion Weapon	3752
38	Conduct Cold Testing Campaign for Gun Design	4434
39	Posses Deliverable Cold Tested HEU Implosion Nuclear Weapon	0
40	Design Gun Weapon	3045
41	Locate & Build Test Site	2190
42	Conduct Cold Testing Campaign for Implosion Design	4434
43	Produce HEUF6 in Kahuta	61
44	Initiate Implosion Weapons Design Program	256
45	Install Centrifuges and Bring Kahuta to Operation	1825
46	Successfully Enrich with Centrifuge	185
47	Decide for Hot Test Option After Indian Test	28
48	Design Centrifuge	1020
49	Design & Operate Centrifuge Cascade	242
50	Design New Labs	730
51	Produce Nat UF6 #2	30
52	Transfer Reprocessing Design to Pakistan	1383
53	Acquire Foreign Funds	971
54	Reprocess Cooled Spent Fuel at New Labs	165

Number	Transitions	Ref Time [d]
55	Build New Labs Pilot Reprocessing Facility and Bring to Operation	2555
56	Decide for Hot Test Option Independently	4008
57	Establish Agreement with French SGN for Reprocessing Plant	1002
58	Build Chasma Reprocessing Facility with SGN	1825
59	Initiate Program to Copy Indian CIRUS Production Reactor	365
60	Design & Build BC-1 Mine & Mill	730
61	Bhutto Approves Centrifuge Enrichment Program	151
62	Produce Nat UF6 #1	30
63	Design Khushab Production Reactor	730
64	Build Khushab-1 Production Reactor	4380
65	AQ Khan contacts Bhutto	122
66	Indians Test Nuclear Peaceful Nuclear Explosive Device	849
67	Design and build CPC Conversion Plant	1460

Path1	Path2	Path3	Path4	Path5	Path6	Path7	Path8
Pu-Imp-Cold	Pu-Imp-Hot	Pu-Imp-Cold-DivKAN	Pu-Imp-Hot-DivKAN	HEU-Imp-Cold	HEU-Gun-Cold	HEU-Imp-Hot	HEU-Gun-Hot
T2	T2	T1	T1	T2	T2	T2	T2
T3	T3	T2	T2	T5	T5	T5	T5
T4	T4	T3	T3	T6	T6	T6	T6
T5	T5	T4	T4	T11	T11	T9	T10
T6	T6	T5	T5	T12	T12	T11	T11
T7	T7	T6	T6	T17	T17	T12	T12
T11	T8	T7	T7	T33	T32	T17	T17
T13	T11	T11	T8	T36	T34	T26	T25
T15	T13	T13	T11	T37	T35	T28	T27
T17	T14	T15	T13	T39	T36	T29	T30
T18	T16	T17	T14	T41	T38	T36	T35
T19	T17	T18	T16	T42	T40	T37	T36
T20	T18	T19	T17	T43	T41	T41	T40
T21	T19	T20	T18	T44	T43	T43	T41
T22	T20	T21	T19	T45	T45	T44	T43
T23	T21	T22	T20	T46	T46	T45	T45
T24	T22	T23	T21	T47	T47	T46	T46
T36	T23	T24	T22	T48	T48	T47	T47
T37	T24	T36	T23	T49	T49	T48	T48
T41	T31	T37	T24	T51	T51	T49	T49

Path1	Path2	Path3	Path4	Path5	Path6	Path7	Path8
T42	T36	T41	T31	T53	T53	T51	T51
T44	T37	T42	T36	T56	T56	T53	T53
T47	T41	T44	T37	T60	T60	T56	T56
T50	T44	T47	T41	T61	T61	T60	T60
T52	T47	T50	T44	T62	T62	T61	T61
T53	T50	T52	T47	T65	T65	T62	T62
T54	T52	T53	T50	T66	T66	T65	T65
T55	T53	T54	T52	T67	T67	T66	T66
T56	T54	T55	T53			T67	T67
T57	T55	T56	T54				
T58	T56	T57	T55				
T59	T57	T58	T56				
T60	T58	T59	T57				
T63	T59	T60	T58				
T64	T60	T63	T59				
T65	T63	T64	T60				
T66	T64	T65	T63				
	T65	T66	T64				

Number	Places	M1	M1 No India Test	M1 Excess funds	DNW Mark
1	Full Fuel Cycle Supporting Weapons Plan for Weapons for Imp	0	0	0	0
2	Untested Implosion Weapon Design for HEU Hot Test	0	0	0	0
3	Untested Implosion Weapon Design for Pu Hot Test	0	0	0	0
4	Untested Gun Weapon Design for Hot Test	0	0	0	0
5	Cooled Spent Fuel	0	0	0	0
6	Incomplete KANUPP	1	1	1	0
7	Safeguarded Cooled Spent Fuel	0	0	0	0
8	Hot KANUPP Spent Fuel	0	0	0	0
9	Pu	0	0	0	0
10	BC-1 U Mine & Mill	0	0	0	0
11	Pu Production R&D for BC-1 Development	0	0	0	0
12	Initial Pu Production Research for New Labs	0	0	0	0
13	HEUF6 (units = kg U)	0	0	0	0
14	Nuclear Program Funds	0	0	100	0
15	Reprocessing Facility Design for New Labs	0	0	0	0
16	Full Fuel Cycle Supporting Weapons Plan for SGN	0	0	0	0

Number	Places	M1	M1 No India Test	M1 Excess funds	DNW Mark
17	Full Fuel Cycle Supporting Weapons Plan for Pu Production	0	0	0	0
18	Full Fuel Cycle – Initial Enrichment Evaluation	0	0	0	0
19	Indigenous Centrifuge Block	0	0	0	0
20	U Production R&D	0	0	0	0
21	Cold Tested Pu Implosion Explosive	0	0	0	0
22	Hot Tested Pu Implosion Explosive	0	0	0	0
23	Hot Tested Pu Implosion Design	0	0	0	0
24	F-16 & Mirage Fighter/Bombers	10	10	10	0
25	Cold Tested Implosion Design	0	0	0	0
26	Deliverable Nuclear Weapon	0	0	0	1
27	U3O8 (Units = kg U)	0	0	0	0
28	SGN Built Chasma Reprocessing Plant	0	0	0	0
29	Option for Developing Test Site	0	0	0	0
30	Pu Production R&D for Metal Fuel	0	0	0	0
31	Pu Production R&D for Heavy Water	0	0	0	0
32	Hot Khushab Spent Fuel	0	0	0	0
33	Fueled Khushab-1	0	0	0	0
34	Hot Tested HEU Gun Explosive	0	0	0	0
35	Hot Tested HEU Implosion Explosive	0	0	0	0
36	Hot Tested HEU Implosion Design	0	0	0	0
37	Hot Tested HEU Gun Design	0	0	0	0
38	Untested HEU Implosion Explosive	0	0	0	0
39	Test Site with Test Shafts	0	0	0	0
40	Untested HEU Gun Explosive	0	0	0	0
41	Untested Pu Implosion Explosive	0	0	0	0
42	Cold Tested HEU Gun Explosive	0	0	0	0
43	Cold Tested HEU Implosion Explosive	0	0	0	0
44	Untested Implosion Weapon Design	0	0	0	0
45	Cold Tested Gun Weapon Design	0	0	0	0
46	Untested Gun Weapon Design	0	0	0	0
47	Decision For Hot Test Option	0	0	0	0
48	Gun Nuclear Weapons R&D	0	0	0	0
49	Indian Nuclear Test for Bhutto	0	0	0	0
50	KANUPP Heavy Water Reactor	0	0	0	0
51	Reprocessing Facility Design for Chasma	0	0	0	0
52	SGN Agreement for Reprocessing Plant for Design	0	0	0	0

Number	Places	M1	M1 No India Test	M1 Excess funds	DNW Mark
53	Foreign Fundraising for Nuclear Program	0	0	0	0
54	Operational Pilot Centrifuge & Cascade Design	0	0	0	0
55	Khushab-1 Production Reactor Design	0	0	0	0
56	New Labs Design	0	0	0	0
57	Centrifuge Enrichment	0	0	0	0
58	Centrifuge Design & Procurement Data from AQ Khan	0	0	0	0
59	Indian Nuclear Weapons Program	1	0	1	0
60	Full Fuel Cycle Supporting Weapons Plan for Weapons for Gun	0	0	0	0
61	Operational Kahuta Centrifuge Plant	0	0	0	0
62	Pu Production R&D for Reactor	0	0	0	0
63	Indian Nuclear Test for Inhibit	0	0	0	0
64	Indian Nuclear Test for Khan	0	0	0	0
65	CPC Uranium Conversion Plant	0	0	0	0
66	Heavy Water	0	0	0	0
67	Implosion Nuclear Weapons R&D	0	0	0	0
68	SGN Agreement for Reprocessing Plant for Build	0	0	0	0
69	Nat UF6 (units = kg U)	0	0	0	0
70	Hot Test Option Blocker	0	0	0	0
71	Uranium Metal Fuel Plant	0	0	0	0
72	New Labs Reprocessing Facility	0	0	0	0
73	KCP-1 Heavy Water Production Plant	0	0	0	0
74	Centrifuge Design	0	0	0	0
75	Khushab-1	0	0	0	0
76	U Conversion R&D	0	0	0	0
77	Centrifuge R&D Chaklala	0	0	0	0
78	Metal Khushab-1 Fuel [1 MTU]	0	0	0	0
79	Initial Pu Production Research	0	0	0	0
80	Nuclear Research Program with Preliminary Weapons Decision (Multan)	1	1	1	0

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T1	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T8	0	0	1	0	0	0	0	0	8	0	0	0	0	0	0
T9	0	1	0	0	0	0	0	0	0	0	0	0	30	0	0
T10	0	0	0	1	0	0	0	0	0	0	0	0	30	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
T51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T54	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T59	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T61	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
T62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T16	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	1000	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0	0	0	1000	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T56	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T57	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T59	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T60	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T62	0	0	0	0	0	0	0	0	0	0	0	1000	0	0	0
T63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T28	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P46	P47	P48	P49	P50	P51	P52	P53	P54	P55	P56	P57	P58	P59	P60
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P46	P47	P48	P49	P50	P51	P52	P53	P54	P55	P56	P57	P58	P59	P60
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T55	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T58	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0

D-	P46	P47	P48	P49	P50	P51	P52	P53	P54	P55	P56	P57	P58	P59	P60
T59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T61	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T64	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T66	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P61	P62	P63	P64	P65	P66	P67	P68	P69	P70	P71	P72	P73	P74	P75
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T23	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P61	P62	P63	P64	P65	P66	P67	P68	P69	P70	P71	P72	P73	P74	P75
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	1	0	0	0	0	0	0	0	1425	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T54	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T58	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T62	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T63	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P61	P62	P63	P64	P65	P66	P67	P68	P69	P70	P71	P72	P73	P74	P75
T65	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P76	P77	P78	P79	P80
T1	0	0	0	0	0
T2	0	0	0	0	0
T3	0	0	0	0	0
T4	0	0	0	0	0
T5	0	0	0	0	0
T6	0	0	0	0	0
T7	0	0	0	0	0
T8	0	0	0	0	0
T9	0	0	0	0	0
T10	0	0	0	0	0
T11	0	0	0	0	0
T12	0	0	0	0	0
T13	0	0	0	0	0
T14	0	0	0	0	0
T15	0	0	0	0	0
T16	0	0	0	0	0
T17	0	0	0	0	0
T18	0	0	0	1	0
T19	0	0	0	0	0
T20	0	0	0	0	0
T21	0	0	0	0	0
T22	0	0	0	0	0
T23	0	0	9	0	0
T24	0	0	9	0	0
T25	0	0	0	0	0
T26	0	0	0	0	0
T27	0	0	0	0	0
T28	0	0	0	0	0
T29	0	0	0	0	0
T30	0	0	0	0	0

D-	P76	P77	P78	P79	P80
T31	0	0	0	0	0
T32	0	0	0	0	0
T33	0	0	0	0	0
T34	0	0	0	0	0
T35	0	0	0	0	0
T36	0	0	0	0	1
T37	0	0	0	0	0
T38	0	0	0	0	0
T39	0	0	0	0	0
T40	0	0	0	0	0
T41	0	0	0	0	0
T42	0	0	0	0	0
T43	0	0	0	0	0
T44	0	0	0	0	0
T45	0	0	0	0	0
T46	0	0	0	0	0
T47	0	0	0	0	0
T48	0	1	0	0	0
T49	0	0	0	0	0
T50	0	0	0	0	0
T51	0	0	0	0	0
T52	0	0	0	0	0
T53	0	0	0	0	0
T54	0	0	0	0	0
T55	0	0	0	0	0
T56	0	0	0	0	0
T57	0	0	0	0	0
T58	0	0	0	0	0
T59	0	0	0	0	0
T60	0	0	0	0	0
T61	0	0	0	0	0
T62	0	0	0	0	0
T63	0	0	0	0	0
T64	0	0	0	0	0
T65	0	0	0	0	0
T66	0	0	0	0	0
T67	1	0	0	0	0

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T1	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	64	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
T54	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0
T55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T59	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T60	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T14	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
T15	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	2000	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T36	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

D+	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T58	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T61	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T65	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T9	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
T27	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P46	P47	P48	P49	P50	P51	P52	P53	P54	P55	P56	P57	P58	P59	P60
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P46	P47	P48	P49	P50	P51	P52	P53	P54	P55	P56	P57	P58	P59	P60
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T47	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T56	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P46	P47	P48	P49	P50	P51	P52	P53	P54	P55	P56	P57	P58	P59	P60
T57	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T63	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T65	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T66	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P61	P62	P63	P64	P65	P66	P67	P68	P69	P70	P71	P72	P73	P74	P75
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T21	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T22	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0

D+	P61	P62	P63	P64	P65	P66	P67	P68	P69	P70	P71	P72	P73	P74	P75
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T45	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	1	0	0	0	1000	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T54	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T55	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T56	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T57	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P61	P62	P63	P64	P65	P66	P67	P68	P69	P70	P71	P72	P73	P74	P75
T61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T62	0	0	0	0	1	0	0	0	1000	0	0	0	0	0	0
T63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T66	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
T67	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0

D+	P76	P77	P78	P79	P80
T1	0	0	0	0	0
T2	0	0	0	0	0
T3	0	0	0	0	0
T4	0	0	0	0	0
T5	0	0	0	0	0
T6	0	0	0	0	0
T7	0	0	0	0	0
T8	0	0	0	0	0
T9	0	0	0	0	0
T10	0	0	0	0	0
T11	0	0	0	0	0
T12	1	1	0	0	0
T13	0	0	0	0	0
T14	0	0	0	0	0
T15	0	0	0	0	0
T16	0	0	0	0	0
T17	0	0	0	0	0
T18	0	0	0	0	0
T19	0	0	0	0	0
T20	0	0	0	0	0
T21	0	0	1	0	0
T22	0	0	0	0	0
T23	0	0	0	0	0
T24	0	0	0	0	0
T25	0	0	0	0	0
T26	0	0	0	0	0
T27	0	0	0	0	0
T28	0	0	0	0	0

D+	P76	P77	P78	P79	P80
T29	0	0	0	0	0
T30	0	0	0	0	0
T31	0	0	0	0	0
T32	0	0	0	0	0
T33	0	0	0	0	0
T34	0	0	0	0	0
T35	0	0	0	0	0
T36	0	0	0	0	0
T37	0	0	0	0	0
T38	0	0	0	0	0
T39	0	0	0	0	0
T40	0	0	0	0	0
T41	0	0	0	0	0
T42	0	0	0	0	0
T43	0	0	0	0	0
T44	0	0	0	0	0
T45	0	0	0	0	0
T46	0	0	0	0	0
T47	0	0	0	0	0
T48	0	0	0	0	0
T49	0	0	0	0	0
T50	0	0	0	0	0
T51	0	0	0	0	0
T52	0	0	0	0	0
T53	0	0	0	0	0
T54	0	0	0	0	0
T55	0	0	0	0	0
T56	0	0	0	0	0
T57	0	0	0	0	0
T58	0	0	0	0	0
T59	0	0	0	1	0
T60	0	0	0	0	0
T61	1	1	0	0	0
T62	0	0	0	0	0
T63	0	0	0	0	0
T64	0	0	0	0	0
T65	0	0	0	0	0
T66	0	0	0	0	0

D+	P76	P77	P78	P79	P80
T67	0	0	0	0	0

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T9	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P46	P47	P48	P49	P50	P51	P52	P53	P54	P55	P56	P57	P58	P59	P60
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P46	P47	P48	P49	P50	P51	P52	P53	P54	P55	P56	P57	P58	P59	P60
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P46	P47	P48	P49	P50	P51	P52	P53	P54	P55	P56	P57	P58	P59	P60
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P61	P62	P63	P64	P65	P66	P67	P68	P69	P70	P71	P72	P73	P74	P75
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P61	P62	P63	P64	P65	P66	P67	P68	P69	P70	P71	P72	P73	P74	P75
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	3000	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T56	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
T57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T58	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0

H	P61	P62	P63	P64	P65	P66	P67	P68	P69	P70	P71	P72	P73	P74	P75
T59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T62	0	0	0	0	0	0	0	0	3000	0	0	0	0	0	0
T63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P76	P77	P78	P79	P80
T1	0	0	0	0	0
T2	0	0	0	0	0
T3	0	0	0	0	0
T4	0	0	0	0	0
T5	0	0	0	0	0
T6	0	0	0	0	0
T7	0	0	0	0	0
T8	0	0	0	0	0
T9	0	0	0	0	0
T10	0	0	0	0	0
T11	0	0	0	0	0
T12	0	0	0	0	0
T13	0	0	0	0	0
T14	0	0	0	0	0
T15	0	0	0	0	0
T16	0	0	0	0	0
T17	0	0	0	0	0
T18	0	0	0	0	0
T19	0	0	0	0	0
T20	0	0	0	0	0
T21	0	0	9	0	0
T22	0	0	0	0	0
T23	0	0	0	0	0
T24	0	0	0	0	0
T25	0	0	0	0	0
T26	0	0	0	0	0

H	P76	P77	P78	P79	P80
T27	0	0	0	0	0
T28	0	0	0	0	0
T29	0	0	0	0	0
T30	0	0	0	0	0
T31	0	0	0	0	0
T32	0	0	0	0	0
T33	0	0	0	0	0
T34	0	0	0	0	0
T35	0	0	0	0	0
T36	0	0	0	0	0
T37	0	0	0	0	0
T38	0	0	0	0	0
T39	0	0	0	0	0
T40	0	0	0	0	0
T41	0	0	0	0	0
T42	0	0	0	0	0
T43	0	0	0	0	0
T44	0	0	0	0	0
T45	0	0	0	0	0
T46	0	0	0	0	0
T47	0	0	0	0	0
T48	0	0	0	0	0
T49	0	0	0	0	0
T50	0	0	0	0	0
T51	0	0	0	0	0
T52	0	0	0	0	0
T53	0	0	0	0	0
T54	0	0	0	0	0
T55	0	0	0	0	0
T56	0	0	0	0	0
T57	0	0	0	0	0
T58	0	0	0	0	0
T59	0	0	0	0	0
T60	0	0	0	0	0
T61	0	0	0	0	0
T62	0	0	0	0	0
T63	0	0	0	0	0
T64	0	0	0	0	0

H	P76	P77	P78	P79	P80
T65	0	0	0	0	0
T66	0	0	0	0	0
T67	0	0	0	0	0

Udata	U1	U2	U3	U4	U5	U6	U7	U8	U9
T1	8	0	0.05	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	30
T3	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0
T13	0	0	0	0.5	1200	1	0	0	0
T14	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0
T16	0	0	0	0.75	1200	1	0	0	0
T17	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0
T19	0	0.75	0	0	0	0	0	0	0
T20	0	0.5	0	0	0	0	1	0	0
T21	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0
T25	0	0	0	0.75	1200	1	0	0	0
T26	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0
T28	0	0	0	0.75	1200	1	0	0	0
T29	0	0.25	0	0	0	0	0	0	0
T30	0	0.25	0	0	0	0	0	0	0

Udata	U1	U2	U3	U4	U5	U6	U7	U8	U9
T31	0	0.25	0	0	0	0	0	0	0
T32	0	0	0	0.75	1200	1	0	0	0
T33	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0
T39	0	0	0	0.5	1200	1	0	0	0
T40	0	0	0	0	0	0	0	0	0
T41	0	0.25	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0
T45	1	0.75	0	0	0	0	3	0	30
T46	0	0	0	0	0	0	0	0	0
T47	0	0	0	0	0	0	0	0	0
T48	0	0	0	0	0	0	0	0	0
T49	0	0	0	0	0	0	0	0	0
T50	0	0	0	0	0	0	0	0	0
T51	0	0	0	0	0	0	0	0	0
T52	0	0	0	0	0	0	0	0	0
T53	0	0	0	0	0	0	0	0	0
T54	0	0.25	0	0	0	0	0	0	0
T55	0	0	0	0	0	0	1	0	0
T56	0	0	0	0	0	0	0	0	0
T57	0	0	0	0	0	0	0	0	0
T58	0	0	0	0	0	0	0	0	0
T59	0	0	0	0	0	0	0	0	0
T60	0	0	0	0	0	0	0	0	0
T61	0	0	0	0	0	0	0	0	0
T62	0	0	0	0	0	0	0	0	0
T63	0	0	0	0	0	0	0	0	0
T64	1	0.25	0	0	0	0	3	9000	30
T65	0	0	0	0	0	0	0	0	0
T66	0	0	0	0	0	0	0	0	0
T67	0	0	0	0	0	0	0	0	0

RF	T1	T45	T64
T1	0	1	1
T45	1	0	1
T64	1	1	0

Zero entries are omitted to conserve space.

Red-CS matrix is zero.

ProlifData

Range To Adversary Targets [km]	400	800
Adversary Defense Rank	1	
Uranium Data (reserves stocks) [MT]	1.00E+03	110

APPENDIX J: STOCHASTIC ANALYSIS OF IMPACT OF INDIAN PNE ON PAKISTAN CASE

Fig. 60 shows the expected and minimum Latencies for Pakistani simulations with uniform transition pdfs with bounds +/- 50% of the activity reference times while varying the occurrence of the Indian PNE as well as the pathway selection interval. Fig. 60 begins on the left with the expected Latency for simulations with an Indian PNE and 1 path selection, a path selection interval of 5 years, and a path selection interval of 1 year. The path selection interval sequence is repeated for expected Latencies from simulations without the Indian PNE. The entire simulation set is repeated for the minimum Latencies. Latency standard deviations appear in Fig. 60 as error bars and the actual Latency time is written as data labels.

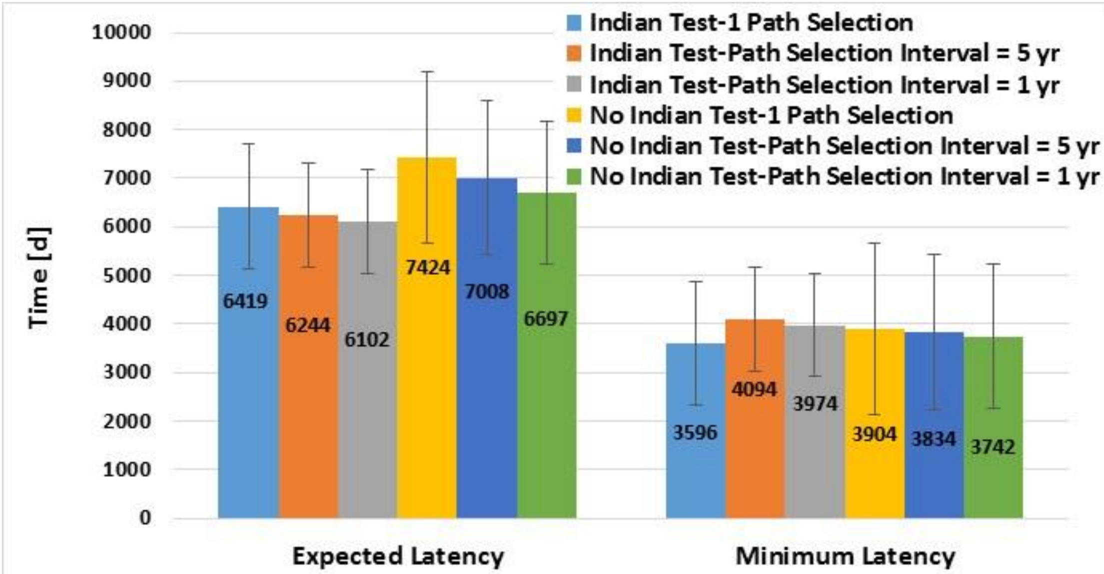

Fig. 60. Impact of Indian nuclear test and path selection interval variation on Pakistani Latency times statistics.

This analysis had both expected and somewhat unexpected results. The expected Latency times for the simulations without an Indian test are all higher than the ones with an Indian test. This agrees with intuition. The decrease in expected Latency time with decreasing path selection interval time is opposite that seen in the U.S. case in Section IV.D. This can be explained by noting the large difference between relatively longer Pakistani Latency Standard times in Fig. 28. A single path selection increases the frequency that a simulation gets locked into one of the longer time paths driving the expected value up. Whereas with the shorter path selection intervals the simulation can switch to the shorter time paths. This effect has a similar impact on the standard deviations. The standard deviations also show the variance for the non-Indian test cases is higher. This increased variance is further demonstrated by the minimum Latencies for all of the simulations without an Indian test are lower than those of the 5 and 1 year PSI simulations with an Indian test. Lower minimum latencies for non-Indian test cases are still surprising.

The unexpected minimum Latencies may also be a result of poor statistics. Pakistan had 8 independent paths. As a result the Latency tool produced over 100 combinatorial paths that could be chosen during path selection. Many of these combinatorial paths were very similar, especially when considering the actual path transitions and noting most of the paths had very similar transitions. The simulations were run with 1000 iterations. While it is likely that the statistics were fine for the expected Latency, the extreme value minimum for each simulation may not have been reliably reached.

APPENDIX K: SOUTH AFRICA TIMELINE AND PETRI NET DATA

Date	Event	Source
1948	Atomic Energy Act and creation of AEB	Venter p55
Nov-50	US-UK & SA nuclear cooperation deal (begin mining process)	Venter p56
Oct-52	1st Uranium production plant established at the West Rand Consolidated mine with assistance from USA and UK	VanDerWalt p30
1954-1958	some research into nuclear military applications	Venter p56
1954	National Institute for Defence Research (NIDR); eventual missile development	Venter p115
Mar-55	16 mines authorised to produce uranium, CSIR designed cyclotron also brought into operation	Venter p58, VanDerWalt p30
Jul-57	bilateral Atoms for Peace agreement with US for purchase of research reactor and training of South Africans in US	Venter p58
1958	Roux's "explicit linkage of peaceful and military nuclear research applications"	Venter p69
1958	Atomic Energy Board (AEB) established 1st nuclear Research program	Venter p29
1959	Amended Atomic Energy Act provided for the research development and ulilzation of nuclear energy	Venter p58
9/5/1959	Cabinet Approves of AEB's proposed nuclear research & development program Operation Kerktoring, Dr. A.J.A Roux appointed Research Director	Venter p70, VanDerWalt p30
Nov-61	Gas diffusion & centrifuge processes used in Manhattan project discarde as being "impractical, out-dated, too expensive and possibly inappropriate for what was required" more prefered method was aerodynamic Becker process (Nov added to simplify math with subsequent dates)	Venter p72
1961	work began at Pelindaba to build nuclear research center	Venter p71
1961	Vortex tube aerodynamic separation process conceived by Dr. Wally Grant developed from Becker aerodynamic (nozzle) but more complex	Venter p72
1961	Pilot U refinement plant produced SA's 1st ingot of refined uranium,	Venter 93

Date	Event	Source
	"parallel research" covered UF6	
1962	SA had evaluated British & French strategic bombers and attempted to purchase british Victor bombers	Venter p70
1962	training and operational conversion of English Electric Canberra light bomber & purchase of buccaneer strike aircraft with pilot training with British pilots in Germany for nuclear delivery	Venter p70-71, Spokane Daily Chronicle, Oct 11, 1962, p10
1963	Missile development program begun under direction of the Armaments Production Board	Venter p116
Mar-63	1st buildings at Pelindaba occupied including AEB hq and some laboratories (guess march to simplify math with subsequent events)	Venter p71
1964	experiments involving UF6 began	Venter p71
1964	SA started an "independent nuclear option"-SA Soviet spy Navy Commodore Dieter Gerhardt	Venter p61
1964	National Institute for Rocket Research (NIRR) established at the Council for Scientific and Industrial Research.	Venter p115
1964	1st missile 'venture' initiated: short range SAM	Venter p116
end of 1964	X-plant completed at Pelindaba	Venter p71
early 1965	Dr. Wally Grant claimed SA was technically capabable of developing nuclear weapons	Venter p85
1965	SAFARI-1 commissioned	Venter p35
Mar-65	SAFARI-1 goes critical	Venter p86
Aug-65	At inauguration of SAFARI-1 PM Verwoerd said it was SA's duty to explore military uses (of nuclear energy) but also its peaceful uses	Venter p85-86
1965	Dr. Andries Visser, member Atomic Energy Board, "the country … shouuld have such a bomb to prevent aggression from loud-mouted Afro-Asiatic states … money is no problem"	Venter p 87
Nov-65	Oct/Nov 1965:Uranium Isotope separation achieved, 2 years later 'the feasibility of the vortex-tube enrichment method had been deonstrated on laboratory scale…'	Venter p89
1965	buccaneer bombers enter service in South Africa	http://www.globalsecurity.org/military/world/rsa/buccaneer.htm
Nov-67	(Oct/Nov maybe): 'the feasibility of the vortex-tube enrichment method had been deonstrated on laboratory scale…'	Venter p89, Albright: Affordable bomb. P40

Date	Event	Source
Nov-67	SAFARI-2/Pelindaba-Zero (Pelinduna) goes critical. SA's 1st indigenously designed & constructed reactor. 2% enriched, Heavy water, <1MW, lab scale. Fuel & D2O supplied by US. Plans started for 30 MWt prototype Pelinduna Reactor for eventual 300 MWt power reactor.	Venter p89
1967	SA decided to drop Pelinduna activities due to cost and pursue light water technologies available, which would require enrichment, and thus continue pursuing XYZ enrichment development program	Venter p89
1968	SA "revealed" interest in PNEs/doesn't sign NPT	Venter p35
Mar-68	"1st Quarter 1968"SA appoints committee to evaluate use of vortex tube enrichment in large scale facility	Venter p90
1968	Lake St Lucia missile test site developed, had its first successful launch in Dec 1968	Venter p116
1969	AEB formed itnernal group to evaluate technical & economic aspects of PNEs (VanDerWalt p36 says early 1970)	Venter p35, Horton p17, Albright Affordable Bomb p41
1969	encouraging lab results from indigenous vortex tube U enrichment method prompted initiation of pilot plant validation process	Venter p78
Jan-69	early 1969After external review of the process, the gov't decided to build a pilot plant	Albright, Affordable Bomb, p40
1969	SAFARI-1 Shutdown	Venter p89
mid/late 1960s	British gov't stored nuclear weapons at Kaalpan military facility near Warrenton, SA	venter p87
1970	PM Vorster revealed SA had developed a new U enrichment process	Venter p35
7/20/1970	Decision to build pilot enrichment plant made, and PM Vorster announces to parliament that SA had developed unique enrichment process	Venter p90, Reiss p7
	Concerned about disclosure of U extraction & enrichment secrets, an stated interest in PNE's, and the covert weapons program, SA decides to not sign NPT at this time	Venter p90
Aug-70	SA passes Uranium Enrichment Act	Venter p93
Nov-70	Uranium Enrichment Coporation of South Africe Ltd (UCOR) established	Venter p35
1970	SAFARI-2 shutdown	Venter p89

Date	Event	Source
Jan-70	AEC releases report identifying wide applications for nuclear explosives	Horton p17
Mar-71	Minister of Mines approves 1970 AEB proposal to develop gun, implosion, boosted, and thermo-nuclear PNE designs (March from Hibbs PNEtoDeterrent)	Libermann p50, Masiza p36, Horton p17, Albright Affordable Bomb p41
Mar-71	Construction of pilot enrichment plant (Y-Plant) begins, use March 1971 Date (same as MinMines approval above), makes even 6 yrs to next task	Venter p78, Stumpf p3
1972	AEB personnel with assistance from NIDR initiate work on PNE hardware at Somerset West propulsion laboratory (Kentron South also known as Somchem in Cape Province) propulsion laboratory	Venter p96
1972-1973	small team of AEB personnel worked on nuclear weapons design at Somchem West propulsion laboratory (assume this is same place as above)	Albright Affordable Bomb p41
May-73	Decision to prioritize gun type over implosion in 1973 (May added for math convenience)	Venter p96, Horton p17
1973	yom Kippur war involvement of USSR, caused SA to change its deterrence goals to striking USSR	Venter p96
1973	Establishement by NIDR of a Propulsion Division at Somerset West, outside Cape Town, and inititation of serious work on development of ballistic as well as aerodynamic missiles.	Venter p119
1973	Search for test site started	VanDerWalt p39, IAEA-GC-35/1075-9/9/93 p5
1973	Lithium separation research started	IAEA-1075
Nov-74	proposal to acquire ICBM 'on the table'	Venter p97
May-74	Gun Type scale weapon design test with a projectile of non-nuclear material at Somchem demonstrated feasibility of gun type design (may from albright)	Venter p73, Albright Affordable Bomb p41
Nov-74	ISSA agreement with Israel to develop missiles: rocket project to launch recon satellites	Venter p40-41
1974	PM Vorster authorizes funding for work/development on nuclear device and perparation of test site, Albright says this occurred after (as a result of) the successful non-nuclear scale test Aff-Bomb p41	Horton p17, Reiss p8, Albright Aff Bomb p41

Date	Event	Source
1974	Decision to build nuclear weapons by PM Vorster (assume this means device as in Reiss above)	Venter p35
1974	SA gov't, concerned about USSR threat, decides to build 7 nucleaer fission devices, construction Kalahari nuclear test site begins (boreholes dug in mid 1970s[Hibbs-SAPNEpt1-93]).	Masiza p37
End of 1974	First stages at lower end of cascade of Y-Plant were commissioned	Venter p78, Albright, Affordable Bomb, p40
1975	Boreholes at Kalahari Desert test site are completed	Masiza p37
1975	"Work on Kalahari shafts commenced"	IAEA-35/1075-9/9/93-Annex1
6/1975	SA announces it has completedd pilot plant to produce UF6 at Valindaba	Masiza p37
May-76	1976: Somchem group does gun type scale test with natural U projectile proving mechanical integrity of design (May added to simplify math in relation to subsequent/precedent tasks)	Venter p74, Albright Affordable bomb p41
	Shortly after Somchem test additional facilities isolated from main site built at Pelindaba for weapon design research both gun-type & implosion	Venter p74
	Building 5000 contained a pulse reactor used in 1979 for a 'dragon tail tickling' experiment. Building 5100 contained control room for 5000 reactor, offices, R&D, and facilities for machining U. Building 5200: criticality facility for determining multiplication factors. 5300: conventional explosives testing.	Venter p74
Apr-76	PM Vorster visits Israel, may have finalized a missile collaboration deal with Israel	Venter p98
8/5-8/6/76	SA Energy Supply Commission (ESCOM) and French Framatome sign contract to build Koeberg (units 1 & 2) nuclear power station	Masiza p37
10/15/1976	SA & France formalize Koeberg agreemet with bilateral agreement	Masiza p37
11/1976	1st Vastrap test shaft completed	IAEA-GC-35/1075-9/9/93 p5
1976 or 1977	a few military scientists conducted feasibility study of delivering nuclear weapons	Libermann Rise&Fall p52
Mar-77	Y-Plant full cascade operation initiated	Venter p78
Mar-77	all activities moved from Somchem to Pelindaba in 1977,	IAEA-Annex 2 p2

Date	Event	Source
	assume early 1977-guess	
Mid 1977	Development work on gun type device completed and 'two greatly oversized "cold" instrumented devices satisfactorily tested'	VanDerWalt p39
Jun-77	AEC finishes work on 1st tungsten gun device	Masiza p38 from Hibbs 'SA secret Nprogram' (both) 1993
Jun-77	"Mid-1977". All preparations at test site were complete (2nd test shaft completed in 1977-IAEA-GC-35/1075-9/9/93 p5, but must've been before this)	VanDerWalt p40
Aug-77	dummy test of test of test was prepared and about to be executed, but test site was discovered internationally and pressure applied to SA gov't (7/30/1977 1st Soviet satellite, 8/6/1977 2nd satellite does "four more passes": Reiss p 10)	VanDerWalt p40, Masiza p38
8/6/1977	USSR discovers preparations at Kalahari Test Site	Masiza p38
8/22/1977	France warns of "grave consequences" if SA tested	Albright Affordable Bomb p41
	"Soon after the Kalahari episode, Vorster ordered the AEB to cancel the PNE program, to close down the test site, and to develop a secret nuclear deterrent."	Libermann p53
1977	Vastrap test site established	Venter p105
by 1977	AEC had assembled all the nonnuclear components of a nuclear device	Reiss p10
Dec-77	Y-plant goes into full operation	Masiza p38 from Spector & Smith p288
1977	SA acquires 30 g of Tritium from Israel	Libermann p52, Libermann Israel & SA Bomb p54
1977-78	SA trades 50 metric tons of yellowcake for almost 30 grams of tritium from Israel	Albright "Slow but Steady" BAS-93
Jan-78	Y-plant produces 1st "high enriched UF6"	Venter p36, Hibbs NFuel5-10-93, Albright Affordable Bomb p40
Jan-78	Y-plant produces 1st HEU, Y-plant has nominal capacity of 10-20 MTswu	Albright & Hibbs p 34
Jan-78	Preparations for a first fast deployment test (non-instrumented hot test) were ready	VanDerWalt p41

Date	Event	Source
2/1978 (estimated "just after")	"Just after initial HEU production, a 2nd smaller device was built by AEC". The claimed intention for this device was with a full uranium loading for rapid fully instrumentalized test at Kalahari test site if required: use date from Reiss below as completion date (more specific)	Hibbs-SAsecNprog-PNEtoDet 1993 p5, Albright Affordable Bomb p42
9/1978	Botha forms Witvlei Committee on nuclear weapons policy	Libermann p53, Reiss p9
10/31/1978	PM P.W. Botha and cabinet decide Armscor, The Defence Force and the AEB should work together on a nuclear weapons program, ARMSCOR given task of manufacturing weapons. NOTE: other references suggest decision was referred to Witvlei (action) committee, and decisions weren't made until committee recommendation in July 1979	VanDerWalt p42, Masiza p38, Albright CuriousConversion
10/1/1978	Components of the 1st workable nuclear device are completed	Reiss p34
1978	SA produced 4674 tons of uranium-oxide	VanDerWalt p32
Jul-79	Decision to build 7 "deliverable nuclear weapons" by Witvlei Committee and put Armscor in charge of production	Venter p64, Reiss p9 ref 13 p36
7/1979	Witvlei Committee recomends "building deliverable nuclea weapons to acquire a 'credible deterrent capability'" and putting Armscor in charge	Libermann p53
Aug-79	Y-Plant shutdown due to "massive catalytic in-process gas reaction between feedstock and carrier gas, hydrogen"	Venter p79, Hibbs92 p1
Aug-79	Y-Plant shutdown from massive chemical reaction contamination, resumed limited operation 8 months later, but not until July 1981 "was it capable of producing more" HEU	Reiss p11
9/22/1979	Vela Incident	Venter p132
Nov-79	enough HEU for 1 fissie core NOTE: use Aug 79 shutdown as HEU completion date	Venter p36
Nov-79	AEB completed 1st device, 55kg HEU (80%)	Venter p36, Reiss p11, Albright Affordable Bomb p42
Nov-79	The '2nd device' was the 1st to be supplied with HEU	Hibbs-SAsecNprog-PNEtoDet 1993
1978-1979	Y-Plant produces mostly 80% HEUF6 which was converted to metal HEU	Venter p79

Date	Event	Source
1980	high security facility built at ARMSCOR for nuclear weapon production (melting, casting, and machinging), all other mechanical work, design & miniaturization, as well as reliability improvements and alternative triggers	VanDerWalt p42
1980	Armscor begins construction of of Kentron Circle (later Advena)	Masiza p38 from Stumpf, Albright Affordable Bomb p43
1980	Construction of tritium handling facility completed	
Apr-80	Y-plant resumes operation after 9 month shutdown, but not until 7/1981 did HEU began to be produced again	Stumpf p4
Jul-81	Y-plant resumes HEU production after accident & restart. HEU production from this point to next device fabrication (4/1982) appears to have doubled from previous production rate.	Hibbs-SAsecNprog-PNEtoDet 1993
1981	Amrscor completed 2 buildings at Kentron Circle, a main manufacturing building and an environmental test facility	Albright-CuriousConversion-BAS1993
1981	Approval of Gouriqua reactor program for Pu & tritium production, final option involved construction of a 150MW pressurized water research & development reactor	IAEA-1075 p6-16, annex 1
Apr-82	Advena manufactured its first nuclear device with HEU: a 'pre-qualification' device. Design refinements and final qulification took another 2-3 years at which point the design was 'frozen'. At this point earlier models were upgraded to reflect subsequent design changes. Deliverable- "It could be kicked out the back of a plane."-Albright Affordable Bomb p43 ("bomber-deliverable" Libermann p54). Albright-Curious Conversion-Design refinements for full qualification took another 2-3 years after which final design was frozen. NOTE: take this as start of manufacture and IAEA date below as finish	Albright-CuriousConversion-BAS1993, Hibbs 5-10-93, Reiss p11
Dec-82	Completion of "first protobype deliverable nuclear weapon" [IAEA]. "1st bomb built at the circle" [Venter]	Venter p104, IAEA-GC-35/1075-9/9/93 p7
1982	by end of 1982 about 50 modules of semi-commercial enrichment plant will be installed. Budget cuts delayed first planned operations	Laufer-4-8-82

Date	Event	Source
	to late 1986/early1987	
2/27/1985	SA AEC announces Valindaba semi-commerical UENR plant will not operate until 1987	Masiza p41
1985	SA reexamines its nuclear startegy and deides nott to pursue hydrogen weapons. Limited production to 7 weapons	Reiss p16, Albright Affordable Bomb p45
9/1985	SA decided to limited production to 7 weapons, cancel PU and tritium work, limited production of lithium-6, but implosion development and tehoretical work on more advvanced designs continued	Albright Affordable Bomb p46, IAEA-GC-35/1075-9/9/93 p7
1986	Israel tests ICBM missile developed	Venter p41
5/7/1986	Scandiflash of Sweden sells SA a 'roentgen absorber' for use with nuclear test	Masiza p42
Aug-87	delivery of 1st qualified and inventory-certified device, this and subsequent weapons were versions of H2 guided glide bomb: Libermann p54	Venter p104, Albright Affordable Bomb p44
1987	Hot Cell facility comes online	Masiza p 42, SIPRI country profile
1987-1989	SA builds 4 more devices	IAEA-1075
1988	10 new buildings built at Advena/Kentron to develop implosion in mid 1980s, "occupation" of new buildings started in 1988 and facilities were still being commissioned when the program was shut down	Albright-SlowSteady-BAS-1993
9-10/1988	SA builds hanger over 1 Kalahari test shaft and inspects it in 2nd half of October 1988	Pabian p8
1988/1989	2 all-terrain mobile launchers for ballistic missiles built nd tested at Advena	Venter p124
6/1/1989	Single stage test vehicle (RSA-1) missile test	Venter p111
7/5/1989	2 stage potential (RSA-2 type) missile test	Venter p111
Jul-89	Flight test of SA missile from Overberg Test Range (same test as described in above entry)	Venter p41
1989	Gouriqua program cancelled	IAEA-1075
11/19/1991	2 stage missile test	Venter p111
1994	Successful flight test of missiles	Venter p38

Number	Transitions	Ref [d]

		1971	1974	1977
1	Generate Funds for Nuclear Program	365	-	-
2	Hot Test HEU Gun Device	12	-	-
3	Produce Converted HEU Metal with Operating Experience	5	-	-
4	H2 Gas Accident Shutdown-Re-Equilibriation Period	700	-	-
5	Build Prototype Deliverable HEU Gun Explosive	244	-	-
6	Posses Qualified Deliverable Nuclear Weapon	0	-	-
7	Posses Deliverable Nuclear Weapon	0	-	-
8	Build Qualified Deliverable HEU Gun Explosive	183	-	-
9	Qualify Deliverable HEU Gun Explosive Design	1768	-	-
10	Re-Design Deliverable HEU Gun Explosive	1005	-	-
11	Produce Converted HEU Metal	21	-	-
12	Initiate Y-Plant Operations and Bring to Equilibrium	275	-	101
13	Load Un-HEU-loaded Device with HEU	92	-	-
14	Refine Design & Build 1st Device for HEU Loading	487	-	405
15	Design & Build Advena/Kentron Circle Weapons Design & Assembly Facility	731	-	-
16	Redefine SA Nuclear Strategy/Goals	678	-	-
17	Prepare Test Site for Cold Instrumented Test	66	-	-
18	Build Tungsten Gun Type Device	92	-	-
19	Build Weapons Research Facilities at Pelindaba	365	-	-
20	Build Test Site	1127	-	-
21	Search for Test Site	365	-	-
22	Prioritize Gun Research over other PNE Research	792	-	-
23	Build Pilot Vortex Tube U-Enrichment Facility (Y-Plant)	2192	1035	-
24	Test Gun Design with Scale Nat U	731	-	-
25	Design and Non-nuclear Scale Test Gun Nuclear Explosive Design	365	-	-
26	Initiate Lithium R&D	1	-	-
27	Produce Nat UF6	30	-	-
28	Site & Build Test Site	1492	-	-
29	Conduct Preliminary Implosion R&D	1825	-	-
30	Focus AEC on Implosion	0	-	-
31	Build Uranium Metal Fuel Plant	1825	-	-
32	Build SA Heavy Water Production Plant	3285	-	-
33	Produce Metal U Fuel	30	-	-
34	Produce Heavy Water	365	-	-
35	Operate SA for 1 Cycle and Unload/Reload Spent Fuel from SA	365	-	-
36	Fuel & Load SA Production Reactor	30	-	-
37	Design & Build SA Reprocessing Facility	2190	-	-
38	Cool & Reprocess Spent Fuel	365	-	-

Number	Transitions	Ref [d]		
		1971	1974	1977
39	Approve Build of Facilities with Completed Designs for Pu Production Facilities	0	-	-
40	Build SA Production Reactor	4380	-	-
41	Possess Deliverable Pu Imp Weapon	0	-	-
42	Produce Tested Nuclear Pu Imp Explosive	180	-	-
43	Conduct Cold Testing Campaign of Pu Implosion Design	4434	-	-
44	Hot Test Pu Explosive Design	12	-	-
45	Conduct Preliminary Pu Production & Reprocessing R&D	1460	-	-
46	Design Implosion Weapon	3752	-	-

Paths	Transitions
Gun Cold	1,3-27
Gun Hot	1-27
Pu Cold	1,27,29-43,45-46
Pu Hot	1,17,27-42,44-46

Number	Places	M1	M1-XFNP	M1-NFXP	M1-XFXP	DNW Mark
1	AEC Resources & Personnel	10	1	100	100	0
2	Nuclear Program Funds	1	1000	10	1000	0
3	Hot Tested Gun Device	0	0	0	0	0
4	HEU Gun Type Nuclear Explosive Device	0	0	0	0	0
5	Cold Instrumented Test Prepared Test Site	0	0	0	0	0
6	Nat UF6	0	0	0	0	0
7	Equilibrated Operating Y-Plant with experience	0	0	0	0	0
8	H2 Gas Issue	0	0	0	0	0
9	Non-Nuclear Scale Tested Gun Nuclear Explosive Design for Test Site	0	0	0	0	0
10	Prototype Deliverable HEU Gun Explosive Design for Design	0	0	0	0	0
11	Plan for 7 Nuclear Weapons Produced by ARMSCOR for Circle	0	0	0	0	0
12	PNE R&D	1	1	1	1	0
13	Pilot Vortex Tube U-Enrichment Facility (Y-Plant)	0	0	0	0	0
14	Pilot Vortex Tube U-Enrichment Facility (Y-Plant) Design	1	1	1	1	0
15	Qualified Deliverable HEU Gun Nuclear Explosive	0	0	0	0	0
16	Pelindaba Weapons Research Facilities	0	0	0	0	0
17	Qualified Deliverable HEU Gun Explosive Design	0	0	0	0	0
18	Un-HEU-loaded Gun Type Nuclear Explosive Device	0	0	0	0	0

Number	Places	M1	M1-XFNP	M1-NFXP	M1-XFXP	DNW Mark
19	Plan for 7 Nuclear Weapons Produced by ARMSCOR for Design	0	0	0	0	0
20	Buccaneer Bombers	15	15	15	15	0
21	Equilibrated Operating Y-Plant	0	0	0	0	0
22	Kentron Circle/Advena Weapons Design and Assembly Facility	0	0	0	0	0
23	Kalahari Test Site Location	0	0	0	0	0
24	Nat U Scale Cold Tested Gun Design	0	0	0	0	0
25	Lithium Separation Research	0	0	0	0	0
26	Prototype Deliverable HEU Gun Nuclear Explosive	0	0	0	0	0
27	Pilot U refinement Plant (U conversion)	1	1	1	1	0
28	Cold Instrumented Test Prepared Test Site Detected	0	0	0	0	0
29	Tungsten Gun Type Mock Nuclear Explosive Device	0	0	0	0	0
30	Kalahari Vastrap Test Site	0	0	0	0	0
31	HEU	0	0	0	0	0
32	Refined AEC Gun Design	0	0	0	0	0
33	Non-Nuclear Scale Tested Gun Nuclear Explosive Design for Weapon	0	0	0	0	0
34	Boosting R&D	0	0	0	0	0
35	Prototype Deliverable HEU Gun Explosive Design for Build	0	0	0	0	0
36	Gun R&D	0	0	0	0	0
37	Deliverable Nuclear Weapon	0	0	0	0	1
38	Implosion & Thermonuclear R&D	0	0	0	0	0
39	Qualified Deliverable Nuclear Weapon	0	0	0	0	1
40	Test Site Planning	0	0	0	0	0
41	U Mines	1	1	1	1	0
42	Focused Implosion & Thermonuclear R&D for Test Site	0	0	0	0	0
43	Reprocessing Facility R&D	0	0	0	0	0
44	Metal Fuel Facility Design	0	0	0	0	0
45	Heavy Water Facility Design	0	0	0	0	0
46	SA Spent Fuel	0	0	0	0	0
47	Fueled SA Production Reactor	0	0	0	0	0
48	SA Production Reactor Design	0	0	0	0	0
49	Preliminary Pu Production R&D for Reactor & Support Facilities	0	0	0	0	0
50	Pu [kg]	0	0	0	0	0
51	Heavy Water	0	0	0	0	0
52	Uranium Metal Fuel Plant	0	0	0	0	0
53	SA Reprocessing Facility	0	0	0	0	0
54	SA Heavy Water Production Plant	0	0	0	0	0
55	Unloaded SA Production Reactor	0	0	0	0	0
56	Metal SA Production Fuel [1 MTU]	0	0	0	0	0

Number	Places	M1	M1-XFNP	M1-NFXP	M1-XFXP	DNW Mark
57	Initial Pu Production R&D (Pelinduna/SAFARI-2)	1	1	1	1	0
58	Tested Pu Imp Explosive Design	0	0	0	0	0
59	Pu Explosive	0	0	0	0	0
60	Untested Pu Implosion Explosive Design for Hot Testing	0	0	0	0	0
61	Untested Pu Implosion Explosive Design for Cold Testing	0	0	0	0	0
62	Focused Implosion & Thermonuclear R&D	0	0	0	0	0

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	380	1	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	55	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	760	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T23	0	10	0	0	0	0	0	0	0	0	0	0	0	1	0
T24	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T30	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	1000	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T45	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T6	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0
T8	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T19	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	55	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T8	55	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	55	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T26	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D-	P46	P47	P48	P49	P50	P51	P52	P53	P54	P55	P56	P57	P58	P59	P60	P61	P62
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

D-	P46	P47	P48	P49	P50	P51	P52	P53	P54	P55	P56	P57	P58	P59	P60	P61	P62
T35	0	1	0	0	0	1	0	0	0	0	9	0	0	0	0	0	0
T36	0	0	0	0	0	1	0	0	0	1	9	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T39	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T42	0	0	0	0	8	0	0	0	0	0	0	0	1	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T44	0	0	0	0	8	0	0	0	0	0	0	0	0	0	1	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0
T3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T11	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T14	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T17	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T24	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	7500	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0

D+	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T16	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T19	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T21	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T7	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T11	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	1	0	1	0	1	0	1	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1

D+	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P46	P47	P48	P49	P50	P51	P52	P53	P54	P55	P56	P57	P58	P59	P60	P61	P62
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P46	P47	P48	P49	P50	P51	P52	P53	P54	P55	P56	P57	P58	P59	P60	P61	P62
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T31	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0
T34	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
T35	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	8	0	0	1	0	0	0	0	0	0	0	0	0
T39	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T45	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	1	55	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P46	P47	P48	P49	P50	P51	P52	P53	P54	P55	P56	P57	P58	P59	P60	P61	P62
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P46	P47	P48	P49	P50	P51	P52	P53	P54	P55	P56	P57	P58	P59	P60	P61	P62
T23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T33	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0
T34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Udata	U1	U2	U3	U4	U5	U6	U7	U8	U9
T2	0	0.25	0	0.75	0	0	0	0	0
T5	3.29	0	0	0	0	0	0	83	20
T6	0	0	0	0	3700	1	0	0	0
T7	0	0	0	0	3700	1	0	0	0
T10	0	0	0	0.75	0	0	0	0	0
T20	0	0.25	0	0	0	0	0	0	0
T23	2.92	0.75	0	0	0	0	1	27740	20
T27	9.13	0	0	0	0	0	0	0	0
T31	0	0.5	0	0	0	0	0	12167	20
T32	0	0.5	0	0	0	0	3	0	0
T37	0	0.75	0	0	0	0	1	1000	20

Udata	U1	U2	U3	U4	U5	U6	U7	U8	U9
T38	0	0.25	0	0	0	0	0	0	0
T40	0.9	0.25	0	0	0	0	3	9000	20
T41	0	0	0	0	3700	1	0	0	0
T42	2.03	0	0	0	0	0	0	16	20
T43	0	0	0	0.5	0	0	0	0	0
T44	0	0.25	0	0.75	0	0	0	0	0

Transitions with all zero value entries omitted.

RF	T23	T40
T23	0	1
T40	1	0

Red-CS = 0.

ProlifData

Range To Adversary Targets [km]	450	1170	1000	2400
Adversary Defense Rank	2			
Uranium Data (reserves stocks) [MT]	1.00E+09	300		

APPENDIX L: NUCLEAR WEAPONS PROLIFERATION PATHWAY UTILITY ATTRIBUTE WEIGHTING SURVEY RESULTS

TABLE L.1.

Means and Standard Deviations for All NWPPUAWS Results

		W(TTFW)		W(NWPR)		W(C&S)		W(NDP)		W(Rel)		W(Sus)	
		mean	std	mean	std	mean	std	mean	std	mean	std	mean	std
All Results		0.30	0.27	0.05	0.06	0.18	0.15	0.18	0.13	0.15	0.13	0.14	0.12
Group	Prolif Expert	0.247	0.170	0.064	0.068	0.160	0.082	0.119	0.066	0.221	0.097	0.190	0.113
	Intell Analyst	0.399	0.440	0.025	0.050	0.242	0.239	0.249	0.231	0.043	0.036	0.042	0.032
	Technical Nuclear	0.431	0.247	0.102	0.088	0.150	0.074	0.145	0.078	0.081	0.014	0.090	0.048
	Nuclear Policy	0.437	0.260	0.053	0.042	0.123	0.117	0.177	0.113	0.085	0.047	0.125	0.075
	MS NE	0.162	0.158	0.046	0.051	0.166	0.099	0.237	0.149	0.212	0.148	0.178	0.113
	PhD NE	0.215	0.188	0.060	0.051	0.128	0.103	0.165	0.154	0.214	0.170	0.218	0.181
	UG NE	0.055	-	0.010	-	0.175	-	0.175	-	0.351	-	0.234	-
	MS Pol	0.071	0.001	0.014	0.004	0.527	0.530	0.156	0.209	0.078	0.105	0.154	0.212
	not given	0.477	0.324	0.050	0.058	0.157	0.121	0.130	0.087	0.093	0.082	0.092	0.091
Country Profile	Reg Power	0.235	0.223	0.061	0.066	0.179	0.130	0.201	0.141	0.168	0.144	0.157	0.119
	Reg Aspirant	0.274	0.266	0.042	0.043	0.173	0.206	0.165	0.140	0.181	0.141	0.165	0.147
	not given	0.437	0.310	0.054	0.057	0.164	0.111	0.133	0.084	0.113	0.089	0.099	0.085
Educ.	Prof Deg	0.328	0.253	0.057	0.057	0.168	0.122	0.165	0.124	0.139	0.121	0.143	0.126
	Ugrad	0.197	0.226	0.044	0.051	0.195	0.200	0.213	0.150	0.186	0.145	0.164	0.118
	High School	0.055	-	0.010	-	0.175	-	0.175	-	0.351	-	0.234	-
	not given	0.705	0.417	0.076	0.107	0.055	0.077	0.055	0.077	0.055	0.077	0.055	0.077
Emp. Sector	Academic	0.213	0.213	0.052	0.056	0.188	0.163	0.195	0.139	0.183	0.144	0.169	0.132
	Gov't	0.487	0.272	0.060	0.062	0.124	0.095	0.103	0.074	0.112	0.084	0.114	0.083
	Industry	0.667	-	0.025	-	0.084	-	0.084	-	0.056	-	0.084	-
	Other	0.437	0.332	0.051	0.059	0.161	0.145	0.184	0.142	0.080	0.044	0.087	0.072
Prof. Disc.	Tech Sci/Eng	0.255	0.227	0.054	0.056	0.164	0.106	0.192	0.136	0.172	0.138	0.163	0.122
	Social Science	0.269	0.271	0.041	0.049	0.257	0.249	0.175	0.134	0.129	0.119	0.130	0.135
	Other	0.622	0.329	0.064	0.072	0.057	0.055	0.079	0.075	0.096	0.084	0.082	0.065
Prof./Stud	Prof.	0.364	0.270	0.061	0.065	0.168	0.132	0.167	0.129	0.120	0.095	0.120	0.093
	Student	0.167	0.161	0.047	0.048	0.183	0.177	0.205	0.148	0.207	0.152	0.191	0.137
	not given	0.477	0.324	0.050	0.058	0.157	0.121	0.130	0.087	0.093	0.082	0.092	0.091

APPENDIX M: MAUA VERIFICATION NETWORK AND DATA

Number	Transitions	Ref
1	Posses Hot Tested Pu Implosion Missile Weapon	0
2	Produce Hot Tested Pu Implosion Explosive Device	5
3	Possess Deliverable HEU Gun Gravity Bomb Weapon	0
4	Design & Build Missile Delivery System	40
5	Possess Deliverable Cold Tested Pu Implosion Missile Weapon	0
6	Produce Nat U	2
7	Build U Mine	25
8	Build Fuel Fab, Reactor, & Reprocessing Facility	50
9	Build Enrichment Facility #2	30
10	Allocate Resources to Nuclear Program	50
11	Hot Test Pu Implosion Explosive	2
12	Design & Build Gravity Bomb Delivery System	20
13	Produce Cold Tested Pu Implosion Device	5
14	Initiate Delivery System Design Program	1
15	Produce Cold Tested HEU Gun Explosive	5
16	Produce Pu	10
17	Operate Enr Facility 2	8
18	Operate Enr Facility 1	8
19	Build Enrichment Facility #1	30

Path 1: Cold Tested HEU Gun Gravity Bomb w/one ENR facility	Path 2: Cold Tested HEU Gun Gravity Bomb w/two ENR facilities	Path 3: Cold Tested Pu Implosion Missile	Path 4: Hot Tested Pu Imp Missile
3	3	4	1
6	6	5	2
7	7	6	4
10	9	7	6
12	10	8	7
14	12	10	8
15	14	13	10
18	15	14	11
19	17	16	13
	18		14
	19		16

Number	Places	M1	DNWMark
1	Nuclear Program Resources: Delivery System	0	0
2	Nuclear Program Resources: U Mine	0	0
3	Gravity Bomb Delivery System	0	0
4	Missile Delivery System	0	0
5	Deliverable Nuclear Weapon	0	1
6	Pu	0	0
7	Missile R&D	0	0
8	Hot Tested Pu Implosion Explosive	0	0
9	Hot Tested Pu Implosion Explosive Design	0	0
10	Cold Tested Pu Implosion Explosive	0	0
11	Fuel Fab, Reactor, & Reprocessing Facilities	0	0
12	Nat U	0	0
13	Gravity Bomb R&D	0	0
14	Cold Tested HEU Gun Nuclear Explosive	0	0
15	U Mine	0	0
16	HEU	0	0
17	Delivery System R&D Block	0	0
18	Enrichment Facilities	0	0
19	Nuclear Program Resources	0	0

D-

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19
T1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
T3	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T4	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T7	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T13	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
T18	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

D+

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19
T1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T10	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T11	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T12	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T16	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

For Infinite Resources Change Allocate Resources to Nuclear Program from 1 to 50 for Nuclear Program Resources, T11

H

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

MAUA Data

	MAUA1	MAUA2	MAUA3	MAUA4	MAUA5	MAUA6	MAUA7	MAUA8	MAUA9
T1	0	0	0	0	0	0	0	0	0
T2	0	0	0	0.75	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	500	2	0	0	0
T5	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0
T7	10	0	0	0	0	0	0	0	0
T8	3	0.5	0.3	0	0	0	3	9000	20
T9	2	0.75	0.2	0	0	0	1	11250	20
T10	0	0	0	0	0	0	0	0	0
T11	0	0.25	0	0	0	0	0	0	0
T12	0	0	0	0	1000	1	0	0	0
T13	0	0	0	0.5	0	0	0	0	0

	MAUA1	MAUA2	MAUA3	MAUA4	MAUA5	MAUA6	MAUA7	MAUA8	MAUA9
T14	0	0	0	0	0	0	0	0	0
T15	0	0	0	0.75	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0

Red-Flow

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	T18	T19
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
T9	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0

Red-CS

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	T18	T19
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	T18	T19
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0

Prolif Data

Range To Adversary Targets [km]	250	900
Adversary Defense Rank	1	
Uranium Data [MT]	2.00E+05	100

APPENDIX N: ROK PETRI NET DATA

Pyro

Number	Transitions	Ref Time [d]
1	Acquire Pu Purification Chemicals	1
2	Develop Pu Purification Chemical Acquisition Source	365
3	Initiate Reprocessing & Actinide Chemistry R&D	1
4	Operate Pu Purification Facility	5
5	Build Pu Purification Facility	365
6	Design Pu Purification Process	365
7	Initiate Pyro Processing R&D	1
8	Operate Pilot Pyro Facility	16
9	Build Pilot Pyro Facility	730
10	Design Pilot Pyro Facility	730
11	Operate/Test Mock Pilot Pyro	365
12	Build Mock Pilot Pyro Facility	365
13	Design Mock Pilot Pyro Facility	1095
14	Design Pyro Process	3650
15	Possess Deliverable Pu Imp Weapon	0
16	Produce Tested Nuclear Explosive	57
17	Prepare and Conduct Subcrit Test Campaign of Pu Design	720
18	Prepare and Conduct Nuclear Test of Pu Explosive with 4 reserve explosives	180
19	Design Pu Explosive	858
20	Initiate Weapons R&D	1

Number	Places	M1-P	M1-C	DNW Mark
1	Pu Purification Chemical Knowledge	0	0	0
2	Pu Purification Chemicals	0	0	0
3	Pu Purification Chemical Acquisition Source	0	0	0
4	Pyro R&D initiated	1	1	0
5	Nuclear Program	1	1	0
6	Pu Metal [kg]	0	0	0
7	Pu Purification Facility	0	0	0
8	Pu Purification Process Design	0	0	0
9	Reprocessing & Actinide Chemistry R&D	1	1	0
10	Spent Fuel Assemblies	12000	12000	0
11	Separated TRU metal 6 kg Ingot (PU/U = 3)	0	0	0

Number	Places	M1-P	M1-C	DNW Mark
12	Pilot Pyro Facility	0	1	0
13	Pilot Pyro Facility Design	0	0	0
14	Mock Tested Pilot Pyro Design	0	0	0
15	Mock Pilot Pyro Facility	1	0	0
16	Mock Pilot Pyro Facility Design	0	0	0
17	Pyro Process Design	0	0	0
18	Pyroprocessing R&D	0	0	0
19	Tested Pu Explosive Design	0	0	0
20	Deliverable Pu Imp Weapon	0	0	1
21	Nuclear Capable Delivery System	1	1	0
22	Nat U Metal [kg]	800	800	0
23	Pu Explosive	0	0	0
24	Untested Pu Explosive Design	0	0	0
25	Weapons Design Program	0	0	0

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
T1	0	0	1	0	0	0	0	0	0	0	0	0	0
T2	1	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	1	0	0	0	0	0	0	0	0
T4	0	1	0	0	0	0	1	0	0	0	1	0	0
T5	0	0	0	0	0	0	0	1	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	1	0	0	0	0
T7	0	0	0	0	0	0	0	0	1	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	1	0	1	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	1
T10	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	8	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	40	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	1	0	0	0	0	0	0	0	0

D-	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25
T1	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0
T10	1	0	0	0	0	0	0	0	0	0	0	0
T11	0	1	0	0	0	0	0	0	0	0	0	0
T12	0	0	1	0	0	0	0	0	0	0	0	0
T13	0	0	0	1	0	0	0	0	0	0	0	0
T14	0	0	0	0	1	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	1	0	1	0	0
T16	0	0	0	0	0	1	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	8	0	1	0
T18	0	0	0	0	0	0	0	0	0	0	1	0
T19	0	0	0	0	0	0	0	0	0	0	0	1
T20	0	0	0	0	0	0	0	0	0	0	0	0

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
T1	0	1	1	0	0	0	0	0	0	0	0	0	0
T2	0	0	1	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	1	0	0	0	0
T4	0	0	0	0	0	4	1	0	0	0	0	0	0
T5	0	0	0	0	0	0	1	0	0	0	0	0	0
T6	1	0	0	0	0	0	0	1	1	0	0	0	0
T7	0	0	0	1	0	0	0	0	1	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	1	1	0
T9	0	0	0	0	0	0	0	0	0	0	0	1	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	1
T11	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
T16	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0

D+	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25
T1	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	1	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0
T11	1	0	0	0	0	0	0	0	0	0	0	0
T12	0	1	0	0	0	0	0	0	0	0	0	0
T13	0	0	1	0	0	0	0	0	0	0	0	0
T14	0	0	0	1	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	1	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	1	0	0
T17	0	0	0	0	0	1	0	0	0	0	0	0
T18	0	0	0	0	0	1	0	0	0	4	0	0
T19	0	0	0	0	0	0	0	0	0	0	1	0
T20	0	0	0	0	0	0	0	0	0	0	0	1

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
T1	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	1	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	1	1	0	0	0	0	0
T7	0	0	0	1	0	0	0	0	0	0	0	0	0

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
T8	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25
T1	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0
T17	0	0	0	0	0	0	0	0	0	0	0	0
T18	0	0	0	0	0	0	0	0	0	0	0	0
T19	0	0	0	0	0	0	0	0	0	0	0	0
T20	0	0	0	0	0	0	0	0	0	0	0	0

PUREX

Number	Transitions	Ref Time [d]
1	Acquire PUREX Chemicals	30
2	Develop PUREX chemical acquisition source	90
3	Initiate Reprocessing & Actinide Chemistry R&D	1
4	Convert Pu Nitrate to Pu Metal	1
5	Build Pu Conversion Facility	180
6	Design Pu Metal Conversion Facility	180
7	Initiate PUREX Processing R&D	1
8	Operate Pilot PUREX Facility	15
9	Build Pilot PUREX	1095
10	Design PUREX Pilot Facility	365
11	Possess Deliverable Pu Imp Weapon	0
12	Produce Tested Nuclear Explosive	57
13	Prepare and Conduct Subcrit Test Campaign of Pu Design	720
14	Prepare and Conduct Nuclear Test of Pu Explosive with 4 reserve explosives	180
15	Design Pu Explosive	858
16	Initiate Weapons R&D	1

Number	Places	MP	MC	DNW Mark
1	Pu Metal Conversion Designed	0	0	0
2	PUREX R&D Initiated	0	1	0
3	PUREX Chemicals	0	0	0
4	PUREX Chemicals acquisition source	0	0	0
5	Nuclear Program	1	1	0
6	Pu Metal [kg]	0	0	0
7	Pu Conversion Facility	0	0	0
8	Pu Metal Conversion Facility Design	0	0	0
9	Reprocessing & Actinide Chemistry R&D	2	2	0
10	Spent Fuel	12000	12000	0
11	Pu Nitrate	0	0	0
12	Pilot PUREX Facility	0	1	0
13	Pilot PUREX Design	0	0	0
14	PUREX R&D	0	0	0
15	Tested Pu Explosive Design	0	0	0
16	Deliverable Pu Imp Weapon	0	0	1
17	Nuclear Capable Delivery System	1	1	0

Number	Places	MP	MC	DNW Mark
18	Nat U Metal [kg]	800	800	0
19	Pu Explosive	0	0	0
20	Untested Pu Explosive Design	0	0	0
21	Weapons Design Program	0	0	0

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
T1	0	0	0	1	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	1	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	1	0	0	0	1	0
T5	0	0	0	0	0	0	0	1	0	0	0	0
T6	0	0	0	0	0	0	0	0	1	0	0	0
T7	0	0	0	0	0	0	0	0	1	0	0	0
T8	0	0	0	0	0	0	0	0	0	1	0	1
T9	0	0	1	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	8	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	40	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	1	0	0	0	0	0	0	0

D-	P13	P14	P15	P16	P17	P18	P19	P20	P21
T1	0	0	0	0	0	0	0	0	0
T2	0	1	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0
T9	1	0	0	0	0	0	0	0	0
T10	0	1	0	0	0	0	0	0	0
T11	0	0	0	0	1	0	1	0	0
T12	0	0	1	0	0	0	0	0	0

D-	P13	P14	P15	P16	P17	P18	P19	P20	P21
T13	0	0	0	0	0	8	0	1	0
T14	0	0	0	0	0	0	0	1	0
T15	0	0	0	0	0	0	0	0	1
T16	0	0	0	0	0	0	0	0	0

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
T1	0	0	1	0	0	0	0	0	0	0	0	0
T2	0	0	0	1	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	1	0	0	0
T4	0	0	0	0	0	1	1	0	0	0	0	0
T5	0	0	0	0	0	0	1	0	0	0	0	0
T6	1	0	0	0	0	0	0	1	1	0	0	0
T7	0	1	0	0	0	0	0	0	1	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	4	1
T9	0	0	0	0	0	0	0	0	0	0	0	1
T10	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0

D+	P13	P14	P15	P16	P17	P18	P19	P20	P21
T1	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0
T7	0	2	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0
T10	1	0	0	0	0	0	0	0	0
T11	0	0	0	1	0	0	0	0	0
T12	0	0	0	0	0	0	1	0	0

D+	P13	P14	P15	P16	P17	P18	P19	P20	P21
T13	0	0	1	0	0	0	0	0	0
T14	0	0	1	0	0	0	4	0	0
T15	0	0	0	0	0	0	0	1	0
T16	0	0	0	0	0	0	0	0	1

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
T1	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	1	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0	0	0
T6	1	0	0	0	0	0	0	0	0	0	0	0
T7	0	1	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0	0	0	0

H	P13	P14	P15	P16	P17	P18	P19	P20	P21
T1	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0

H	P13	P14	P15	P16	P17	P18	P19	P20	P21
T13	0	0	0	0	0	0	0	0	0
T14	0	0	0	0	0	0	0	0	0
T15	0	0	0	0	0	0	0	0	0
T16	0	0	0	0	0	0	0	0	0

Centrifuge

Number	Transitions	Ref Time [d]
1	Operate U Metal Conversion Facility	1
2	Build U Metal Conversion Facility	180
3	Design U Metal Facility	180
4	Operate Centrifuge WGU Plant	1
5	Reconfigure LEU Plant for WGU production	60
6	Build 3 MSWU Centrifuge LEU Plant	1385
7	Design 3 MSWU Centrifuge LEU Plant	180
8	Possess Deliverable U Gun Weapon	0
9	Produce U Gun Explosive	1
10	Design U Gun Explosive	365
11	Initiate Weapons R&D	1

Number	Places	MP	MC	DNW Mark
1	WGU Metal	0	0	0
2	U Metal Conversion Facility Design Completed	0	0	0
3	3 MSWU Centrifuge LEU Plant Design Completed	0	1	0
4	U Metal Conversion Facility	0	0	0
5	U Metal Conversion Facility Design	0	0	0
6	WGUF6	0	0	0
7	3MSWU Centrifuge WGU Plant	0	1	0
8	Nat UF6	1.00E+09	1.00E+09	0
9	3 MSWU Centrifuge LEU Plant	0	0	0
10	URENCO assistance	1	1	0
11	Nuclear Program	3	3	0
12	3 MSWU Centrifuge LEU Plant Design	0	0	0
13	Deliverable U Gun Weapon	0	0	1
14	Nuclear Capable Delivery System	1	1	0
15	Weapons Design Program Initiated	0	0	0

Number	Places	MP	MC	DNW Mark
16	U Gun Explosive	0	0	0
17	U Gun Design	0	0	0
18	Weapons Design Program	0	0	0

D-	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18
T1	0	0	0	1	0	28	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	1	6000	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0
T9	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
T11	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

D+	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18
T1	28	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
T4	0	0	0	0	0	28	1	0	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T7	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
T11	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18
T5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T7	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0