Appendix and Supplement to "Analyzing and Reducing the Risks of Inadvertent Nuclear War between the United States and Russia"

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Modeled Systems and Scenarios

Systems and response procedures described here are assumed to have been used since approximately 1975, and current C3I systems and launch protocols have been in place for the past 37 years. There is limited publically available data on the historical frequency of MDCs, TACs or MACs in the United States, or their equivalents in the USSR and Russia, over the same period. In the United States, during the period 1977–1983, the number of MDCs per year ranged from 43 to 255, and the number of TACs per year were either zero or two.[1] No MACs are known to have ever occurred in the United States.[2] In the USSR or Russia, the 1983 satellite sensor warning incident was roughly equivalent to a TAC that was not promoted to the level of a MAC, and the 1995 Norwegian scientific rocket incident was roughly equivalent to a MAC in which leaders made a decision not to counterattack in response to the initially serious indicators of a possible submarine-launched Trident missile.[3]

The decision procedures depend on the level of tensions between the United States and a nuclear adversary, and associated strategic intelligence. In the United States, a high level of nuclear tensions would produce high strategic-intelligence estimates of the current likelihood of an attack (somewhat similar to a Bayesian prior estimate of attack probability, to be combined with incoming satellite and radar data). As Blair[4] put it, "NORAD in effect assigned equal weight to infrared satellite sensors, ground radar sensors, and strategic intelligence. Positive indications from any two of these sources were sufficient to justify a high-confidence assessment. This formula posed a danger that heightened nuclear tensions (strategic warning) could have combined with a false alarm from a tactical sensor to convince NORAD that a Soviet attack was under way."

Strategic intelligence warning has not necessarily been used in precisely the same way in Soviet/Russian systems as in U.S. systems. However, statements about their procedures suggest that in a crisis, Soviet/Russian nuclear forces could or would be put on "high alert," that "putting the troops on high alert probably would be accompanied by the transfer of the battle management system from regular combat duty to combat mode." Under such conditions "the satellite signal may not play such a significant role" as it otherwise would in activating the Kazbek communication system for leaders' orders, i.e. in a crisis situation Soviet/Russian satellite systems may not have the same dual-phenomenology role that they would during low-tension conditions in confirming indications of an incoming first strike attack. Furthermore, "a 'missile attack' signal can be transmitted even if it is based only on data reported by radars" though in those cases "the criteria for the reliable identification of targets could be somewhat stricter and the tracking time somewhat longer than for missile launches detected directly by the satellite system."[5]

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This appendix is also posted at
http://scienceandglobalsecurity.org/archive/2013/06/analyzing_and_reducing_the_ris.html

Historical information on frequency and duration of U.S.-Russia crises (roughly corresponding with periods of significant heightening of nuclear alert levels) is somewhat limited. In U.S. forces, the main instance of significantly heightened strategic alert, i.e. at least a Defense Condition / DEFCON 3 alert level is the 1962 Cuban Missile Crisis. The main period of high tension is often regarded to been the 13 days from 15 October 1962 when senior U.S. leaders were told of the missiles in Cuba, until U.S. and Soviet leaders reached agreements on 28 October 1962,[6] though U.S. forces were at either DEFCON 3 or DEFCON 2 alert levels for a total of 30 days beginning on 22 October 1962 when U.S. President Kennedy announced the blockade[7] and Soviet forces were on alert for virtually the same 30 day period.[8] Other known cases of U.S. forces at alert levels of at least DEFCON 3, such as the brief DEFCON 3 alert in the Yom Kippur War of October 1973, arguably do not qualify as U.S.-Russia crises posing the same risk of inadvertent war between the United States and Russia as the Cuban Missile Crisis, though they also arguably posed greater than normal peacetime risks.[9] Another case of DEFCON 3 alert was during the terrorist attacks of 11 September 2001.[10]

In Soviet and Russian forces, instances of heightened alert include several during the Cuban Missile Crisis,[11] with combined durations that may have been somewhat longer than the U.S. forces' alerts;[12] during the 1968 invasion of Czechoslovakia and during parts of the period of high East-West tensions in the early 1980s[13], especially around the time of the KAL 007 shoot-down and the ABLE ARCHER exercises in late 1983.[14]

Early warning systems could provide dangerous signals besides ones that specifically indicated the launch or movement of a missile. Even sensor outages could be interpreted as an indication of an attack. In the United States, "NORAD had become worried that an inexplicable outage of a tactical sensor might actually be the handiwork of saboteurs. This threat (and jamming) was considered serious enough to justify treating an outage as a positive indication of attack in the context of a nuclear crisis."[15] (Soviet/Russian procedures were somewhat analogous. Under conditions of a crisis "the delivery of a first strike can be considered, under Russian military doctrine, in the case of an attack on key elements of the early warning system or the command, control and communications systems." [16]) This paper treats unresolved MDCs as one example of an outage of a tactical sensor, based partly on the similarities in MDC occurrence rates and durations given by Marsh and Wallace et al. and the sensor outage rates and durations given by Blair.[17]

Usually, TACs comprise a small subset of MDCs where one detector system (usually, a satellite with infrared detectors of hot missile plume gases) indicates a launch and a different detector system (i.e. a ground-based radar) provides a confirming indication of launch. If there are confirming indications of launch from more than one separate ground-based radar systems, then NORAD reports high confidence in its assessment of the threat, otherwise NORAD reports low confidence. At least under normal circumstances, only high-confidence threat assessments will lead to a MAC where the leader then decides whether to launch an attack in response.[18] However, during periods of high U.S.-Russia tensions or crises, "positive indication from only one tactical sensor system" would be required for a high-confidence threat assessment. In addition, "the loss of a tactical sensor to presumed hostile action" would be treated as the equivalent of a "a positive tactical indication" of an attack.[19] Thus, under conditions of a U.S.-Russia crisis, this paper treats an unresolved MDC as an additional type of event that would be treated as a TAC-level indication of an attack, similar to Wallace et al. and Sennott.

This paper separately estimates rates of inadvertent nuclear war during both low-tension and high-tension periods, to account for the possibility that conditional probabilities of launch prevention failure could be substantially higher in periods of high U.S.-Russia tensions than during low-tension periods. This is partly because the literature suggests that leaders will be more psychologically or strategically predisposed to launch missiles in response to apparently credible indicators of an attack during a crisis period than during a low-tension period.[20] It is also because of this paper's assumptions about the technical features of early warning systems and nuclear postures.

Additional Model Input Parameter Values

Table A1: Decision times (minutes)

Scenarios		Launch Under Attack	Launch On Warning	References and Comments
For Russia receiving indications of attack	ICBM	Triangular (2, 11, 20)	Triangular (9, 16, 23)	"Clean and informed decision time" values based on "Optimistic," "Best Guess," and "Pessimistic" values from Wallace et al.[21] The mode values of 0.001 minutes are effectively 0 minutes, as in the "Best Guess" values of 0 minutes in Wallace et al.
	SLBM or equivalent	Triangular (0, 0.001, 1)	Triangular (0, 0.001, 1)	
For United States receiving indications of attack	ICBM	Triangular (8, 15.25, 22.5)	Triangular (15, 20.25, 25.5)	
	SLBM or equivalent	Triangular (0, 0.001, 2.5)	Triangular (0, 3.25, 5.5)	

Table A2: Other Model Input Parameter Values

Parameter Name	Values	References and Comments
P(Launch response | mistaken MAC-level indicators of nuclear attack during low U.S.-Russia tensions)	$f(p) = 2(1-p)$ i.e. Equation 5 with n = 1	One historical case seemed applicable, the 1995 Norwegian rocket event in Russia,[22] so n = 1 in Equation 5.
P(Launch response | mistaken MAC-level indicators of nuclear attack during U.S.-Russia crisis)	Uniform(0, 1)	No historical cases seemed applicable, so a uniform distribution was used (i.e. an uninformative Bayesian prior, or n = 0 in Equation 5).
Mean resolution time y for MDCs (minutes)	Triangular(1, 3.5, 6)	Based on Wallace et al.[23] and Sennott.[24]
Probability of ICBM attack indicators vs. SLBM or	Uniform(0,1)	Both nations can operate SSBNs near each other. Russia has long been

equivalent attack indicators		concerned about U.S. SSBNs near Russia.[25] Though Russian SSBNs may have been using relatively limited patrol areas in recent years,[26] reportedly they are resuming permanent patrols in international waters[27]
Probability of nation receiving indicators	Equal probability for United States and Russia	–
P(Nuclear terrorist attack would be in United States or Russia | nuclear terrorist attack somewhere in world)	Uniform(0,1)	These are somewhat arbitrary because of the lack of data or expert judgment. However, this simple parameter decomposition roughly parallels the "usual" false alarm fault tree, and the product of uniform distributions gives a probability distribution with most density much closer to 0 than to 1, which seems reasonable.
P(Resemblance of nuclear terrorist attack to TAC-level indicators of nuclear attack from the other nation | nuclear terrorist attack)	Uniform(0,1)	
P(Promotion of nuclear terrorism TAC-level indicators of nuclear attack to MAC level)	Uniform(0,1)	

The Computational Model

This section contains additional figures of the influence diagrams for modules in the computational model, implemented using Analytica software. For more information on the model, see the main paper, "Analyzing and Reducing the Risks of Inadvertent Nuclear War between the United States and Russia." Opening some specific nodes in the Analytica model will provide additional comments on how they work. Analytica software is available from the manufacturer, Lumina Decision Systems, at http://www.lumina.com/support/downloads/. The free "player" license will allow readers to open, explore and run the model described in this paper. The model typically runs and displays results in about a minute on a standard laptop.

Figure S1 shows the user interface for the computational model, which is displayed when the user opens the model file in Analytica. The interface gives the user an easy way to generate and display a number of model outputs by clicking once on any of the "result" buttons. Additional information on model structure, algorithms, and parameter values is accessible by double clicking on the modules at the bottom of the user interface. For example, the module "Main Fault Tree and Model Components" contains the same simplified fault tree figure given in Figure S3.

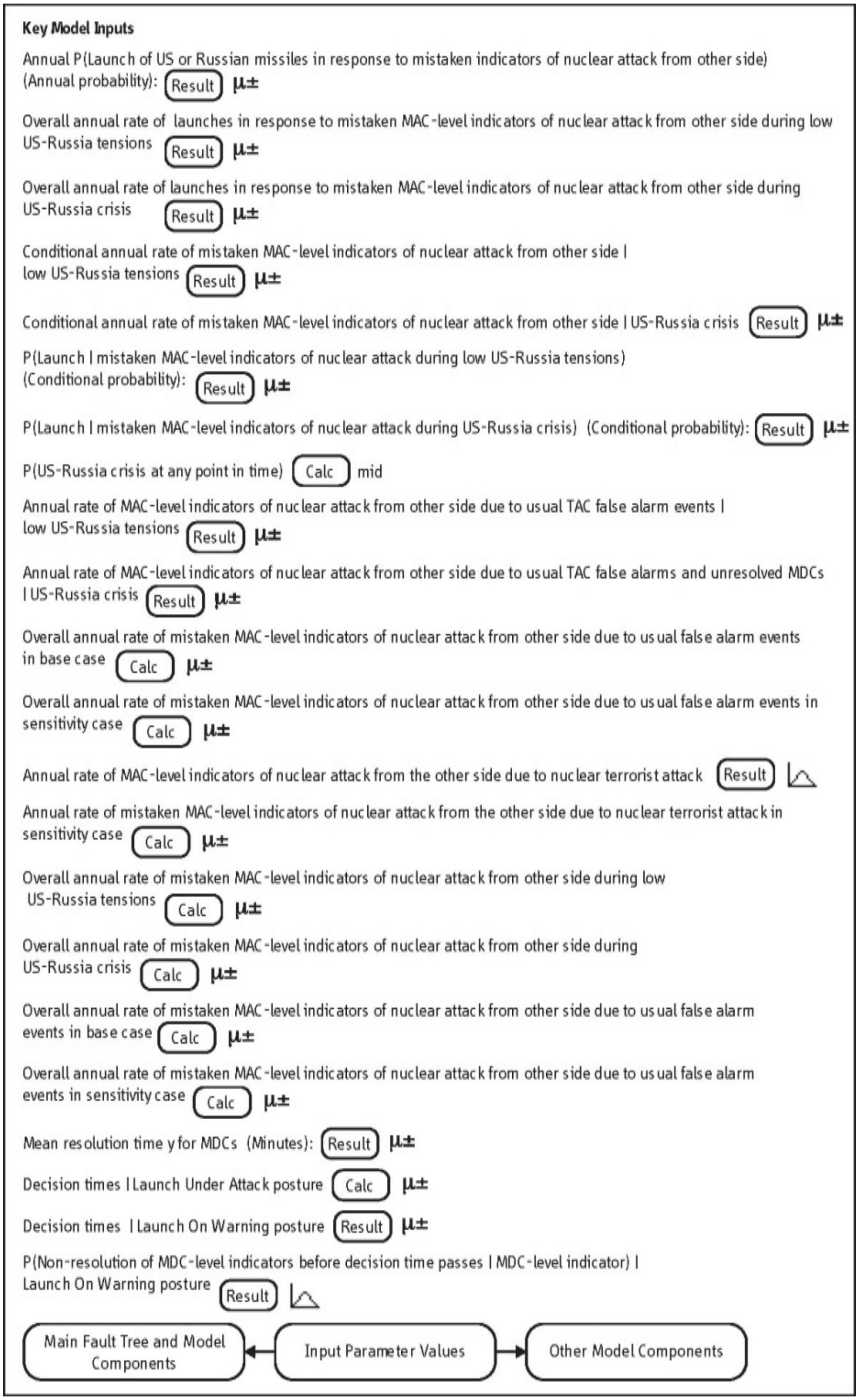

Figure S1. Main user interface of computational model

Figure S2 shows the user interface for displaying and/or modifying input parameter values. This allows users to explore effects of making changes to model parameter values, should they desire to do so, even with a free "player" license of Analytica.

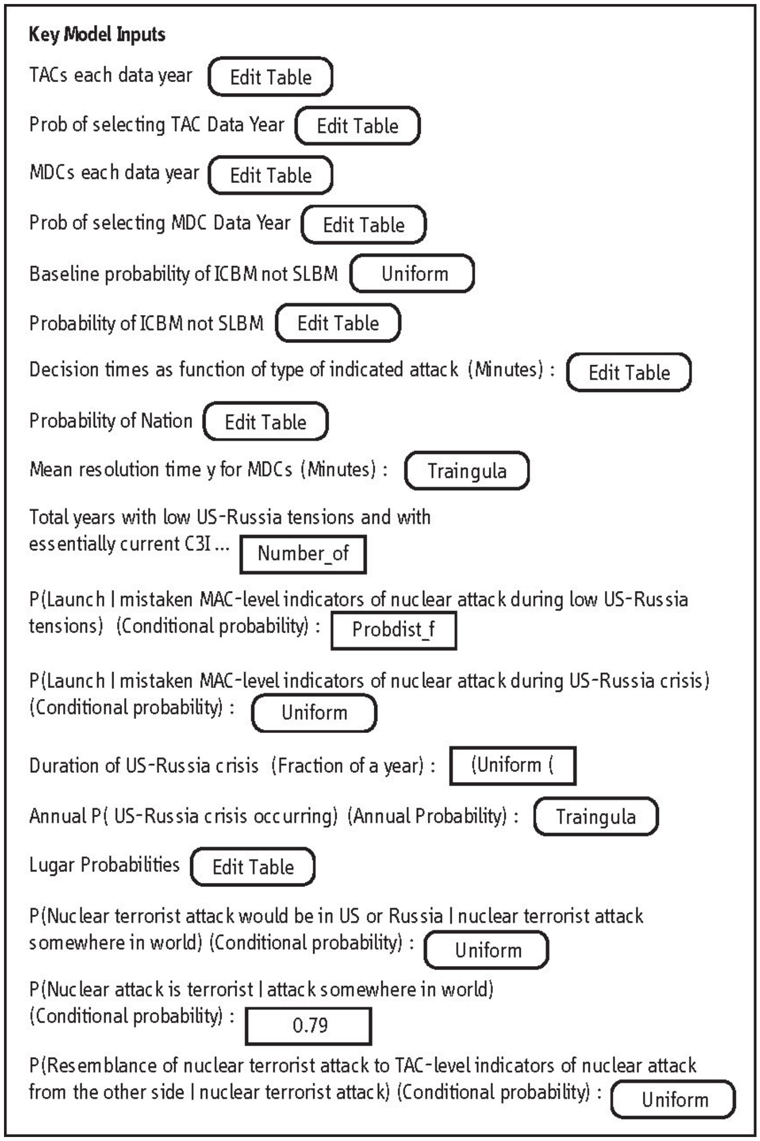

Figure S2 Model user interface for input parameter values

Figure S3 is a the main fault tree used in the model. The diagram generally follows the form of the fault tree previously given in Figure 2 in the main paper. Figure S3 uses the influence diagram directed-graph convention, where nodes represent model parameters, and arrows between model parameter nodes indicate the direction of influence of one parameter on another parameter. Figure 3 also uses the influence diagram directed-graph convention, where nodes represent model parameters, and arrows between model parameter nodes indicate the direction of influence of one parameter on another parameter. For example, the annual rate of launch of U.S. or Russian missiles in response to mistaken indicators of nuclear attack depends on (specifically, is the sum of) the rates of such launches during both low U.S.-Russia tensions and during U.S.-Russia crisis periods. (That is true with the "Danger Calm" base case model assumptions; with the "Safe Calm" sensitivity case assumptions, the annual rate of inadvertence is simply equal to the rate of inadvertent launches during U.S.-Russia crisis periods). Furthermore, the annual rates of such launches depend on the annual rates of mistaken indicators of nuclear attack and the conditional probabilities of decisions to launch in response to mistaken attack indicators.

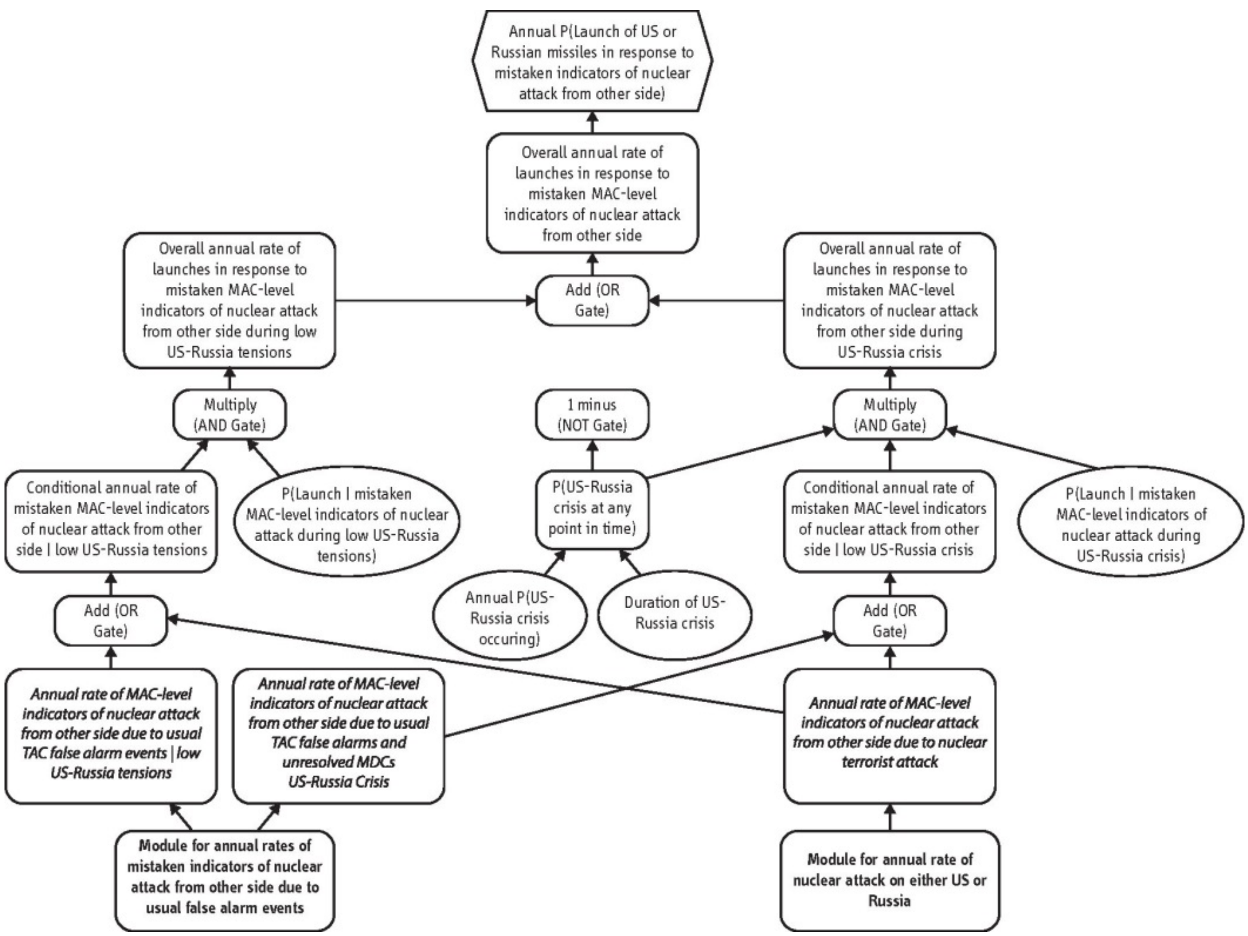

Figure S3 Main Fault Tree in Inadvertence Probability Estimation Computational Model

Figures S4 and S5 show the modules for estimating the annual rates of mistaken serious indicators of nuclear attack that would be due to usual false alarm events and nuclear terrorist attack, respectively. Figure S6 shows the module for estimating decision times.

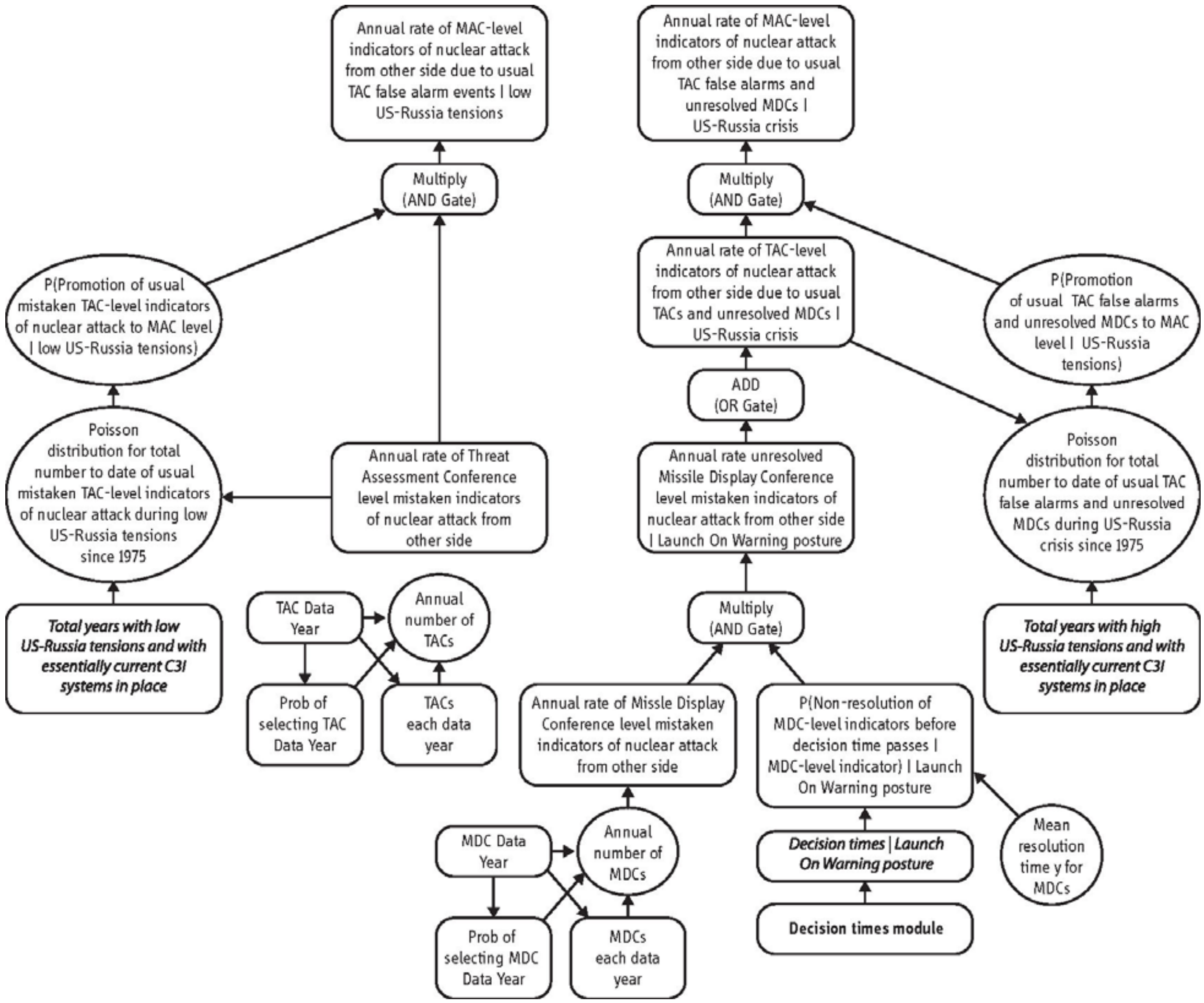

Figure S4 Module for annual rates of "usual" nuclear attack false alarms

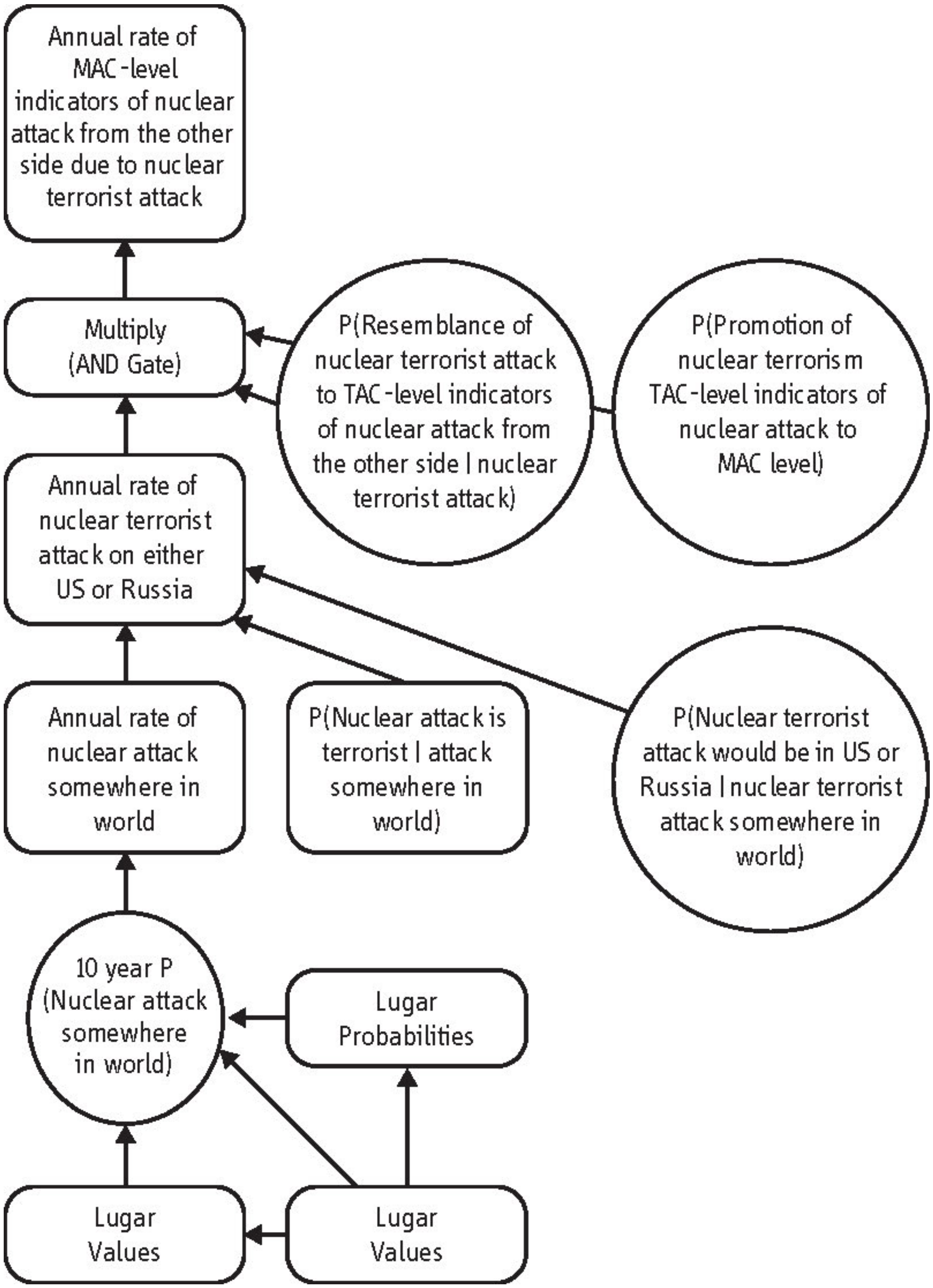

Figure S5, Module for annual rate of nuclear terrorist attack on either United States or Russia

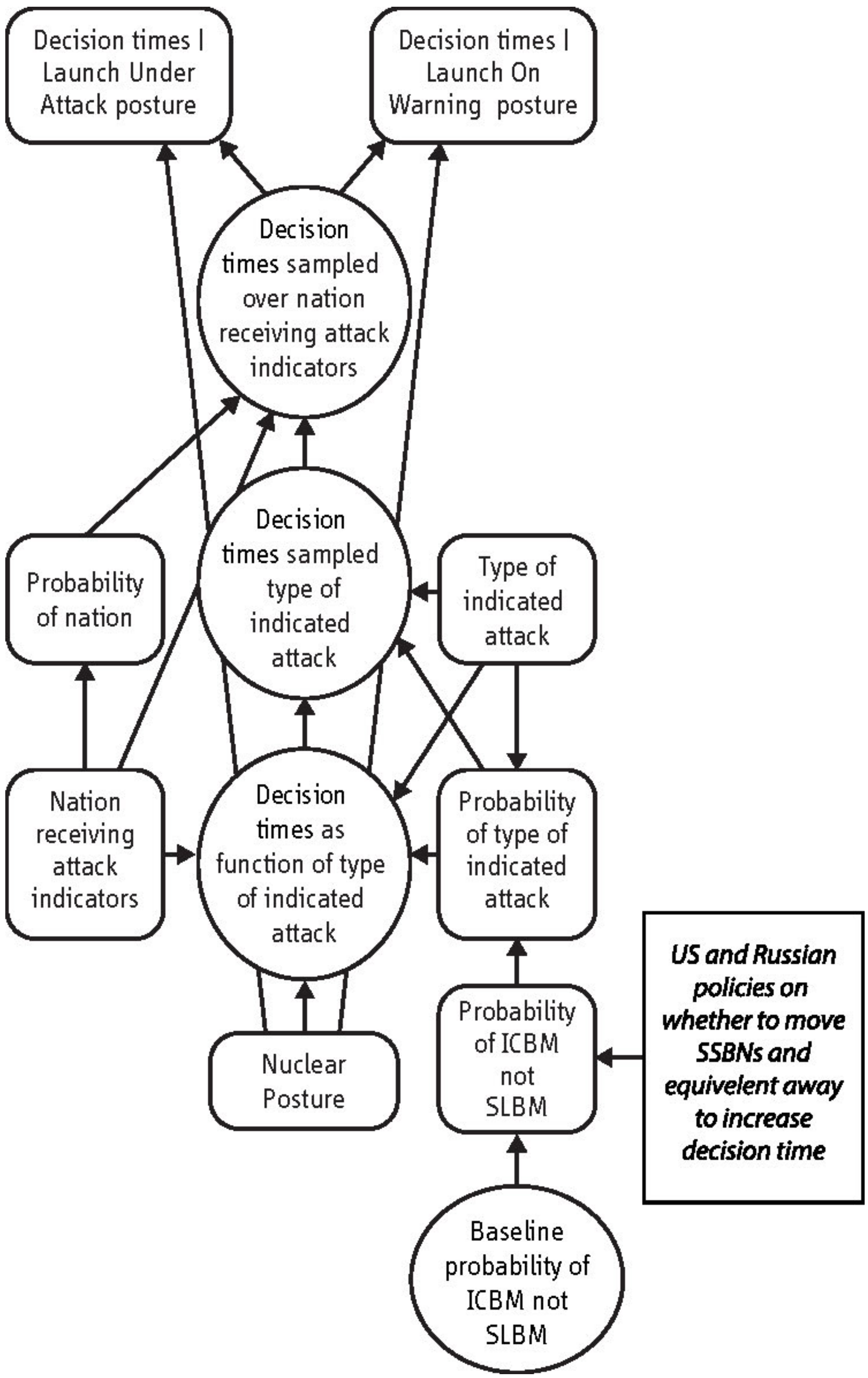

Figure S6. Decision times module

The remaining figures show other modules and calculations in the computational model.

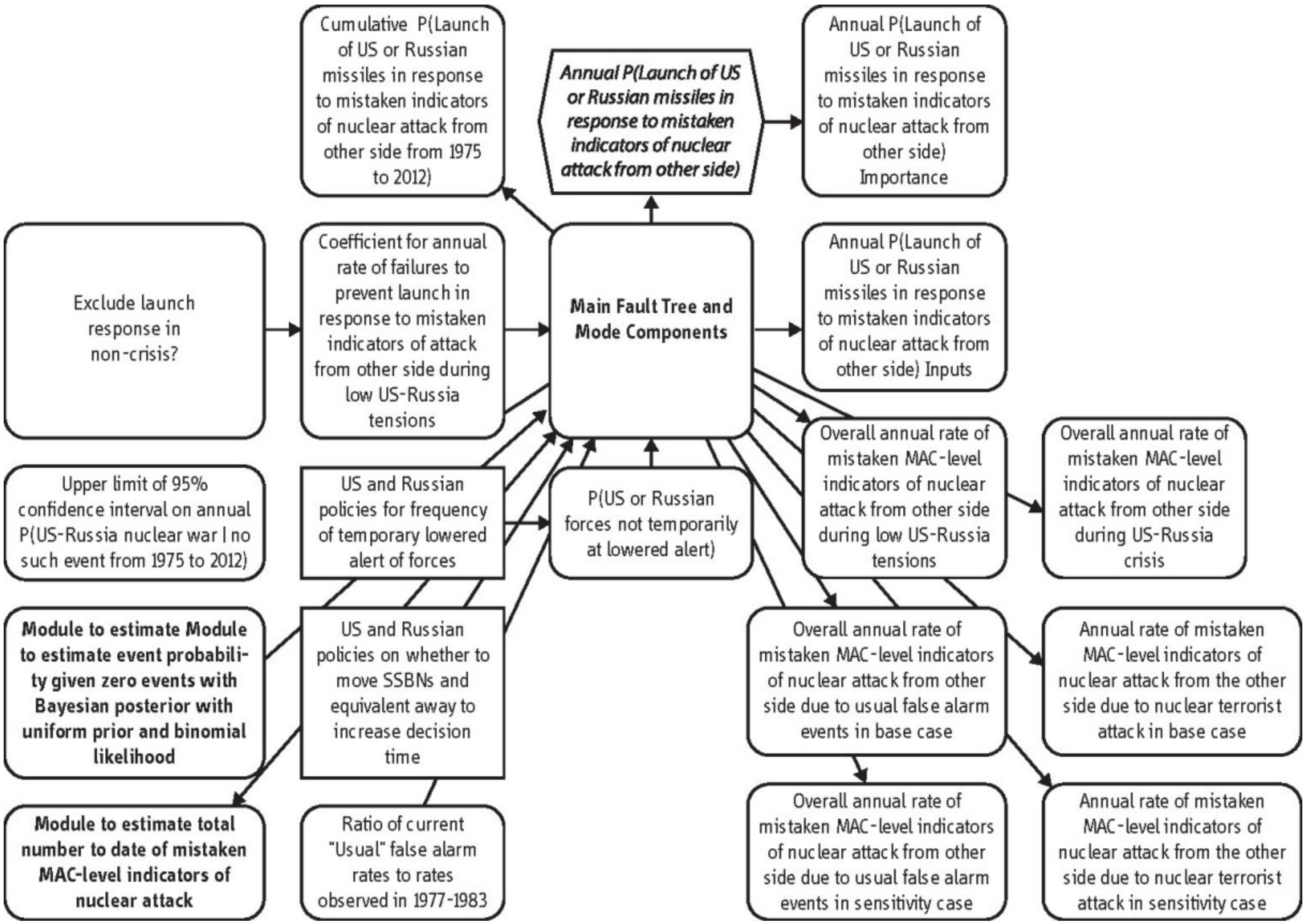

Figure S7 Other model components

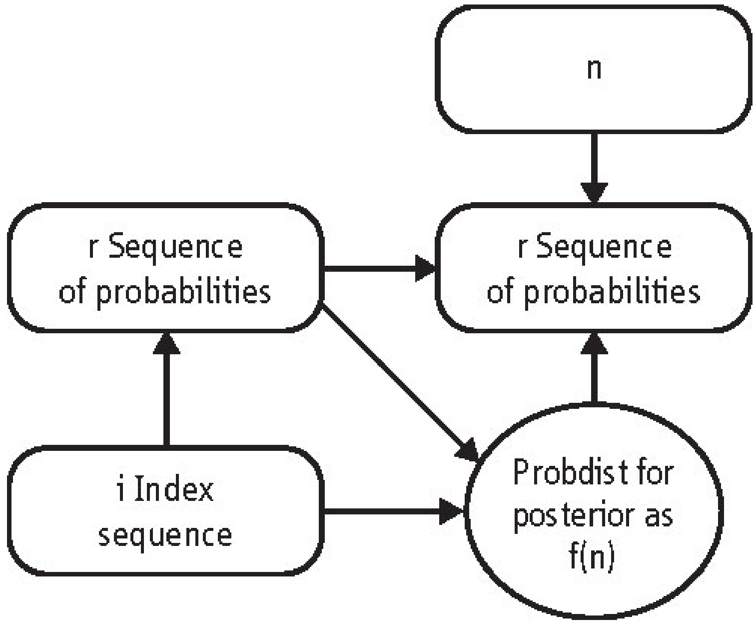

Figure S8. Module to estimate event probability given zero events with Bayesian posterior with uniform prior and binomial likelihood.

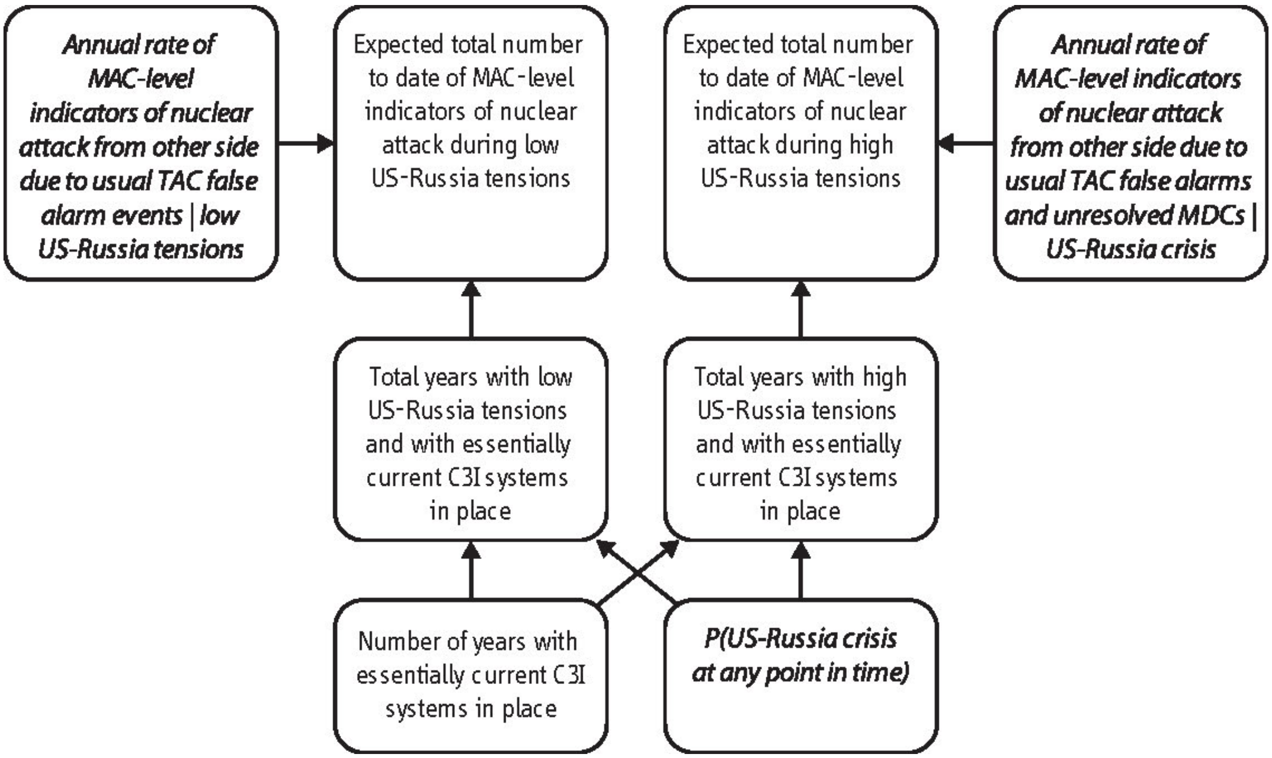

Figure S9 Module to estimate total number to date of mistaken MAC-level indicators of nuclear attack

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