Strategic Offense, Defense, and Arms Control (SODAC) Model

User's Manual

A Project by SPARTA, Inc.
for
The Defense Threat Reduction Agency/
Advanced Systems and Concepts Office
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SPONSOR: Defense Threat Reduction Agency. Dr. Stephen Younger, Director

Advanced Systems and Concepts Office. Mr. Richard Gullickson, Director

BACKGROUND: The Defense Threat Reduction Agency (DTRA) was founded in 1998 to

integrate and focus the capabilities of the Department of Defense (DoD) that address the

weapons of mass destruction threat. To assist the Agency in its primary mission, the Advanced

Systems and Concepts Office (ASCO) develops and maintains an evolving analytical vision of

necessary and sufficient capabilities to protect United States and Allied forces and citizens from

WMD attack. ASCO is also charged by DoD and by the U.S. government in general to identify

gaps in these capabilities and initiate programs to fill them. It also provides support to the Threat

Reduction Advisory Committee (TRAC), and its Panels, with timely, high quality research.

ASCO ANALYTICAL SUPPORT: SPARTA, Inc. provides analytical support to DTRA

through a series of projects on chemical, biological, and nuclear weapons issues. This work was

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project leader. Mr. Guy T. Grundman, II, was the principal author for this documentation.

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STRATEGIC OFFENSE, DEFENSE, AND ARMS CONTROL (SODAC) MODEL

USER'S MANUAL

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I. INTRODUCTION

The Strategic Offense, Defense, and Arms Control (SODAC) Model is designed to simulate strategic force behavior among multiple countries, or, "players." It is intended as a tool for analysts, commanders and decision-makers to simulate strategic environments, project adversary behavior, and identify optimal courses of action.[1]

This User's Manual is intended to familiarize the reader and user with the capabilities of the SODAC Model and to facilitate its utilization. It explains the model's basic functions, documents technical details, and provides a step-by-step set of instructions for operating the model. After reviewing the manual, you should be skilled enough to run most strategic game applications on the model. Additional use will improve your ability to use SODAC.

The User's Manual is written in a concise format. The tone is informal to ensure clear communication and instruction. The manual covers the basics of Getting Started, General Characteristics of the model, Specific Functions, actually Operating the Model, a Practical Example, and Potential Applications. The Appendices contain a Glossary of terms, tips for Troubleshooting, and a Technical Details section.

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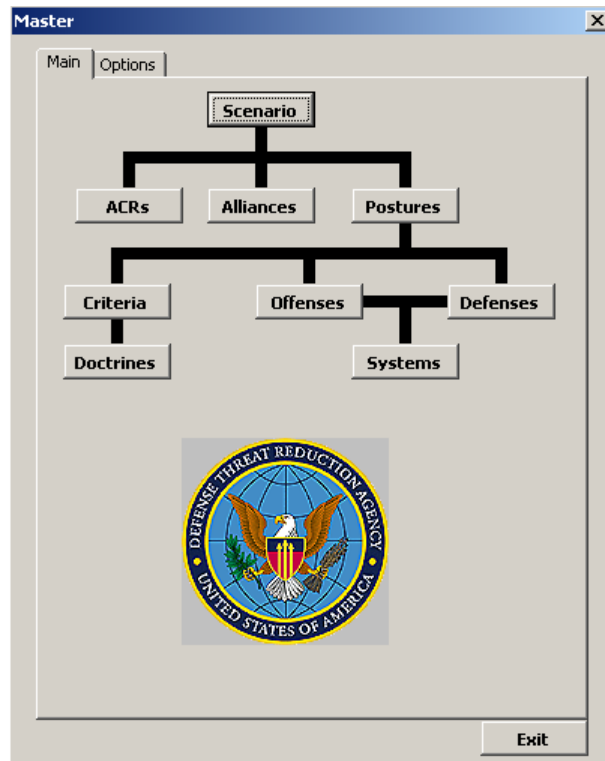
[1] The SODAC Model Version 2.0 presented here is a substantial update to the original Version 1.0. Contained in the revised SODAC Model are enhancements to model performance, including additional measures of merit, expanded capabilities, refined presentation, and improved processing speed. SODAC 2.0 is also supported by detailed documentation, primarily the SODAC User's Manual and Model Primer.

II. GETTING STARTED

The SODAC Model consists of a database[2] of strategic information constructed in Microsoft Access and an exchange model operating off of Microsoft Excel.

The first step in utilizing the SODAC Model is to load the program.

1) Insert the program disk or CD into your computer.
2) Click on "My Computer."
3) Click on either the A: drive, or your CD.
4) You will be asked whether you want to open the application or save to disk. Select *Save*.
5) Save to either the C: drive, or your personal drive. This will allow the application to run more quickly than running it from the program disk.
6) Select both the Excel Spreadsheet and the Database, then *Save* them.
7) Right-click on the Excel file before opening and ensure that "Read-Only" is not checked. Do the same for the database file. De-selecting "Read-Only" is usually necessary when copying the files from the CD.
8) Open the Excel program and then select the "DTRA" spreadsheet.
9) You will be asked to *Disable* or *Enable Macros*; Select *Enable Macros*.
10) You will then be asked which database to use; the DTRA database will be highlighted. Click *OK* to select the default DTRA database or select another database that you have modified/created.

The model will open showing the "Master" screen, with the DTRA logo and a series of button options: SCENARIO, ACRS, ALLIANCES, POSTURES, CRITERIA, DOCTRINES, OFFENSES, DEFENSES, and SYSTEMS. SODAC may be run after accepting certain pre-set items or profiles under these button options.

Screens, terminology, and model functions will be described in greater detail in the following sections of the manual.

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[2] SODAC provides a default ("starter") database for initial use. The default database compiles public information on strategic and economic resources for three primary players, modeled nominally after the United States, the Russian Federation, and the People's Republic of China. It was assembled from reputable, open-source materials found in strategic literature and relevant websites such as the Federation of American Scientists (FAS), http://www.fas.org/. (FAS was chosen because it offers the greatest degree of accessibility and detail in a single source. The FAS data is considered sufficiently accurate and reliable for the default database.) The database may be modified or reconstructed to reflect other real world players. You may also compile and substitute another set of data as the database to serve your purposes. Database options will be discussed in later sections.

III. GENERAL CHARACTERISTICS

This section will introduce you to characteristics and functions that are either standard throughout the model or important for model operation.

Manual Terminology

The explanations found in this User's Manual are most useful if you are familiar with the terminology. The following terms ("bolded" here for illustration) are represented in the font you will see them presented in throughout the manual:

- "(**Screens**)", a type of Graphical User Interface (GUI), serve as the control boxes that you will use to interact with the model.
- **Windows** are screen sections displaying data that you may select for use.
- **Fields** are boxes located on the screens that contain values for the model that you may adjust or input.
- **List boxes** are controls on a given field that enable you to scroll down and select from a range of data.
- **Selection Boxes** and **Selection Circles** are smaller fields that allow you to specify what values you are adjusting.
- "(**Spreadsheets**)" are forms created by Excel to accompany model data.
- **FUNCTIONS** are the main operations conducted by the model.
- Finally, ***Tabs*** and ***Buttons*** are the switches on a screen used for accessing a particular operation.

Throughout the manual, you will notice colored text boxes offset from the page. These text boxes provide additional illustration to specific passages in the manual.

Using the Master Screen

After selecting and opening the database, you will be presented with the "Master" screen illustrated below, through which you will operate the model. The background of the model will be an "EMBLEM_SHEET" spreadsheet with a large DTRA logo emblazoned in the center. (Note: There will also be a "SPREADSHEET_TEMPLATES" tab that is inaccessible from the "Master" screen.) The "Master" screen contains all of the relevant model functions represented by a button (SCENARIO, ACRS, ALLIANCES, POSTURES, CRITERIA, DOCTRINES, OFFENSES, DEFENSES, and SYSTEMS). Understanding how to manipulate the specific functions is critical to successfully operating the model. Perhaps the two most important functions are SCENARIO and DOCTRINES. The SCENARIO function allows you to design and run a model simulation, while the DOCTRINES function lets you specify how players employ their strategic forces. However, rather than attempting to explain these functions initially, it may prove more useful to first describe the model's general characteristics and capabilities. Section IV offers a full discussion of what the specific functions are and how they fit into the SODAC Model.
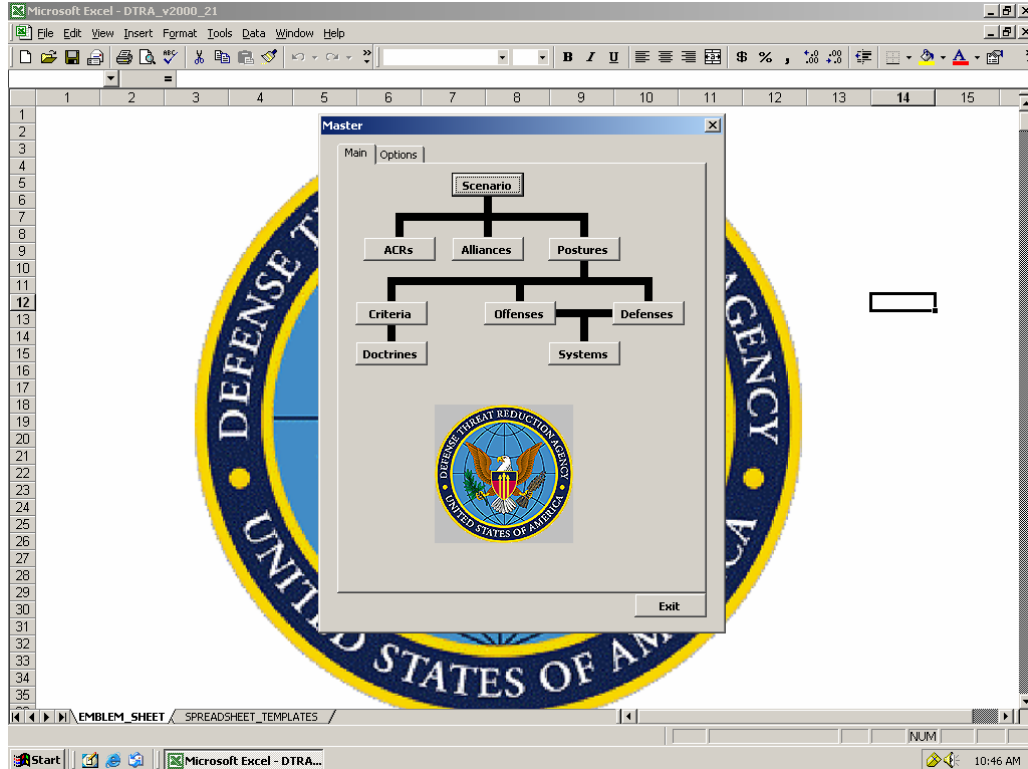
The "Master" display has two tabs, *Main* and *Options*. Using the buttons on the *Main* tab, you can manipulate certain aspects of the model's performance that are explained below. The *Options* tab contains additional features that enable you to define how the model operates. For example, Run Mode is a field on the *Options* tab that allows you to decide between operating the model interactively ("Interactive") or automatically ("Automated"). The default position is "Interactive." "Interactive" allows you to control game play throughout every turn, accepting or rejecting the changes recommended by the computer. In doing so, it also presents you with information on the strategic adjustments made by other players in the scenario so that you can make an informed decision on how to act next. In the "Interactive" mode, decision-making is defined partially in advance and partially in real-time, with you, the user, interpreting developments and acting on the player's interests. By contrast, "Automated" instructs the model to run the simulation by itself, optimizing each player's behavior to the extent possible based on the specified preferences, thresholds, and constraints. In the "Automated" Run Mode, a player's decision-making process is defined in advance. You cannot actively participate in a player's decision-making process during the course of the run. The Number Turns field allows you to specify how many iterations the game will run (1-49). The *Options* tab also grants you the option of saving the model information to an Excel file (Save Data to Excel selection box). If you select this option, the computer will save a workbook of information for the scenario you have just run—with separate spreadsheets for each turn—to the folder out of which you are running the model. The saved information will be labeled by the time-stamped scenario name (e.g. "BENT_TEST_01_122003113619AM").

If you exit out of this screen and wish to return, you can reenter to it by going to the "Tools" menu on your Excel tool bar and selecting "DTRA."

Structure and Options

All of the buttons on the *Main* tab of the "Master" screen, with the exception of SCENARIOS, present you with three options: to design a new game (*New*), modify an existing game (*Edit*), or purge a previous game (*Delete*). Whenever *New* or *Edit* is selected, you are given the opportunity to save any modifications (*Save*, *Save As*) or exit out of the screen (*Cancel*). Creating a new option rather than editing an existing one will require you to specify a name for that option and then confirm it by selecting the *Okay* button.   *Delete* will purge any item selected in a window from the model.

Most fields contain a list box that you can manipulate to select stored data items. For example, almost all of the major screens contain the Turn # field with list box. The purpose of the Turn # field is to allow you to see how the current category (OFFENSES, ALLIANCES, etc.) has changed, if at all, from turn to turn. While the length of game iterations (i.e. "turns") are adjustable, one iteration typically represents a year in the model scenario.

If you wish to exit the model, select the *Exit* button on the "Master" screen and close the relevant programs.

Performance

SODAC is an integrated model comprised of discrete, modular elements, each of which can be independently manipulated. These elements, or functions, build on one another to create a model scenario. The model's structure makes it extremely flexible. It is capable of numerous operations, yet it is also easy to adjust and modify so as to suit your individual needs.

It is anticipated that you will use SODAC for a variety of strategic analyses:
- **trilateral balance of power (e.g. U.S.-Russia-China)**
- **regional strategic balancing (e.g. India-Pakistan-China)**
- **impact of rogue regimes on strategic interaction (e.g. U.S.-China-North Korea)**
- **Etc.**

**You may also use SODAC to examine the same strategic scenario under different or alternate conditions:**
- **U.S.-China-Russia governed by cooperative arms control regimes**
- **U.S.-China-Russia engaged in an arms race**
- **Etc.**

Remember: SODAC is designed for flexibility. You modify it to fit *your* needs.


Whenever changes are made to the model, you are essentially creating a "new" version of the game. However, changes can be made in a couple of ways: by creating entirely new profiles (CRITERIA, DOCTRINE, etc.) for a given player "from scratch" (i.e. based on new inputs) using the *New* button, or by modifying the player profiles currently stored in the model using the *Edit* button. Moreover, because some of the profiles contain elements of one another (e.g. POSTURE includes CRITERIA, etc.), it is possible to create a new profile and then incorporate it into an edited version of another profile. The myriad of options available and the explanations for those options can be confusing. To alleviate that confusion, we use "new" in this manual to refer to changes made by using the *New* button and "modify" to signify changes made with the *Edit* button. For the average user seeking to test basic hypotheses, the *Edit* function may be more useful. The advanced user can utilize the *New* function to incorporate additional data or to construct more rigorous country profiles.

The model can be manipulated and used in any number of ways. However, there are two basic approaches worth highlighting. The first is a "bottom-up" approach. The model is designed in such a way that individual functions (e.g. CRITERIA) can be manipulated either independently or together with other functions to test various hypotheses. These manipulated elements can then be tied together in a hypothetical scenario.
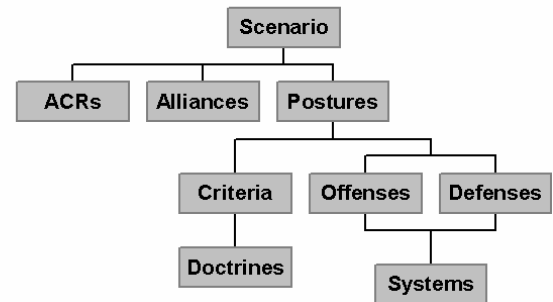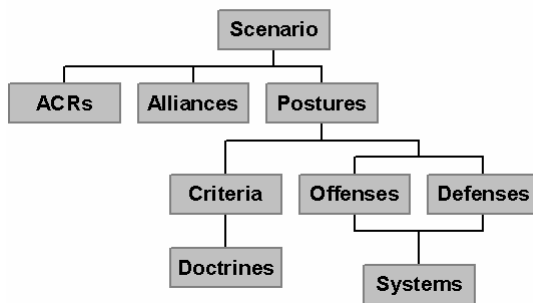
Alternatively, you may begin with a hypothetical scenario in mind and work "top-down", tailoring the sub-elements to that scenario. The "bottom-up" approach is most applicable for a detailed picture when you are testing small variations within or between major scenarios. The "top-down" approach may prove more useful for comparing larger issues and major scenarios (i.e. "the big picture").

In addition to changing conditions in the model, you may also elect to change information in the database itself. The default SODAC database is intended as a "starter" database for initial use and testing. It was compiled from open-source materials and information found on publicly available websites. Making changes to the model allows you to specify how the model should operate on the given set of data. Making changes to the database, on the other hand, allows you to control what information guides model operations. There may be a variety of reasons for making changes to the database, whether it is updating information to reflect new developments or adding missing information to make the database more complete. For instance, you might

change the database to represent a particular type of player or position that is not adequately represented by the existing data. The primary method for making changes to the database is to modify it through Access prior to running a simulation and then to save the revised database under a new name. Be advised that changes made to the database through the model itself will permanently alter the database, not just for a particular scenario. For example, if you are editing "Offense_1" and change the number of warheads, this change will take effect for all scenarios that include "Offense_1". As a precaution, you may wish to save the default database in its pristine form. That way, if you need to start fresh, you can always obtain the default database again either by copying it from the original CD or retrieving an already saved copy.

You also have the option of building and loading an entirely new database for use in your model. The model currently comes equipped with a default database on which you may exercise most applications. However, if you wish to examine a scenario by incorporating entirely new data not contained in the default database—e.g. a country profile for India or Pakistan—you may design your own in Access and then instruct the model to reference that database.

When operating SODAC, it is important to distinguish between what you, as the user, can and cannot change in the model. The SODAC Model is dynamic in some respects, but static in others. Certain model functions and the ways in which they instruct the computer to act on behalf of a player are pre-set. For example, the DOCTRINES function guides the computer on how a player would use its strategic forces to achieve its goals and CRITERIA. You may choose to select, change, or de-select specific conditions on the DOCTRINES function (e.g. selecting a "Launch Posture" of "Rideout") prior to running a scenario so as to influence how that player achieves its objectives. You may also influence the decision-making process in the "Interactive" mode by accepting or rejecting the computer's recommended changes, thus altering a player's response behavior based on the observed data. The "Interactive" mode acts as a surrogate of sorts for dynamic behavior. However, you cannot change the conditions of the DOCTRINES profile (e.g. "Launch Posture" will remain "Rideout"), or those any of the other major functions, during the course of the game, regardless of how the game plays out. The model will continue to run the scenario according to the conditions specified *before* the game. In reality, states may alter their positions and preferences to reflect changes in the strategic environment (e.g. changing the "Launch Posture" from "Rideout" to "Other" in a deteriorating security situation). However, the model contains no provisions for dynamic or evolving preferences. SODAC is designed to explore one possible scenario and outcome at a time. This design is meant to preserve the model's scientific integrity by allowing you to experiment with more extreme circumstances while preventing strategic behavior from automatically trending towards an equilibrium. Instead, you may run multiple scenarios under different conditions to achieve the same result.

While the model is extremely flexible, certain parameters have been built into it to approximate realistic conditions. These parameters typically come in the form of limitations and thresholds established by the CRITERIA and DOCTRINES functions. The model will not allow you to manipulate the data in a way that would violate these parameters. It will inform you when it cannot carry out your directed function. For example, if you type in a value greater than 100% for the minimum percentage of midcourse interceptors, the model will prevent you from saving the corresponding CRITERIA. However, you do have the option of altering the parameters to accommodate changes you would like to make.

The idea behind the SODAC Model is to allow you, the user, to evaluate various strategic situations by examining how other players, competitors or adversaries, will react to your behavior. The model is not designed for theater or tactical scenarios, per se.[3] However, you may modify the model to adapt it to certain tactical situations by adjusting data values and preferences (e.g. "range"). A weapons exchange model estimates how the players would interact. It is assumed that each player will attempt to secure its own interests—generally understood as "safety" or a security comfort level of deterrence vis-à-vis the potential threat from other players. The SODAC Model contains a model optimizer[4] that attempts to maximize a player's stated strategic goals and preferences by analyzing the data and recommending the most appropriate course of action, given the constraints built into the system. The exchange model is applicable between competitors. In other words, SODAC models competitor or adversary behavior, not competition between allies. Players engaged in some form of alliance are not thought to engage in any form of strategic exchange with each other. Their combined efforts may, however, be directed against a competitor or group of competitors. You may instruct the computer on how thoroughly it should attempt to optimize and evaluate player choices. However, such modifications may come at the expense of run time.

The logical foundation for strategic decision-making rests in player choice. Each player possesses a set of decision rules and is confronted with a set of exogenous factors (e.g. force postures, player preferences, etc.). The virtual outcomes of players' decisions—which signify the conclusion of the model "round"—represent the preconditions for subsequent rounds of interaction. A player reaches a decision by going through a series of steps: perception of the threat, determination of possible courses of action, application of decision criteria to evaluate these courses of action, and selection of a preferred action. Many of these factors are programmed into a player's strategic profile. The outcome arising from the policy adopted by the actor as well as simultaneous choices by the other game players constitutes the end of a turn. At the beginning of each turn, a player possesses objective knowledge of the other players' existing strategic offensive and defensive forces, as well as their prior strategic behavior. Each player also possesses a declining order of preference for the types of actions favored by the other players in the scenario. When constraints prevent a player from acting within its normal preferences, it will resort to alternatives in a fashion that deviates as little as possible from the usual parameters of its strategic personality. The model simulates the decision-making process for each player using the criteria stated above. Players will analyze all feasible options before choosing an action. This analysis consists of two parts. First, the player identifies which options are consistent with its preferences. Second, the player assesses which options will satisfy its security requirement. Players will seek a course of action that satisfies their security requirements (i.e. acceptable choices) in a way that is most consistent with their behavioral preferences. The optimal end-state is stability, an environment that occurs if all actors possess net offensive capabilities consistent with their deterrence doctrines and simultaneously choose the option of no further action. Of course, sub-optimal end-states are also possible in the SODAC Model.

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[3] As stipulated in the original DTRA task, the model is intended to simulate strategic (i.e. national-level ability to wage nuclear war), not tactical (i.e. theater or battlefield capacity for nuclear exchange), behavior.
[4] Optimization is explained further in Appendix C1.

> **SODAC simulates players' linear decision-making process on strategic issues. You establish the player's type, posture, and preferences through the model functions and the model estimates how that player would react under the defined conditions. Each decision or action influences successive behavior.**
>
> **For example, the U.S. recently released its 2002 Nuclear Posture Review (NPR). Under the terms of the NPR, the U.S. will store downloaded strategic warheads in an operational reserve for contingency purposes. You are curious as to how that decision might influence Russian and Chinese nuclear behavior. Will Russia and China react in the same manner? Will they maintain their current force levels, reduce their numbers of warheads and delivery systems, modernize and build, or adopt another approach? If they do decide to modernize and arm, how fast will they proceed? Will their response lead to a spiraling arms race? And how will subsequent decisions influence one another? You can modify SODAC to simulate potential scenarios that might result from the fallout of the 2002 NPR.**

Players are color-coded for easy reference. BLUE, RED, and GREEN nominally represent the United States, Russia, and China, respectively. ORANGE and PURPLE are not initially assigned to represent real countries. They may be tailored, though, to fit the profile of any number of nuclear powers (e.g. Britain, France, India, and Pakistan).

BLUE is the default player for the user of the model. What this means is that in the "Interactive" mode, you will be operating the model as player BLUE and the computer will make recommendations according to BLUE's goals and capabilities. Since the user is assumed to be from the U.S., the profile for BLUE is constructed around the U.S. strategic position. However, player designations are notional, so BLUE may be modified to represent any actor (e.g. if you play the role of China, you will simply modify BLUE's preferences and force structure to reflect those of China). In the "Automated" mode, the computer will play the roles of all selected players, based on their defined parameters. Regardless of the Run Mode you select, you must specify the functions of any players active in the scenario you intend to run (i.e. BLUE's posture, GREEN's criteria, etc.).

Part of SODAC's utility comes from its flexibility. The model may be manipulated and adjusted on a number of levels to suit your individual needs. However, maximum flexibility may also produce contradictions at times. For instance, while the player designations (colors) are notional, the specific functions (i.e. POSTURES, OFFENSES, etc.) are modular and pre-programmed in the default database (e.g. "OFFENSE_1" reflects the U.S. offensive forces). You may select any specific function for any player, regardless of how the function is oriented. (The reasons for doing so may vary, but could include your belief that a given function more accurately represents the type of player you wish to study.) Theoretically, then, you may select a function that does not correspond to your selected player's profile (e.g. "OFFENSE_1" and GREEN). There are two mechanisms built into SODAC to prevent this from happening. First, an Affiliation field is included on the POSTURES, OFFENSES, and DEFENSES functions. The purpose of this field is to identify what profiles and systems are available (or will be in the future) to what players and to screen out those that are not. Thus, player GREEN would not be able to access a posture profile

with an affiliation of BLUE. Likewise, only GREEN weapons systems would be available to GREEN. If no posture profile with the appropriate affiliation exists, you must create one for the player. The other mechanism for screening out inconsistencies is the computer model itself. When the model begins its run, the computer will compare the data for each specific function with the profile for your selected player. If the computer identifies any discrepancies, it will automatically adjust for them. If, for example, you attempt to marry an offensive posture that deploys an American Minuteman III ("MMIII") missile with player GREEN that represents China, the computer will recognize the inconsistency and make the Minuteman III missile unavailable for player GREEN. Nevertheless, it is primarily your responsibility, as the user, to make sure that the selections are consistent and appropriate.

Once you have conducted a game, it will be time-stamped and stored in the Scenario window under the title you assign it (e.g "BGvsR_5Yr_max_10182002125556PM"). It is assumed that you, the user, may have many purposes for running games on the SODAC Model. For instance, you may wish to test different moves or behavior under the same scenario. Thus, the model offers you the option of replaying the same scenario interactively. Perhaps you want to continue the model scenario you just ran, "picking up" where it left off in order to evaluate how behavior changes over time or circumstance. To do this, you merely select a previously run game from the scenario window and then proceed with the new (extended) game. The extended game will begin at the highest turn number completed in the previously run game. You may even choose to stop a run during the course of play, make changes to it, and then pick up again. Under the "Automated" Run Mode, this means allowing the model to complete its run and then modifying the game for future runs. Under the "Interactive" mode, it means stopping the run between turns by selecting *Exit Run*, making changes to the scenario (e.g. changing BLUE's criteria from "Unilateralist" to "Cooperativist"), and then reinitiating the game. If you choose to edit an interactive game by exiting prematurely, the model will display the Turn # at which you exited or the last completed Turn #. Once you have made your changes, select *Save* and the computer will save the data for the Turn # displayed on the form.   (Note: If you choose to stop and pick up again, you will be starting where you left off. That is, the starting point for a scenario that has been stopped and picked back up will be the last turn completed before you exited the original run. If you completed five full turns before exiting the run and starting again, the picked up scenario would display "Turn 5." The changes you make to the original run will only be reflected from that point on. It is possible to modify data for the turns you completed before you exited the original run—in this case, turns 1-4—but those changes would essentially have no effect since the starting point for the new run would be where you left off.)

A final word should be said about saving data from scenario runs. When a scenario is run to completion, all of the information from each of the turns (e.g. Turns 0-4) is saved to the database under the time-stamped SCENARIO name (e.g "BENT_TEST_01_122003113619AM"). Likewise, the corresponding profiles that make up that scenario (POSTURES, CRITERIA, etc.) are saved with the same time-stamp (e.g. "Posture_1_122003113619AM"). However, the original scenario and its components are NOT overwritten. Again, when you run a scenario, you are essentially creating a new product. The purpose of the time-stamp is to both denote that a run has taken place and to distinguish the run scenario from the original scenario on which it was based. Partially-run scenarios and continued scenarios are no different in this regard. In the original scenario, Turn 0 represents the game's initial conditions. In a continued or "picked-up"

scenario, the model recognizes the last turn played and treats it as the starting point for the new run. When this subsequent run is completed, it is again saved under the time-stamped SCENARIO name. The only difference is that this subsequent run displays information from the additional turns (e.g. Turns 5-9) as well as the original ones (e.g. Turns 0-4). At no point are the original model files changed. For configuration control, the SODAC Model prohibits you from incorporating run scenario data into a non-run scenario. In other words, you cannot insert a profile from the scenario you have just run into a scenario that you have yet to run. This configuration control was added to prevent unnecessary confusion and avoid technical complications.

As evidenced by this description, the SODAC Model is capable and flexible enough to accommodate most applications.

IV. SPECIFIC FUNCTIONS

Despite its adaptability and sophistication, the SODAC Model can be quite straightforward to use. Model operation essentially revolves around the set of buttons displayed on the "Master" screen. To make efficient use of the model, you must first familiarize yourself with its basic functions.

SCENARIO

Scenario

SCENARIO is a "story" (i.e. simulation) that contains the accumulated data and profiles for all of the other functions. It is comprised of the ACRs (Arms Control Regimes), ALLIANCES, and POSTURES functions, with POSTURES containing additional functional sub-elements. Put another way, a SODAC scenario is a strategic story built around the combination of arms control regime, alliance arrangement, and player posture information (which is, itself, determined by a mix of factors—in this case, offensive forces, defensive forces, and criteria). Scenarios structure a simulation in which players build or reduce forces to meet security goals, given a series of pre-set conditions. The SCENARIO function allows you to both design and run a simulation. It is the primary interface between the user and the model, making it one of the most important model functions. When you select the SCENARIO button on the "Master" screen, you are instructing the model to access a story composed of several other stored profiles. On the screen, you are presented with a window (displayed below) containing these stories, as well as several additional buttons: *New, Edit, Delete, Run, Report, and Replay*.
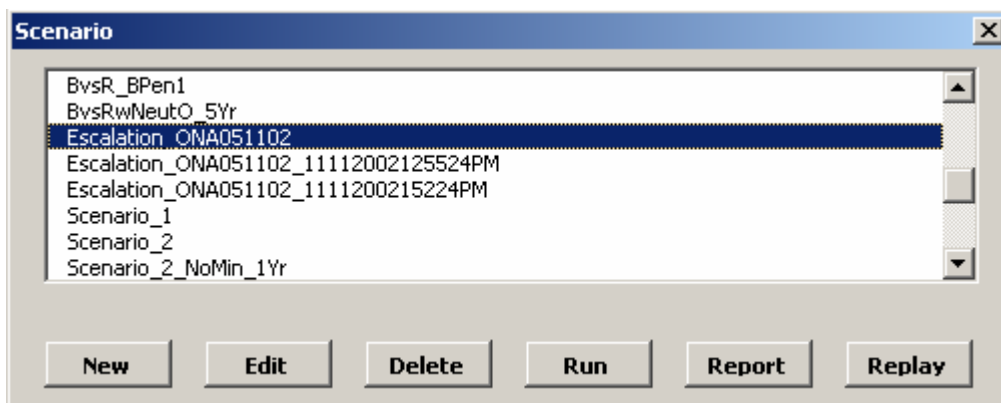
If you wish to create a new scenario, select *New* and specify a scenario name. Once you specify the name, confirm it by selecting *Okay* or disregard by selecting *Cancel*. Selecting *New* or *Edit* opens a "Scenario Edit" screen containing a series of fields. These fields include: Postures (all players, with corresponding selection boxes), Alliances, Arms Control Regime, Description, Start Year, Turn Duration, Learn Mode, and Turn #. The Postures, Alliances, and Arms Control Regime fields contain their own set of *New, Edit*, and *Delete* buttons. Fields may also be manipulated by their list boxes.

The Posture fields allow you to a) specify what players are active in the scenario and b) define the postures adopted by each player. The BLUE player is the default player for the user. To specify which other players are active in the scenario, mark the selection boxes to the left of those players' Posture fields. (In the graphic above, the user has selected GREEN and RED.) The Alliances field lets you choose a pattern of alliances reflecting the relationships between selected players. You may also specify whether treaties—and, if so, which ones—govern strategic decisions by defining the Arms Control Regime field (see the ACRs description).

The Description field provides you with more detailed pieces of information about the selected scenario. It also allows you to explain the conditions present in that scenario. The last four fields pertain to the operation of the model for the given scenario. You can manipulate the Start Year field to designate the year in which the game should initiate its run (1980-2006). Turn Duration enables you to specify the length of iterations in the game (i.e. how long each turn represents) in terms of model years (1-5 years). (Note: The longer the Turn Duration, the faster you can get results for a given number of years. However, results may be less accurate or less realistic with a larger turn duration.) Finally, the Turn # field indicates the current round of play.

Learn Mode warrants special attention. The model can operate under a range of assumptions as to how players make security decisions and resource allocations. The Learn Mode field allows you to instruct the model on how to make these choices in the game using the model optimizer; either "none" (learn mode is not activated), "Choice 1 then maximize" (attempt first move with pre-set preferences/parameters, then maximize primary measure if first attempt fails), "Go straight to maximize" (identify best possible solution given interacting preferences and constraints), or "Choice sequence or maximize" (conduct "quick check" to decide whether to proceed with the choice sequence or go directly to maximizing the primary measure). A player that has selected "Choice 1 then maximize" for its Learn Mode will attempt to pursue its end objectives in its preferred manner (i.e. independent of other players) in the first move; the model optimizer will not initially balance the player's behavior against the scenario constraints (e.g. economics, competitor's response). If this first attempt succeeds, the player will adopt its preferred defense posture and will try the same approach in subsequent turns. If, however, this first attempt should fail, the model optimizer would activate and begin adjusting the player's behavior—usually downward—to come as close as possible to its specified preferences while also adhering to the scenario constraints. For example, a player may begin with ambitious procurement plans, but once it finds itself unable to implement those plans (either because of the costs or conflicts with other players), it will moderate them and seek a procurement rate that is sufficient for accomplishing its goals without exceeding its resources or conflicting with other players.

On the other end of the spectrum is "Go straight to maximize." Under this Learn Mode, the model would immediately begin balancing players' forces. Using the same example, the player would not try to pursue overly ambitious procurement plans first. Instead, it would immediately begin moderating its procurement program to satisfy the scenario's constraints. The main difference between "Go straight to maximize" and "Choice 1 then maximize" is that the former assumes that constraints exist and must be met without first testing them; the latter might experiment with a more aggressive approach before adopting a more moderate one. The final Learn Mode, "Choice sequence or maximize", is a hybrid of the other two. While it does not attempt to pursue a player's preferred strategy immediately, it does briefly consider whether such an approach is feasible. If it is, the player will proceed with its preferred strategy. If not, the model begins to maximize the player's behavior to the extent possible. In a sense, this Learn Mode is akin to a state using its intelligence apparatus to vet an ambitious procurement plan before it actually implements it. "Go straight to maximize" allows you to seek a strategic equilibrium as quickly as possible. "Choice 1 then maximize" allows you to conduct experiments with bolder player behavior. Finally, "Choice sequence or maximize" approximates real conditions by first considering the feasibility of certain behavior before pursuing it. Once you have finished making the necessary additions or changes, select *Save/Save As* or *Cancel*.

One possible real-world application of the Learn Mode might be North Korea's continuing policy of brinksmanship. The ambiguity of North Korea's current nuclear status makes it difficult to model exactly on SODAC. However, consider a scenario set 5 years in the future in which North Korea has become an undeclared nuclear power, albeit a weak one. North Korea may still prefer to treat its nuclear arsenal as a "bargaining chip" against the declared nuclear powers.   The question is how would the declared nuclear powers, especially China, Russia, and the U.S., respond to North Korean nuclear behavior? And how would North Korea adjust its forces to respond in kind?

You can use SODAC to simulate a similar North Korean scenario. First, you program one of the players with a profile similar to that of North Korea's and with preferences that reflect a weak but aggressive posture. You then select a Learn Mode that reflects North Korea's penchant for leveraging its nuclear power to seek concessions (e.g. "Choice 1 then maximize"). This Learn Mode will instruct the model to pursue North Korea's interests first, before resorting to maximization under the constraints, roughly mimicking North Korea's strategy of pushing as hard as it can before backing down. You may compare the North Korean Learn Mode with those of the declared nuclear powers, who are less prone to bold strategic behavior (e.g. "Go straight to maximize" or "Choice sequence or maximize"), or to alternate Learn Mode strategies that North Korea might consider.

The other part of the SCENARIO function is the actual operation of the game. Returning to the "Master" screen, you will select the SCENARIO button once again. The Scenario window will appear along with the series of buttons previously described. To initiate a game, highlight a scenario in the window and select the *Run* button. If you have created or edited a new scenario and saved it, you may choose to run that scenario. Selecting *Run* will initiate the game and allow you to interact with the model based on the parameters built into the selected scenario. (Note: Operation of the game will be discussed further in the next section.)

Other options for operating the model include *Report* and *Replay*. Once you have stored and run a particular scenario, you may wish to gather information for further analysis. The *Report* button will generate a detailed account of the game, including major measures of performance. This report, which assembles Microsoft Excel data into a normal Word document, will be automatically saved to your default file. This report, which assembles scenario data into a normal tab-delimited text file, will be automatically saved to a default file, which will be called "[Scenario_Name].report." The other option under SCENARIO is to *Replay* the game. This button enables you to display charts showing how each of the measures varied for each player during the course of the run. For additional information, consult the section on "Analyzing Measures."

(See also POSTURES, ALLIANCES, and ACRs)

ACRs (Arms Control Regimes)

ACRs

For the purposes of this model, treaties, or arms control regimes (ACRs), promote cooperation between competitors by way of adjusting players' force structures. Treaties put limitations on strategic systems, compelling players to reduce or modify their forces to adhere to the terms of the agreement. The treaties stored in the database follow the provisions of and reflect the force structures stipulated in the actual strategic arms agreements that were negotiated by the U.S. and the Soviet Union and/or its successor states. You may choose to modify these provisions for any given player or apply them to a player that was not historically subject to those provisions. To access this function of the model, select the ACRs button and then decide whether to create a new arms control regime or modify an existing one. The model will consult the database to establish the terms of the designated ACR. If you select *New* or *Edit*, an "ACR Edit" screen will appear containing numerous categories of fields.

ACR Edit for START1/ABM

	Blue	Green	Orange	Purple	Red
Delivery Vehicles	1600	1600	99999	99999	99999
Warheads	6000	6000	99999	99999	99999
ICBMs	1600	1600	99999	99999	99999
ICBM Warheads	4900	4900	99999	99999	99999
Super Heavy ICBMs	154	154	99999	99999	99999
Super Heavy ICBM Warheads	1540	1540	99999	99999	99999
Mobile ICBM Warheads	1100	1100	99999	99999	99999
MIRVed ICBMs	1600	1600	99999	99999	99999
Ballistic Missiles	4900	4900	99999	99999	99999
MIRVed Ballistic Missiles	4900	4900	99999	99999	99999
Ballistic Missile Warheads	4900	4900	99999	99999	99999
SSBNs	44	62	99999	99999	99999
SLBMs	1600	1600	99999	99999	99999
MIRVed SLBMs	4900	4900	99999	99999	99999
SLBM Warheads	4900	4900	99999	99999	99999
Bombers	1600	1600	99999	99999	99999
Bomber CMs	1600	1600	99999	99999	99999
CMs	6000	6000	99999	99999	99999
AirBreather Warheads	6000	6000	99999	99999	99999
Total Interceptors	100	100	99999	99999	99999
Boost Phase Interceptors	0	0	99999	99999	99999
Midcourse Interceptors	100	100	99999	99999	99999
Terminal Interceptors	100	100	99999	99999	99999

Available in
1991

Implement by
2003

Save   Save As   Cancel

The categories include: Delivery Vehicles, Warheads, ICBMs, ICBM Warheads, Super Heavy ICBMs, Super Heavy ICBM Warheads, Mobile ICBM Warheads, MIRVed ICBMs, Ballistic Missiles, MIRVed Ballistic Missiles, Ballistic Missile Warheads, SSBNs, SLBMs, MIRVed SLBMs, SLBM Warheads, Bombers, Bomber CMs, CMs, AirBreather Warheads, Total Interceptors, Boost Phase Interceptors, Midcourse Interceptors, and Terminal Interceptors.

Fields are organized in a matrix for each of the five players (i.e. BLUE, GREEN, ORANGE, PURPLE, RED). You may alter the number of systems for a given category in any of the player fields. Players or categories not involved in a particular scenario will display a default number of "99999" in their fields. There are two additional fields for the ACRs function, Available in and Implement by. The Available in field allows you to specify when (in what "year" or turn) a particular ACR becomes available to the players. The Implement by field instructs the model on when ("year" or turn) to activate the treaty constraints specified by you. During turns leading up to the Implementation Year, the model will generate constraints that serve to make "even reductions" in force levels in order for players to meet the treaty constraints by the implementation year. As always, select *Save/Save As* or *Cancel* to finish using the ACRs function.

The ACRs function contains options for arms control regimes that have either expired, been subsumed, or have yet to be formed, as well as the ones that are currently in effect in the real world. Bear in mind that this range of options is designed to allow you to test multipolar strategic interaction under past, present, future, and alternative conditions. For example, options for future arms control regimes (e.g "START 5") let you evaluate how strategic interaction might be affected if subsequent—and, perhaps, improved—arms control programs were established. Others, such as the Strategic Arms Reduction Treaty (START) 2 were never fully and officially ratified by all of the concerned parties.[5] However, states may continue to conduct their strategic planning as if START 2 were in effect, adjusting force levels in accordance with the proposed provisions of START 2. Still other ACRs have come and gone. Though now considered defunct as a result of the December 2001 U.S. withdrawal, the 1972 Anti-Ballistic Missile (ABM) Treaty is still listed as an ACR option in the SODAC Model. There are two main reasons for this. First, the ABM Treaty was in force for almost 30 years prior to the U.S. withdrawal. Therefore, any simulations set prior to December 2001 must take the ABM Treaty into account. Second, preserving the ABM Treaty option allows you to conduct analyses on how limitations on missile defenses would impact strategic behavior in other scenarios. It also allows you to examine the counterfactual case—i.e. how would a strategic scenario be influenced if the ABM Treaty or a similar ACR were still in effect?

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[5] START 2 has been effectively replaced by the Strategic Offensive Reductions Treaty (SORT) of May 2002. However, while the terms of the SORT agreement are (purposefully) vague, they approximate the provisions outlined in START 2 in some respects. Therefore, the decision to retain the START 2 option in lieu of a SORT option is driven by the lack of specificity in the SORT agreement and the remaining similarities found between each of the ACRs.

ALLIANCES

Alliances

Alliances are general agreements made between two states to coordinate their strategic behavior. In the SODAC Model, alliances simulate security cooperation against one or more other players. The ALLIANCES function allows you to define players' relationships with one another. It directs the model on how players should interact with one another (i.e. as partners or opponents). On the "Master" screen, select the button for ALLIANCES. Selecting *New* or *Edit* will produce an "Alliance Edit" screen that presents you with two options for defining alliances. The first is a matrix of fields for characterizing relationships between players. Relationships are categorized by the following types: "Firm Alliance", "Potential Ally", "Neutral", "Primary Competitor", "Secondary Competitor", and "Tertiary Competitor." You may specify the type of relationship by using the list box for the matrix field that corresponds to any two players.

The second option also offers a matrix that asks you to specify the ranges between particular players. Ranges are divided into Self, Short, Medium, Intermediate, and Intercontinental. As before, the range for an individual player will automatically default to Self. Range denotes both the geographic scale of interaction between players and the operational capabilities of strategic systems. It instructs the model as to what systems may be employed against a particular opponent, depending on whether the opponent is within range or not. Only systems that can range at least as far as the distance between opponents are included in the run (e.g. in an exchange between players with a specified range of Medium, only systems that can reach at least 1000 km would be considered). At the bottom of the screen are the familiar *Save*, *Save As*,

Cancel buttons and Turn # field. Once you have defined the alliance relationships, save or cancel your data.

(Note: The matrix field is staggered to represent alliances between *different* players.   There is no need to specify an alliance between the same player. As it is throughout the model, BLUE is the default player for the user. Fields are omitted in the matrix where the same player meets—e.g. GREEN-GREEN.)

 The Alliances function can be used to establish a complex series of overlapping relationships. For instance, in the current context, China and Russia may consider each other a "Potential Ally" by virtue of their mutual agreement to oppose hegemony (read: the U.S.). The U.S. and the U.K. would likely consider themselves to be in a "Firm Alliance." For its part, India could be considered "Neutral" with regard to strategic interaction between the superpowers.

In terms of competitive relationships, China would almost certainly consider the U.S. its "Primary Competitor." However, competitor designations do not have to agree. The U.S. might still consider Russia to be its "Primary Competitor", despite its assurances to the contrary. In that case, the U.S. would likely label China as a "Secondary Competitor", with an emerging rogue nuclear state like Iran as a "Tertiary Competitor."

POSTURES

Postures

Posture is the position adopted by a player relative to its environment and the other players in that environment. It is a combination of the player's strategic capabilities and preferences. The POSTURES function enables you to design that position. When you select POSTURES, the model accesses a profile containing the player's strategic criteria (i.e. preferences, capacity), offensive, and defensive positions (i.e. force structure, doctrine, etc.). First, you will elect to create a new posture, edit, or delete an existing one. When creating a new posture, you must first specify a name and then confirm it by selecting the *Okay* button. If you choose to edit an existing posture, select one from the posture window and select the *Edit* button. A "Posture Edit" screen will appear. Choosing *New* or *Edit* grants you the opportunity to develop a new posture, based on new inputs or by modifying an existing posture profile (respectively). Once you have chosen *New* or *Edit*, you must define the three fields that comprise posture: Criteria, Offensive Forces, and Defensive Forces. Each field gives you the options of *New, Edit,* or *Delete*. You may also specify the player affiliation and Turn # via the list boxes at the lower part of the "Posture Edit" screen. (Note: Preferences for First Strike Strategy, Launch Posture and so forth are addressed under the DOCTRINES function.) After defining the fields, you must either save the new posture

you have developed—assuming you want to simulate it in the model—or cancel it to consider alternatives. Remember that if you select *Cancel*, the changes you have made will be lost.

(See also CRITERIA, OFFENSES, and DEFENSES)

CRITERIA

The CRITERIA function allows you to establish certain thresholds and parameters for a scenario. These thresholds, or criteria, contain information on a player's strategic goals, preferences, and capabilities. Goals (i.e. "criteria") are the main strategic or security objectives of the player. Preferences are the players' selected methods for achieving those goals. Capabilities refer to the player's stockpile and its ability to exercise its power (e.g. by building forces). All three influence an actor's strategic behavior. The model optimizer processes this information and designs behavior intended to meet those basic criteria. First, you will select either the *New* or *Edit* button. The next screen to appear, "Criteria Edit", will display several fields by which you may define a player's preferences. These fields cover economic characteristics, desired force structure, and attitudes toward other players. The screen also contains the Turn # field and list box.

Economic characteristics help determine what moves (e.g. force structure acquisitions) are financially feasible for a player. The Initial GDP field allows you to specify a gross domestic product at the start of the game. The GDP Profile field contains pre-set trends for GDP growth or decline over the course of the game. Alternatively, you may incorporate a GDP File that you have created and stored for a player by accessing *Select GDP File*. To opt between GDP Profile and GDP File, mark one of the selection circles adjacent to these fields. The three remaining economic fields allow you to establish maximum military expenditures under different circumstances. Norm Max GDP lets you stipulate what percentage of a player's GDP should be allocated for defense under normal (i.e. non-threatening) circumstances. The Abs Max GDP field refers to the percentage of GDP allocated for defense under extraordinary (i.e. threatening) circumstances. Finally, the Max Mil Exp Strategic Forces field establishes the maximum percentage of the defense budget allocated for strategic forces.

In the next set of fields, Min Interceptors (% of total), you specify the minimum percentage of interceptors dedicated to the Boost Phase, Midcourse, and Terminal defense missions, respectively. Similarly, the set of fields below that, Min Warheads (% of total), allow you to specify the minimum percentage of warheads stationed on Land-Based, Sea-Based, and Air-Based platforms, respectively.

The CRITERIA screen also contains fields for three, distinct sets of preferences. The Preference 1 field lets you specify whether a player is "Unilateralist" or "Cooperativist" in its behavior. The Preference 2 field asks whether the player favors "Offense" or "Defense." The Preference 3 field allows you to indicate whether a player is "Minimalist" or "Maximalist" in its orientation to the strategic balance. A "Maximalist" player will measure its forces against the combined forces of

all of its adversaries. A "Minimalist" player is concerned only with the bilateral balance between one adversary at a time, even when there are multiple players.[6] You may choose to check the boxes off to the side of these preference fields if you wish to Implement Offensive ACR Constraints and/or Implement ABM Constraints.

The final set of fields on the CRITERIA screen asks you to specify a doctrine vis-à-vis a player's competitors. These fields contain a set of *New, Edit*, or *Delete* buttons by which you can create or modify a player's "Doctrine/Employment" preferences. To adjust those doctrinal preferences, first identify which competitor you are referring to by selecting the circle to the immediate right of the field. Then use the drop down box to scroll through various doctrine options. You may choose to create a new "Doctrine/Employment" strategy, modify an existing one, or delete one from the record. If you select *New* or *Edit*, another screen will appear entitled "Doctrine/Employment." This screen contains several fields that allow you to establish a player's DOCTRINE. Once you have made the necessary changes to the CRITERIA profile, select *Save/Save As* or *Cancel*.

(See also DOCTRINES)

DOCTRINES

Doctrine refers to the policy that guides a player's strategic force behavior. In essence, doctrine defines a player's strategic goals and how, in accordance with those goals, the player would expect to use its strategic forces in the event of an exchange. In this model, doctrine is a sub-function of CRITERIA that incorporates value measures, force allocations, and strategic preferences. The DOCTRINES function offers you the opportunity to set the terms of a player's strategic plans and instruct the computer on how to employ the player's strategic forces. The model then factors these plans into the player's strategic behavior, informing the optimizer on how to achieve the player's stated goals. This capability makes DOCTRINES, along with SCENARIO, one of the most important model functions. To operate this function, select the DOCTRINES button from the "Master" screen and then select either *New, Edit,* or *Delete*. You will be presented with a "Doctrine/Employment Edit" screen that contains several fields, as well as the Turn # list box.

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[6] The "Maximalist"-"Minimalist" preference holds certain implications for strategic behavior. A "Maximalist" player will often have to build up more forces to balance the combined strength of multiple adversaries. The decisions of a "Minimalist" player, on the other hand, are driven by the strength of its most powerful adversary. However, "Maximalist"-"Minimalist" should not be confused with "maximizing" a measure. Regardless of the player's orientation, the model will still attempt to maximize the player's conditions.

The top of the "Doctrine/Employment Edit" screen allows you to specify what measures the model should consider in determining player behavior, how to weight those measures, and which one is most important. You may select a maximum of 8 measures for the model to consider. A Measure window displays the measures currently selected for consideration. Below the window are *New* and *Delete* buttons. To dismiss a currently selected measure from further consideration, highlight it with the cursor and select *Delete*. If you wish to add a measure, select *New*. The New button will access an "Available Measures" screen with a window displaying various combinations of measures under different circumstances that are available to the player. To add a measure, highlight it with the cursor and select *Add*. The highlighted measure will then be transferred to the primary Measure window for consideration by the model. If you do not wish to add a measure or if you wish to exit the "Available Measures" screen, select *Cancel*. On the "Doctrine/Employment Edit" screen there are also 8 Value fields corresponding to the maximum number of allowable measures. You may use these fields to assign numerical values to the measures displayed in the adjacent window. When more than one measure has been selected for consideration, you must specify which is most important to the player by marking the appropriate Primary selection circle.

Core to the exchange model are the doctrinal "measures." Measures are strategic principles that frame player behavior and tell the model exactly how players' should use their forces to achieve

their strategic goals. In other words, they instruct the model on how strategic interaction should be viewed, what principles should be consulted when employing strategic forces, and how they should be prioritized. Measures apply thresholds (or, criteria) to players' strategic behavior, thresholds that drive the model's decisions on offensive and defensive force adjustments. They are intended to guide players to a desired strategic outcome. However, they should not be confused with measures of (strategic) military effectiveness. SODAC Model measures are not valuations of player or system performance so much as guidelines that inform player behavior.

The available measures are further classified into distinct units, depending on how you wish to treat the measure. These units include warheads ("WH"), "Yield", "EMT", "CMP", and "SUA." Specifying a certain unit for the measure will tell the model to process data for that measure according to the selected unit. For instance, "Effective Balance WH" will instruct the model to calculate the total ratio of forces (before, during, and after an exchange) in terms of warhead levels when making strategic decisions for a player. Measures are also characterized by descriptive sub-categories—such as "Total", "Non SOF", "PreWar", and "Post (COLOR) 1st Main Strike"—that define the conditions under which strategic interaction occurs and how the selected measures should be applied under those conditions. Note that "Post BLUE First Main Strike" means that the model's default player has launched first; otherwise, the default player (BLUE) is assumed to have launched second (e.g. "Post RED First Main Strike"). Using the same example as before, "Effective Balance WH Post BLUE 1st Main Strike" would tell the computer to calculate the total ratio of forces, in terms of warhead levels, that would exist after the default player (BLUE) launched a nuclear first strike.

Measures are valued as either Relative Percentages ("Rel %") or Absolute Numbers ("Abs Num"; "Absolute"). If a measure is treated as an Absolute Number, the model will strive to achieve an objective quantity of the specified measure for a player. If the measure is treated as a Relative Percentage, the model will attempt to achieve a proportional quantity with regard to other players. For example, if a value of 20 were selected for the measure "RVs Negated WH Absolute PostRED1stMainStrike", the model—acting on behalf of a (BLUE) player—would attempt to negate 20 of its adversary's (RED) warhead re-entry vehicles in the event of a RED first strike. However, if the measure were treated as a Relative Percentage of 20, the model would attempt to keep BLUE's value for "RVs Negated WH Absolute PostRED1stMainStrike" at least 20% of RED's value for that measure, so that if RED's value for "RVs Negated WH Absolute PostRED1stMainStrike" were 50, then BLUE's value would have to be at least 10.[7] During a run, all measures are calculated for all players at every turn. However, only the set of selected measures have thresholds applied to them in order to drive the model's offensive and defensive adjustments.

The various options for measures, units, and categories allow you to simulate different principles or priorities that might guide states when using strategic forces during a potential conflict. They construct alternate realities or scenarios in which you can evaluate how states might behave according to the doctrinal measures they follow. In reality, strategic doctrine is often guided by

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[7] In a sense, Relative Percentage is more responsive to changes in an adversary's force structure than Absolute Numbers. Once a player achieves an absolute measure value, it may discontinue further force adjustments. However, if it values the measure as a Relative Percentage, it will continue to adjust according to its adversary's behavior.

more than one measure or principle. Measures are not necessarily mutually exclusive. During the latter part of the Cold War, for example, planners were concerned not only with preserving a capacity for "Guaranteed Retaliation", but also ensuring that re-entry vehicles penetrated to their designated targets. Therefore, SODAC grants you the option of selecting multiple measures to direct a player's strategic behavior.

The next set of fields covers the characteristics, deployment modes, and expected utility of a player's strategic forces in the event of a hypothetical strategic exchange. The three general categories of Land-Based, Sea-Based, and Air-Based platforms parallel those of offensive forces. (Note: Land-Based platforms are further subdivided into "Fixed" and "Mobile" systems.) Each category of forces has percentage fields for Main Strike Allocation, Oper Reserve Strike Force, First Strike Readiness Rate, Retaliation Alert Rate, and overall Launch Posture. All of the fields with the exception of Launch Posture require a numerical percentage. Launch Posture is a player's preference on when to launch its strategic forces. This field asks you whether a player prefers its strategic forces to withstand (i.e. "Rideout") and then respond to a strategic first strike or not (i.e. "Other"). Remember that selecting "Rideout" means that your strategic forces are subject to potential damage that may or may not make them unavailable for retaliatory strikes. If, however, you specify a first strike strategy or select "Other", your forces will not be subject to potential damage since they will have been launched prior to an adversary's weapons impact.

The final four fields provide additional details about a player's doctrine and strategic forces employment. Damage Requirement allows you to specify the required probability of destruction—the percentage of damage a player needs to inflict on an adversary in the event of an exchange in order to achieve that player's goals. The First Strike Strategy field tasks you with identifying the basic targeting approach in a player's first strike preference, be it the adversary's strategic offensive forces ("SOF") or other military targets ("OMT"). (Note: The definition of First Strike Strategy deviates somewhat from conventional use of the term. It is not used to indicate a pre-emptive or unprovoked nuclear strike. True nuclear first strikes or pre-emptive strikes are proscribed by the model. It is merely a type of offensive preference. First Strike Strategy refers to how a player chooses to use its strategic forces for the first time once it decides to do so. Thus, a First Strike Strategy could, in fact, be executed in response to an adversary's incoming attack.) For model purposes, "OMT" refers to Army bases and non-strategic Air Force and Naval installations; war-supporting industries and population centers are not included under a player's First Strike Strategy. (It is assumed that a state executing a first strike strategy will initially target an enemy's warfighting forces.) Defend SOF asks you whether or not you wish to defend your strategic offensive forces (i.e. "yes" or "no"). If you opt to Defend SOF, your interceptors will be used proportionally to defend against the entire incoming attack, including the protection of your own strategic offensive forces. Conversely, if you decide not to Defend SOF, your interceptors will be used only against the portion of the incoming attack not targeted at your SOF. The rationale for not defending SOF may be that you expect to use your SOF in the opening minutes of a nuclear exchange; defending assets you have already expended would be a waste of your interceptors. On the other hand, you may wish to Defend SOF if you intend to rideout a first strike and then retaliate. The Defend SOF field preserves this option. (Note: The Defend SOF option does not apply to Boost Phase interceptors.) Finally, the Retaliation Strategy field enables you to decide the manner in which you would respond to an exchange (i.e.

whether you wish to target "SOF" or "OMT"). As with the other functions, you must save or cancel the inputs you have made under the DOCTRINES function.
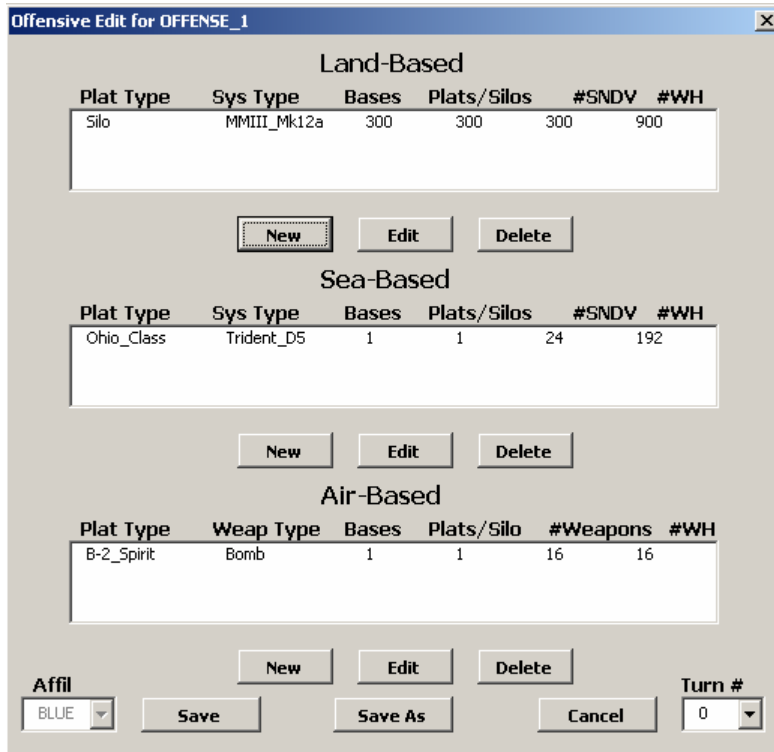
You can manipulate the DOCTRINES function to test real world hypotheses on strategic doctrine. For instance, China describes itself as a cooperative, minimalist nuclear power that ultimately seeks complete disarmament. It officially embraces a defensive, retaliatory strategic posture and a doctrine of minimum deterrence (e.g. measure of "Guaranteed Retaliation") that emphasizes a countervalue strike capability. However, current trends suggest China may be moving in the direction of limited deterrence, with a more robust strategic arsenal capable of conducting some counterforce as well as countervalue missions. China has also embarked on a massive modernization program to its strategic force (the Second Artillery) that includes both qualitative (e.g. accuracy, reliability, perhaps RVs) and quantitative improvements.

You want to simulate this purported shift. To do that, you access the DOCTRINES function for GREEN, select a measure that might reflect such a shift (e.g. "RVs Penetrating…"), adjust the basing scheme to increase the Main Strike allocation, and allot a greater role for Sea Based offensive forces.

OFFENSES

Offenses are the strategic systems possessed by a player that could be used to attack or inflict damage on an adversary. The OFFENSES function enables you to manipulate the structure of a player's offensive forces. It directs the model to access a stored offensive profile assigned to the player in question. Once you choose to operate the OFFENSES function, you will be presented with the familiar *New*, *Edit*, or *Delete* options. Selecting *New* or *Edit* will allow you to manipulate the level of strategic forces.
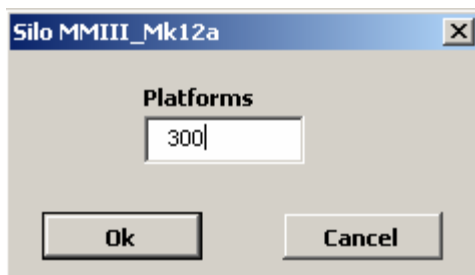
An "Offensive Edit" screen will appear with three windows representing Land-Based, Sea-Based, and Air-Based systems, respectively. In addition, the "Offensive Edit" screen contains an Affiliation (Affil) field that associates a particular profile with a given player and a Turn # field that specifies a particular turn. The windows will display relevant information for the specific systems you have selected. Each window will also have its individual set of *New*, *Edit*, and *Delete* buttons. If you select the *New* button, another window will appear with an inventory of strategic systems available to you. Select the *Add* button to add the system to a player's inventory or select *Cancel* to back out of the screen.
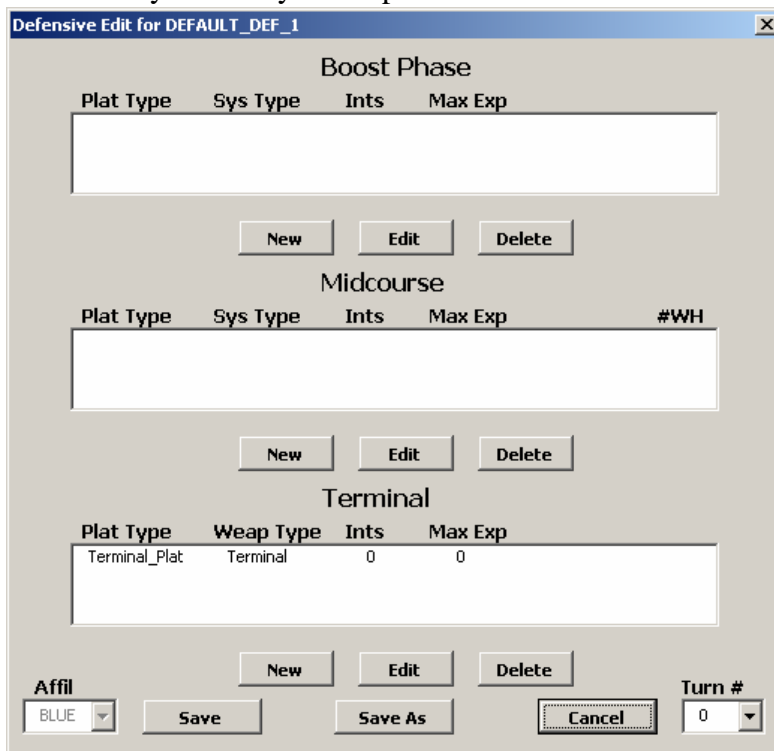
If you wish to edit the number of platforms for systems currently deployed in a window, highlight the system and select the *Edit* button. A window will appear identifying the system and allowing you to change the number of Platforms deployed for that system. Once you have made those changes, either confirm them with the *Okay* button or discard/abandon them with *Cancel*.

Once you have made all your changes, be sure to save the revised data by selecting the *Save* or *Save As* buttons.

DEFENSES

Defenses are the interceptor systems used by a state to protect against the strategic offensive forces that could be launched by an adversary in the event of a hypothetical attack. The DEFENSES function, which allows you to manipulate a player's strategic defenses, works in the same way as the OFFENSES function. First, decide whether to create a new Defenses profile, edit an existing one, or delete a profile. Selecting *New* or *Edit* will allow you to manipulate the defensive systems at your disposal.

A "Defensive Edit" screen will appear with three windows representing the U.S.-designated phases of missile defense: Boost-Phase, Midcourse, and Terminal. The windows will contain information on the systems available under each phase. The "Defensive Edit" screen will also display the same Affiliation and Turn # fields found in the OFFENSES function. When you select the *New* button, a window will appear listing the types of systems available for that particular defensive phase. If you wish to add a system to your inventory, highlight the system and select the *Add* button. Otherwise, select *Cancel*.
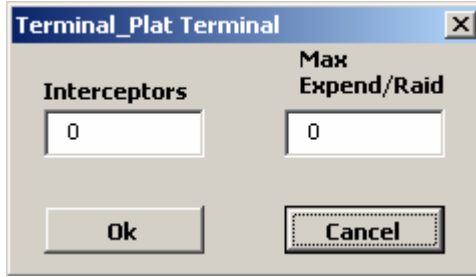
You may also choose the *Edit* button to highlight and modify systems displayed in the defensive forces windows. If you select *Edit*, a separate window with two fields (Interceptors and Max Expend/Raid) will appear identifying the defense phase and platform (e.g. "Terminal_Plat"). You may change the number of Interceptors assigned to that phase and/or the maximum rate (%) at which they are expended. Once again, use *Okay* or *Cancel* to confirm or abandon your changes.

Finally, save changes to the data or cancel out of the screen.

SYSTEMS
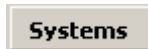
Systems are organizations of equipment, personnel, and/or resources integrated to perform a specific mission. In the SODAC Model, systems are the strategic platforms that support both offensive and defensive forces. The SYSTEMS function allows you to manipulate the specific characteristics of a strategic system. The SYSTEMS button commands the model to open database information on various strategic platforms. You will begin by selecting the SYSTEMS button. To create a new system, select *New*. To modify an existing system, highlight the system in the window and select *Edit*. A "System Edit" screen for the selected system will appear with numerous fields.

Systems are functionally oriented. That is to say, they are not scenario or player-specific, but focused rather on the characteristics of a single strategic platform. These characteristics are represented by the following fields: "SystemName, PlatformName, MovementType, ForceType, CostRandD($/Year), CostP($/Year), CostOandM($/Year), NumProcedrerYear, Year Available BLUE, Year Available GREEN, Year Available ORANGE, Year Available PURPLE, Year Available RED, Year Out of Production, "Year Out of Service, Yield(MegaTons), CredibleDecoysPerWH, LaunchReliability %, DetonationReliability %, Range(km), Hardness(psi), WHperSNDV, SNDVperPlatform, PlatperBase, Accuracy(naut miles), STARTTreatyCnt, Basing, CarrierPenFactor %, WeaponPenFactor %, Coverage %, and Pk %.

The MovementType field will display a default setting of "Air-Based", "Land-Based", or "Sea-Based" for offensive weapons, and "BoostPhase", "Midcourse", or "Terminal" for defensive weapons, depending on the type of system. You may modify MovementType via its list box.

The ForceType field immediately below it will automatically indicate whether the system is offensive or defensive; you cannot alter this characteristic unless the system has both offensive and defensive traits.

Similarly, the Basing field automatically indicates whether the system is "Fixed" or "Mobile." If the system has multiple basing options, you may use the list box to select the basing method you prefer for that system. For the rest of the fields, you may enter numerical data directly. (Note: Fields that do not apply will be obscured and inaccessible. Systems that will never reasonably be available to a player will default to "99999.")

In addition to the above fields, there is a column of selection boxes on the right side of the screen. These selection boxes capture attributes of the strategic system you are editing. They include DeliveryVehicles, Ballistic, MIRVedBM, ICBM, MIRVedICBM, SuperHeavy, MobileICBM, SLBM, MIRVedSLBM, CruiseMissile, Bomb, ABM, BoostPhase, Midcourse, and Terminal. You may select all the boxes (i.e. attributes) that apply to that particular system. (Note: If the selected system is offensive, the latter three selection boxes—which pertain to defensive systems—will not be accessible.)

Once you have made all necessary adjustments to the SYSTEMS profile, select *Save* or *Cancel*.

V. <u>OPERATING THE MODEL</u>

Once you have familiarized yourself with and adjusted the model's specific functions, you are ready to run a simulation. As previously mentioned, there are two run modes built into the model, "Interactive" and "Automated." To run the model automatically, simply select "Automated" in the Run Mode window on the *Options* tab, select the appropriate scenario, and press *Run*. The computer will begin processing the data and running the exchange model on its own until the completion of the game (i.e. the designated number of turns). Under the "Automated" mode, you cannot actively participate in or modify a player's decision-making process during the course of the game. However, the computer will present the results for further analysis after it has completed its run.

<table>
<tr><td>

Operating the Model—"Automated" Mode

1. Select "Automated" mode
2. Specify model functions and create game scenario
3. Select *Run* on the Scenario screen
4. (Model will cycle through all turns and generate results on completion of run)
5. Analyze results generated at end of run

</td><td>

Operating the Model—"Interactive" Mode

1. Select "Interactive" mode
2. Specify model functions and create game scenario
3. Select *Run* on the Scenario screen
4. Accept or reject strategic recommendations made by computer
5. Analyze strategic data between turns
6. Analyze results generated at end of run

</td></tr>
</table>

Because using the model interactively is somewhat more involved, this manual will focus on running a simulation when the Run Mode is "Interactive." Make sure you are on the "Master" screen with all of the major function buttons displayed. Select the SCENARIOS button to begin.

1. <u>Initiating a Game</u>

Highlight a simulation from the SCENARIOS window and select *Run*. The exchange model will begin loading the necessary data and preparing the game. A running message is displayed on the lower tool bar of the computer screen informing you what actions are being taken by the exchange model. The "Master" screen will switch to a "Changes" spreadsheet with a new GUI/screen. The "Changes" spreadsheet will display all of the data values and changes recommended by the model.

2. <u>Strategic Decision-making</u>
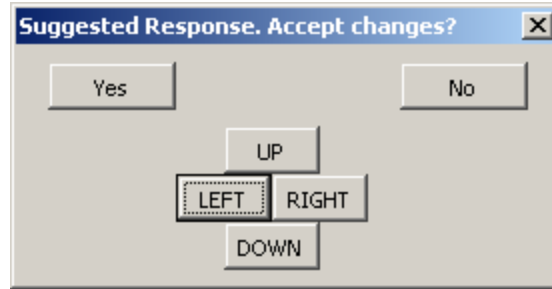
You will begin at Turn 0. The new screen will read "Suggested Response. Accept Changes?" It contains six buttons: *Yes, No, Up, Down, Right,* and *Left*. The directional buttons are the primary means for navigating the model's spreadsheets. The model optimizer automatically factors in the programmed criteria, examines the data, and proposes the most appropriate course of action. It is designed to either achieve the goals (i.e. thresholds) you input into the model or come as close as possible to achieving those goals in the face of certain constraints. Once the optimizer compares player thresholds, it will recommend to you suggested changes to achieve your player's (BLUE's) goals. It is your decision whether or not to accept these suggested changes.

- If you select *No*, the model will display a third "Posture Edit" screen and a new "Exchange1" spreadsheet, showing the data values for each player. The new screen contains three fields and six buttons. The first two fields, Offensive Forces and Defensive Forces, display the model's suggested OFFENSE and DEFENSE profiles.[8] Below each field is an *Edit* button for you to modify these profiles. If you elect to edit the forces, an "Offensive (or) Defensive Edit" screen will appear with the familiar Land-Based, Sea-Based, and Air-Based windows. After you make the necessary adjustments, either save them (*Save New Force*) or disregard them (*Cancel*). You will then return to the "Posture Edit" screen, where you will find a third field, a list box with which you can identify the player whose posture you are editing. (default: BLUE) The four additional buttons on the screen are *Restore Orig Posture, Restore Model Suggestion, Update Measures,* and *Continue*. If you wish to retain the same posture values that you started the round with, select *Restore Orig Posture*. If you wish to shift back to the model's suggested adjustments, select *Restore Model Suggestion*. If you wish to see the impact of your changes, select *Update Measures*. Finally, if you wish to accept the model's suggestions or the changes you have since made, select *Continue* and the model will proceed to the next step. (Note: Under certain circumstances, when you select the *Continue* button, the model will inform you of restrictions and details about the game you are running.)

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[8] The rationale for displaying the suggested profiles rather than the default/original ones—even after you have selected *No*—is that the suggested profiles are probably closer to achieving the player's specified goals than the default/original profiles. You may always change the profiles to restore the original, default conditions if you so desire.
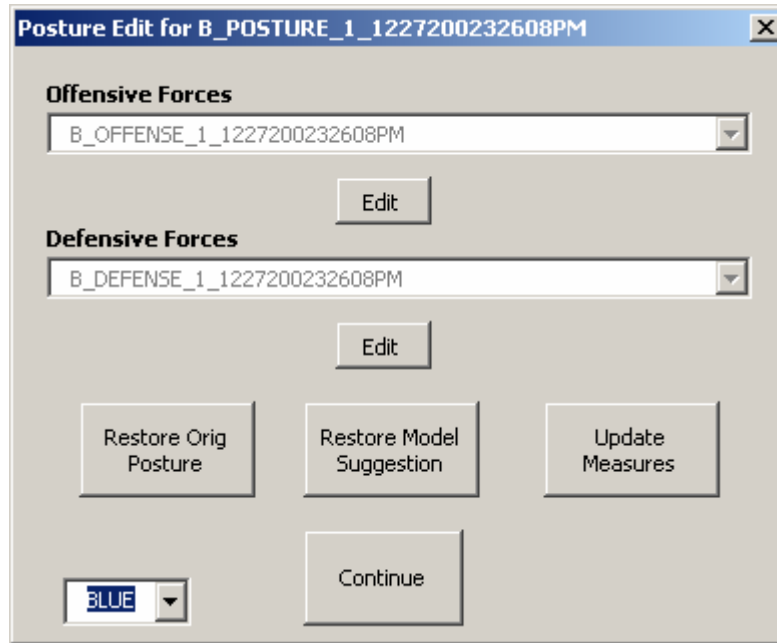
The *Update Measures* button will instruct the model to calculate the measures based on what you had at the beginning of the round and brief them to you. You may continue to go back, modify the profiles, and update the measures until you have satisfied any constraints not being met. When you are satisfied with your changes, you must confirm the model's briefing by selecting the *Ok* button. Once you have selected *Ok*, the model will bring up a "User Response" screen and the "Changes" spreadsheet. You may choose to *Continue* or navigate the "Changes" spreadsheet with the directional buttons. When you select *Continue*, you will be transferred back to the "Posture Edit" screen and "Exchange1" spreadsheet. From here, you will decide whether to continue on or make further changes. As before, select *Continue* to move to the next step.

● If you select *Yes*, you are accepting the model's suggested changes and the model will proceed to the next step.

3. Analyzing Measures

After accepting or rejecting the model's proposed changes, you will be presented with a "Chart options for Turn (#) screen. It is accompanied by a "ChartData" spreadsheet that may be navigated by the directional buttons displayed on the "Chart options" screen. (Note: The "ChartData" spreadsheet is primarily for the model itself and is not intended as a tool for the user or player to intervene or modify data.) The "Chart options" screen, however, is a tool for analyzing the results of play between turns. You may use the buttons and options on this screen to review strategic forces data and construct charts for the simulation you are running.

In the upper-left hand corner of the screen is a *Resize Form* button that allows you to adjust how the screen is displayed. The rest of the screen is organized by function. Below the *Resize Form* button on the left side of the screen are two sections of fields, Raw Data and Charts, containing selection boxes and fields for various measures. The right side of the screen contains directional buttons for navigating the accompanying "ChartData" spreadsheet and a series of option buttons for analyzing measures in the game. At the bottom of the page is another series of fields and list boxes that deal with uncertainty in the game.

The Chart options operate in conjunction with one another. That is to say, the option buttons on the right control functions for the values selected on the left. Put simply, after you specify what you want to look at, you choose how you would like to analyze it.

A. You will begin by selecting values from the Raw Data and Charts sections of the screen. The Raw Data section contains three selection boxes and three corresponding fields. The selection boxes represent Warheads, Interceptors, and Platforms, respectively. The corresponding fields (list boxes) allow you to specify which player is being analyzed with respect to the selected measure.

	1	2	3	4	5
1					
2	PLATFORM	SYSTEM	WARHEADS@TURN 0	WARHEADS@TURN 1	DELTA
3	B_Silo	B_ICBM_G1	900	513	-387
4	B_Silo	B_ICBM_G2	500	0	-500
5	B_Silo	B_ICBM_G3	0	0	0
6	B_SSBN_G2	B_SLBM_G2	3456	576	-2880
7	B_SSBN_G1	B_SLBM_G1	0	0	0
8	B_SSBN_G2	B_SLBM_G3	0	0	0
9	B_Bomber_C_G1	B_ALCM	1440	496	-944
10	B_Bomber_P_G1	B_Bomb	0	0	0
11	B_Bomber_P_G2	B_SRAM	0	0	0
12					
13					

Likewise, the Charts section displays a series of selection boxes and fields/list boxes for use in constructing charts of your model run. The selection boxes include a series of measures labeled Warheads, Interceptors, Cost, GRetal, ALoss, EffBal, RVsNeg, and RVsPen.

- If you select Warheads or Interceptors, you have the option of creating a chart displaying the numbers of Warheads or Interceptors for each of the turns and all of the players.
- If you wish to analyze the cost record during the game, select Cost and use the list box to specify whether you wish to create a chart for Research & Development ("R&D"), Operations & Maintenance ("O&M"), or unit "Production." The rest of the Charts measures have two fields each.
- If you select GRetal, you can analyze the level of guaranteed retaliation that would be achieved as a result of your turn. First choose whether to chart Total retaliatory forces or non strategic offensive forces ("NonSOF"). You will then specify what unit of retaliation you wish to chart (e.g. "Warheads", "Yield", "EMP", "CMP", "SUA").
- Alternatively, you may wish to examine the losses averted by your decision. When you select ALoss (Averted Loss), you will again need to specify whether to chart Total or NonSOF. You will then identify the unit of loss you want to chart (e.g. "Warheads", "Yield", "EMP", "CMP", "SUA").
- Another option is to evaluate the effective balance between players. Effective Balance (EffBal) is somewhat different from the other measures. You will first determine whether to chart the pre-war ("Prewar") or inter-conflict/post-strike balance ["Post(Player)1stMainStrike"] (e.g. "PostRED1stMainStrike"). Next, you will specify the unit of balance you would like to chart (e.g. "Warheads," "Yield", "EMP", "CMP", "SUA").
- The RVsNeg measure addresses how many of your adversary's re-entry vehicles would be negated or defeated by your move. RVsNeg automatically assumes a conflict setting. Therefore, you will first specify what player struck first (e.g. "PostBLUE1stMainStrike") and then what unit you wish to analyze ("Warheads", "Yield", "EMP", "CMP", "SUA").
- Similarly, the RVsPen measure assesses how many re-entry vehicles effectively penetrated established defenses. Like the RVsNeg measure, RVsPen assumes a conflict setting. Specify the chronology (i.e. which player struck first— "PostBLUE1stMainStrike") and identify the unit of measure ("Warheads", "Yield", "EMP", "CMP", "SUA").

Warheads in Arsenal
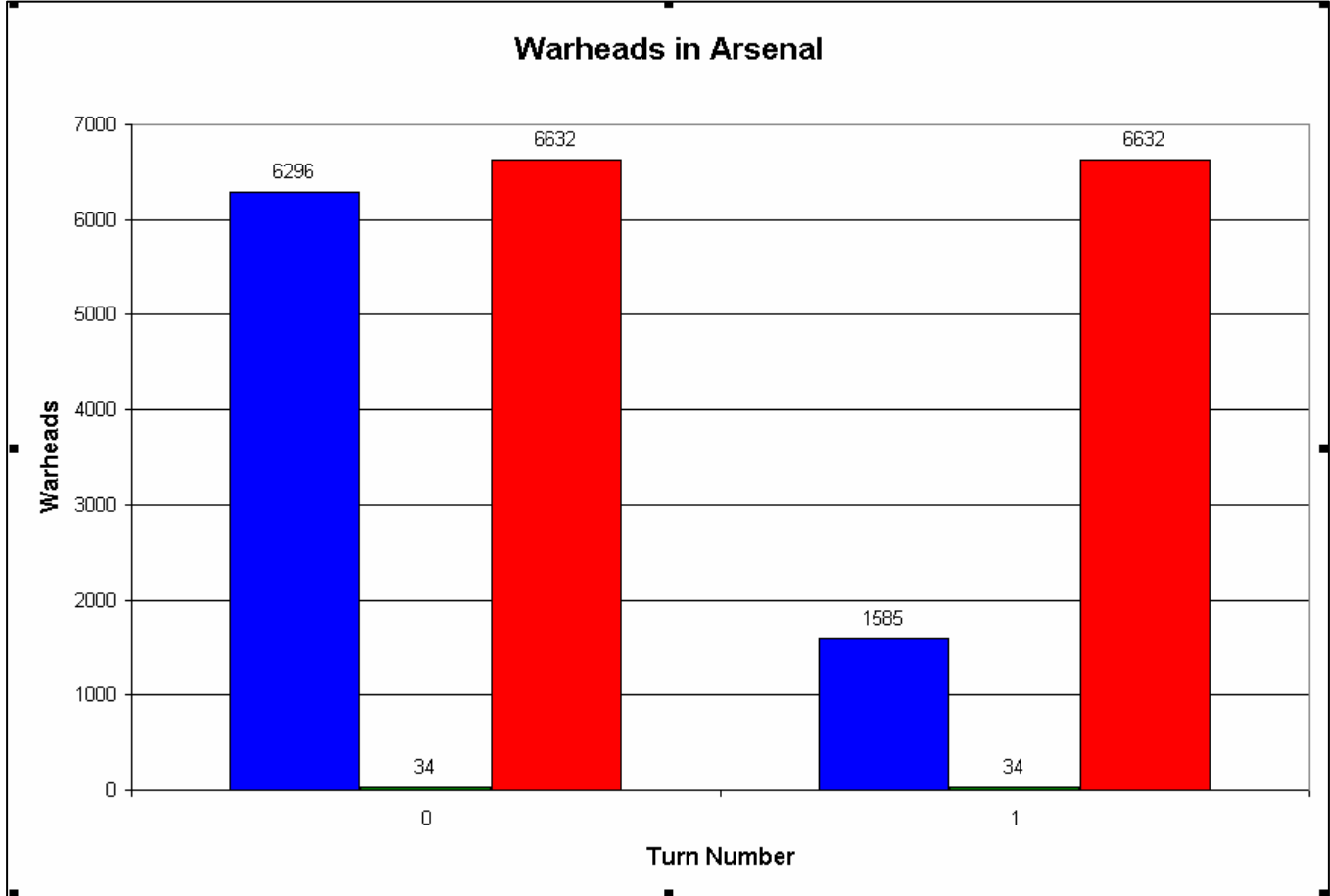
B. You may also choose to factor in a degree of uncertainty into your model run. Moving to the bottom of the screen, select the list box entitled Uncertain Variable (e.g. "Damage Requirement"). Identify what player this uncertainty applies to in the adjacent list box. In the last two fields, specify the statistical range of uncertainty. (+%, -%)

C. Once you have specified the measures and range of uncertainty, you will use the option buttons on the right side of the screen to analyze the selected measures. The option buttons include *Display Raw Data, Generate Chart, Save All Charts, Check Uncertainty, Continue to Next Turn,* and *Exit Run*. The latter two buttons are more or less self-explanatory. The *Display Raw Data* button corresponds to the Raw Data section on its left. It creates a spreadsheet with the data values for a selected measure and player (e.g. "Warheads, BLUE"). This raw data spreadsheet provides details for each turn in the game, as well as the overall change, or "delta", in value for the selected measure. The *Generate Chart* button corresponds to the Charts section below it and allows you to create graphical representations of the selected measures on a spreadsheet entitled "Measures." *Save All Charts* creates a workbook containing all of the charts the model can create for the scenario. Finally, the *Check Uncertainty* button enables you to change one of several variables in a run by a certain percentage figure in order to determine what

effect that variable has on the results (e.g. changing the values for BLUE's "Damage Requirement" by +/- 10% and displaying the change in the resulting measure values). In other words, the *Check Uncertainty* button serves as a tool for identifying the "drivers" behind a particular result in a simple (i.e. 2-player) scenario.

When you have finished analyzing the measures and are prepared to begin the next iteration of the game, select *Continue to Next Turn*. You will then proceed to Turn 2.

4. Completing the Game

Repeat this sequence for the duration of the game (e.g. 5 turns). After your last turn, when you have analyzed the measures under the "Chart options" screen, the game will automatically end. The "Master" GUI will disappear and the "Master" spreadsheet with the DTRA logo in the background will be prominently displayed. At this point, you are able to navigate the various spreadsheets directly. The SCENARIO you have just run will be saved to the model database. To access the model again, select the "Tools" menu from the Microsoft Excel toolbar and scroll down to "DTRA." The "Master" GUI/*Main* tab will reappear.

VI. Practical Example

> **U.S., China, and Russia** (Simulating Asymmetry in the Interactive Mode)
>
> An analyst with the DOD's Office of Net Assessment (ONA) wants to see how U.S. force structure decisions will influence Russian and Chinese strategic behavior. The analyst plans to use the SODAC Model to design a game in which future U.S., Russian, and Chinese strategic postures adjust to one another. In his story, the U.S. and China have entered into a low-intensity arms race with minor weapons procurements/deployments. Emboldened by its prodigious economic growth, China has undertaken a massive modernization effort and a more moderate but still significant armament program. China is increasingly frustrated with American interventionism, particularly in the Taiwan Strait. America's evolving nuclear strategy and ambitious missile defense program further add to China's resentment, prompting China to challenge American strategic dominance. Russia, in a strategically powerful but relatively weak position, takes a more neutral course, pursuing arms reduction. Russia's ambiguous position encourages both the U.S. and China to view it as a potential ally.
>
> Part of the analyst's experiment is to assume that the nuclear powers are embarking on a more conflictual path. In this hypothetical scenario, mistrust has built to the point that arms control has been replaced by arms race. The analyst plans to examine what would happen under moderate to extreme circumstances, involving greater levels of confrontation and strategic competition.
>
> Rather than inputting all original data himself, the analyst decides to create a new scenario by modifying some of the existing sub-elements. He may choose to design the game "top-down," by working through the SCENARIO button, or "bottom-up", adjusting the profile elements and then integrating them into a scenario he has created. For the sake of expediency, he chooses to work "top-down." At this point, he is less concerned with variations in a proposed course of action than he is in comparing the proposed action to other policy alternatives. He also opts to run the model interactively, so that he may directly participate in the decision-making process and test some of his hypotheses.

A. The analyst selects the SCENARIO button on the "Master" screen and then opts to create a new scenario. Pressing the *New* button, he is presented with a window for labeling his new scenario. His concept is to create a scenario wherein the strategic posture of all three actors is influenced by the others. He labels his scenario "Escalation_ONA051102" and confirms it with the *Okay* button. He does not need to access the *Options* tab since the default Run Mode for SODAC is "Interactive."
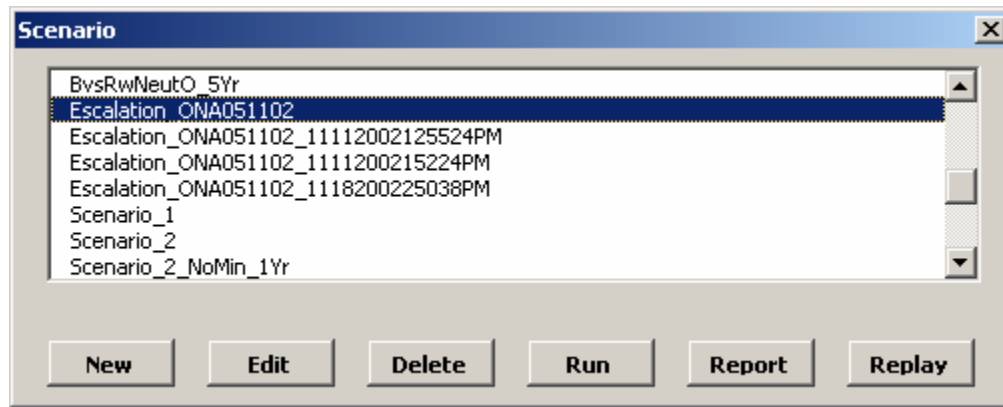
B. The model next displays a "Scenario Edit" screen in which the analyst can manipulate player postures. He first defines the BLUE player posture, representing the U.S. Using the list box on the BLUE Posture field, the analyst selects "Posture_1" and then presses the *Edit* button. Remember, the analyst is primarily concerned with comparing major policy alternatives, so he does not feel it necessary to evaluate or adjust specific details of the players' postures. He is already somewhat familiar with the model and the profiles. The analyst wants to change some values for BLUE's offensive forces profile. Selecting *Edit* serves two purposes, then: 1) it re-familiarizes the analyst with the posture he is editing and 2) it allows him to make minor adjustments.

The *Edit* button will call up a "Posture Edit" screen, with fields for CRITERIA, Offensive Forces (OFFENSES), and Defensive Forces (DEFENSES). Each established scenario is comprised of programmed elements including ACR, ALLIANCES, POSTURES, CRITERIA, DOCTRINES, OFFENSES, and DEFENSES. Likewise, these programmed elements display programmed values or profiles. In this case, the Criteria field indicates that "Posture_1" incorporates "Criteria_1." The analyst selects the *Edit* button below the Criteria field, examines the values for "Criteria_1", determines them to be acceptable, and decides to make no changes; he selects *Cancel* to return to the "Posture Edit" screen. He does the same with the Defensive Forces field. The analyst then comes back to the Offensive Forces field, choosing to retain the "OFFENSE_1" posture for BLUE. He selects *Edit*, bringing up an "Offensive Edit" screen. He wants to assign a more robust offensive force to BLUE by having BLUE deploy a Sea-Based offensive system. He moves to the Sea-Based window on the "Offensive Edit" screen and selects *New*. A new window appears with Available Sea Elements: "Ohio_Class   Trident_D5." The analyst highlights the system with his mouse and selects *Add*, thus equipping the BLUE player with a Sea-Based strategic system. Finally, he presses *Save* to store his changes, first returning to the "Posture Edit" screen, then selecting *Save* again to return to the "Scenario Edit" screen.
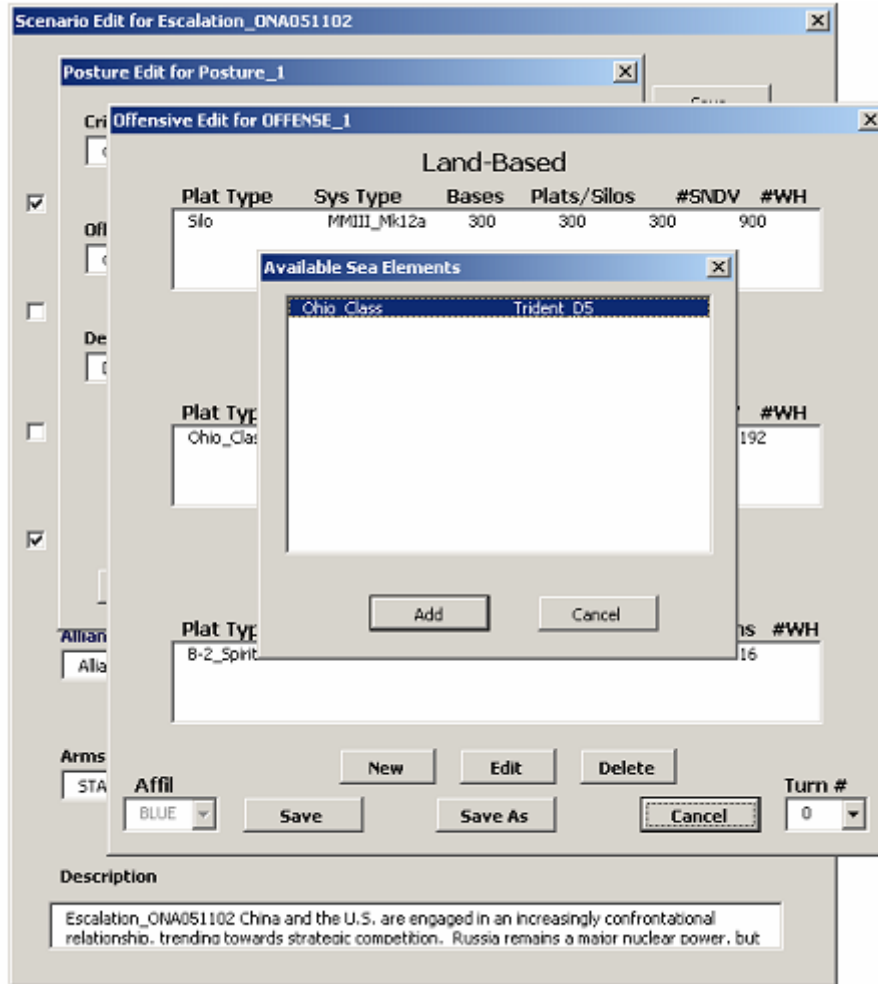
Having finished with player BLUE, the U.S., the analyst moves to player GREEN, representing China. The model automatically recognizes BLUE as the default player (U.S.) in all scenarios. Therefore, the analyst must indicate GREEN's participation by marking the selection box to the left of the GREEN Posture field. As with BLUE, the analyst is interested in modifying one minor aspect of GREEN's profile. He uses the list box to select "Posture_2" for GREEN, then presses the *Edit* button below the field. On the subsequent "Posture Edit" screen, he examines the values for CRITERIA and Defensive Forces (DEFENSES), electing to make no changes. However, the analyst does intend to modify GREEN's offensive posture—"OFFENSE_2." Selecting the *Edit* button below the Offensive Forces field, the analyst enters the "Offensive Edit" screen. He chooses to add a Sea-Based offensive system for GREEN by selecting *New*, highlighting the system ("Delta_IV   SS-N-23_M1"), and pressing *Add*. (Note: In the analyst's scenario, this would signify China's acquisition of SSBN/SLBM capability.) Once he has confirmed everything else on the screen, he will select *Save* to return to the "Posture Edit" screen, and *Save* once again to return to the "Scenario Edit" screen.
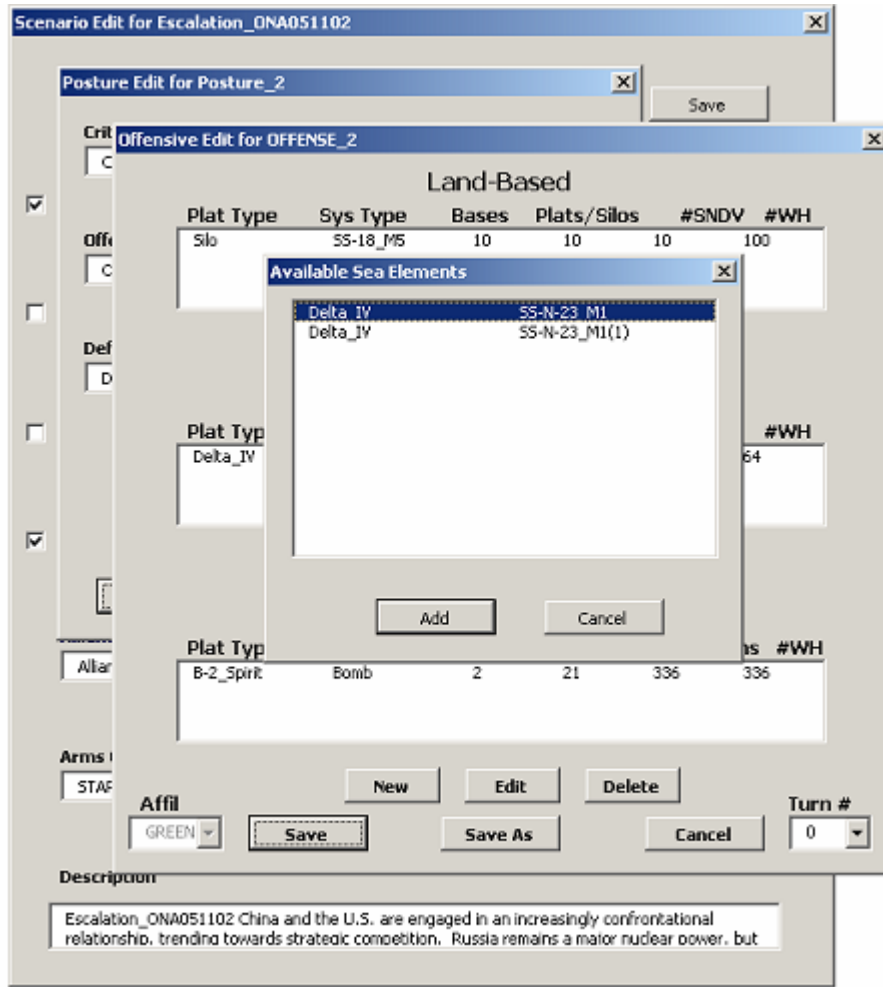
The analyst repeats this process for player RED (i.e. Russia), selecting "Posture_5" and choosing to change RED's offensive posture to "OFFENSE_5." He further alters RED's offensive posture by reducing the number of Land-Based, offensive platforms (i.e. "Silo SS-18_M5") from 180 to 100 units, to simulate Russia's trend towards unilateral reductions. He saves all inputs and changes, then returns to the "Scenario Edit" screen.
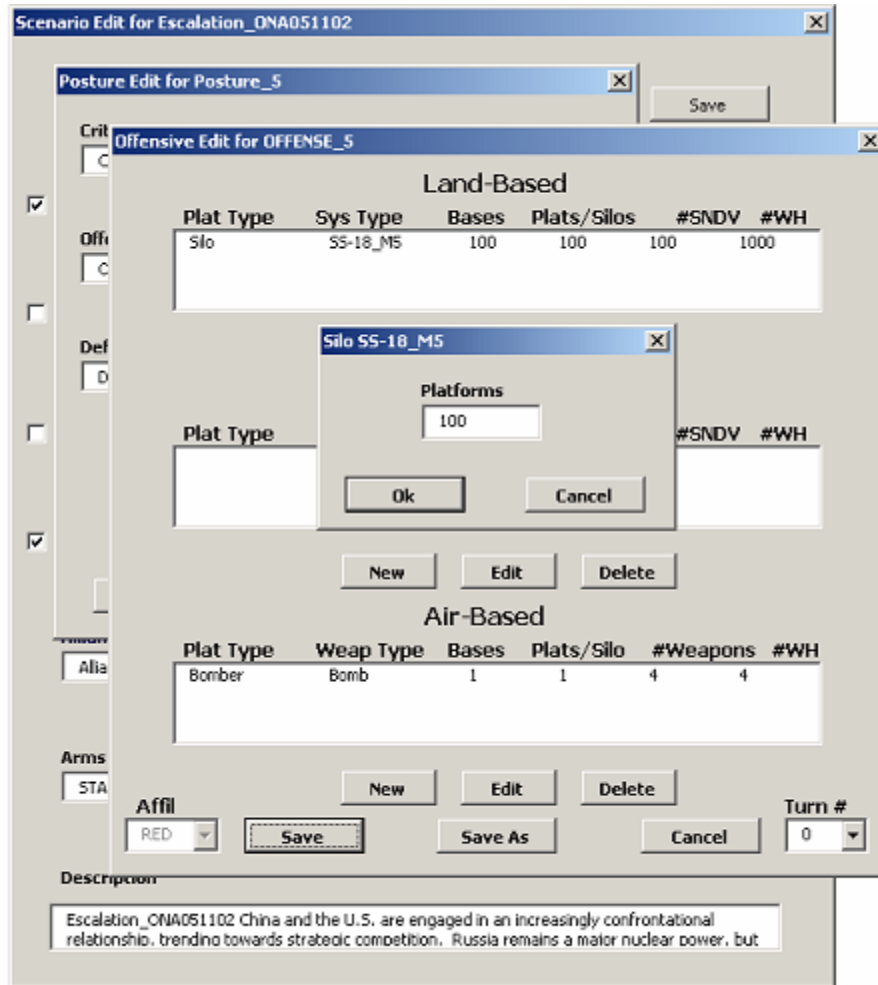
No alliance system is initially specified for his new "Escalation" scenario, so the analyst uses the list box on the Alliances field to select "Alliance_2." To tailor the alliance system to his scenario, the analyst must edit the relationships and ranges between players. Selecting the *Edit* button for the Alliances field, he accesses the "Alliance Edit" screen. The analyst uses the list boxes/fields that correspond to various pairs of players to define their alliance relationships. Since China and the U.S. are opposed in his story, he defines the BLUE-GREEN relationship as "Primary Competitor." Russia is not entirely disengaged or neutral, but nor is it overtly supportive of either side. The potential exists for it to tacitly support either the U.S. or China. Thus, the analyst defines both the BLUE-RED relationship and the GREEN-RED relationship as "Potential Ally." Next, the analyst specifies the operational ranges between players. The range between the U.S. (BLUE) and either of the other players (RED, GREEN) is "Intercontinental." However, Russia and China's (RED and GREEN) closer proximity mean that their range is set at "Intermediate."

To simulate a plausible arms control environment, the analyst selects "START2/ABM" for an Arms Control Regime (ACR). In reality, START 2 was never ratified and the U.S. withdrew from the ABM Treaty in December 2001. However, the analyst is interested in exploring how an arms race might still progress under limitations on strategic offenses and defenses. Since it is a future scenario, he sets the Start Year field for "2003"—the year in which his scenario begins to unfold. He chooses to retain the "5" Year timeframe for the game. Understanding the intricacies of a trilateral nuclear relationship, he sets the Learn Mode on "Go straight to maximize," which instructs the model to seek a solution that is as close as possible to the player's primary measure threshold. He does not specify a Turn #. Finally, for his own benefit and record, he explains the details of the scenario in the Description window.

Once all changes and inputs have been made, the analyst selects the *Save* (or *Save As*) button on the "Scenario Edit" screen and the scenario is stored in the model database for future use.

(Note: It is critical that you save any input or changes for each screen that you have been working on. Because the elements are discrete, you must not only save changes to individual profiles, but you must also save those profile changes in the larger scenario, etc.)

C. The analyst has now defined the parameters for his game scenario and he is ready to use the model. After he saves his inputs on the "Scenario Edit" screen, he is returned to the "Master" screen, the main GUI. He selects the SCENARIO button

again and scrolls down through the window to find his stored scenario, "Escalation_ONA051102." Highlighting the scenario, he selects the *Run* button to begin the game.

When the game is initiated, the model optimizer processes all of the values and data defined by the analyst. Comparing the analyst's preferences/thresholds with economic and strategic constraints, the optimizer proposes a course of action designed to achieve or come as close as possible to achieving the analyst's specified goals. The proposed course of action in Turn 1 seems acceptable to the analyst, so he selects *Yes* on the "Suggested Response. Accept Changes?" screen.
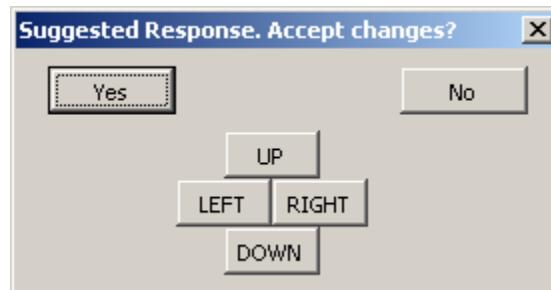
The analyst next arrives at a "Chart options for Turn 1" screen through which he can study how the game is playing out. The analyst is playing the role of BLUE (the United States). BLUE is interested primarily in how GREEN (China), and to a lesser extent, RED (Russia), react to its warhead stockpile decisions. He marks the selection box for Warheads and uses the list box to identify GREEN as the player he wants to examine. He then selects the *Display Raw Data* button and a "GREEN" spreadsheet appears displaying all of GREEN's strategic platforms and warhead numbers for both Turn 0 (the beginning of the game) and Turn 1. The analyst notes that there is no substantial change (or "Delta") in GREEN's numbers. He then does the same for RED and finds the same result. BLUE's behavior apparently has not provoked a major response (in terms of warheads) from either of the other two players in Turn 1.

The analyst is well aware that economics play a large role in the trilateral relationship. BLUE enjoys the largest economy by far. He is curious as to whether GREEN or RED can sustain their current strategic trends given their economic situations. The analyst marks the selection box next to Cost and uses the list box to choose Operations & Maintenance ("O&M") costs. He then selects the *Generate Chart* button, which offers graphical Operations & Maintenance cost projections for all three players from 2003 (the game start point) through 2007. (Note: The length of time reflects the Turn Duration designated by the analyst-user= 5 years.) The chart illustrates no substantial change in cost over the next several years for any of the players. Given the rapid growth of GREEN's economy and RED's unilateral arms reductions, the "O&M" costs for each player may in fact account for a smaller percentage of their economies than they do now. In other words, the analyst hypothesizes that GREEN and RED's current strategic

trends will actually become more affordable for them in the years to come, if current economic trends continue.

Satisfied with his analysis from Turn 1, the analyst selects the *Continue to Next Turn* button and proceeds with the game. The optimizer's suggested response for Turn 2 proposes little to no change. In this iteration, the analyst is interested in what moves would preserve the status quo. Given his analysis from the previous turn, the analyst agrees with the suggested response and again selects the *Yes* button to accept the model's changes. On the "Chart options for Turn 2" screen, he examines the same measures (Warheads-"GREEN", "RED"; Cost- "O&M") that he reviewed in Turn 1. Again, the model shows no Delta in either of the player's warhead stockpiles. This time the model generates O&M cost charts from 2003 to 2012. (5 year turn duration over the course of two turns) The charts likewise illustrate no significant changes in O&M costs for any of the players. By accepting the model's suggested responses, the analyst has been able to preserve the status quo. He decides to take a different approach in the next turn.

In Turn 3, the analyst rejects the model's proposed course of action by selecting *No* on the "Suggested Response. Accept Changes?" screen. This time, he is interested in how more aggressive behavior by BLUE would influence GREEN and RED, as well as how they would respond in strategic terms. The analyst plans to test how GREEN and RED will react to a modest deployment of missile defenses by BLUE. He selects the *Edit* button under the Defensive Forces field on the "Posture Edit" screen, highlights the Midcourse platform, selects *Edit*

again on the "Defensive Edit" screen, and changes the number of platforms from 0 to 10. He then selects *Save New Force* and returns to the "Posture Edit" screen, where he selects *Continue*.
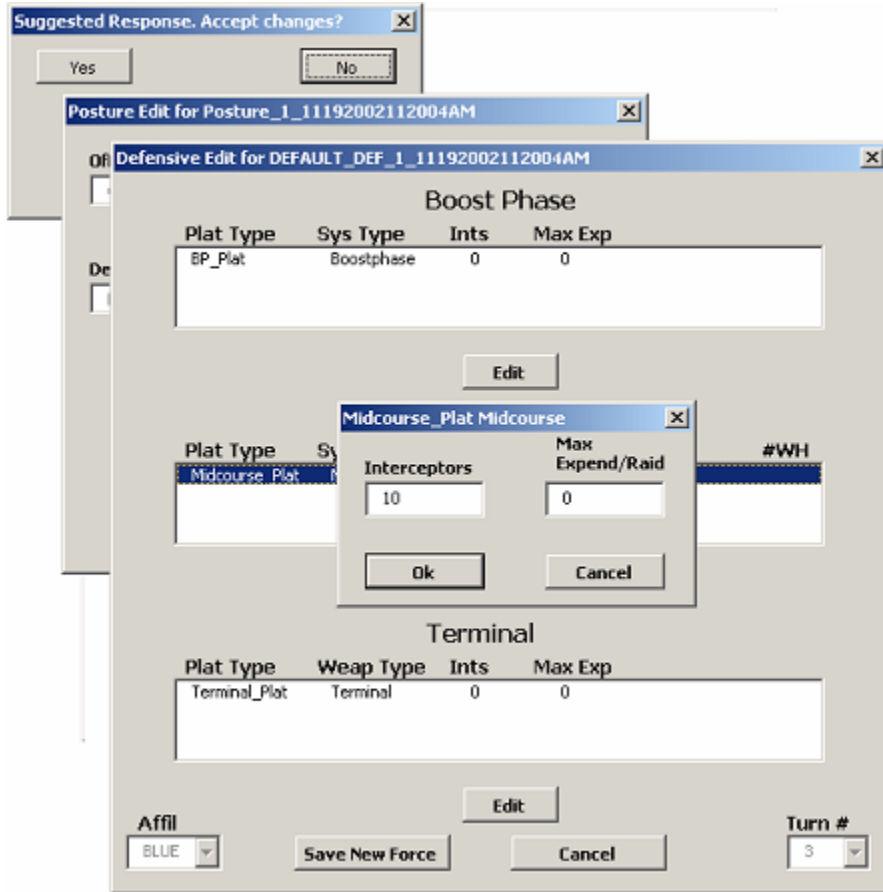
Before proceeding further, the model briefs the analyst with the following message:
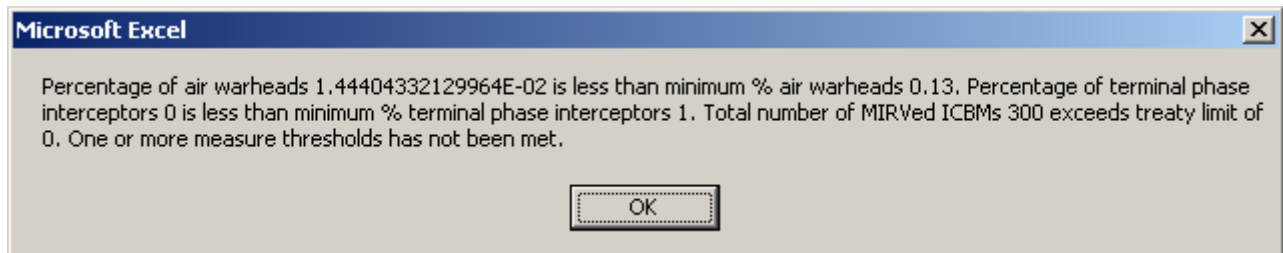
This message informs the analyst that he is deviating from his designated thresholds and preferences. He selects the *Ok* button to confirm that he is aware of this deviation and proceeds to the "Chart options for Turn 3" screen. Once he arrives, he examines the same measures he has consistently examined throughout the game. Somewhat surprisingly, the model forecasts no GREEN or RED

changes in response to BLUE's deployment of missile defenses. However, cost projections for BLUE naturally rise with the deployment of new systems. Satisfied with his experiment, the analyst moves on to Turn 4.

For Turn 4, the model's suggested changes must accord to the terms of START2/ABM, meaning that BLUE will withdraw 300 of its ICBM platforms. With the analyst's deployment of missile defenses, this would be a de-escalation of sorts. Therefore, the analyst opts to accept the suggested changes and examine how they will impact GREEN and RED's behavior.

From the "Chart options for Turn 4" screen, the analyst examines the same measures he has consistently examined. This time, there is a profound change ("Delta") in BLUE's warhead numbers, but no similar change for RED or GREEN. Also, when he generates the chart for the O&M costs, the analyst finds that BLUE's costs have dropped dramatically, unlike those of GREEN or RED. Finally, the analyst selects Continue to Next Turn. Since the model was pre-set to 4 turns, the model simulation ends and the "EMBLEM_SHEET" spreadsheet with the DTRA logo appears.

D. With the simulation complete, the analyst now begins to deconstruct the game and consider its implications. He is intrigued by the lack of profound change on the part of GREEN and RED. He had expected some kind of response by one of the two, particularly GREEN, as BLUE's primary competitor. GREEN's decision not to respond forces the analyst to reconsider his hypotheses.

- Does it mean that GREEN (China) or RED (Russia) is genuinely interested in preserving the nuclear balance through minimum deterrence? If so, what is their motivation?
- On the other hand, why do GREEN and RED fail to reciprocate when BLUE unilaterally cuts its forces, thus putting it at a numerical disadvantage in terms of warheads?
- Do GREEN and RED still find it necessary to rely on their nuclear stockpiles for security (perhaps because of slow or failed conventional modernizations?) or are they attempting to compete with BLUE?
- Would BLUE (the U.S.) accept being at a disadvantage? (e.g. in terms of overall warhead or SNDV numbers) Would the BLUE consider reducing its force levels below that of RED and GREEN. Would BLUE tolerate modernization and expansion of the GREEN/RED arsenals beyond that of its own?
- How did RED's ambiguous status factor in, as a "Potential Ally" to both GREEN and BLUE?
- What impact, if any, did BLUE's decision to deploy missile defenses have on GREEN and RED and how does/did it affect the strategic balance? Would deployment of larger numbers of interceptors, or other types of strategic defense, provoke a different reaction from GREEN or RED?

- Are the drop in O&M costs advantageous for BLUE? (i.e. releasing more money to be allocated elsewhere?)

The analyst concludes that given the parameters of this game, Russia and China are unlikely to respond to U.S. dominance or even minor upgrades to the U.S. position, so long as the status quo (economically, strategically, etc.) holds. However, the model does not answer "why" this is the case. The analyst speculates that either the two countries are genuinely interested in preserving the strategic balance or they simply do not have the resources to compete with the U.S.

This simulation illustrates how the model is intended to provoke as many questions as it answers. This one run conducted by the analyst was intended to solve a few minor questions. In the process, however, it raised others that the analyst can now explore through succeeding runs. From here, the analyst can test any number of additional hypotheses or scenarios related to this original story. For instance, he may return to this scenario and modify BLUE's behavior to make it more extreme, perhaps through further offensive force deployments or a more robust missile defense system. As a result, he may find that more extreme behavior by BLUE will prompt a more aggressive response by GREEN, but not RED (Russia). He might then conclude from these additional findings that fairly extreme behavior by the U.S. would be required to provoke a similar response by China. However, Russia would appear to be set on a particular strategic path somewhat independent of American and Chinese behavior.

VII. POTENTIAL APPLICATIONS

SODAC is designed as a modeling tool for personnel, analysts, and agencies involved in national security planning and strategic issues. The model's flexibility allows it to serve a variety of purposes. However, it is primarily intended for military planners, arms control specialists, and upper-level decision-makers who are interested in the nexus between strategic forces and foreign policy.

The table below illustrates some, but not all, of the potential applications for the SODAC Model:

User	Task	Application
Defense Threat Reduction Agency (DTRA)	Strategic Force Planning, Arms Control, Foreign Policy Assessment	• projecting strategic behavior • conducting risk assessments • analyzing foreign policy implications
U.S. Strategic Command (STRATCOM)	Strategic Force Planning, Arms Control	• conducting U.S. risk assessments • evaluating U.S. strategic posture on *operational* level • making adjustments to U.S. force structure • projecting adversary force structure
Office of Net Assessment (ONA)	Strategic Force Planning	• projecting adversary behavior/force structure • evaluating U.S. strategic posture on *national* level • conducting U.S. and adversary risk assessments
U.S. Department of State (State)	Arms Control, Foreign Policy Assessment	• analyzing policy implications of strategic behavior • identifying optimal strategic balance • negotiating arms reduction agreements
"Think Tanks", Federally Funded Research and Development Centers (FFRDC) (e.g. RAND)	Foreign Policy Assessment, Arms Control, Strategic Forecasting	• projecting adversary behavior/force structure • evaluating U.S. strategic posture on *national* level
Academia	Foreign Policy Assessment, Teaching/Research	• analyzing policy implications of strategic behavior • introducing strategic concepts with "hands-on" tools

VIII. APPENDICES

The Appendices contain supporting material and documentation for the SODAC Model and User's Manual.

A. Glossary[9]

ABM	Anti-Ballistic Missile Treaty; signed between the U.S. and U.S.S.R. in 1972; placed limits on ballistic missile defense forces; (U.S. withdrawal, December 2001)
ABS MAX GDP	Absolute Maximum Gross Domestic Product; the maximum percentage of GDP that a player can expend on defense needs under extraordinary (i.e. threatening) circumstances
ABS NUM	an objective, non-percentage number (see ABSOLUTE)
ABSOLUTE	an objective, non-percentage number (see ABS NUM)
ACCURACY(naut miles)	accuracy of offensive systems with regards to distance to desired impact point such a system can expect to achieve
ACR	Arms Control Regimes; agreements and institutions designed to limit and/or reduce strategic arms production and deployment; (see also TREATY)
AFFIL	Affiliation; determines what offensive or defensive systems are available to each player (can be BLUE, GREEN, RED, ORANGE, and PURPLE)
AIR-BASED	strategic offensive forces launched from aircraft (e.g. ALCM)
AIR BREATHER WARHEADS	warheads delivered by a missile or airplane with an engine requiring the intake of air for combustion of its fuel, as in a ramjet or turbojet
ALCM	Air-Launched Cruise Missile; air-based strategic offensive System launched from long-range bombers; (*START*: "an

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[9] Where applicable, this glossary has accepted the definition of terms put forth in the Strategic Arms Reduction Treaty (START). Where a distinct definition has been necessary for model purposes, the glossary has cited the START definition for additional reference. (See the START Treaty Annex, http://www.defenselink.mil/acq/acic/treaties/start1/annexes/start_da.htm)

air-to-surface cruise missile of a type, any one of which has been flight-tested from an aircraft or deployed on a bomber after December 31, 1986")

ALLIANCES   function that allows the user to stipulate the nature of interaction between players; alliance is a formal agreement for cooperation and coordination of strategic effort (either "Firm Alliance" or "Potential Ally")

ALOSS   (see AVERTED LOSSES)

AVERTED LOSSES   measure of how much damage a player can avoid by striking first rather than retaliating; a measure of potential capabilities if no actual exchange occurs; <u>not</u> a measure of damage averted by changing force structure between turns

BALLISTIC   (*MDA*: Ballistic Trajectory defined as "trajectory traced after the propulsive force is terminated and the body is acted upon only by gravity and aerodynamic drag") [10]

BALLISTIC MISSILES   (*START*: "a missile that is a weapon-delivery vehicle that has a ballistic trajectory over most of its flight path"); (*MDA*: "Any missile that does not rely upon aerodynamic surfaces to produce lift and consequently follows a ballistic trajectory when thrust is terminated.")

BALLISTIC MISSILE
WARHEADS   warheads deployed on ballistic missiles

BASES   figure that translates the number of weapons of a given type into the number of targets needed to attack that weapon type; bases are the locations at which strategic forces are stationed

BASING   field on the "Systems Edit" screen that indicates whether a particular strategic system's basing option is mobile or fixed

BATCH   run mode option that allows the user to run the model based on pre-programmed settings

BOMB   an explosive device fused to detonate under specified conditions; typically free-fall nuclear weapon deployed on aircraft

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[10] For more information on missile defense and ballistic missile terminology, see the Missile Defense Agency (MDA) website, http://www.acq.osd.mil/bmdo/.

BOMBER CMs	cruise missiles delivered by bombers; field that enables the user to stipulate how many bomber-delivered cruise missiles are allowed under a particular Arms Control Regime
BOMBERS	aircraft designed for delivery of long-range and/or large-scale airstrikes, in this case with nuclear weapons; (*START*: "an airplane of a type, any one of which was initially constructed or later converted to be equipped for bombs or air-to-surface missiles")[11]
BOOSTPHASE	(see BOOST-PHASE)
BOOST-PHASE	(*MDA*: "first phase of a ballistic missile trajectory during which it is being powered by its engines"; "usually lasts 3 to 5 minutes"; "reaches an altitude of about 200 km whereupon powered flight ends")
BOOST PHASE INTERCEPTORS	defense systems designed to intercept offensive missiles during launch stages or early in flight
CANCEL	button that allows the user to terminate or discard model Inputs
CARRIERPENFACTOR %	Carrier Penetration Factor %; the probability that a strategic weapons carrier will penetrate an adversary's defenses
CHARTS	graphical representations of selected model measures
CHECK UNCERTAINTY	button that allows the user to change the percentage of a variable calculated in the exchange model to determine what effect the variable has on the measure results
CMs	cruise missiles (see CRUISEMISSLE)
CMP	Counter Military Potential (Equivalent Megatonnage per nautical square mile—EMT/nmi^2); descriptive category of measure that calculates a player's strategic force capacity to threaten or destroy an adversary's military assets
COMPETITOR	player identified as an adversary by the user; ranked as "Primary," "Secondary," or "Tertiary"

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[11] START also distinguishes between "bomber" and "heavy bomber." The latter must either have a range greater than 8000 kilometers or it must be equipped for long-range nuclear ALCMs.

CONTINUE | button on the "Posture Edit" screen that allows the user to accept the model's suggestions or the user's own edits and proceed to the next turn in the game

CONTINUE TO
NEXT TURN | button on the "Chart options" screen that advances the model to the next decision in the game

COOPERATIVIST | player preference that favors coordination and interaction in strategic behavior over unilateral moves

COST | financial expenditure for strategic forces; pertains to cost associated with offensive/defensive forces; either Operations and Maintenance(O&M), Procurement/Production(P), or Research and Development(R&D).

COSTOandM(%/YEAR) | field on the "Systems Edit" screen that indicates the cost (in U.S. $dollars) per year for operations and maintenance of a selected strategic system; model calculates cost based on how many years during a given turn an offensive/defensive system was in place for a given player

COSTP(%/YEAR) | field on the "Systems Edit" screen that indicates the cost (in U.S. $dollars) per year for procurement of a selected strategic system; model calculates the cost of systems built or added during a turn

COSTRandD(%/YEAR) | field on the "Systems Edit" screen that indicates the cost (in U.S. $dollars) per year for research and development of a selected strategic system; model assumes a player will spend R&D money on systems until they become available some time in the future

COVERAGE % | percent of an attack that an interceptor type can intercept

CREDIBLEDECOYSPERWH | field on the "Systems Edit" screen that indicates the number of deception devices (i.e. decoys) that are fitted to a warhead for a particular strategic system

CRITERIA | function that allows the user to establish thresholds and parameters for a player in a scenario; thresholds are information on a player's goals, preferences, and capabilities, as well as costs and doctrines

CRUISEMISSILE   (*START*: "a missile that is an unmanned, self-propelled weapon-delivery vehicle that sustains flight through the use of aerodynamic lift over most of its flight path")

DAMAGE
REQUIREMENT   the required probability of destruction—the % of damage a player needs to inflict on its adversary during an exchange

DEFEND SOF   field that allows the user to decide whether to deploy a player's defenses against an adversary's inbound weapons aimed at SOF targets

DEFENSES   function that allows the user to select systems used by a player to guard against strategic offensive actions by an adversary

DEFENSIVE FORCES   (see DEFENSES)

DELETE   button that allows the user to purge items from the model database

DELIVERYVEHICLES   (see DELIVERY VEHICLES)

DELIVERY VEHICLES   systems for transporting and deploying (nuclear) weapons against targets; typically bombers, long-range ballistic missiles, and ALCMs

DESCRIPTION   field that provides further details about a scenario

DETONATIONRELIABILITY %   probability that weapon will detonate over its target

DISPLAY RAW DATA   button on the "Chart options" screen that allows the user to create a spreadsheet of data values for a selected measure and player

DOCTRINES   a player's strategic goals and how, in accordance with those goals, the player would expect to use its strategic forces in the event of an exchange; function that allows the user to specify a player's strategic force behavior; incorporates threat values, force allocations, and strategic preferences; (*MDA*: "Fundamental principles by which the military forces or elements thereof guide their actions in support of national objectives.")

EDIT   button that allows the user to modify aspects of the model

EFFBAL   (see EFFECTIVE BALANCE)

EFFECTIVE BALANCE   the ratio of forces between competitors measured before
                                any potential exchanges (i.e. Prewar), after the default side
                                launches first (i.e. Post BLUE First Main Strike), and after
                                the default side launches second (e.g. Post RED First Main
                                Strike)

EMBLEM_SHEET   the spreadsheet (with accompanying tab) that displays the
                                DTRA logo behind the model operations screens

EMT   Equivalent Megatonnage; the actual explosive power of a
                                weapons system—measured in millions of tons of TNT
                                (megatons)—raised to the two-thirds power; evaluation of a
                                weapons system's destructive power; 1 EMT generates a 2-
                                3 psi shockwave over the equivalent area of 58 km^2

EXIT RUN   button on the "Chart options" screen that enables the user
                                to terminate a running game and depart the scenario

FIRM ALLIANCE   mutually confirmed agreement for coordination of effort
                                (or self)

FIRST STRIKE
READINESS RATE   percentage of strategic forces operational and prepared for
                                use in first strike

FIRST STRIKE
STRATEGY   player's preferred strategy on targeting and sequencing the
                                use of strategic offensive forces; either "OMT" or "SOF"

FIXED   type of land-based strategic system deployed in a static,
                                permanent location, such as ICBMs in silos

FORCETYPE   field on the "Systems Edit" screen that indicates whether
                                the strategic system is offensive or defensive in mission

GDP FILE   tab-delimited text file that contains projected GDP figures
                                for a given player

GDP PROFILE   characteristics of a player's gross domestic product;
                                pre-set trends for GDP growth over the course of the game

GENERATE CHART   button on the "Chart options" screen that allows the user to
                                create a graphical representation of his/her decisions with
                                regard to selected measures

GRETAL	(see GUARANTEED RETALIATION)
GUARANTEEED RETALIATION	the total strategic capability (i.e. forces) guaranteed to survive an initial attack, successfully launch, successfully penetrate adversary defenses, and successfully detonate at its target; the total strategic retaliatory capability that can be reasonably expected to survive and respond
HARDNESS(psi)	measure (in pounds per square inch) of weapons systems' survivability—the physical ability of a system or its location to withstand the overpressure blast effects of a nuclear first strike
ICBM	Intercontinental Ballistic Missile; land-based strategic offensive system; (*START*: "a land-based ballistic missile with a range in excess of 5500 kilometers")
ICBM WARHEADS	warheads deployed on Intercontinental Ballistic Missiles
INTs	(see INTERCEPTORS); number of interceptors
INITIAL GDP	a player's gross domestic product at the beginning of the game; a measure of a player's available economic resources
INTERACTIVE	run mode option that provides for user input between each turn
INTERCEPTORS	defense systems designed to intercept and defeat offensive missiles
INTERCONTINENTAL	(greater than 5500 km), range of player relationship and corresponding strategic systems
INTERMEDIATE	(between 3000 and 5500 km), range of player relationship and corresponding strategic systems; (*INF Treaty* covers weapons with ranges between 500 and 5500 km)[12]
LAND-BASED	strategic offensive forces launched from the ground (e.g. ICBM)
LAUNCH POSTURE	player's preference on when to launch its strategic forces; either launching after a first-strike ("Rideout") or not

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[12] For additional reference, see the Intermediate-range and Shorter Range Nuclear Forces Treaty (INF), http://www.defenselink.mil/acq/acic/treaties/inf/inf.htm.

("Other")

LAUNCHRELIABILITY %	probability that a weapon successfully exits its base/silo and completes its preliminary flight phases
LEARN MODE	field that allows the user to instruct the model on how to make choices in the game using the model optimizer; guides the optimizer on how to process previous results and incorporate them into a player's strategic behavior
MAIN STRIKE ALLOCATION	percentage of strategic forces tasked with executing main strike
MASTER	interface that greets the user and allows for operation of the Model
MAX EXP	(see MAX EXPEND/RAID)
MAX EXPEND	(see MAX EXPEND/RAID)
MAX EXPEND/RAID	Maximum Expenditure per Raid; maximum rate (%) at which interceptors are expended in defending against incoming offensive missiles; allows the user to retain interceptors for defense in future attacks
MAXIMALIST	type of player that assumes that its competitors will coordinate against it; thresholds and constraints for this player must be met against a combined team consisting of all opponents
MAX MIL EXP STRATEGIC FORCES	field that establishes the maximum percentage of the defense budget allocated for strategic forces
MEASURE	strategic principles that guide players doctrine and instruct the model as to how to use players' strategic forces to achieve their goals; apply thresholds that drive model decisions on offensive and defensive force adjustments
MEDIUM	(between 1000 and 3000 km), range of player relationship and corresponding strategic systems
MIDCOURSE	(*MDA*: "portion of a ballistic missile's trajectory between the boost phase and the reentry phase when reentry vehicles and penaids travel at ballistic trajectories above the

atmosphere"; "the missile has completed firing its propulsion system"; "longest part of its flight"; "can last as long as 20 minutes")

MIDCOUSRE INTERCEPTORS   defense systems designed to intercept hostile missiles during mid-flight en route to target

MINIMALIST   type of player that assumes that none of its competitors will coordinate against it; thresholds and constraints for this player must be met separately against each of its competitors

MIN INTERCEPTORS
(% of total)   minimum percentage of ballistic missile defense interceptors assigned to one of three missions (boost phase, midcourse, terminal)

MIN WARHEADS
(% of total)   minimum percentage of warheads deployed on one of three strategic platforms (Land-Based, Sea-Based, Air-Based)

MIRV   Multiple Independently Targeted Reentry Vehicle; a reentry vehicle carried by a delivery system that can place one or more reentry vehicles over each of several separate targets

MIRVed BALLISTIC MISSILES   ballistic missiles that contain multiple independently targeted re-entry vehicles

MIRVedBM   (see MIRVed BALLISTIC MISSILES)

MIRVedCM   cruise missiles that contain multiple independently targeted re-entry vehicles

MIRVedICBM   (see MIRVed ICBMs)

MIRVed ICBMs   intercontinental ballistic missiles that contain multiple independently targeted re-entry vehicles

MIRVedSLBM   (see MIRVed SLBMs)

MIRVed SLBMs   submarine launched ballistic missiles that contain multiple independently targeted re-entry vehicles

MOBILE   type of land-based strategic system deployed on a transporter whose location varies

MOBILEICBM	intercontinental ballistic missiles that are transported and not based in a fixed location; (*START*: mobile launcher of ICBMs is defined as "a road-mobile launcher of ICBMs or a rail-mobile launcher of ICBMs")
MOBILE ICBM WARHEADS	field that displays the number of warheads mounted on mobile ICBM's that are allowed under a particular Arms Control Regime
MOVEMENTTYPE	field on the "System Edit" screen that indicates the method of travel/basing and/or mission for a strategic system; Air-Based, Land-Based, Sea-Based (offensive); BoostPhase, Midcourse, Terminal (defensive)
NEUTRAL	relationship between players not characterized by cooperation or competition; non-aligned, officially impartial
NEW	button that allows the user to input new data into the model in order to create an original profile
NON SOF	non-Strategic Offensive Forces; descriptive category of measure that characterizes the strategic balance between players calculated without strategic offensive forces
NORM MAX GDP	Normal Maximum Gross Domestic Product; the maximum percentage of GDP that a player may expend on defense needs under normal (i.e. non-threatening) circumstances
NUMBER TURNS	field on the *Options* tab that allows the user to specify the number of game iterations
NUMPROCUREDPERYEAR	field on the "System Edit" screen that indicates the rate per year at which a strategic system is purchased and deployed
OFFENSES	function that allows the user to select systems that could be used to conduct strikes or inflict damage on an adversary.
OFFENSIVE FORCES	(see OFFENSES)
OK	(see OKAY)
OKAY	button that allows the user to confirm and accept changes made to the model

O&M   Operations & Maintenance; the cost of maintaining and
                                            using strategic forces

OMT   Other Military Targets; first strike preference for targeting
                                            adversary's non-strategic or supporting military capabilities

OPER RESERVE
STRIKE ALLOCATION   Operational Reserve Strike Allocation; percentage of
                                            strategic forces kept in reserve for follow-on strike

OPTIMIZER   Solver; the Microsoft Excel built-in optimizer

Pk %   probability that a missile defense intercept will result in a
                                            warhead kill

PLATFORM   type of strategic weapons system; system on which a
                                            weapon is based

PLATFORMNAME   field on the "System Edit" screen that indicates to the user
                                            the name of the type of weapons system selected

PLATFORMS   number of weapons system types

PLATPERBASE   field on the "Systems Edit" screen that indicates the
                                            number of platforms for a particular strategic system
                                            assigned to a given base

PLATS/SILOS   number of a weapons system type (i.e. ICBM's) based
                                            in silos

PLAT TYPE   type of weapons system platform selected

POST (COLOR) FIRST
MAIN STRIKE   the period after a player launches the first salvo in a
                                            nuclear exchange; a descriptive category of measure that
                                            describes player behavior and force disposition under
                                            actual or potential conditions of nuclear exchange

POSTURES   function that allows the user to define the position adopted
                                            by a player relative to its strategic environment and the
                                            other players in that environment; combination of the
                                            player's strategic capabilities and preferences

POTENTIAL ALLY   player whose interests and attributes make it a natural

candidate for alliance with the user's player; interim step to "Firm Alliance/Self"

PREWAR   strategic forces measured before any potential nuclear exchange; descriptive category of measure that characterizes player behavior and force disposition prior to conditions of nuclear exchange

PRIMARY   selection circle on "Doctrine/Employment Edit" screen that allows the user to specify what measure is most important

PRIMARY COMPETITOR   player identified as the foremost competitor by the user

PRODUCTION   the cost of manufacturing and deploying strategic systems

RANGE   denotes both the geographic scale of interaction between players and the corresponding operational ranges of strategic systems that might be employed in such a relationship; e.g. "self," "short," "medium," "intermediate," "intercontinental"

RANGE(km)   field on the "Systems Edit" screen that indicates the operational distance (in kilometers) of a particular strategic system in

RAW DATA   values and statistics for selected measures, displayed in spreadsheet format

R&D   Research & Development; the cost of conceptualizing and designing strategic systems

REL %   for a particular measure, the relative percentage between one player's measure value to that of its competitor

RELATIONSHIP   the nature of interaction between players; e.g. competitor ("Primary", "Secondary", "Tertiary"), alliance ("Potential", "Firm"), or "Neutral"

REPLAY   button that allows the user to display chart results from a previously played game

REPORT   button that allows the user to generate information on a Game

RESIZE FORM   button on the "Chart options" screen that allows the user to

adjust the display of the Chart options GUI

RESTORE MODEL
SUGGESTION   button on the "Posture Edit" screen that allows the user
                              to restore the model's suggested changes to strategic force
                              structure

RESTORE ORIG POSTURE   button on the "Posture Edit" screen that allows the user
                              to disregard the model's suggestions and restore the
                              strategic forces posture that it began the game with

RETALIATION
ALERT RATE   percentage of strategic forces that would be operational and
                              available for use in a counterstrike

RETALIATION
STRATEGY   player's preferred strategy on when and how to respond to
                              an offensive strike; either "OMT" or "SOF"

RIDEOUT   launch posture preference to survive and retaliate to an
                              adversary's first strike

RUN   button that allows the user to initiate a game

RUN MODE   field on the *Options* tab that allows the user to choose
                              interactive or automated operation of the model

RV   Re-entry Vehicle; a warhead's means of transportation;
                              often loaded onto a missile or launch vehicle; designed to
                              protect the warhead upon entering the earth's atmosphere
                              on approach to target; (*MDA*: "part of space vehicle
                              designed to re-enter the Earth's atmosphere at the terminal
                              point of its trajectory")

RVs NEG   (see RVs NEGATED)

RVs NEGATED   re-entry vehicles that have been defeated or denied access
                              to their targets, often by a player's strategic defenses

RVs PEN   (see RVs PENETRATING)

RVs PENETRATING   re-entry vehicles that have defeated or gained access to
                              targets, in spite of a player's strategic defenses

SAVE   button used to save a database item under its current name

SAVE ALL CHARTS   button that allows the user to save to one workbook charts

showing each measure's changes for each player over the course of a run

SAVE AS   button used to save a database item under a new name

SAVE DATA TO EXCEL   field on the *Options* tab that allows the user to record performance data from a game to an Excel spreadsheet for further review

SAVE NEW FORCE   button on the "Offensive (or) Defensive Edit" screens that allows the user to save modifications made to Offensive or Defensive forces during the course of a game

SCENARIOS   function that allows the user to construct a "story" (i.e. game) containing accumulated data and profiles for all of the other functions; primary interface between the user and model that allows the user to both design and run a game

SEA-BASED   strategic offensive forces launched from ships (e.g. SLBM)

SECONDARY COMPETITOR   player identified as the second most important competitor by the user

SELECT GDP FILE   button on the Criteria function that allows the user to access an external database for a player's GDP information

SELECTION BOX   box that indicates which field or function has been activated; often adjacent to another field

SELECTION CIRCLE   circle that indicates which field or function has been activated; often adjacent to another field

SHORT   (less than 1000 km); range of player relationship and corresponding strategic systems

SLBM   Submarine Launched Ballistic Missile; sea-based strategic offensive system; (*START*: "a ballistic missile with a range in excess of 600 kilometers of a type, any one of which has been contained in or launched from a submarine")

SLBM WARHEADS   warheads deployed on Submarine Launched Ballistic Missiles

SNDV   Strategic Nuclear Delivery Vehicles; systems for transporting and deploying strategic nuclear weapons (e.g. bombers, ICBM's, SLBM's, CM's)

SNDVPERPLATFORM   field that displays the number of Strategic Nuclear Delivery
                             Vehicles based on a platform or weapons system type

SOF   Strategic Offensive Forces; first strike preference for
                             directly targeting adversary's strategic warfighting
                             capabilities

SPREADSHEET_TEMPLATES   spreadsheet that contains formats to be used by the
                             exchange model portion of the program

SSBN   ballistic missile submarine

STARTTREATYCNT   field that displays the number of warheads per missile
                             permitted by START Treaty counting rules

START YEAR   field that allows the user to specify the year in which the
                             model initiates the game

SUA   Standard Urban Area; descriptive category of measure that
                             calculates the total urban area that would be affected during
                             a nuclear exchange; 200 km^2 (equivalent to New York
                             metropolitan area)

SUB CATEGORY   secondary category for measures; additional information
                             that allows the user to specify measures under varying
                             circumstances (e.g. Effective Balance Absolute PreWar)

SUPERHEAVY   measurement of weight that determines, in part, the
                             performance of a ballistic missile; vehicle with a launch
                             weight greater than 106,000 kilograms or a throw-weight
                             greater than 4350 kilograms

SUPER HEAVY ICBMs   an intercontinental ballistic missile of a type, any one of
                             which has a launch weight greater than 106,000 kilograms
                             or a throw-weight greater than 4350 kilograms[13]; field on
                             the ACRs function that specifies how many Super Heavy
                             ICBMs are allowed under a particular treaty

SUPER HEAVY ICBM
WARHEADS   warheads deployed on a Super Heavy ICBM; field on the
                             ACRs function that specifies how many Super Heavy
                             ICBM Warheads are allowed under a particular treaty

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[13] The definition for "Super Heavy ICBM" is interchangeable with the START I Treaty's definition for "heavy
ICBM", defined as "an ICBM of a type, any one of which has a launch weight greater than 106,000 kilograms or a
throw-weight greater than 4350 kilograms."

SYSTEMS

function that allows the user to shape the strategic platforms and forces supporting a player's offensive and defensive missions; systems are organizations of equipment, personnel, and/or resources integrated to perform a specific mission

SYSTEMNAME

field on the "System Edit" screen that indicates to the user the name of a selected weapons system

SYS TYPE

type of weapons system selected

TERMINAL

(MDA: "final portion of a ballistic missile's trajectory between the midcourse phase and trajectory termination")

TERMINAL INTERCEPTORS

defense systems designed to intercept hostile missiles late in flight on approach to target

TERTIARY COMPETITOR

player identified as the third most important competitor by the user

THRESHOLD VALUE

for a particular measure, the value at which behavior changes according to satisfied criteria

TOTAL

descriptive category of measure that characterizes the strategic balance between players calculated with all available strategic assets

TOTAL INTERCEPTORS

total number of interceptors combined (boost-phase, midcourse, and terminal)

TREATY

an agreement or institution designed to reduce tension and promote cooperation between competitors by way of reducing strategic forces; note: a treat does not necessarily signify an alliance (see also ACR)

TURN #

field that instructs model to display elements that correspond to selected turn number for the current form

TURN DURATION

field that allows the user to stipulate how many units of time (given in numbers of "years") each turn in the game represents (can vary from 1-5 years)

UNCERTAIN VARIABLE

selected variable will be used with the Check Uncertainty function (see CHECK UNCERTAINTY)

UNILATERALIST	player preference that favors individual, self-interested action over "Cooperation"
UNITS	standard quantity for a particular strategic measure (e.g. Warheads, Yield, EMT, CMP, SUA)
UPDATE MEASURES	button on the "Posture Edit" screen that allows the user to evaluate his/her position after the previous move and prior to the next move; calculates measures based on what the user identifies at the beginning of the game round
VALUE	quantitative assessment of worth for a given set of data; field that assigns numerical values to selected measures to denote amount or relative worth; either "Rel %" or "Absolute"
WARHEADS	section of the delivery vehicle containing the weapons payload; also, the number of warheads present for weapons system type; (*START*: "a unit of account used for counting toward the 6000 maximum aggregate limit and relevant sublimits as applied to deployed ICBMs, deployed SLBMs, and deployed heavy bombers"); (*MDA*: "A weapon, usually thermonuclear, contained in the payload of a missile.")
WEAPON	in terms of the model, a strategic system designed to inflict damage or injury on an adversary by either drawing down the adversary's own weapons or counting towards the standard urban area (SUA) metric
WEAPONPENFACTOR %	Weapon Penetration Factor %; the probability that a strategic weapon will penetrate an adversary's defenses
WEAPONS	the number of strategic systems designed to inflict damage or injury on an adversary; (see WEAPON)
WEAP TYPE	the type of strategic weapon equipping an offensive air-based platform
WH	Warhead (see WARHEADS)
WHPERSNDV	Warheads per Strategic Nuclear Delivery Vehicle; field that displays the number of warheads carried by a missile or bomber
YEAR AVAILABLE BLUE	field on the "Systems Edit" screen that indicates what year

in the model scenario the BLUE player may acquire a particular strategic system

YEAR AVAILABLE GREEN

field on the "Systems Edit" screen that indicates what year in the model scenario the GREEN player may acquire a particular strategic system

YEAR AVAILABLE ORANGE

field on the "Systems Edit" screen that indicates what year in the model scenario the ORANGE player may acquire a particular strategic system

YEAR AVAILABLE PURPLE

field on the "Systems Edit" screen that indicates what year in the model scenario the PURPLE player may acquire a particular strategic system

YEAR AVAILABLE RED

field on the "Systems Edit" screen that indicates what year in the model scenario the RED player may acquire a particular strategic system

YEAR OUT OF PRODUCTION

field on the "Systems Edit" screen that indicates what year in the model scenario a particular strategic system will no longer be manufactured

YEAR OUT OF SERVICE

field on the "Systems Edit" screen that indicates what year in the model scenario a particular strategic system will be de-activated and withdrawn from the arsenal

YIELD

measure of nuclear warhead's explosive power (in megatons); (*MDA*: "The total effective energy released in a nuclear—or atomic—explosion.")

YIELD(MEGATONS)

measure of nuclear warhead's explosive power in millions of tons of TNT (see YIELD)

+%

field on the "Chart options" screen that allows the user to check the uncertainty of a variable by entering a number that will adjust the current value for the given variable by a positive percentage in order to determine what effect this positive change has on the measure results

-%

field on the "Chart options" screen that allows the user to check the uncertainty of a variable by entering a number that will adjust the current value for the given variable by a negative percentage in order to determine what effect this negative change has on the measure results

#SNDV   number of Strategic Nuclear Delivery Vehicles

#WEAPONS   number of weapons

#WH   number of warheads

B.   Troubleshooting

Errors and "Bugs"

If you encounter an error or "bug" during operation of the model, first back out of the model and start again.
- Close unnecessary applications to minimize potential sources for errors.
- Replicate operation to confirm the error is legitimate.
- Test associated operations to see if they cause a similar error.

Applications and Software

The model is compatible with Microsoft Office 2000. Earlier versions of Office utilize different Access database formats that most likely will be incompatible with the model database.

Switching to other applications while the program is running may prove problematic, perhaps because of the Operating System. On a Windows 98 machine, the process of switching to another application can cause a Microsoft Automation Error in some cases, whereas in other cases the program continues to run unaffected. On a Windows 2000 machine, switching to another application may cause the program to pause until the user clicks on the Excel icon again. Therefore, caution should be used in such cases, since the result can be unpredictable. If an Automation Error occurs, the user will need to close out of Excel completely and then restart the model.

Database Complications

The database can become fairly large (on the order of tens of Megabytes) as more and more scenario run results accumulate in it. As the database becomes populated and gets to be 10 MBytes-plus, data retrieval will slow down perceptibly for actions such as deletion of items, generation of reports, and replay of results. Therefore, the user might occasionally need to "archive" databases and start with a "clean" database that contains no run results before running more cases.

Even deleting old scenario results does not necessarily reduce the size of the database file. One way to reduce the size of the database file is to open the file in Microsoft Access, then go to the menu and click on Tools/Database Utilities/Compact and Repair Database. This should probably be done on a semi-regular basis to keep the database file size under control.

C. Technical Materials

Appendix C contains technical documentation and resources that accompany the SODAC Model.

1. OPTIMIZATION

Solver, the optimizer, takes a set of variables and a set of constraints and will attempt to maximize or minimize a particular cell value by changing the values of the variables. In our case, the variables consist of the numbers of platforms and interceptors for a player's offense/defense and the item maximized or minimized is cost or one of the measures. The constraints consist of 5 categories:

1) Constraints on the system variables themselves. (i.e. the number of platforms for SystemX cannot exceed 100 in the current turn, due to industrial capacity, out-of-production, etc.)
2) Cost constraints. The cost of building, maintaining and doing R&D on various systems cannot exceed a certain percentage of a player's GDP for each year that makes up the current turn. (If turn 1 encompasses the years 2001 through 2003, then a corresponding cost constraint will be in place for each of these years.)
3) Triad constraints/ratios. This refers to the percentage a player wants for each type of warhead (land, sea and air) and interceptor type (BP, MC, Term).

4) Treaty constraints. For players that obey offensive and/or defensive aspects of treaties, constraints are placed on the various categories so that the player is constrained to make even reductions on number of warheads, number ICBMs, etc. each year leading up to the treaty implementation year in order to meet the objectives.
5) Measure constraints. The threshold values set for Guaranteed retaliation, RVs Negated, etc. tend to increase offensive and/or defensive force structure.

The choice sequences employed force a player to attempt to minimize cost while enacting the five types of constraints and changing the values in the variable cells. If the first attempt fails to meet all constraints, then a second attempt will be made. The only difference between the first and second attempt might be that the first time, the model's variables consist of offensive forces only, while in the second attempt the model's variables
consist of both offense and defense, depending on what the player's criteria preferences are. If the second attempt were to fail to meet the constraints also, then the optimizer will, as a final attempt, try to maximize one of the measures, specifically the primary measure, while still enacting all of the constraints except for the measure constraints. The exception is that a constraint will be enacted for the primary measure which is to be maximized. For example, if the primary measure is Number of Guaranteed Retaliation Warheads, and its associated original threshold was 1000 warheads, then when this measure is maximized, a new constraint of 1100 warheads will be enacted for this measure. This 10% addition to the threshold is an arbitrary number used simply to help prevent the optimizer from greatly "overshooting" the original threshold value for this measure.

Analysis of run performance has demonstrated that when measure constraint(s) are too high (or too low in the case of RVs Penetrating), the optimizer will tend to "spin wheels." That is, attempting to minimize cost while meeting the measure constraints in these cases can often result in failure. Therefore, the model would, for many turns possibly, make 2 attempts while minimizing cost before making the third attempt in which it maximized the primary measure.

The model now allows for several "learning modes". If "none" is selected, the model will run in its original manner, that is, to go through the entire choice sequence every turn. If "Choice 1 then maximize" is selected, the model will attempt the first part of the choice sequence, say minimize cost while modifying offensive platforms, and if this attempt fails, the model will maximize the primary measure. If "Maximize measure" is selected, as the name suggests, the model will skip straight to maximizing the primary measure. If "Choice sequence or maximize" is selected, the model does a "quick check" to help decide whether the optimizer will go through the choice sequence or go straight to maximizing the primary measure. This "quick check" does the following, without utilizing Solver:

a) Maximize each variable. That is, set each variable cell to the constraint value associated with that variable. For example, if there are 50 platforms of System X at the beginning of the turn, and the constraint on this system is 100, then set that cell value to 100. For systems just becoming available this turn, it works similarly, except that the initial value would be zero instead of 50, etc.
b) Loop though each of the measure constraints and see if they all have been met now that the system variables have been maximized.
c) If any one of the measure constraints is not met, such as Number of Guaranteed Retaliation Warheads only reaching 900, not its threshold of 1000, then the model will not waste time going through the choice sequence and will simply maximize the measure through the optimizer. However, if all measure constraints are met after maximizing each system variable, then go through the choice sequence, since there's a reasonable chance that all constraints may be met even when minimizing cost.

It should be noted that when the optimizer is "maximizing a measure" it doesn't necessarily have to maximize all the system variables, although often this does occur in practice, especially in the absence of treaty and triad constraints. So the "quick check" of maximizing the system variables can mimic what the optimizer will do in some cases, but not in every case.

2. MODEL PERFORMANCE AND MATHEMATICAL FOUNDATION

Model Fundamentals

- **Actor behavior driven by expected force performance**
- **Force performance measures based on the number of warheads and their destructive capability**
  - Raw Force Totals
  - Yield
  - Equivalent Megatonnage
  - Counter Military Potential
  - Area Destroyed
  - Negated by Defense
  - Penetrating Defense
- **Force performance measures combined to produce measures of effectiveness**
  - Guaranteed Retaliatory Capability
  - Averted Losses
  - Balance of Power
  - BMD Performance

Measures of Performance

- **Force performance measured several ways**
  - Total number of effective warheads (Raw force totals)
  - Total effective force yield
  - Total effective equivalent megatonnage
    - $\text{Yield}^{(2/3)}$
  - Total effective counter military potential
    - $\text{Yield}^{(2/3)} \div \text{Accuracy}^2$
  - Number of Standard Urban Areas destroyed
    - $(\text{Yield}^{(2/3)} \times 58) \div 200$
    - 1 EMT generates a 2-3 psi shock wave over the equivalent area of 58 sq km
    - 200 sq km defines a "Standard Urban Area" - equivalent to New York metropolitan area
  - Warheads negated
  - Warheads penetrating defense
- **All performance measures based on number of warheads**

Measures of Effectiveness

- **Guaranteed Retaliatory Capability**
  - Effective capability of those forces surviving a 1st strike
    - Measured against total forces, or those available for non-SOF targets
  - Key measure of deterrence and stability
- **Averted Losses**
  - The difference between striking first, and waiting to be struck
  - Measured in terms of enemy capability to inflict damage on friendly side
    - Total damage, or damage against non-SOF targets
  - Key measure of crisis stability
- **Balance**
  - Measures equivalence of forces
    - Total forces, or those available for non-SOF targets
  - Provides insights into perceptions of advantage
  - Basic stability measure
- **BMD Performance**
  - Minimalist measure – RVs negated (for example 20)
  - Maximalist measure – RVs penetrating (for example, 0)

Underlying Model Structure

$$w_e = w_a \times p_s \times p_l \times p_p \times p_d$$

w_e Effective Weapons

w_a Weapons available

p_s Probability of Survival against Enemy strike

p_l Probability of Launch

p_p Probability of Penetration against Enemy defenses

p_d Probability of Detonation

Guaranteed Retaliatory Capability

$$R_g = w_m \times p_{sm} \times p_l \times p_{pm} \times p_d + \; w_r \times p_{sr} \times p_l \times p_{pr} \times p_d$$

Main Strike   Reserve Strike

R_g Guaranteed retaliatory capability
w_m Weapons available for retaliatory strike
p_{sf} Probability of Surviving Enemy 1st strike
p_l Probability of Launch
p_{pr} Probability of Penetration for Retaliatory strike
p_d Probability of Detonation
w_r Weapons available reserve strike
p_{sr} Probability of Surviving Enemy Reserve strike
p_{pr} Probability of Penetration for Reserve strike

Averted Losses

$$l_a = (w_f \times p_l \times p_{pf} \times p_d) - (w_r \times p_{sr} \times p_l \times p_{pr} \times p_d)$$

Enemy 1st Strike   Enemy Retaliatory Strike

l_a Averted Losses
w_m Weapons available for 1st strike
p_{lr} Probability of Launch
p_{pr} Probability of Penetration of 1st strike
p_{dr} Probability of Detonation
w_r Weapons available for Retaliatory strike
p_{sr} Probability of Survival of Retaliatory strike
p_{pr} Probability of Penetration for Reserve strike

Balance

$$B_{ib} = \frac{(w_f \times p_l \times p_{pf} \times p_d) + (w_{rr} \times p_{sr} \times p_l \times p_{pr} \times p_d)}{(w_f \times p_l \times p_{pf} \times p_d) + (w_{rr} \times p_{sr} \times p_l \times p_{pr} \times p_d)}$$

$$B_{pbb} = \frac{(w_{rr} \times p_{sr} \times p_l \times p_{pr} \times p_d)}{(w_r \times p_l \times p_{pf} \times p_d) + (w_{rr} \times p_{sr} \times p_l \times p_{pr} \times p_d)}$$

$$B_{pbr} = \frac{(w_r \times p_l \times p_{pf} \times p_d) + (w_{rr} \times p_{sr} \times p_l \times p_{pr} \times p_d)}{(w_{rr} \times p_{sr} \times p_l \times p_{pr} \times p_d)}$$

B_{ib}	Initial balance (from Blue's perspective)
B_{pbb}	Post Blue 1st Strike balance (from Blue's perspective)
B_{pbr}	Post Red 1st Strike balance (from Blue's perspective)
w_f	Weapons available for first strike
w_r	Weapons available for retaliation strike
p_{sf}	Probability of Surviving Enemy 1st strike
p_l	Probability of Launch
p_{pr}	Probability of Penetration for Retaliatory strike
p_d	Probability of Detonation
w_{rr}	Weapons available reserve strike
p_{sr}	Probability of Surviving Enemy Reserve strike
p_{pr}	Probability of Penetration for Reserve strike

Weapon Availability

$$w_? = w_a \times p_s \times p_l \times p_p \times p_d$$

$$w_a = w \times a_s \times r_a$$

w_a Weapons available

w Weapons

a_s Strike Allocation

r_a Alert Rate

- **Strike Allocation**
  - Percent of forces intended for a particular strike
- **Alert Rate**
  - Percent of forces on-line - not down for maintenance

Probability of Survival

$$w_? = w_a \times p_s \times p_l \times p_p \times p_d$$

$$p_s = \frac{(w \times r_a) + (w_a - w_{at}) + (w_{at} \times p_{sv})}{w}$$

w_a	Weapons available
r_a	Alert rate
w_{na}	Weapons not attacked
w_{at}	Weapons attacked
p_{sv}	Probability of survival

- **Alert rate**
  - For mobile weapons - percent at sea in the air or out of garrison at 0 hour
  - For silo-based weapons - percent ready for launch under attack
- **Probability of survival**
  - Based on target hardness, and number, yield, accuracy, reliability, and penetration of weapons allocated against
- **Weapons Attacked**
  - Based on number of weapons available, number of targets, number of weapons required to achieve desired probability of damage, projected reliability, probability of penetration

Probability of Survival

$$p_s = \frac{(w \times r_a) + w_{na} + (w_{at} \times p_{sv})}{w}$$

$$p_{sv} = p_{svr}^{w_a}$$

$$w_r = \frac{1}{\log(p_{svr}) \div \log(damage_{rqmt})}$$

$$P_{svr} = 0.5^{\left(\frac{yield^{2/3}}{accuracy^2} \cdot \left(\frac{hardness}{16}\right)^{2/3}\right)} \times p_l \times p_p \times p_d$$

$yield$	Megatonnes
$accuracy$	CEP in nautical miles
$hardness$	Pounds per square inch
$damage_{rqmt}$	Probability of Destruction Required
p_{svr}	Raw probability of survival
p_l	Probability of launch (Reliability)
p_p	Probability of penetration
p_d	Probability of detonation (Reliability)
w_r	Weapons required
w_a	Weapons allocated (Equals weapons required to point of exhaustion, then zero)

Probability of Penetration

$$w_? = w_a \times p_s \times p_l \times p_p \times p_d$$

$$p_p = \frac{(w_a - w_e) + (w_e \times (1-P_k)^{f_d})}{w_e}$$

$$w_e = \frac{i_a}{f_d} \times \frac{w_a}{w_a + d_a}$$

w_a	Offensive Weapons in Strike
W_e	Weapons engaged
p_k	Probability of kill
f_d	Firing Doctrine
I_a	Interceptors Available
I_a	Decoys in Strike

- **Weapons Engaged**
  - Based on number of interceptors available, strike size, number of credible decoys accompanying strike
- **Firing Doctrine**
  - Based on number of interceptors, expected raid size
- **Decoys in Strike**
  - Based on system characteristic of credible decoys per warhead

Assumptions & Limitations

- **Perception**
  - Planning done with perfect knowledge of offensive and defensive capabilities
- **Targets**
  - Targets limited to 2 categories
    - Strategic Offensive Forces - silos, sub bases, main airbases
    - Other - bunkers, dispersal fields, military bases, c2 nodes, war supporting industries, urban areas
  - Alert, non-silo based forces not targetable
  - Targets geographic distribution not considered
  - Each target affected independently
- **Offensive Force Targeting**
  - Non optimized
  - Starts with softest targets, weapons allocated in order of appearance in database
- **Offense Performance**
  - Damage model based on overpressure only
- **Defense Performance**
  - Strikes uniformly distributed
  - Credible decoys uniformly distributed
  - Firing Doctrine derived with perfect knowledge of raid size