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A Microcomputer Workshop Exploring The Dynamics of Arms Races

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ABSTRACT

This microcomputer workshop is being developed to encourage exploration, testing, and discussion of the impact of alternative arms-building policies. The model allows participants to adjust parameters that reflect a number of psychological, technical, and political factors. For example, participants can represent one country's tendency to overestimate the strength of the other and underestimate its own strength. Before releasing the model to the public, we are reviewing its conceptual soundness and its educational effectiveness to be sure that it reflects empirically supported technical, psychological, and political realities. The presentation of this paper and the early versions of the workshop are part of this preliminary review process.

INTRODUCTION

How can countries maintain an adequate national security while at the same time avoiding a potentially destabilizing escalation in the numbers and power of weapons? Increases in military capability improve a country's sense of security while at the same time diminishing its adversary's perceptions of security. If the adversary responds by increasing its armaments, the consequent escalation of forces can create a dynamic frequently called an "arms race."

"Exploring the Dynamics of Arms Races" is a microcomputer workshop being developed to encourage participants to explore, test, and discuss the impact of alternative arms-building policies. Participants adjust competing countries' parameters, one at a time, on a simulation model to reflect the most plausible and rational policies they think each country could adopt. Each country's objective is to maintain a level of arms consistent with its national security objectives relative to its perception of the level of arms of the opposing country.

The model allows participants to adjust parameters that reflect a number of psychological and political biases. For example, participants can represent one country's tendency to overestimate the strength of the other and underestimate its own strength. The model also incorporates realistic delays for changing perceptions and closing gaps in the relative levels of arms.

When participants adjust parameters for each country in isolation to reflect policies that are most "rational" from that country's point of view, the combined simulation for both countries will frequently show an accelerating arms buildup. The workshop also shows that uncertainty and fear about the adversary's total offensive capability can amplify a

country's tendency to overestimate the numbers and destructiveness of opposing arms and underestimate its own strength. These kinds of psychological, political, and competitive forces can continue to drive arms races even when negotiations lead countries to choose parities or even build downs as their policy goals.

This project started as a result of a trip by Jay W. Forrester to Moscow in October of 1983 for discussion of how system dynamics could be applied to social problems. There was some interest shown in exploring the forces underlying arms races (Forrester 1984). After his return, Professors Jay W. Forrester, Peter M. Senge, John D. Sterman and David P. Kreutzer of the System Dynamics Group; Professor Nazli Choucri of the Political Science Department at M.I.T.; and Dr. Ron Heifetz and Bruce Allyn from the Kennedy School of Government at Harvard met monthly to discuss how best to use computers to increase public understanding of the arms race.

In the spring of 1984 Forrester created a simple model, with suggestions from Sterman and Senge, to illustrate to the group what a system dynamics model could contribute. Shortly thereafter, Sterman and I modified this model into a workshop for our summer session. This model is similar to the conceptual framework for studying NATO-Warsaw Pact force strength competition proposed by C. White in 1981. The model has two goal seeking loops competing over their relative force ratios as well as separate levels for the actual and perceived levels of arms. This feedback representation with economic constraints follows in the tradition of British meteorologist Lewis Richardson who developed a mathematical model of arms races in 1919 that has become a standard way of analyzing arms races in political science. (Schrodt 1982, p. 108.) There is some empirical research supporting this kind of representation (Ward 1984, p. 196). The conceptual soundness of the present model and its educational effectiveness needs much more research and review before it is released to the public.

The purpose of this paper is to solicit advice on the technical and psychological correctness of the model and workshop and to check to make sure it does not convey unsupportable and biased viewpoints. For this same reason we have been testing preliminary versions of the workshop with high school and college students, teachers, political scientists, business people, experts in arms control, visitors from the Soviet Union and members of our own defense establishments. From these experiences we have modified the software presentation style and model several times and anticipate several more rounds of modifications prior to release.

USING SIMULATION MODELS FOR EDUCATION AND DISCUSSION

This workshop is part of a larger ongoing project to develop educational software for use in homes, schools, and businesses to illustrate how simulation models can improve understanding of complicated problems. One purpose of the project is to show how a model can improve communication between persons with opposing viewpoints by demonstrating the consequences of differing underlying assumptions. We plan to create several companion models that reflect other ideas about causes of arms races, such as Professor Nazli Choucri's theory of lateral pressure as a cause of international competition.

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In order to more adequately incorporate other viewpoints and increase the use of models for educational discussion, the materials will become available to the public on software disks. The model was originally written in Micro-DYNAMO, however, in order to be able to provide the model at a nominal cost with permission to copy and change material on the disks we are developing our own software. Karl Buttner, an MIT undergraduate, and Junko Vietze, a member of the System Dynamics Group staff, have been working with me to create simulation software that is easier to use and has more advanced interaction capabilities such as stories, help files, and built in explanations. We hope the response to this permission to copy will be that people will build their own models and modifications to more accurately express their own viewpoints, analyze others viewpoints and send us their new models and responses.

WORKSHOP FORMAT AND OVERVIEW OF MODEL STRUCTURE

In the workshops, I introduce the model by explaining that system dynamics is a way of looking at problems at three levels: events, patterns of behavior and underlying causal structure. I ask workshop participants to think of examples of events in their lives related to arms races. Participants usually volunteer examples such as the bombing of Hiroshima, newspaper headlines of debates over the MX missle, Strategic Defense Initiative, Cuban missile crises, or Geneva peace talks. These are written on a chalkboard.

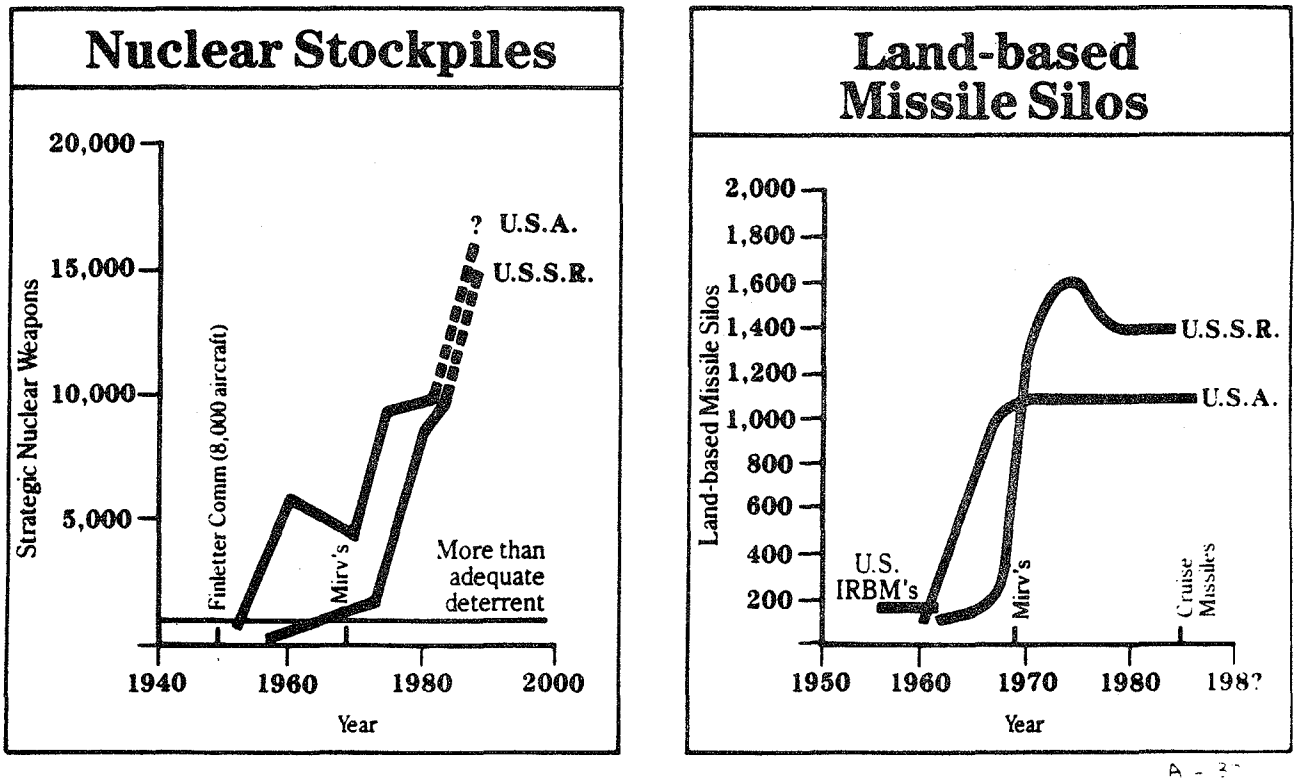

Figure 1. Examples of patterns of behavior associated with US-USSR arms race (Weisner 1985, p. 9).

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I then ask them to think of patterns of behavior over time. The most frequently suggested example volunteered is an exponential growth in nuclear arms. I then show them examples of estimates of the real data by Jerome Weisner shown in Figure 1. Looking at the numbers of nuclear warheads possesed by each side gives the impression that we are seeing exponential growth.

I then ask participants to think of a cause and effect explanation or structure that could produce such an escalation in arms. In all but one workshop they have volunteered some version of the positive feedback loop seen in Figure 2. Figure 3 is then presented as an elaboration of Figure 2. This format has turned out to be more effective than an earlier format where I presented Figure 2 then Figure 3 in a lecture mode. In its current form Figure 3 is very difficult for general audiences to understand. When they see it merely as an elaboration of their own idea, it seems to be less difficult. It is still much too complicated. In our software for the IBM PC we do not have sufficient pixel resolution on the screen to be able to present Figure 3. I am experimenting with a new intermediate diagram with simple, intuitively obvious, icons. The intelligence sector in the lower right hand corner is represented with a satellite. The evaluation of domestic arms and the estimate of opposing arms is processed in the classic five sided symbol of the Pentagon. The margin of superiority and effects of economic constraints are in a picture of the Capitol building. The rates and levels associated with the arms in production and stockpile are replaced with pictures of workmen and missiles. This oversimplification breaks with system dynamics symbol tradition but is necessary to communicate to the general public.

By moving a cursor over the symbol of interest, a window on the screen prompts you with your choices. If you are above the Capitol building for example, the prompt would be "would you like to change your margin of superiority?" If so, you do it by adjusting a thermometer like symbol that "floats" through readings of 10%, 15%, 20%, etc. so that you do not have to type in numbers. This more intuitive display and interaction style is particularly valuable for adult groups who are usually far less familiar with computers than high school students.

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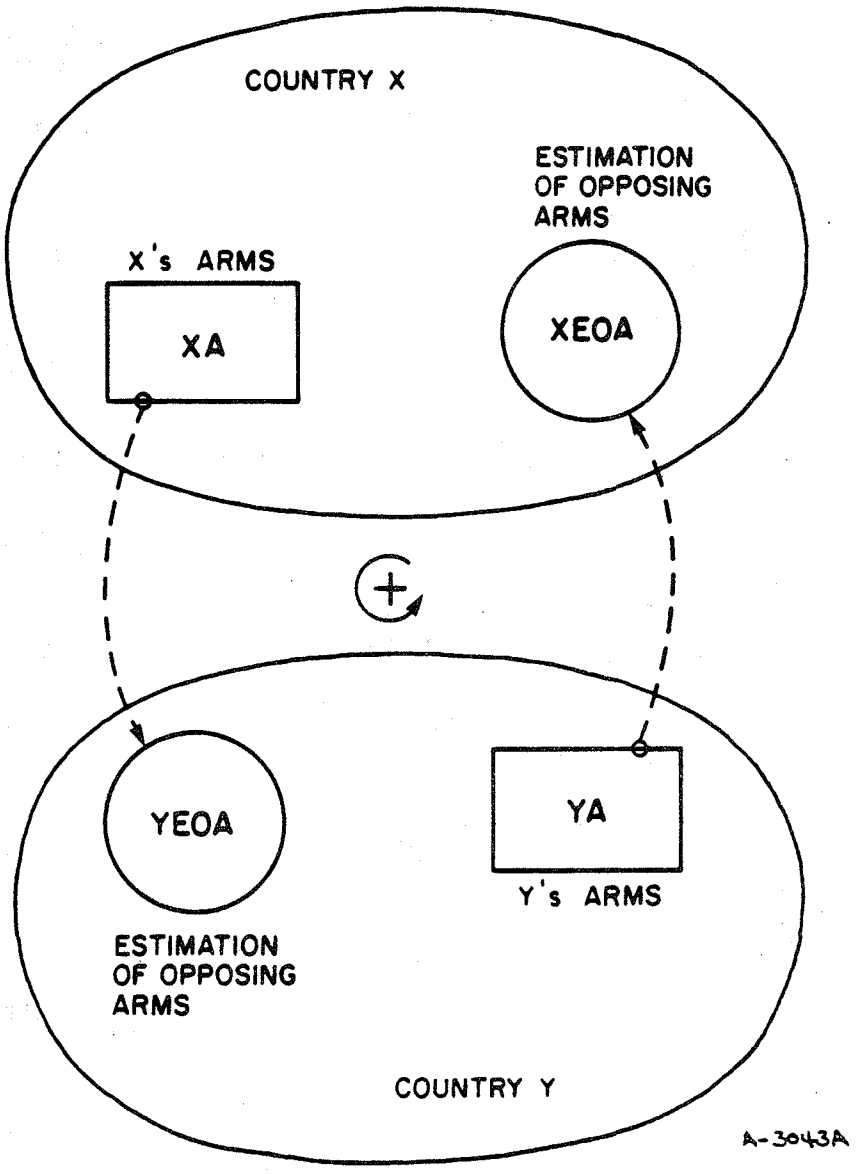

Figure 2. A positive-feedback loop connecting countries X and Y can produce exponential growth. If country X attempts to raise its level of arms above Y, and country Y attempts to keep its level of arms above X, arms spiral upward.

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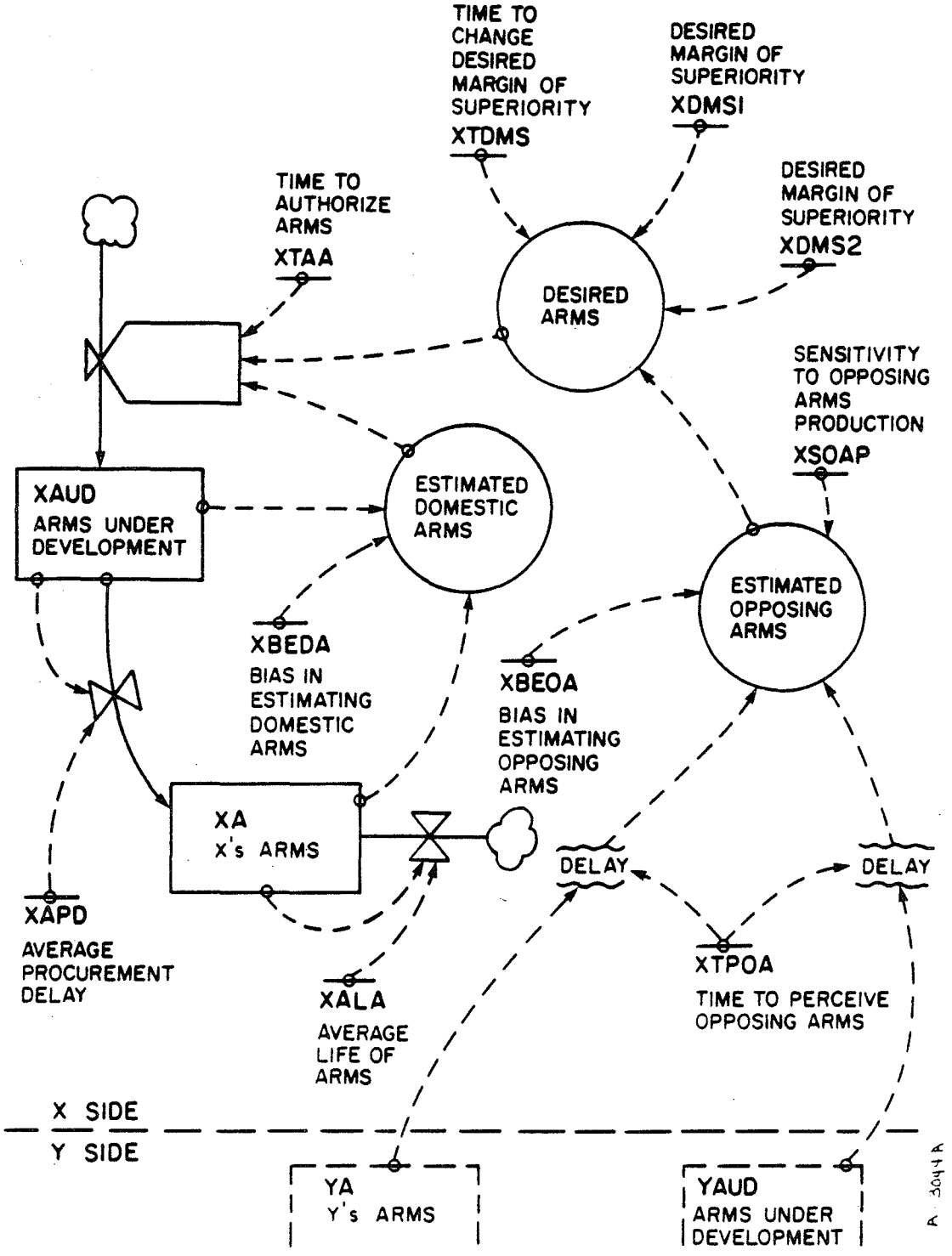

Figure 3. A flow-diagram of country X's arms planning. Country X's intelligence system estimates country Y's arms. After taking into account its desired margin of superiority (or inferiority), X determines its own desired level of arms. X then evaluates its own capability and authorizes spending on new weapons. After a procurement delay, X has a new level of usable arms. Country Y has a similar structure. Also shown are the policy levers that allow testing of alternatives.

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USING THE SIMULATIONS

After this brief presentation of the structure we proceed through a series of simulations. The strategy here is to demonstrate that the model is a way of extending, testing, and exploring their own assuptions. Rather than presenting my opinions, we use partial model testing and purposefully set the original parameters to neutral or even incorrect values. A guided series of exercises requires the participant to correct parameter values or choose values they think are more plausible.

This seems to be effective for three reasons. First, it is more fun to learn about the model by playing with it than by having a longer lecture on the structure. Second, many people assume that arms races are caused by evil or misguided generals and politicians. By producing arms races from participants' own chosen policies, the model provokes a rethinking of prior assumptions and illustrates the importance of structure in producing behavior. It also introduces the concept of bounded rationality. Third, it emphasizes that this is a hypothetical logical excercise, the purpose of which is to stimulate thinking and not a policy recommendation based on the analysis of the real system.

SUMMARY OF SIMULATIONS

DPK843: This model simulation shows an "equilibrium" with all policies in a neutral condition. Both countries start with 100 units of arms, accurately perceive the other side's level of arms, and desire only parity.

DPK844: Before using a model you should always "test-drive" it. Here we see country X's response to a 10% exogenous increase in arms at country Y starting from equilibrium. X's response is too slow. How could you speed it up?

DPK845: Shortening X's time to adjust arms, XTAA, from 5 to 2 gives a more plausible response time. Country Y is still held constant for test purposes.

DPK846: A 10% bias in estimating opposing arms is added to the conditions in DPK845. Country Y is still held constant.

DPK847: Country Y is now allowed to respond. Country X is able to unilaterally drive an arms race even though both countries desire only parity. Country X's bias is equivalent to a desired margin of superiority.

DPK848: In addition to the 10% bias shown in Figure 9, Country X desires a 10% margin of superiority. This increases the rate of growth of the arms race.

DPK849: At year 30, Country Y changes its definition of security and is now willing to accept a margin of arms 25% less than Country X. This is sufficient to offset the growth pressure caused by X's desired margin and bias thereby producing a slow decline in arms.

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DPK850: When more realistic policies are added to the rest of Country X, however, the same strategy which ended the arms race in Figure 11 now is overwhelmed and no longer works.

DPK851: When more realistic values are added for Y as well, the rate of growth is even faster.

DPK852: Both countries now have more realistic policies. Y no longer accepts a 25% margin of inferiority at time 30. This rate of growth is closer to, but still slower than, the real growth rates in the U.S. arsenal.

DPK853: If both countries agree to set their desired arms to 15% below what the other side has there is still an arms race. The biases and inaccuracies in evaluating domestic and foreign arms are sufficient to produce an arms race even when both countries have a goal of a build down.

DPK854: A build down is theoretically possible if the commitment is sufficiently aggressive to offset the growth pressures from the biases and inaccuracies. These simulations are not an analysis or proposal, but merely a logical exercise for studying the interaction of selected policies.

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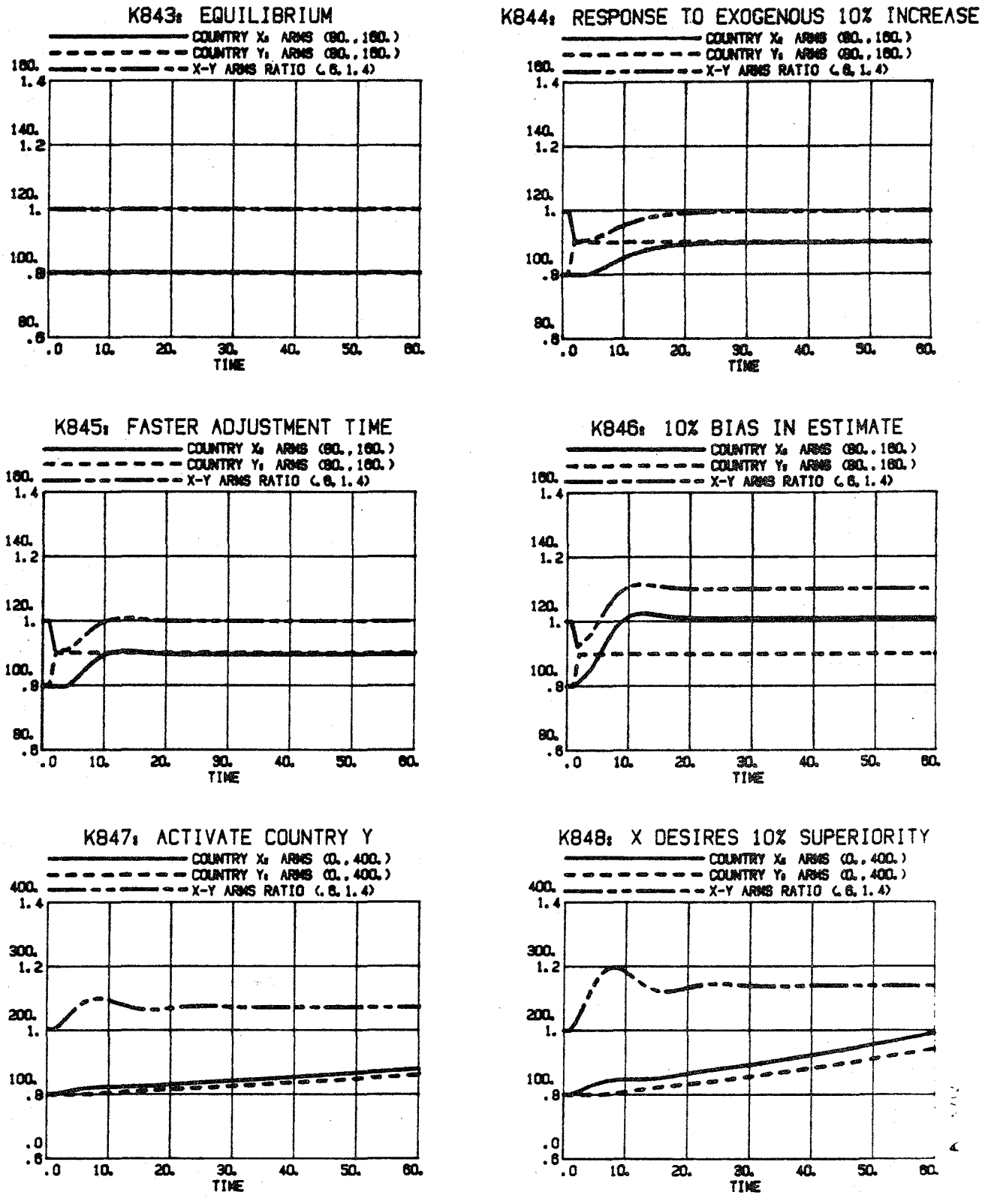

Figure 5. Selected simulation runs from workshop.

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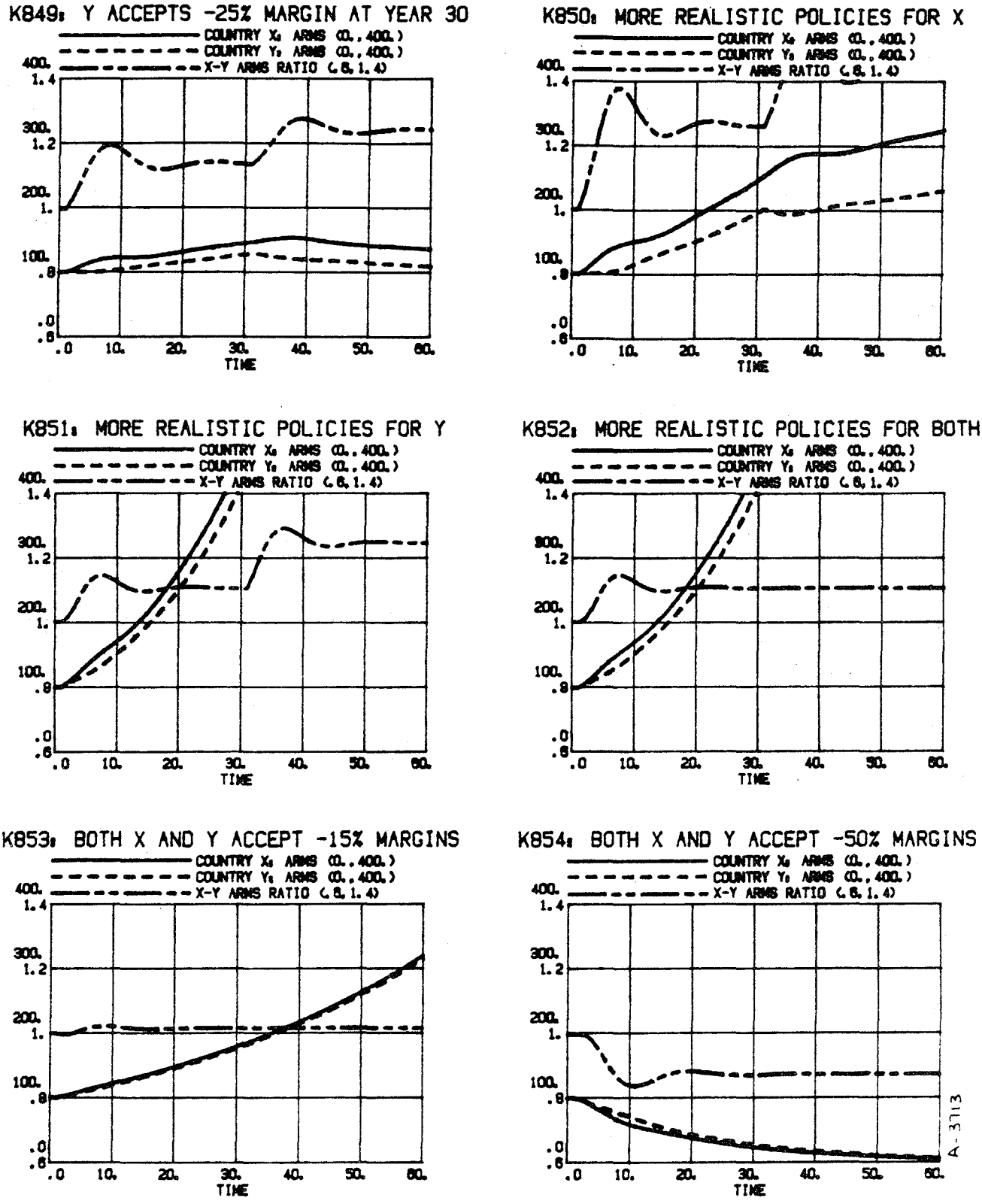

Figure 6. Selected simulation runs from workshop (continued).

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ISSUES AND COMMENTS RAISED IN TRIAL TESTING

With the advent of new generations of weapons technologies and the continued instability in certain sectors of the international there is growing public concern and discussion of arms races. While most people seem to view themselves as patriotic citizens and support the need for their countries to be secure against attack or manipulation by adversaries, there is little agreement on how to best achieve such security.

The phrase "arms race" connotes a wide range of images to different people. For some, it brings to mind an exponential escalation of weapons that could potentially lead to disaster. To others, the arms race is an unfortunate necessity forced upon us by hostile and agressive adversaries. There are some who have expressed the notion that arms races are innocuous and perhaps even a beneficial stimulant to the economy and to the advancement of science and technology. There are also political components across the range of perspectives. Although greatly oversimplified, those who regard themselves as liberal seem to be more likely to see the primary issue of the arms race as the threat of nuclear war and the destruction of civilization. On the other hand, people who describe themselves as more conservative seem to place more emphasis on the threat of domination or manipulation by foriegn adversaries (Marks 1985).

It has been interesting to notice how these differences in starting assumptions affect what you see in the model. Liberals tend to notice that even if both countries are building arms very quickly, but at the same rate, neither country is any more or less secure. On the other hand, one defense contractor noticed that because the model represented depreciation and obsolesence of the arsenal, a country needs a constant stream of replacement orders just to stay even. He said this is something "freeze people" often don't realize. Many of the weapons, such as the MX missile and the B1 bomber, that many think of as an escalation of arms, he views merely as replacements for aging outdated weapons such as the Trident and B52. He has raised issues which could show how a dynamic model could add a great deal of precision to the "freeze" debate. If a freeze is thought of in terms of freezing the investment rate, and that is higher the rate of obsolesence, the level of arms will still increase. There would be very different implication depending on whether a freeze were to be proposed in terms of expenditures, expenditures as a fraction of GNP, absolute numbers of weapons, or the total technological destructiveness of the weapons. Again, it is important to note that the model is not a proposal, but merely and examination of the relationship between structure and behavior.

For me, the experience of showing the model to dozens of groups has been interesting and educational and has lead me to change my opinion about what is the best way of using a simulation model for stimulating public debate. One striking feature of almost everyone I've talked to is that no matter where they stood on the issue from the most radical or most conservative, they almost always view their own position on the issue as the most reasonable. They view the other positions on the political spectrum as often naive, suspicious, demented, misinformed, etc. but seldom more correct than their own.

There have been many interesting comments. One older man said, "it disturbs me to see so many bright, well intentioned young people wasting their time and energy over an issue that they really can't have much influence on." He accepts Wiesner's assertion that above a certain threshold of overkill, additional weapons don't really add to security. But, "so what, arms races don't matter. Give the generals what they want. At a time when there is unemployment and excess capacity in the economy it would irresponsible to cut back on military expenditures."

One expert expressed concern that the model might be misused to mislead the public to support a particular political position. Another suggested that using country X and country Y rather than the US-USSR was naive and unnecessary. Another interesting comment was that there may be occasions in negotiations and debate where a better, clearer, more explicit representation of each parties viewpoint is not useful and may even be counter-productive.

These are the kinds of reactions we need to analize and think about over the next year as we work on turning the model into a tool of stimulating thinking, discussion, and debate about national security and arms races.

CONCLUSIONS AND NEXT STEPS

The conceptual soundness of the present models and their educational effectiveness need to be reviewed by a variety of evaluators before releasing the model to the public. We must be sure that it is correct both technically and psychologically. It must not convey unsupportable and biased viewpoints.

I have added a single economic sector to illustrate the "guns versus butter trade-offs" and also the long-term versus short-term trade-offs possible with higher fractions of a nation's output devoted to military expenditures. Some evidence indicates that military investments are not as efficient as capital investments. To the extent that increases in military expenditures come from domestic capital investment rather than consumption there is a danger that the military will get a larger fraction of a smaller GNP. This idea needs much more research and review before preliminary testing in the workshop model. It is just one example of a potentially sensitive issue where a cautious approach is called for.

There is still much work to be done on the software adding error checking and a more facile and intuitive interaction. One important change in our thinking arising from the workshop tests is that it will be more difficult than we thought to design the software to be entirely self-explanatory, thereby replacing the need for a workshop leader and making possible wide distribution. The reaction so far is that a highly valuable part of the workshop are the stories, interpretations, and answers to questions, provided by the workshop leader. Although we have a limited number of stories and data stored in interactive menus within the software the messages and purpose is not sufficiently clear to adequately replace a workshop leader.

The number of weapons has escalated continuously for the last forty years

despite a number of administrations and treaties. This suggests that there must be deeper underlying forces that can propel an arms race. The study of these underlying political and psychological forces and the structure of the information channels of the relationship between both countries, with interactive feedback simulation models, represents important areas of research and public education. Considering these system properties when proposing solutions will probably increase the likelyhood of success.

System dynamicists often assert that when dealing with people of different languages, viewpoints, geographical, and organizational contexts, an explicit simulation model represented in graphic and intuitive terms can aid communication by providing a vivid picture of what each party is thinking. The model can be a conversation piece, a map of your current understanding. When your logic goes amiss you have, a way of testing for inconsistencies in your thinking. The explicity history of your assumptions allows you or others to go back to your wrong turn and start anew. The future research and design of this workshop exploring the dynamics of arms races should be interesting test case for these assertions. Perhaps we will learn how to broaden the discussion from national security to international or global security. With the rapidly changing technology of weapons we may not be able to have one without the other.

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