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ABSTRACT

From a base in military models, computer simulation has evolved to provide a wide variety of applications in social science. General purpose simulation packages and languages such as FIRM, DYNAMO, and others have made significant contributions toward policy discussion in the social sciences and have well-documented efficacy in instructional settings compared to traditional settings. With the microcomputer revolution has come a revival of computer simulation, first in pre-collegiate education, then in a variety of other areas including urban policy, social processes, and research methodology. In spite of the significant body of research and software in social science it is striking that (1) this research and teaching tradition exists almost entirely outside the "mainstream" of social science journals and textbooks, and (2) the impact of computer simulation has had a relatively greater impact on teaching than research. These findings reflect the state of the social sciences. Attempts at simulation in research-poor environments inevitably lead to models characterized by low reliability, oversimplification, and neglect of causal factors. These three obstacles are the reason why computer simulation has remained a specialized area within social science and is removed from the mainstream practice of social scientists. It is concluded that computer simulation in social science, though a positive way of accumulating knowledge, is apt to remain the step-child it has always been. Over 90 related references conclude the publication. (LH)

Computer Simulation in Social Science

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COMPUTER SIMULATION IN SOCIAL SCIENCE

Computer simulation is the step-child of the behavioral revolution that swept social science after World War II. It is recognized as being part of the family of tools used by social scientists but it is largely hidden well out of the way. It is entirely possible, indeed commonplace, to complete a social science methodology sequence or even a doctoral degree without a serious encounter with computer simulation.

Computer simulation is a topic widely acknowledged to be of importance to social science yet one about which it is difficult to gain information. It is largely omitted from social science textbooks and most of its literature is not published in social science journals. It is the purpose of this essay to bring together some of this literature to provide an overview of computer simulation in social science, its history, its use in teaching and research, and its potential for playing a more significant methodological role in the future.

Social science computer simulation is not a new topic. Two decades ago John Hartman compiled a bibliography of 74 references on social science simulation (1). There have been numerous computer-based instructional materials (2), including simulations (3), widely available since the 1960's, long before the recent microcomputer-based revival of interest in simulation. For those willing to search, even textbook coverage was available. Harold Guetzkow's Simulation in the Social Sciences: Readings appeared

in 1962 (4) while William Coplin's Simulation in the Study of Politics, presenting a dozen computer-related simulations, appeared in 1968 (5). Rand Corporation studies of simulation also have been available since at least 1962 (6). Richard Gonzalez and Claude McMillan's methodology text, Machine Computation: An Algorithmic Approach, treated social science computer simulation fifteen years ago (7). Likewise, a text by Michael Inbar and Clarice Stoll presented 14 case studies of social science simulation in 1972 (8).

Not only is computer simulation in social science not a new topic, but in some ways it is a topic which peaked a over a decade ago during a period of funding agency support. Some simulations were sponsored by the Office of Education under its REACT (Relevant Educational Applications of Computer Technology) program (9) and others through the National Science Foundation's CAUSE and LOCI programs (10), as well as through private agencies such as the EXXON Foundation (11).

Yet in spite of examples of interest in the broader implications of computing for social experimentation (12) it is to military-sponsored efforts that one must turn to find the early popularization of social science computer simulation. For years the Rand Corporation, ABT Associates, the Raytheon Company, Simulmatics Corporation, Consolidated Analysis Centers, the General Research Corporation, the Army War College, the Studies Analysis and Gaming Agency, the National Military Command System Support Center and other governmental and government-contract organizations produced voluminous materials related to the use of computer simulation in national defense and foreign policy

applications.

The Rise of Computer Simulation in National Defense and Foreign Policy Analysis

In the 1961 - 1965 period the Raytheon Corporation developed the TEMPER (Technological, Economic, Military and Political Evaluation Routine) model for the Joint War Games Agency of the Department of Defense (13). This was a model for the analysis of international relations in the context of the 'Cold War', assuming a three-bloc (East, West, Third World) international relations structure as perceived circa 1960. Using a 117 nation data base, TEMPER allowed simulation of the behavior of up to 39 nation-groups at a time. Written in FORTAN for a CDC 1604B computer, TEMPER incorporated a wide variety of social, economic, political and cultural variables drawn from a 1960 data base (14).

TEMPER was limited by its dependency on mainframe computing, but the advent of time-sharing on mainframe computers was then making possible interactive simulations or 'man-machine models'. Time-sharing meant that computer simulation could be far more widely and efficiently used as a tool for international relations instruction and experimental exploration.

TEMPER was a generalized international relations simulation but numerous more specific models were explored in the 1964-1976 period. These included Abt Associates' ARPA URB-COIN urban counter-insurgency game under Project AGILE, exploring the feasibility of a computer model of guerrilla warfare (15) ; Rand Corporation's model of border control, infiltration, and

insurgency (16); and General Research Corporation's NINTSIM simulation of tactical nuclear war and conventional military operations in the context of nuclear threat (17).

Also funded with military (ARPA) money, Harold Guetzkow at Northwestern created the Inter-Nation Simulation (INS) in the 1960's. INS evolved into a "man-machine model" in which a computer was used as a message center/randomizer/umpire for a student role-playing game on international relations (18). It had grown out of the tradition of "all-person" role-playing games that had become prominent in international relations and other areas (19). Instructors utilized these games to conduct small group decision-making experiments in a simulated international setting trying to determine, for example, behavior under nuclear threat.

Also at Northwestern, Paul Smoker, working on a subcontract with Harold Guetzkow developed the International Processes Simulation (IPS) as a more complex, second-generation version of INS, further developing a type of man-machine modelling that at that time was coming to be seen as one of the main approaches to international relations as also, for example in William Coplin's World Politics Simulation (WPS) (20). Others carried the concept even further, as in SIPER, an "all-computer" version of INS and one of the first global computer models. (21)

Computer-based international relations simulations were brought into the classroom as well in the early 1970's. For example, Consolidated Analysis Centers, Inc., in 1971 developed a curriculum for the National War College utilizing an

international relations database, statistical analyses, and simulation (22). The following year Kenneth S. Heitzke and Daniel A. O'Donohue introduced military computer gaming experimentally in the curriculum of the Army War College (23).

In 1972 a survey by the Rand Corporation showed some 132 simulations, models, and games in use throughout the Department of Defense(24). However, interest in simulation and gaming peaked around this time, albeit at a rather high level. A 1975 catalog showed 152 simulations and models in use in the Department of Defense, including only two politico-military simulations (25), while the same catalog in 1977 listed only 139 (26). A 1979 Rand study stated that the Department of Defense was allocating $30-$40 million to war modelling, simulation, and gaming (27).

The development of military and foreign policy simulations had been subject to significant criticisms. As early as 1958, R. J. Weeker and G. H. Snure of the System Development Corporation had attributed the failure to make significant research gains through simulation studies to the highly abstract and sterilized nature of the social science which underpinned such models (28).

As late as 1975, even a complex project on long-range environmental forecasting of European environments, undertaken by CACI Inc. for the Advanced Research Projects Agency, utilized a relatively simple model with a dozen equations, least-squares estimation, and stochastic process forecasting (29). After over a decade of military simulations, the models in use often lacked predictive credibility.

From the mid-1970's military and foreign policy simulations

entered a phase in which less emphasis was placed on the research utility of simulation in a scientific sense and more on its utility in policy discussions. As the final technical report on the above-cited CACI Inc. study noted, forecasting models came to be seen as aids to generating meaningful, interesting, alternative futures for discussion in comparison with the strategic implications of contrasting developments (30). On this basis CACI Inc. produced a later report emphasizing politico-military scenario generation for use in a broader policy-making context (31).

This recasting of the purposes of simulation from a determinative to a processual role was much in keeping with other critiques of simulation in social science, notably Hayward R. Alker Jr.'s scathing 1974 article, "Computer Simulations: Inelegant Mathematics and Worse Social Science?" In this article Alker had called for complementing simulation approaches with developmental, philosophical, and mathematical approaches to minimize the abuses of simplistic simulation research (32). Likewise, in 1979 two Rand authors critiqued military simulations and gaming, calling for greater professionalism and improved sensitivity and utility analysis (33).

These critiques are reflected in the best known recent Rand simulation for the military, the Rand Strategy Assessment Center (RSAC) automated wargaming program, a computer simulation with rule-based artificial intelligence features (34). Not intended to serve as a direct guide to military policy akin to intelligence information, RSAC is meant to provide a simulated event

environment which can serve as a basis for discussion and assessment of policy makers' decisions in a developmental process.

Of course, ASAC in many ways reflects a series of earlier efforts in military and foreign policy simulation, particularly those oriented toward curriculum applications. Such earlier efforts had included, for example, the World Politics Simulation of the Industrial College of the Armed Forces (35), intended to convey an appreciation of the problems faced by national leaders.

At the same time, however, classified research at the Department of Defense continued to press ahead with computer simulations. The Joint Chiefs of Staff have recently commissioned a million-dollar world simulation, for example, and the Soviet Union is known to employ such planning models as well (36). In spite of the continuance of such models, however, there was a a tendency toward emphasis on specifically defense simulations rather than the broader sociopolitical ones. This continuing tradition is inaccessible to social scientists lacking security clearance and has thus been widely ignored within the academic community (37).

In general, the military-sponsored studies led those involved to function somewhat as an elite interest group largely talking among themselves and this heavily funded area of social science computing eventually ceased to be seen as a very significant approach to international relations. Many of the unclassified simulations which were developed have languished, relatively unused or unavailable. On the other hand, the North American Simulation and Gaming Association, publishers of

Simulation and Games, has helped keep alive the simulation tradition and are now beginning to move into computerized simulations. A number of others, such as Paul Smoker, are still currently involved in developing new world simulation projects. (38)

It should be emphasized that military contracts were not the sole vehicle for computer simulation in international affairs. In fact, Oliver Benson's "Simple Diplomatic Game" was an explicit forerunner of TEMPER, Raytheon's early military simulation (39). Other academic efforts paralleled many of the military-sponsored developments. Academics such as the team under Charles McClelland at the USC-LA School of International Relations began using time series analysis to simulate event flows in international relations in the early 1970's (40).

Other academic simulations, such as the world-famous simulation (the "Club of Rome model") by Jay Forrester, depicting world crisis through declining resources (41), also brought simulation techniques into the classroom as well as research. World modelling simulations such as Forrester's, in fact, became the center of academic action in international relations computing, eclipsing the earlier man-machine models and military-related games discussed above. (42) In addition, certain specialized topics such as the modelling of arms races, also continue as lively simulation arenas. (43) Nonetheless, as Phil Schrodt recently said of 1950-1984 computer simulations in international affairs, "We've now had about 25 years of research in this field. What have we gotten out of it? -- not a whole heck

of a lot in my estimation." (44)

Jonathon Wilkenfeld's recent article on "Computer Assisted International Studies" builds on the academic tradition of computerized simulation (45). Interestingly, Wilkenfeld emphasizes the instructional value of international relations computer simulations as an aid to student debate of economic and social issues - an emphasis not very different from the shift in military simulations toward a focus on the computer-generated scenario as a policy discussion aid.

Educational Uses of Computer Simulation in Social Science

Computer simulation has had a wider impact in social science instruction than in research. Simulations by nature are simplifications of reality, often with exaggerated cause-effect linkages. Yet these very features can be effective in a teaching context. Moreover, the interactive nature of learning through simulation forces the student into a more active role than do lectures or readings. It lends itself to reiterative analysis processes without unduly slowing the student down to a snail's pace as do manual calculation (or even batch mainframe) methods.

In 1970 Fred S. Coombs and John G. Peters tested and confirmed the hypothesis that computer-based American government games would enable political science students to achieve at a higher level while evaluating the games at least as favorably as traditional teaching methods (46). Likewise, Mark H. Maier and Thomas Venanzi, experimenting with a "Science and Society" course through simulations on topics like nuclear strategy, nuclear power and radiation, the IQ debate, and sociobiology, confirmed

that learning improved when students take an active rather than passive role (47).

In spite of this evidence from the university level, apart from military and international affairs simulations, pre-collegiate teaching provides the greatest level of social science computer simulation activity. There are a number of reasons for this. Even the most simplified simulations have teaching value at some level, even if it is the elementary grades. Pre-collegiate teachers are more accustomed to using teaching aids which go beyond the book-and-lecture format so beloved by university professors. The budget for microcomputers and accompanying software, factors which have had enormous potential for increasing student and teacher access to computer simulation, are frequently greater in high schools and even elementary schools than they are in college-level social science departments, ironic as that may seem.

Whatever the reason for the greater currency of computer simulation at pre-collegiate levels, social science simulations like "Oregon Trail" have been found to be excellent tools for teaching and reinforcing interpersonal skills (48). Though a few simulations such as "Change Agent" (49), "Market", "Elect" and "USPop" (50) may be found from the late 1960's and early 1970's, this is really a post-microcomputer phenomenon, which is to say post-1979.

Some of the earliest pre-collegiate social science simulations for microcomputers were "Hammurabi", a resource-allocation game in which the student plays an ancient ruler, and "Westward 1847", a game in which the player must lead a wagon

train to the West Coast (51). The Minnesota Educational Computing Consortium (MECC) quickly became a leader in pre-collegiate microcomputing, including some social science simulations such as "Oregon Trail", adapting earlier games and creating new ones (52). A few commercial firms such as Softside ("Miner", "Convoy") (53), Instant Software ("Santa Paravia", "Fiumaccio") (54), Strategic Simulations ("President Elect")(55), and McGraw-Hill ("Geography Search")(56) also began to enter the precollegiate market with simulations, often with arcade qualities.

Interestingly, one of the early entries derived from the military simulations discussed earlier. The "War-and-a-Half Logistics Game" from ADT Microcomputer Software allowed the player to maintain the world balance of power among ten nations through judicious allocation of supplies and resources. Its reviewer found in it little of educational value (57). However, others such as one dealing with the anatomy of revolution were received favorably in the pre-collegiate market (58).

In spite of these early simulations and games, social studies still trails other areas in computer utilization and there is a growing perception of the need to go beyond very simplified canned simulations (59). One successful effort has been the linkage of 14 Michigan high schools to a more sophisticated political science simulation at the University of Michigan (60). Though this project involved telecommunications linkage to a university computer, the real need is for microcomputer instructional materials which reflect "good social

science".

General Simulation Packages and Languages for Social Science

University-based general computer simulations for social science have been widely available for over a decade. Their effectiveness compared to traditional alternatives has been systematically documented. Nonetheless, these instructional simulation packages remain underutilized in social science curricula.

SIMSCRIPT was among the first important simulation languages and is still utilized extensively in military and industrial applications such as CACI Inc.'s TAC THUNDER simulation of NATO air defense.(61) In social science, however, SIMSCRIPT has been little used compared to other languages and packages.

PRINCE, developed by Bill Copeland at Syracuse University, for example, was systematically evaluated at six colleges in 1975. Use of PRINCE, a man-machine model with updatable scenarios and data sets, was found to improve students' abilities to define political issues and to do so more concisely, and to be able to make more specific suggestions as to how to deal with more actors in seeking solutions to a political problem (62).

EXPER-SIM (Experimental Simulation) is a general-purpose simulator for experiments in social sciences or other disciplines (63). Roy E. Miller and David A. Bositis randomly assigned students to two sections of a course, both studying the same analytic problems but one using EXPER-SIM and the other the more traditional SETUPS. (SETUPS are Supplementary Empirical Teaching Units in Political Science, sponsored by the American Political

Science Association, containing printed materials on the problem, sample data sets, and exercises to be completed using a statistical package such as SPSS). Comparison of pre- and post-test scores in both groups showed EXPER-SIM students made greater gains in substantive learning, in analytic reasoning, and in computer-related learning than did the SETUPS students (54).

In the same period, almost a decade ago, George Conklin of North Carolina Central University, modified EXPER-SIM to serve functions similar to PROFIS, a set of introductory sociology simulations he developed between 1972 and 1982. Conklin's classroom testing showed that computer simulation could be used successfully to enhance the teaching of analytic techniques without detracting from a crowded curriculum (55).

EXPER-SIM, sponsored by Exxon Foundation, grew out of MESS (the Michigan Experiment Simulation System, a mainframe batch version) and LESS (the Louisville Experiment Simulation System, an interactive version). FIRM (Florida Interactive Modeler), distributed by COMDUIT, was an EXPER-SIM system rewritten for DEC and Apple computers and enhanced by psychologists at the University of Florida as a small computer version of the earlier mainframe simulators. FIRM comes with experimental simulations on cognitive dissonance, frustration-aggression, conformity, delayed opinion change, and other topics, but can be utilized to illustrate almost any data-validated theory in the social sciences (56).

MICRO-DYNAMO, a mainframe simulation language translated to the microcomputer and distributed with an excellent text by Addison-Wesley, provides a somewhat more difficult but powerful

vehicle for multivariate simulation of many social phenomena (57). It is supplied with eight simulations, including Jay Forrester's "Club of Rome" model of world resource crisis, an ecology simulation, a heroin addiction simulation, and an urban growth simulation.

Other more specialized simulation languages are available for microcomputers also, though little used in social science. GPSS (General Purpose Simulation System), for example, allows the instructor to simulate any phenomenon characterized by queueing and service allocation problems (e.g., modelling student registration day procedures, social service delivery plans, police patrol locations) (53)

The FIRM simulation approach (based in regression-type modelling), DYNAMO (based on closed systems of equations modelling dependent variables over time), and GPSS (based on probability theory and queuing problems) all focused on mathematical simulations with a minimum of text. Recently, however, a new simulation language, ESL (event simulation language), developed by Philip Schrodt of Northwestern University, has been developed to provide text scenarios which branch upon user response to decision points. This text-based event simulation language still incorporates event stacks, stochastic processes, quantitative trigger points, and other aspects of mathematical modelling, but in a format designed more for instructional than predictive use on topics such as foreign policy simulation. (59)

Special Purpose Simulations for Social Science

It is not accurate to treat social science simulations as spin-offs from military-funded efforts. Ithiel de Sola Pool, later to become involved with military simulation, had wide impact in social science through his voting simulation efforts on behalf of John F. Kennedy in the 1960 elections (70). Since then both political scientists and media organizations have pursued the simulation of voting behavior (71). Other early though largely isolated examples of social science simulations can be cited, such as Werner Grunbaum's use of Monte Carlo techniques in simulating judicial decision-making (72).

Nonetheless, it is still true that the possibilities opened by military/international affairs simulations led to the exploration of applications to other areas, among the first of which were those dealing with urban problems (73). Back in 1963 a Research Analysis Corporation paper by Lester G. Hawkins, Jr., discussed existing urban-development and community-renewal planning simulations and the extension of gaming to nonmilitary environments (74). In the 1968-1973 period the Rand Corporation, a major military contractor, undertook extensive projects with the City of New York, some involving extensive urban policy simulations (75). As with the military simulations, Rand's urban simulations proved controversial and problematic.

Educational urban simulations fared considerably better. The CITY III simulation from Envirometrics, for example, allowed 30 - 200 college-level students to "run" five cities and make economic, political, and social decisions (76). In the mid-seventies the METRO-APEX computer-assisted simulation similarly

allowed political science students to make political, planning, industrial, environmental, and economic decisions over a five-week period (77).

Urban policy issues are a particular case of a broad range of managerial simulations of complex groups or organizations, some of which are of interest to social scientists (78). For example, UNESCO's Educational Simulation Model (ESM), developed in the early 1970's, modeled educational demand and educational system fluctuations and was used in several countries (79). Within a decade such educational simulations had been incorporated in management training simulations for educational administrators (80). To take another example, the British Library has developed a systems dynamics simulation modeling activities of social science disciplines as information systems (81). Whether in school, library, or other organizational settings, such simulation efforts have broad implications for social science.

Special purpose simulations have been developed in a large number of other areas pertinent to social science. Game theory and simulation of various aspects of political and other types of bargaining are an example (82), as are simulations of various statistical and methodological techniques and processes (83), simulation of public opinion formation (84), simulation of social diffusion processes such as neighborhood segregation (85), models of the economy (86), managerial models (87), legislative voting (88), policy making/resource allocation simulations (89), psychological (90), sociological (91), and other simulation topics.

Artificial Intelligence

Artificial intelligence (AI) software is the latest development in social science simulation. Growing out of the systems modelling tradition, AI has already become a broad term with many diffuse meanings. It is used to refer to expert systems (92), for example, typically branching rule-application decision software combined with a semantic processor for interfacing in conversational English. On the other hand, AI can be used as an algorithm-generating as well as algorithm-applying approach. Likewise, as Phil Schrodt's recent work suggests, AI can involve pattern recognition in event series - simulating a decision-making process in which the decision-maker compares current event sequences with past ones and their associated consequences, uses the past as a template for current actions, the adjusts the event database for current consequences (93). This "adaptive precedent-based logic" exemplifies AI as a continually evolving problem-solving system, not an equation-based deterministic model.

Conclusion

From a base in military-sponsored models, computer simulation has evolved to provide a wide variety of applications in social science. General-purpose simulation packages and languages such as FIRM, DYNAMO, and others have made significant contributions toward policy discussion in the social sciences and have well-documented efficacy in instructional settings compared to traditional methods. With the microcomputer revolution has come a revival of computer simulation, first in pre-collegiate

education but now in a variety of other areas including urban policy, social processes, and research methodology.

In spite of the significant body of research and software in social/science simulation, however, what is more striking from a disciplinary point of view is that this research and teaching tradition exists almost entirely outside the "mainstream" journals and textbooks that epitomize the social science disciplines.

The second striking fact that the foregoing overview of social science computer simulation provides is the relatively greater impact of such models on teaching compared to research. Without belittling the significant general and applied research applications of simulation, the history of military-sponsored as well as academic simulations shows a tendency toward deemphasis on such purposes as forecasting and predictive analysis and increased emphasis on the uses of simulation as a vehicle for generating scenarios, enhancing policy discussions, developing decision-making skills of policy makers, and for other essentially educational functions.

These findings reflect the state of the social sciences. Computer simulation requires a level of causal specification rare in most social science research arenas. Attempts at simulation in research-poor environments inevitably lead to models characterized by low reliability, oversimplification, and neglect of causal factors not tapped by current measurement systems.

Oversimplification, inappropriate specification, and inaccuracy of measurement are the rule, not the exception in

social science simulation. In fact, there is probably no social science simulation which cannot be subjected to substantial criticism on one or more of these grounds. These three obstacles are the reason why computer simulation has remained a specialization within social science which is removed from the mainstream of what social scientists do. Since computer simulation also requires programming skills, scarce among social scientists, it is hardly surprising that this has not become a widespread technique.

On the positive side, however, simulation is an interactive way of learning which forces one to operationalize variables and to state precisely what we know and what we do not know about a given subject. That is, it is impossible to approach a simulation unless one has clarity of thought about one's topic. Even if simulations never predicted reality with any degree of precision they would still be highly useful because they are a way of learning to think scientifically and they are a way of disciplining investigation. Thus, simulation is a way of accumulating knowledge.

Realistically, computer simulation in social science is apt to remain the step-child it has always been. The widespread availability of microcomputers virtually assures at least a modest increase in the utilization of simulation but there is not now on the horizon a strategy for realizing the potential which computer simulation holds for the social sciences or even for the consolidation of many of the clusters of simulations discussed in this essay, their refinement, and their dissemination in more user-friendly and available formats.

NOTES

1. John J. Hartman, Annotated Bibliography on Simulation in the Social Sciences (Ames, IA: Iowa Agricultural and Home Economics Experiment Station, Department of Sociology and Anthropology, 1966). See also M. Shubik, The Literature of Gaming, Simulation, and Model-Building: Index and Critical Abstracts, Publication R-620-ARPA (Santa Monica, CA: Rand Corporation, June 1972).

2. Daniel L. Klassen, "Computer Based Curriculum Materials for the Social Sciences: Classroom Teacher Generated Materials", Journal of Educational Data Processing, Vol. 8, No. 5 (1971): 6-10.

3. William D. Coplin, "Approaches to the Social Sciences Through Man-Computer Simulations", Simulation and Games, Vol. 1, No. 4 (Dec. 1970): 391-410.

4. Harold Guetzkow, ed., Simulation in the Social Sciences: Readings (Englewood Cliffs, NJ: Prentice-Hall, 1962)

5. William D. Coplin, ed., Simulation in the Study of Politics (Chicago: MArkham, 1968).

6. R. W. Conway, "Some Tactical Problems in Simulation Method", Rand Memorandum RM-3244-PR (Santa Monica, CA: Rand Corporation, October 1962). For a listing through 1985, see Computer Simulation: A Bibliography of Selected Rand Publications, Publication SB-1042 (Santa Monica, CA: Rand Corporation, August 1985).

7. Richard F. Gonzalez and Claude McMillan, Jr., Machine Computation: An Algorithmic Approach (Homewood, IL: Richard D. Irwin, 1971).

8. Michael Inbar and Clarice S. Stoll, Simulation and Gaming in Social Science (Riverside, NJ: The Free Press, 1972). See also, Alan Brier and Ian Robinson, Computers and the Social Sciences (NY: Columbia University PRess, 1974): ch. 6; Robert B. Coats and Andrew Parkin, Computer Models in the Social Sciences (Cambridge, MA: Winthrop, 1977).

9. Northwest Regional Educational Lab, Social Studies: Application Units. Course II, Teachers. Computer-Oriented Curriculum (San Carlos, CA: Tecnica Education Corporation, 1971).

10. Jerry W. Gustafson, Improvement of Social Science Education via the Development of A Social Science Laboratory. Final Report. (Washington, DC: National Science Foundation, Grant SER-78-064891, 1982). CAUSE supported the creation or enhancement of a number of social science computer laboratories; that described by Gustafson was unusual in establishing a gaming/simulation lab facility.

11. The EXXON Foundation funded EXPER-SIM, discussed below, among other projects.

12. H. Sackman, Experimentally Regulated Evolution in Computer-Aided Societies (Santa Monica, CA: System Development Corporation, Professional Paper SP-2068, May 1965).

13. Michael F. Cook et al., TEMPER as a Model of International Relations: An Evaluation for the Joint War Games Agency, Department of Defense. Final Report. (Cambridge, MA: Simulmatics Corp, 1966).

14. Raytheon Co., TEMPER (Washington, D.C.: National Military Command System Support Center, 1965). Seven volumes, including Game Handbook (Vol. III, AD-470 241L); Technical Manual (Vol. IV,

AD-473 050L); Operations Manual (Vol. V, AD-470 069L; Reference Manual (Vol. VI, AD-470 070L); and Data Collection Manual (Vol. VII, AD-470-071L). See also W. C. Clemens, Jr., "A Propositional Analysis of the International Relations Theory in TEMPER - A Computer Simulation of Cold War Conflict", pp. 59-101 in W. D. Coplin, ed., Simulation in the Study of Politics (Chicago: Markham, 1968).

15. Abt Associates, The Urb-COIN Game (Cambridge, MA: Abt Associates, 1966).

16. G. F. Schilling, Analytic Model of Border Control (Santa Monica, CA: Rand Corporation, Report No. RM-6250-ARPA, 1970).

17. Norman Farrell, Philip H. L[illegible]ery; and John E. Shepherd, Method for Integrative Simulation (MINTSIM) (Mclean, VA: General Research Corporation, Report No. OAD-CR-142, January 1976).

18. Harold Guetzkow, "The Use of Computer Simulation in the Study of International Relations", in H. Guetzkow, ed., Simulation in the Social Sciences: Readings (Englewood Cliffs, NJ: Prentice-Hall, 1962). On INS see W. J. Crow, "A Study of Strategic Doctrines Using the Inter-Nation Simulation", Journal of Conflict Resolution, Vol. 7 (Sept. 1963): 580-589; Charles F. Hermann, Crisis in Foreign Policy: A Simulation Analysis (Princeton, NJ: Center of International Studies, Princeton University, by Bobbs-Merrill, 1969. Harold Guetzkow, "Simulation in International Relations" and H. R. Alker, "Decision-Makers' Environments in the Inter-Nation Simulation", chapters 1 and 2 respectively in William D. Coplin, ed., Simulation in the Study of Politics (Chicago: Markham, 1968)

both discuss INS. INS2, a microcomputer version developed by Bahram Farzanegan and the North American Simulation and Gaming Association, is distributed by NCSU Software, Raleigh, from Fall, 1985. The "man-machine" simulation concept is also explored in John W. Loughary, Man-Machine Systems in Education (NY: Harper and Row, 1966); H. M. Parsons and H. W. Sinaika, Man-Machine System Experiments (Baltimore: Johns Hopkins University Press, 1973). See also PLATO system simulation by Richard Rosecrance at Cornell on Middle East crisis decision-making in branching multiple choice format. Control Data Corporation distributes PLATO, an educational system for mainframe computers.

19. Sidney F. Giffin, The Crisis Game: Simulation of International Conflict (Garden City, NY: Doubleday, 1965): note page 9. Clark C. Abt, Serious Games (NY: Viking, 1970): 46 ff. See also Foreign Policy Association, Simulation Games for the Social Studies Classroom (NY: FPA, 1968); Richard F. Barton, A Primer on Simulation and Gaming (Englewood Cliffs, NJ: Prentice-Hall, 1970); (William A. Nesbitt, Simulation Games for the Social Studies Classroom (NY: Crowell, 1971) (Englewood Cliffs, NJ: Prentice-Hall, 1970); G. I. Gibbs, ed., Handbook of Games and Simulation Exercises (Beverly Hills, CA: Sage, 1974). For an example outside international relations, see William A. Gamson, SIMSOC: Simulated Society, 2nd Ed., Instructor's Manual (NY: Free Press, 1969).

20. Paul Smoker, International Processes Simulation: A Man-Computer Model (Evanston, IL: Northwestern University, Aug. 1968); Paul Smoker, "International Relations Simulations: A Summary", pp. 417-464 in H. R. Alker, K. W. Deutsch, and A. H.

Stoetzel, eds., Mathematical Approaches to Politics (San Francisco: Jossey-Bass, 1973). See also, Warren R. Phillips and Stuart J. Thorson, Simulation for Policy Planning (Columbus, OH: Research Foundation, Ohio State University, 1973).

21. Stuart A. Bremer, Simulated Worlds: A Computer Model of National Decision-Making (Princeton, NJ: Princeton University Press, 1977).

22. W. W. Fain, Development and Presentation of a National War College Elective Course to Demonstrate the Use of Quantitative Techniques in the Study of International Relations. Final Report. (Arlington, VA: Consolodated Analysis Centers, Inc., Sept. 1981). See also the accompanying three volumes: Course Description and Syllabus (Vol. I, AD-735 906); Workshop Manuals (Vol. II, AD-735 907); and Instructor's Supplement (Vol. III, AD-735 908).

23. Kenneth S. Heitzke and Daniel A. O'Donohue, Politico-Military Gaming in the USAWC Curriculum (Carlisle Barracks, PA: Army War College, March 1972).

24. Martin Shubik and Garry D. Brewer, Models, Simulations, and Games: A Survey (Santa Monica, CA: Rand Corporation, May 1972).

25. Harry J. Walther, Catalog of War Gaming and Military Simulation Models, 6th Edition (Washington, DC: Studies Analysis and Gaming Agency, June 1975).

26. Donald J. Berg and Marcia E. Strickland, Catalog of War Gaming and Military Simulation Models, 7th Edition (Washington, DC: Studies Analysis and Gaming Agency, August 1977).

27. G. D. Brewer and M. Shubik, The Ware Game: A Critique of Military Problem Solving (Cambridge, MA: Harvard University

Press, 1979).

28. R. J. Meeker and G. H. Shure, Updating Some Group Rules for Man-Machine Simulation (Santa Monica, CA: System Development Corp., April 1968).

29. G. Robert Franco, Herman M. Weil, Aaron Greenberg, and Douglas Hartwick, Quantitative Methods for Long-Range Environmental Forecasting: Long-Range European Projections (Arlington, VA: Caci Inc.-Federal, 1974). Three volumes: Summary (Vol. I. AD-A022 657); Technical Volume (Vol. II, AD-A022 658); Research Guide (Vol. III, AD-A022 659).

30. Herman M. Weil and John J. McIlroy, Stochastic Simulations of Long-Range Forecasting Models. Volume I, Executive Summary. (Arlington, VA: Caci Inc.-Federal, 1975). See also Research Findings (Vol. II, AD-A019 013); Technical Appendix (Vol. III, AD-019 014).

31. John J. McIlroy and Richard H. Van Atta, The Application of Quantitative Methods to Scenario Generation (Arlington, VA: Caci Inc., Nov. 1975). See also M. Gordon, "Burdens for the Designer of a Computer Simulation of International Relations", pp. 222-245 in D.B. Bobrow and J. L. Schwartz, eds., Computers and the Policy-Making Community (Englewood Cliffs, NJ: Prentice-Hall, 1968).

32. Hayward R. Alker, Jr., "Computer Simulations: Inelegant Mathematics and Worse Social Science?", International Journal of Mathematical Education in Science and Technology, Vol. 5, No. 2 (April-June 1974): 139-155. J. David Singer, though positive, also presented problems of simulation in "The Historical Experiment as a Research Strategy in the Study of World

Politics", Social Science History, Vol. 2, No. 1 (1977): 15-18. A more recent summary of problems in computer simulation is Wallace E. Larimore and Raman K. Mehra, "The Problem of Overfitting Data", Byte, October, 1985: 167-180.

33. G. D. Brewer and M. Shubik, The War Game: A Critique of Military Problem Solving (Cambridge, MA: Harvard University Press, 1979). See also an earlier critique of specifically combat models, J. A. Stockfish, Models, Data, and War: A Critique of the Study of Conventional Forces, Rand Publication R-1526-PR (Santa Monica, CA: Rand Corporation, March 1975).

34. The Rand Strategy Assessment Center (RSAC) is an automated wargaming program to improve analytic modelling/simulation with rule-based artificial intelligence features. See H. J. Shukiar, Rand Publication P-6978, "The Rand Strategy Assessment Center System Perspective" (Santa Monica, CA: Rand Corporation, June 1984). It features a simulation model (Force Agent) with AI-based superpower actors (Red Agent and Blue Agent), and third-country AI actors (Scenario Agent). See W. Schwabe, Rand Publication P-7115, "Knowledge Engineering for Rand Strategy Assessment Center Military Command Level Modules" (Santa Monica, CA: Rand Corporation, July 1985). See also James A. Dewar, William Schwabe, and Thomas L. McNaugher, Rand Publication N-1781-DNA, Scenario Agent: A Rule-Based Model of Political Behavior and Strategic Analysis (Santa Monica, CA: Rand Corporation, Jan. 1982). See also the earlier report, H. A. DeWeerd, A Contextual Approach to Scenario Construction (Santa Monica, CA: Rand Corporation, Sept. 1973).

35. Simulation and Computer Directorate, World Politics Simulation (Washington, DC: Industrial College of the Armed Forces, 1969).

36. Michael D. Ward, "Simulating the Arms Race", Byte, October, 1985:213-222. See pp. 213-4.

37. Based on interview with Jim Thompson, a former DOD official involved with simulation gaming, by author. On classified gaming see the study by Rand authors Garry D. Brewer and Martin Shubik, The War Game (Cambridge, MA: Harvard University Press, 1979). See also Jim Thompson and A. Grant Whitley, "Improving Conventional Defense in Europe", in Linda P. Brody and Joyce Kaufman, The Future of Nato (NY: Praeger, 1985); and E. H. Hall et al., Rand Publication N-2099-NA, "Overview of RSAC System Software: A Briefing" (Santa Monica, CA: Rand Corporation, Jan. 1985) - on the Rand Strategy Assessment Center.

38. Based on interview by author with Marvin S. Soroos, a former associate of Harold Guetzkow, now teaching international relations at NCSU.

39. Oliver Benson, "A Simple Diplomatic Game", pp. 504-511 in J. N. Rosenau, ed., International Politics and Foreign Policy (NY: Free Press, 1961). TEMPER staff communicated and visited with Benson; interview of Benson with author, August 1985. The Simple Diplomatic Game was expanded in BASIC by Jeff Krennd and is now in the Inter-University Consortium for Political and Social Research archives.

40. Charles A. McClelland et al., The Management and Analysis of International Event Data: A Computerized System for Monitoring and Projecting Event Flows. Final Report. (Los Angeles, CA:

Vol. 78 (1984): 297-317. See also an related but earlier effort with a quite different approach, Charles F. Hermann and Margaret G. Hermann, "An Attempt to Simulate the Outbreak of World War I", pp. 340-363 in Harold Guetzkow, Philip Kotler, and Randall L. Schultz, Simulation in Social and Administrative Science (Englewood Cliffs, NJ: Prentice-Hall, 1972).

44. Philip A. Schrodt. "Artificial Intelligence and International Crises: The Application of Pattern Recognition to the Analysis of Event Sequences", paper to the American Political Science Association, Annual Meeting, August 1984, Washington, DC, p. 2. For a review of international relations models, see Philip A. Schrodt, "The Role of Stochastic Models in International Relations Research", pp. 199-221 in Michael Don Ward, ed., Theories, Models, and Simulation in international Relations (Boulder, CO: Westview, 1985).

45. Jonathon Wilkenfeld, "Computer-Assisted International Studies", Teaching Political Science, Vol. 10, No. 4 (Summer 1983): 171-176.

46. Fred S. Coombs and John G. Peters, "Computer-Based Games as a Political Laboratory", Teaching Political Science, Vol. 3, No. 3 (April 1976): 249-262.

47. Mark H. Maier and Thomas Venanzi, "Simulations in a Science and Society Course", Journal of College Science Teaching, Vol. 13, No. 4 (Feb. 1984): 300-301, 303.

48. Robert Isenberg, "Cooperation and Computing", Classroom Computer News, Vol. 2, No. 2 (Nov./Dec. 1981): 24-25.

49. Michigan State University, Behavioral Science Elementary Teacher Education Program. Final Report (East Lansing, MI:

University of Southern California, School of International Relations, Sept. 1971).

41. Jay W. Forrester, World Dynamics (Cambridge, MA: MIT Press, 1973). Compare his earlier work, Industrial Dynamics (Cambridge, MA: MIT Press, 1961). See also Donella H. Meadows et al., The Limits to Growth (NY: Universe Books, 1973); John Clark and Sam Cole, Global Simulation Models: A Comparative Study (NY: Wiley, 1975): ch. 2; Robert E. Shannon, Systems Simulation: The Art and the Science (Englewood Cliffs, NJ: Prentice-Hall, 1975); Peter Kelman, "Jay Forrester and the Science of Optimism", Classroom Computer News, Vol. 3 No. 3 (Jan./Feb. 1983): 21-25.

42. Further development of world modelling beyond the Club of Rome is found in the Latin American model of A. O. Herrana et al., Catastrophe or new Society? A Latin American World Model (Ottowa: International Development Research Center, 1976). UNESCO, the International Political Science Association, and others sponsored a 1977 meeting on such models, reported by H. R. Alker, K. W. Deutsch, and A. S. Markovits, "Global Opportunities and Constraints for Regional Development - Review of Interdisciplinary Simulation Research Toward a World Model as a Framework of Studies of Regional Development", Social Science Information Vol. 16 No. 1 (1977): 83-102.

43. Philip Schrodt, "Microcomputers in the Study of Politics: Predicting Wars with the Richardson Arms-Race Model", Byte, Vol. 7, No. 7 (July 1982): 108-134. Michael Ward has sought a more complex variant model: "Differential Paths to Parity: A Study of the Contemproary Arms Race," American Political Science Review,

Michigan State University, Oct. 1968).

50. Daniel L. Klassen, "Computer Simulation in the Social Sciences/Social Studies", paper presented to the Association for Educational Data Systems, Annual Convention, New Orleans, LA, April 16-19, 1973.

51. Walter Koetke, "Vicarious Learning: Sometimes Simulations Say It Better", Kilobaud Microcomputing, Vol. 5, No. 2 (Feb. 1981): pp. 10+.

52. Robert Price, "Oregon Trail", Educational Computer, Vol. 3, No. 1 (Jan./Feb. 1983): 54. See also "Cupertino Cowgirl Pioneers Computers", Personal Computing, Vol. 5 No. 7 (Sept. 1981): 55. Thorwald Esbensen, "A Program Goes to Market", Educational Computer, Vol. 2 No. 5 (Sept./Oct. 1982): 13-15; Nina Stromberg, "Across the Plains". Electronic Learning, Vol. 2 No. 2 (Oct. 1982): 71-2; Peggy Smith, "Across the Plains", Educational Computer, Vol. 3 No. 1 (Jan.-Feb. 1983): 50.

53. Erwin Osborn, "Life and Death Decisions: One Way to Make History Come Alive", Electronic Learning, Vol. 1, No. 1 (Sept./Oct. 1981): pp. 51-52.

54. Larry Noonan, "Computer Simulations in the Classroom", Creative Computing, Vol. 7, No. 10 (Oct. 1981): 132-138.

55. Edward Wright, "President Elect", Educational Technology, Vol. 22, No. 1 (January 1982): 52-53. See also Deborah Rutzen, "Program Simulates the Making of a President", Classroom Computer News, Vol. 3, No. 2 (Nov./Dec. 1982): 60-65.

56. Henry Olds, "Geography Search", Classroom Computer News, Vol. 2, No. 3 (Jan./Feb. 1982): 34-36. See also David Needle,

"Software Fosters Group Dynamics and Basic Skills", Infoworld, Vol. 4 No. 35 (6 Sept. 1982): 24-5; Graham Unwin and Mollie Cohen, "Community Search", Electronic Learning, Vol. 2 No. 3 (Nov. 1982): 81-2; Peter Owens, "Probing the Search Series", Popular Computing, Vol. 2 No. 12 (Oct. 1983): 220-228.

57. Barbara Martin, "The War-and-a-Half Logistics Game", Educational Technology, Vol. 22, No. 10 (Oct. 1982): 55-56. Abt went out of the simulation software business about 1980.

58. Mark Rothman, "Using the Microcomputer to Study the Anatomy of Revolution", Computing Teacher, Vol. 10 No. 1 (Sept. 1982): 16-20. See also Michael Roessler, Annam. Manual (Freeport, NY: Educational Activities, Inc., 1983).

59. Nancy Roberts, "Who's Last in Line for Computers? The Social Studies Teacher", Classroom Computer News, Vol. 3, No. 2 (Nov/Dec 1982): pp. 17+. See also Roger Berg, "Analytical Criteria for Microcomputer-Based Simulation /Games", paper presented to the Social Science Education Consortium, Annual Meeting, Athens, GA, 8-11 June 1983.

Many of the readily available microcomputer simulations for social science, some designed for the collegiate market, are often equally oversimplified (though this is sometimes instructionally desirable). See, for example, the historical simulation, "Napoleon's Empire" (Kent, WA: New Worlds Software, 1984), emphasizing military board-game-type moves and underemphasizing interactive sociopolitical aspects. See James E. Sargent, "History on a Disk: A Review of Microcomputer Simulations", Social Science Microcomputer Review, Vol.3 No. 3 (Fall 1985). For a review of simulations for upper secondary and

lower undergraduate education, see Jeffrey A. Hart, "Using Microcomputer Simulations in the Classroom", paper to the American Political Science Association, Annual Meeting, New Orleans, August 1985; Jeffrey A. Hart, "Conflict Simulations and Role-Playing Games", Social Science Microcomputer Review, Vol. 3 No. 2 (Summer 1985).

60. Mary D. Edwards, "A Statewide Classroom Simulation in Michigan", Electronic Learning, Vol. 4 No. 3 (Nov.-Dec. 1984): p. 45.

61. Otis F. Bryan and Michael C. Natrella, "Testing Large-Scale Simulations", Byte, October, 1985: 183-194. For an example of a SIMSCRIPT-based study, see Rand Publication R-632-NYC, G. M. Carter and E. Ignall, "A Simulation Model of Fire Department Operations" (Santa Monica, CA: Rand Corporation, Nov. 1970).

62. Lawrence A. Bloom et al., "An Evaluation of PRINCE Materials for Teaching General Political Strategy Skills", paper to the American Educational Research Association, Annual Meeting, Washington, DC, April, 1975. An even earlier example is "Explanation", a game to teach the question formation-generalization-explanation research process, used in conjunction with an information retrieval system containing an inventory of 5,312 social science propositions: Charles H. Adair et al., Two Simulated Inquiry Environments: A Social Simulation Game and a CAI-Based Information Retrieval System (Tallahassee, FL: Computer-Assisted Instruction Center, Florida State University, May 1970).

63. John G. Hedberg, "The Technologies of EXPER SIM", paper to

the American Educational Research Association, Annual Meeting, San Francisco, CA, April, 1976.

64. Roy E. Miller and David A. Bositis, "EXPER-SIM vs. SETUPS: An Experiment-Based Comparative Evaluation Using Causal Modelling Techniques", paper to the American Political Science Association, Annual Meeting, Washington, DC, 1-4 Sept. 1977. See also, Leslie A. Baxter, "Instructional Practices: The Use of EXPER SIM in the Undergraduate Speech Communication Curriculum", Communication Education, Vol. 28 No. 3 (July 1979): 210-217.

65. George H. Conklin, "Experimental Simulation in Introductory Sociology: Modifying EXPER-SIM to Meet the Needs of Beginners", paper to the Conference on Computers in the Undergraduate Curricula, East Lansing, MI, 20-22 June 1977. Conklin's PROFIS system was distributed by CONDUIT (1982) and his later NSF-sponsored 8-lesson sociology package, CLEAR (Computerized Learning and Review), by Holt Rinehart and Winston (1982).

66. C. Michael Levy and Marc W. Durnin, FIRM: Florida Interactive Modeler: Author and Programmer Manual (Iowa City, IA: CONDUIT, 1981); Jeffrey D. Elliot et al., FIRM: Volume I, The Nature of Attitudes and Attitude Change (Iowa City, IA: CONDUIT, 1983) and FIRM: Vol. II, Interpersonal Dynamics (Iowa City, IA: CONDUIT, 1983).

67. Nancy Roberts et al., Introduction to Computer Simulation: The System Dynamics Approach (Reading, MA: Addison-Wesley, 1983). See also George P. Richardson and Alexander L. Pugh, Introduction to System Dynamics Modeling with DYNAMO (Cambridge, MA: MIT Press, 1981).

68. "GPSS/PC", Social Science Microcomputer Review, Vol. 3 No. 1

(Spring 1985): 63-5. See discussion in Alan Brier and Ian Robinson, Computers and the Social Sciences (NY: Columbia University Press, 1974): 85-86. See also Susan L. Solomon, Simulation of Waiting Line Systems (Englewood Cliffs, NJ: Prentice Hall, 1983). EDS (Event-based Discrete Simulation), a related simulation language, is described in R. B. Coats and A. Parkin, Computer Models in the Social Sciences (Cambridge, MA: Winthrop, 1977): 171-178.

69. Philip A. Schrodt and Ronald Sherwin, "Programming an Event-Based Political Simulation", Byte, October, 1985. ESL is distributed by Third Point Systems of Monterey, CA.

70. Ithiel de Sola Pool, Robert P. Abelson, and Samuel L. Popkin, Candidates, Issues, and Strategies: A Computer Simulation of the 1960 Presidential Election (Cambridge, MA: MIT Press, 1964). See discussion in Alan Brier and Ian Robinson, Computers and the Social Sciences (NY: Columbia University Press, 1974): 135-187. See also T. G. Harvey, "Computer Simulation of Peergroup Influences on Adolescent Political Behavior", Midwest Journal of Political Science, Vol. 16, No. 4 (1972): 570-602; M. J. Shapiro, "The House and the Federal Vote: A Computer Simulation of Roll-Call Voting", pp. 264-95 in Harold Guetzkow, P. Kotler, and R. L. Schultz, eds., Simulation in Social and Administrative Science (Englewood Cliffs, NJ: Prentice-Hall, 1972); J. D. Laing, "Computer Models of Political Coalitions", Political Science Annual, Vol. 4 (1973): 41-74.

71. Steven L. Coombs, Michael Fried, and Stewart H. Robinovitz, "An Approach to Election Simulation Through Modular Systems",

Oxford University Press, 1973), ch. 10 in William D. Coplin, ed., Simulation in the Study of Politics (Chicago: Markham, 1968); W. R. Schaffer, Computer Simulation of Voting Behavior (NY: Oxford University Press, 1973); Patrick Doreian and Norman P. Hummon, Modelling Social Processes (NY: Elsevier, 1976): ch. 5.

72. Werner F. Grunbaum, "Analytical and Simulation Models for Explaining Judicial Decision-Making", pp. 307-334 in Joel B. Grossman and Joseph Tanenhaus, eds., Frontiers of Judicial Research (NY: John Wiley, 1969).

73. Paul H. Ray and Richard D. Duke, "The Environment of Decision-Makers in Urban Gaming Simulations", ch. 6 in William D. Coplin, ed., Simulation in the Study of Politics (Chicago: Markham, 1963), discusses the M.E.T.R.O. and simpler METROPOLIS man-machine models analogous to those found in contemporary military-sponsored games.

74. Lester G. Hawkins, Jr., Perspectives on Public-Systems Gaming (McLean, VA: Research Analysis Corporation, Nov. 1969). See also Jay W. Forrester, Urban Dynamics (Cambridge, MA: MIT Press, 1969).

75. Matthew Greenberger, Matthew A. Crenson, Brian L. Crissey, Models in the Policy Process: Public Decisionmaking in the Computer Era (NY: Russell Sage, 1976): chs. 7-9. See also G. M. Carter and E. Ignall, A Simulation Model of Fire Department Operations, Publication R-632-NYC (Santa Monica, CA: Rand Corporation, Nov. 1970). The programmer's guide for this simulation is Rand Publication R-1188/2-HUD/NYC. Other Rand studies dealt with water quality (R-632-NYC, R-708-NYC, R-709-NYC, R-1009-NYC, R-1010-NYC, R-1586-NYC, R-1774-NYC, R-1791-NYC),

police patrolling (R-1625/2-HUD/NYC, P-5463, P-5464), and welfare (R-1897-NYC, R-1991-NYC). See also the Rand paper P-3734, J. P. Crecine, "Computer Simulation in Urban Research" (Santa Monica, CA: Rand Corporation, Nov. 1967).

76. Peter House, Development of Metropolitan (CITY III) Model. Final Report (Washington, DC: Envirometrics, Inc., June 1970).

77. Jane Wolin, "Computerized Gaming and Simulation in Higher Education: The METRO-APEX Experience", paper to the Conference on Computers in the Undergraduate Curricula, East Lansing, MI, 20-22 June 1977. See also related film, Dan Isaacson, "Apex City", Computing Teacher, Vol. 9, No. 20 (Feb. 1982): 20. See also Louis E. Alfeld and Alan K. Graham, Introduction to Urban Dynamics (Cambridge, MA: MIT Press, 1976).

78. John D. Ford, Jr. and Harold Borko, Computer Applications in the Behavioral Sciences (Santa Monica, CA: System Development Corporation, August 1962). See also Jon E. Roeckelein, Simulation of Organizations: An Annotated Bibliography (Alexandria, VA: Human Resources Research Office, George Washington University, Dec. 1967).

79. UNESCO, The UNESCO Educational Simulation Model (ESM). Report and Papers in the Social Sciences No. 29 (Paris: UNESCO, 1974). See also Robert T. Grauer, "On the Modeling of Educational Systems", Journal of Educational Technology Systems, Vol. 4 No. 4 (1975-1976): 281-198.

80. Brent W. Poppenhagen and Richard J. McArdle, "Computer Simulation and Decision-Making: The Preparation of Mid-Level Managers for Higher Education", paper to the International

Conference on Improving University Teaching, Berlin, West Germany, July 1982. See also work by the Rand Corporation on educational administration for the Air Training Command: M. B. Carpenter-Huffman and M. Gallegos, Rand Publications R-1700-AF, R-1701-AF, R-1702-AF, and R-1703-AF, MODIA (Santa Monica, CA: Rand Corporation, 1977), 4 vols. Rand has also developed a model for university enrollment projections: S.J. Carroll and D. A. Relles, Rand Publication R-1735-NSF, "The Transition from High School to College: A Study of Freshman Enrollments in Florida" (Santa Monica, CA: Rand Corporation, Aug. 1975).

81. Pauline Oswitch, "Modelling Information System Dynamics: A Perspective", Library and Information Science Research, Vol. 5, No. 2 (Summer 1983): 129-155.

82. Gerald H. Shure and Robert J. Meeker, Real-Time Computer Studies of Bargaining Behavior: The Effects of Threat Upon Bargaining (Santa Monica, CA: System Development Corporation, Sept. 1963). See also Rufus P. Browning, Glenn W. Foster, and Daniel A. Blasinki, Computer Programs for Simulation of Political Bargaining (East Lansing, MI: Computer Institute for Social Science, Michigan State University, June 1970); Q. E. Overstreet, "Simulation Models of the Prisoner's Dilemma Game", in J. M. Dutton and W. H. Starbuck, eds., Computer Simulation of Human Behavior (N.Y.: Wiley, 1971): 260-273; Jeffrey Hart and Marc Simons, The Prisoner's Dilemma. Manual. (Raleigh, NC: NCSU Software, NCSU, 1984). Hayward Alker of MIT's Political Science Department is currently working on the "Sequential Prisoner's Dilemma" project, part of Project Athena, at MIT (telephone conversation with author, Aug. 1985).

83. F. R. Abbatt and J. R. Hartley, "Teaching Planning Skills by Computer", International Journal of Mathematical Education in Science and Technology, Vol. 5 No. 4 (Oct.-Dec. 1974): 665-671; Stephen C. Weiting, SIMSEARCH (Iowa City, IA: Department of Sociology, University of Iowa, 1975); Joyce Lee Shields, An Empirical Investication of the Effect of Heteroscedasticity and Heterogeneity of Variance on the Analysis of Covariance and the Johnson-Neyman Technique (Alexandria, VA: Army Research Institute for the Behavioral and Social Sciences, July 1978); Mark D. Shermis and Susan L. Albert, "CAPSAS: Computer Assisted Program for the Selection of Appropriate Statistics", paper to the American Educational Research Association, Annual Meeting, 7-11 April 1980; Kenneth Wald, "How to Cross-Tabulate Your Students, Teaching Political Science, Vol. 8 No. 2 (Jan. 1981): 223-226; Topics in Research Methods: Survey Sampling. Manual (Iowa City, IA: CONDUIT, 1984); Frank M. Howell, "SAMP: Survey Sampling", Social Science Microcomputer Review, Vol. 3 No. 1 (Spring 1985): 77-79; Ellen S. Vasu, Michael L. Vasu, and Susan F. Babcock, "Teaching the Elaboration Model Using Computer Simulation", Simulation and Games, Vol. 16, No. 1 (March 1985): 33-48. On Monte Carlo simulation techniques see Brent M. Rutherford, The Accuracy, Robustness and Relationships Among Correlational Models for Social Analysis: A Monte Carlo Simulation. An Occasional Paper, (Eugene, OR: Center for Advanced Study of Educational Administration, Oregon University, Sept. 1972); Hovav Talpaz, "Computer Assistance in Teaching Dynamic-Stochastic Systems Analysis", paper to Conference on Computers in the Undergraduate

Curricula, Fort Worth, TX, 16-18 June 1975; Actuarial Micro Software, Simulations: Monte Carlo Simulations and GASS (Winston-Salem, NC: Actuarial Micro Software, 1984). For an application of Monte Carlo simulation techniques to a social science topic see Thomas H. Hammond and Jane M. Fraser, "Studying Presidential Performance in Congress", Political Methodology, Vol. 10, No. 2 (1984): 211-244.

84. Jaime G. Carbonell, Ideological Belief System Simulation. Technical Report (New Haven, CT: Department of Computer Science, Yale University, May 1977).

85. Robert S. Yuill, A Simulation Study of Barrier Effects in Spatial Diffusion Problems. Technical Report 1. (Evanston, IL: Northwestern University, Nov. 1964); D. J. Bartholomew, Stochastic Models for Social Processes (NY: Wiley, 1967): 323-380; Richard L. Morrill, "The Negro Ghetto: Problems and Alternatives", pp. 391-411 in Harold Guetzkow, Philip Kotler, and Randall L. Schultze, Simulation in Social and Administrative Science (Englewood Cliffs, NJ: Prentice-Hall, 1972); William D. Richards, Jr., and Peter R. Monge, "A Computer Simulation of Human Communication", paper to International Communication Association, Annual Conference, Montreal, 25-29 April 1973; Raymond F. Hopkins, "Mathematical Modelling of Mobilization and Assimilation Processes", pp. 375-415 in Haywood R. Alker Jr., Karl W. Deutsch, and A. H. Stoetzel, eds., Mathematical Approaches to Politics (San Francisco: Joseey-Bass, 1973); Edwin Dethlefsen and Carlisle Moody, "Simulating Neighborhood Segregation", Byte, Vol. 7 No. 7 (July 1982): 178-206; on CONDUIT's "Diffusion Game" see George W. Wallace, "Beginning

Microcomputer Instruction on a Shoe-String", Southern Sociologist, Vol. 14 (Spring, 1983): 25; Carl Moody, Edwin Dethlefson, Jeffrey Hart, and Wayne Aiken, Neighborhood Segregation Model. Manual. (Raleigh, NC: NCSU Software, NCSU, 1984).

86. Simple simulations of the economy as well as other topics are found in Lawrence L. McNitt, BASIC Computer Simulation (Blue Ridge Summit, PA: Tab Books, 1983). See also, Michael K. Evans and Lawrence R. Klein, The Wharton Econometric Forecasting Model (Philadelphia: Economic Research Unit, University of Pa., 1967); Michael D. McCarthy, The Wharton Quarterly Econometric Forecasting Model MARK III (Philadelphia: Economic Research Unit, University of Pa., 1972); J. Williamson, "A Computer-Based Economics Game for Social Studies Instruction: International Balance of Payments", Journal of Educational Data Processing, Vol. 7 (1970): 181-192; T. H. Naylor, Computer Simulation Experiments with Models of Economic Systems (NY: Wiley, 1971); M. C. McCracken and C. A, Sonnen, "A System for Large Econometric Models - Management, Estimation, and Simulation", Proceedings, Association for Computer Machinery, Annual Conference, NYC, 1972, pp. 964-973; K. P. Anderson, A Simulation Analysis of U. S. Energy Demand, Supply, and Prices, Rand Publication R-1591-NSF/EPA (Santa Monica, CA: Rand Corporation, October 1975); Martin Greenberger, Matthew Crenson, and Brian Crissey, Models in the Policy Process: Public Decision-Making in the Computer Era (NY: Russell Sage, 1976): ch. 6 ("Econometric Modeling"); R. B. Coats and A. Parkin, Computer Models in the Social Sciences

(Cambridge, MA: Winthrop, 1977): ch 8, presents a simple model; T. H. Naylor, ed., Simulation Models in Corporate Planning (NY: Praeger, 1979); T. H. Naylor, ed., Simulation in Business Planning and Decision-Making (La Jolla, CA: Society for Computer Simulation, 1981); Hugh J. Watson, Computer Simulation in Business (NY: Wiley, 1981); John D. Sterman and Dennis Meadows, "STRATEGEM-2: A Microcomputer Simulation Game of the Kondratiev Cycle", Simulation and Games, Vol. 16, No. 2 (June 1985): 174-202. See also Peter H. Ritchken and Gregory B. Getts, "A Portfolio Risk-Management Simulation Game", Simulation and Games, Vol. 16, No. 1 (March 1985): 49-62.

87. Warren J. Erikson and Owen P. Hall, Jr., Computer Models for Management Science (Reading, MA: Addison-Wesley, 1983) covers 14 managerial techniques, providing each model on a microcomputer disk as well as in the text. An early example is John P. Crecine, Governmental Problem-Solving: A Computer Simulation of Municipal Budgeting (Chicago: Rand McNally, 1969. See also William D. Berry, "Testing Budgetary Theories with Budgetary Data: Using Simulations to Assess the Risks", paper to the Southern Political Science Association, Savannah, GA, Nov. 1984. For an interesting critique of the failure of management science models in military research administration, see E. S. Ojdana, Jr., and J. P. Weyant, Rand Publication R-1847-PR, An Assessment of Selected Models Used for Evaluating Military R&D Projects (Santa Monica, CA: Rand Corporation, Sept. 1976).

88. Michael J. Shapiro, "The House and the Federal Role: A Computer Simulation of Roll-Call Voting", American Political Science Review, Vol. 62 (Summer 1968): 494-517. See also Wayne L.

Francis, "Simulation of Committee Decision-Making in a State Legislative Body", Simulation and Games, Vol. 1 No. 3 (Sept. 1970): 235-62; Richard L. Cole and Stephen J. Wayne, "Predicting Presidential Decision on Enrolled Bills: A Computer Simulation", Simulation and Games, Vol. 11 No. 3 (Sept. 1980): 313-325.

89. For example, the leading American government text (Burns and Peltason) is now supplied with an instructional simulation in which the student plays the President in making national budget decisions. See "President" in American Government Simulations, Vol. II (Englewood Cliffs, NJ: Prentice-Hall, 1985). See also D. B. Borow, "Computers and a Normative Model of the Policy Sciences", Policy Sciences, Vol. 1 No. 1 (1970): 123-134; R. B. Smith, "Presidential Decision-Making During the Cuban Missile Crisis: A Computer Simulation", Simulation and Games, Vol. 1 No. 2 (1970): 173-201; B. Hayes-Roth et al., Rand Publication R-2670-ONR, "Human Planning Processes" (Santa Monica, CA: Rand Corporation, Dec. 1980) - describing a computer simulation of a cognitive model of planning processes set forth in their 1979 papers, Rand Publications N-1173-ONR and P-6266. Further work is described in B. Hayes-Roth et al., Rand Publication P-6688, "PLANNER'S WORKBENCH: A Computer Aid to Re-Planning" (Santa Monica, CA: Rand Corporation, Oct. 1981). See the critique of simulation in policy planning by W. E. Walker, Rand Publication P-6654, "Models in the Policy Process: Past, Present, and Future" (Santa Monica, CA: Rand Corporation, Sept. 1981).

90. Arthur I. Siegal and Jay J. Wolf, Man-Machine Simulation Models: Psychosocial and Performance Interaction (NY: Wiley-

Interscience, 1969); J. C. Finney et al., "Computer Simulation of Psychologists' Decision-Making", Proceedings of the Association for Computing Machinery, Annual Conference, NYC, 1972, pp. 899-902. For further bibliography, see R. B. Coats and A. Parkin, Computer Models in the Social Sciences (Cambridge, MA: Winthrop, 1977): 81-3.

91. J. T. Gullahorn and J. E. Gullahorn, "Computer Simulation of Human Interaction in Small Groups", Simulation, Vol. 4 (1965): 50 - 61; describes "HOMUNCULUS" simulation on human behavior under cross-pressure, using Monte Carlo techniques; J. P. Gremy, "The Use of Computer Simulation Techniques in Sociology", International Social Science Journal, Vol. 23, No. 2 (1971): 204-218; J. T. Gullahorn and J. E. Gullahorn, "Social and Cultural System Simulations", pp. 144-190 in Harold Guetzkow, Philip Kotler, and Randall L. Schultz, eds., Simulation in Social and Administrative Science (Englewood Cliffs, NJ: Prentice-Hall, 1972); J. Kenneth Monts et al., "Interdisciplinary Instruction on the Dynamic Simulation of Social Systems", Teaching Sociology, Vol. 4 No. 4 (July 1977): 315-332; George Conklin, PROFIS (Iowa City: CONDUIT, 1982); George Conklin, CLEAR (NY: Holt, Rinehart, and Winston, 1982); Ronald E. Anderson, "Instructional Computing in Sociology: Current Status and Future Prospects", Teaching Sociology, Vol. 8 (Jan., 1982): 171-195. Recent simulations include Ron Anderson, Computerized Activities in Sociology (NY: Random House, 1985), including the "Social Indicators Game" and three others; and William Bainbridge, Experiments in Sociology, computer materials to accompany Rodney Stark, Sociology (Belmont, CA: Wadsworth, 1985), including the "Germany 1919-1960"

simulation and others.

92. See Benjamin Radcliff, "Multi-Criteria Decision-Making", Social Science Microcomputer Review, Vol. 4, No. 1 (Spring, 1986): forthcoming. See also D. A. Waterman and M. A. Peterson, Rand Publication R-2717-ICJ, "Models of Legal Decision-Making, Research Design and Methods" (Santa Monica, CA: Rand Corporation, 1981); A. M. Shoben, Rand Publication P-6552, "Expert Systems: Newest Brainchild of Computer Science" (Santa Monica, CA: Rand Corporation, June 1981).

93. Philip A. Schrodt. "Artificial Intelligence and International Crises: The Application of Pattern Recognition to the Analysis of Event Sequences", paper to the American Political Science Association, Annual Meeting, August 1984, Washington, DC; "Adaptive Precedent-Based Logic and Rational Choice: A Comparison of Two Approaches to the Modeling of International Behavior", paper to the Conference on Dynamic Models of International Conflict, November 1984, Boulder, CO, rev. Jan. 1985. See also Dwain Mefford, "Formulating Foreign Policy on the Basis of Historical Analogies: An Application of Developments in Artificial Intelligence", paper to the International Studies Association, April 1984; Haywood R. Alker and C. Christensen, "From Causal Modeling to Artificial Intelligence: The Evolving UN Peace-Making Simulation", pp. 177-224 in J. A. LaPonce and P. Smoker, eds., Experimentation and Simulation in Political Science (Toronto: University of Toronto Press, 1972).