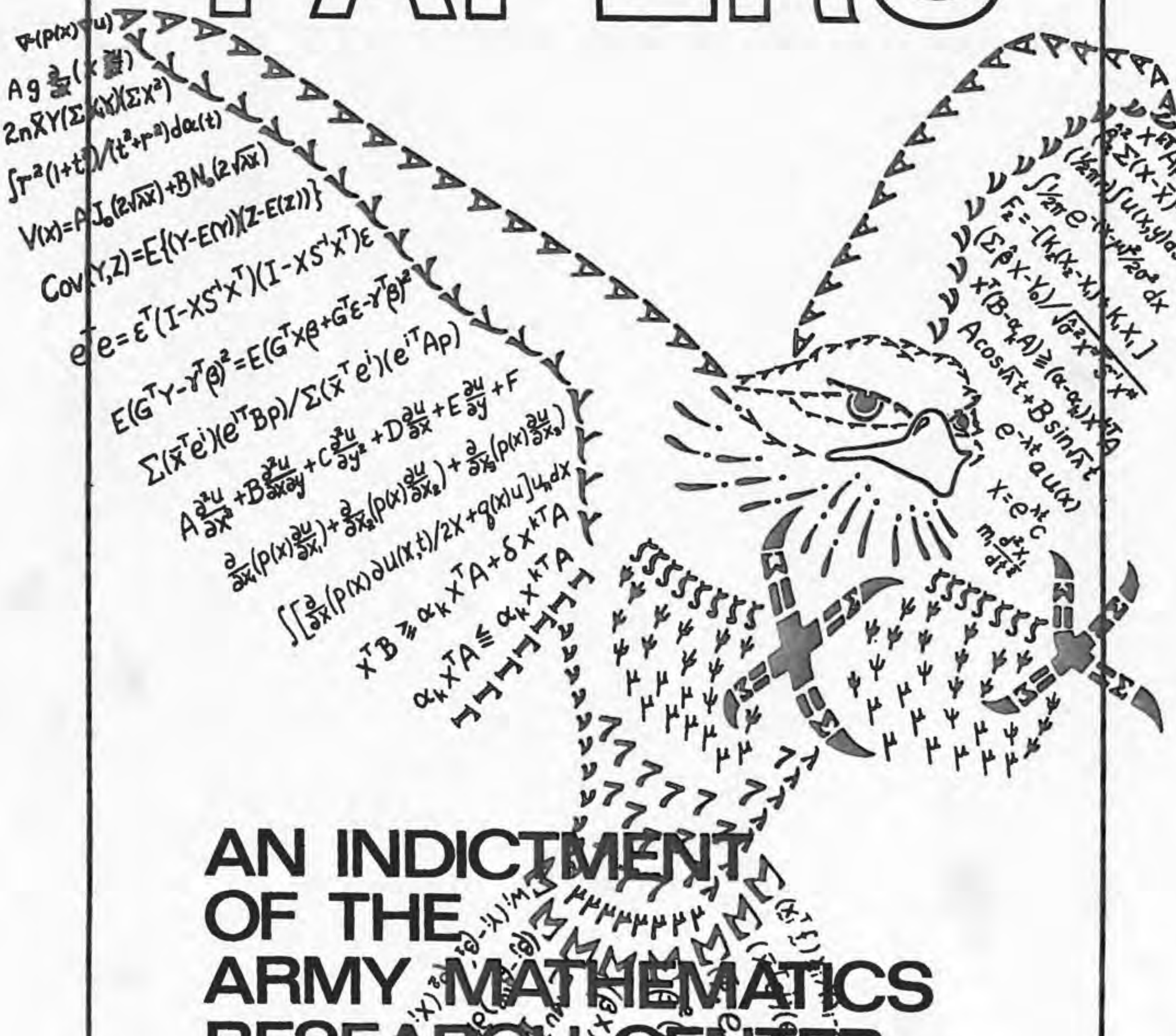
$1.25

THE AMRC PAPERS



AN INDICTMENT OF THE ARMY MATHEMATICS RESEARCH CENTER

THE AMRC PAPERS

by Science for the People
Madison Wisconsin Collective

For additional copies, permission to use copyrighted material or correspondence, please write: Science for the People
306 North Brooks Street
Madison, Wisconsin 53715

Our special thanks to Take Over newspaper and RPM printing cooperative for their aid in preparing this book for printing. We are also grateful for financial support from the Madison Sustaining Fund and the Science for the People collectives in Chicago and Minneapolis.

Contents

Who We Are

Science for the People is a nationwide group of women and men, scientists and non-scientists. We are united in recognizing that science, to a great extent, supports today's diseased social order by being available solely to governmental, military and corporate decision-makers. To change this reality, we have been organizing political actions by which wider circles of people might gain access to useful scientific knowledge. We believe that such a struggle is an essential part of the movement to build a just social order in the United States and the world.

The political uses to which science is now put strongly affects the lives and work of both non-scientists and scientists. Scientific innovations are used to devise new weaponry and war strategies; scientific ingenuity is applied towards new and often useless or destructive consumer goods to keep profits high; and scientific developments are used to control peoples throughout the world who challenge those currently in power.

Since science safeguards the privileged position of a few, we are working to transform the applications of science, and the nature of scientific work, so that science can develop with the positive end of serving all people.

This does not mean that we are practitioners of "anti-science". We envision a redirection of scientific activity which will allow ordinary people to see their needs reflected in the efforts of the researchers. Science will take on this new form only with the direct participation of millions of non-scientists in the political decisions which guide science.

As one application of this philosophy, the Madison Collective has researched the activities of the Army Mathematics Research Center, an institute which specifically serves the goals of the United States and the political system of domination which its Army defends, for example in Indochina, the Philippines, Brazil and Iran. As a result of our investigation, we hope that the public becomes aware of AMRC's work and forces the replacement of this military center with an institute which genuinely serves all the people.

Bonnie Acker	Helen Lankenau
Marjorie H. Barnes	Dennie Nadeau
Meryl Bisberg	Tom Phillips
Joe Bowman	Jane Sellar
Robin Dennis	Paul Still
Doug Hanson	Lorne Taichman
Henry W. Haslach, Jr.	Steve Roffler

We show that AMRC's permanent staff, in a highly productive mathematical atmosphere provided by the remaining staff, are deeply involved in the most fundamental aspects of military research: the design and testing of weapons, and the creation of military and political strategy.

The mathematical papers published by AMRC provide AMRC spokesmen with the excuse that no secret work is done, in accordance with a University regulation, and that the Center's total work is found in the "open literature." But what is omitted from publication are the ways in which this so-called "pure research" is in reality directly applied towards solving the Army's mathematical problems. The clearest method of this application is through the permanent staff's consultations with Army base mathematicians, involving lectures, symposia, and orientation sessions with large groups of Army personnel, and other times the advising of smaller groups of Army mathematicians on specific problems. In assessing the actual work done by AMRC for the Army, the Annual, Semi-Annual and Quarterly Reports of the Center were used as sources; and although the actual applications of the research are kept secret, we were able to combine information from a number of sources to understand those uses (see section on our research method).

Format of our Report

Because the Center's consulting is of central importance to the Army, we have placed information about AMRC's dealings with Army bases and projects in Part I. This part also contains the bulk of the new material against AMRC which has never before been published, an original contribution by our group because it links AMRC's reports of its Army contacts with the Army's own statements about its research and objectives. Because our group has representatives from almost discipline within the biological and physical sciences, we are able to provide a more thorough technical interpretation of Army Math's work than other reporters have previously done. Part I also contains an analysis of American international policy during the last two decades, to describe the changes in that policy to which AMRC has adapted.

Part II contains AMRC's contract with the Army and a full description of the staff's daily operations and obligations to the military. Army Math's early history, current status, and its relation with the University of Wisconsin are given in Part III.

People's Mathematics

It is not just the overtly violent nature of military and corporate policies which outrages us. We protest an equally destructive phenomenon, the military's subtler usurptation of human and physical resources which prevents any viable solutions to our social crises. A research community using the same mathematical skills now in the service of the Army could solve pressing public problems and help our society chart future courses of action. A transformed Mathematics Research Center could deal with people's real needs, if democratic popular control and participation were constitutionally insured from its inception. Part IV of this report describes our proposal for such a People's Mathematics Research Center. At this stage in our struggle, this proposal is meant only as a suggestion to spark discussion. We urge people reading this, and examining the case against Army Math, to form their own visions of an alternative research center and share it with friends. In this way, bit by bit, we will create the consensus for a transformation of not only one AMRC, but the whole American society.

Postscript

We will welcome questions about our research from other groups and people wanting to undertake similar projects. We hope this report will inspire many more people to look at their own surroundings, to expose scientific violence where it exists, and to construct strategies for replacing that violence with a new vision of the way science could be.

In Solidarity,

Science for the People

To what end do you work?

I take it the only aim of science is to ease human existence.
But if the scientist allows himself to be indimidated
by the self-seeking men in power, if he rests content with
hoarding knowledge for the sake of knowledge, then science
can be turned into a cripple, and your new machines will mean
only new drugeries. In time you may discover all that is
to be discovered, but your progress will be away from the
progress of humanity, and the gulf may become so wide one day
that your cheering at each new achievement will be echoed
by a universal howl of horror.

The movement of the heavenly bodies
has become clearer to the people, the movement
of their rulers is still obscure.

...the pursuit of science calls for particular courage.
She trades in knowledge which is won by doubt. Above all,
she creates knowledge for all men, and thus makes doubters
of all men.

The misery of the many is as old as the rocks.
According to our preachers and teachers it is as indestructible
as the rocks. But our new art of doubt has delighted the
the great public. They snatched the telescopes out of our hands
and trained them on their tormentors; all those men of greed
and violence who, having made selfish use of the fruits of science,
could feel its cold eye staring at misery, which is ancient
but artificial -- and could clearly be brought to an end
if only those that caused it were brought to an end.

Galileo speaking in
Bertolt Brecht's The Life of Galileo (Act 1)

PART I
HOW AMRC HELPS THE ARMY

INTRODUCTION

"Naturally, MRC must produce results of value to the Army. Otherwise, the Army would terminate its support. I handle this by inviting as members of MRC persons whose work has the possibility of application to military problems. It is quite explicity stated in the MRC contract that MRC is not to work on the applications themselves. However, members of MRC do commit themselves to be available for consultations by mathematicians from the Army who have questions in the range of competence of the MRC member."

AMRC Director J. B. Rosser
quoted in Mathematics for Death

The Army Mathematics Research Center has helped the Army in many ways: by holding mathematics conferences at the University of Wisconsin on problems which interest the Army and by consulting directly with Army scientists. To determine exactly what uses the Army has found for this mathematical technology, we have studied in detail the consulting between AMRC and the Army which is recorded in Army Math's Annual, Semi-Annual, and Quarterly Reports.

Our report emphasizes AMRC consulting because it is through such consulting that the Center transforms "pure" mathematics into information useful to the Army. The Army also profits from AMRC's conferences, Technical Reports, and the informal conversations which are not often recorded.

WARF building - home of the Army Mathematics Research Center after the 1970 bombing.

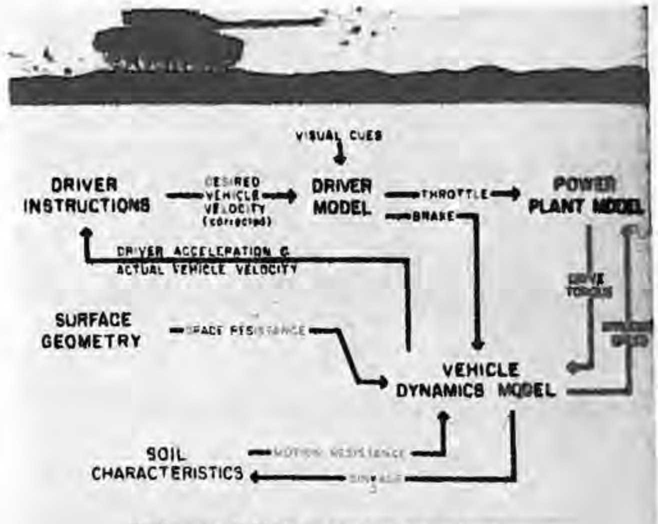
CONSULTING ON GUERRILLA WARFARE

Alone, consulting reports reveal little, as an example from AMRC's 26 April 1968 Quarterly Report indicates:

> "In response to a detailed request for assistance with a problem concerning measures of effectiveness which was received from Dr. David R. Howes, U.S. STAG, Bethesda, Maryland, on March 6, 1968, Prof. Rosser wrote to Dr. Howes to suggest a meeting between STAG personnel and Prof. Bernard Harris."
> (26 April 1968 Quarterly Report)

To understand the reality behind this bureaucratic prose, we had to place together information on Professor Harris (a statistician), US-STAG, Dr. Howes (a creator of a computer model for guerrilla warfare), and US military policy at the time of the consultation (President Johnson's phase in the Indochina War). All this data, described in our section on STAG, demonstrates that the "measures of effectiveness" mentioned in the AMRC Report are the death and destruction by gunfire, as represented statistically in Howe's computer model of guerrilla combat.

STAG has been using such mathematical models to develop Army tactics for Indochina and the other guerrilla wars in the Third World where the US is involved.



Mathematical Model of Vehicle/Man System

MATHEMATICAL MODEL of Vehicle/Man System. "Our efforts will be aimed at providing the techniques for training, testing and evaluating the small unit programs, with particular emphasis on effective training in an environment of high personnel turbulence." (Army R&D September-December 1971)

MATHEMATICAL MODELS

As this trail of Army-AMRC consulting was traced, the Army's growing dependence on mathematical models became obvious.

Common-sense Mathematical Models

Below, we give examples of mathematical models stripped down to their basic essentials. In these "common-sense" models, a single equation expresses the behavior of the system. The accuracy of the predictions of these crude models depends upon the system's behaving in accordance with relatively sweeping assumptions. Complicated models would account for many more contingencies than the models below, and thus would give more reliable predictions. However, simplified models are especially advantageous because they often give adequate predictions without requiring extensive use of a computer.

Suppose that during an hour, a living cell in a biology lab splits once, thus creating two cells. In this case, the mathematical model which describes the growth of a cell after any number of hours is $N=2^h$ where N equals the number of cells after h hours. Thus, if we want to know how many cells there will be after 3 hours, we replace the h with a 3 and the model predicts an answer: $N=2^3=2x2x2=8$ cells.

Of course, this assumes many things, such as that no cells are dying during the three hours. If all assumptions are true, then the model is good; if not, the model will lead to false predictions.

Suppose we know how fast a car is moving and want to predict how far it will travel in 4 hours. The model is $d=st$, where the distance d equals the speed s multiplied by the time t. So if the car moves at 30 mph, the distance we predict is $d=30x4=120$ miles.

The assumption here is that the car travels with constant speed. If this assumption is correct, then the car will actually travel a total of 120 miles just as predicted.

MODELS FOR THE ARMY

Through its mathematical modeling AMRC has helped the Army in three important areas. First, they have helped design new weapons and the technological components of new weapons systems. Second, they have aided in the testing of weapons. Third, AMRC has helped analyze and plan strategies for future warfare systems. Again, the real situation is simulated as a game in mathematical terms. The player of the game is the Army strategist, who tries out various strategies to determine which best attain the Army's goal. The assumption is then made that the strategy working best in the game will work when the situation is faced in actual combat.

ARMY RESEARCH BASES

The Army transforms AMRC's mathematical tools into military hardware and strategy at a number of research bases, such as the STAG operation in Maryland. These bases are a crucial step in the process which pipes "pure" University research into the American military machine. Gathered there are the scientists and engineers who apply AMRC's work to strategies and weaponry. Providing these bases with the latest mathematical techniques has been AMRC's primary purpose since its birth.

In tracing the results of AMRC's consulting, we have divided the numerous consulting reports first according to the Army base involved. By studying AMRC's descriptions of their consulting, together with the individual bases' research publications, we have often identified the exact Army project for which the AMRC mathematicians were summoned. From our discoveries, it is clear that AMRC has contributed to Army projects which have been hidden from the public. One of these, as we will demonstrate, is STAG's guerrilla warfare modeling. The extent and importance of AMRC's work can be judged far more clearly from this evidence than from the partial glimpses which AMRC spokesmen allow.

We are presenting our evidence of AMRC's consulting with the ten Army bases for which we obtained the most evidence. These ten bases are grouped according to the kinds of weapons they produce: counter-insurgency weapons, conventional weapons, chemical and biological weapons, and missiles.

The research on each group of weapons is first placed in its political context. Then, the bases working on those weapons are described, beginning with an over-view of the bases' research, and concluding with the details of AMRC's consultations there. A table of AMRC's contacts with additional bases follows this analysis.

In the next sections we provide a framework for understanding the political climate in which this research began and is now carried on. Included is a short history of post-Korean War US military strategy, recent trends in this strategy, and university complicity in these developments. The research method we used to study AMRC's consulting is explained at the end of our report.

"TERRAIN MODEL OF VIETNAM VILLAGE is used at Picatinny Arsenal to determine flare illumination requirements for Southeast Asia combat operations." (Army R&D November 1971).

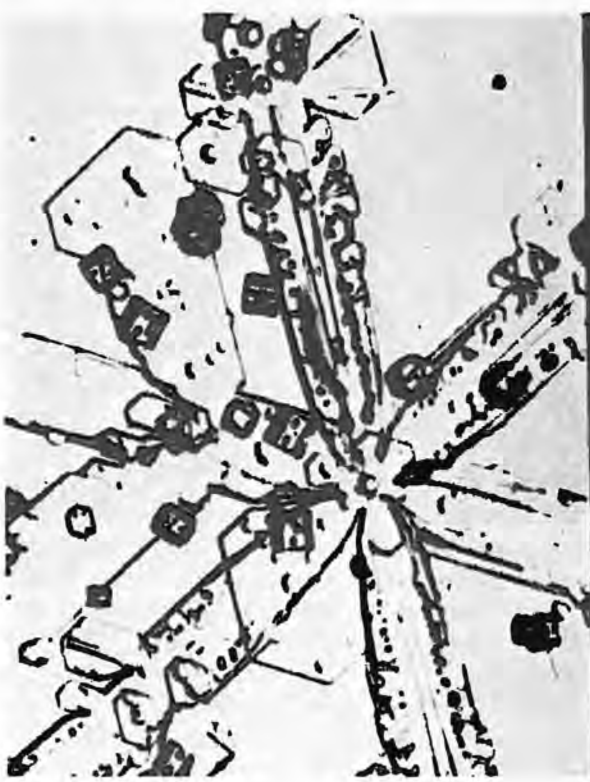
AN INTRODUCTION TO

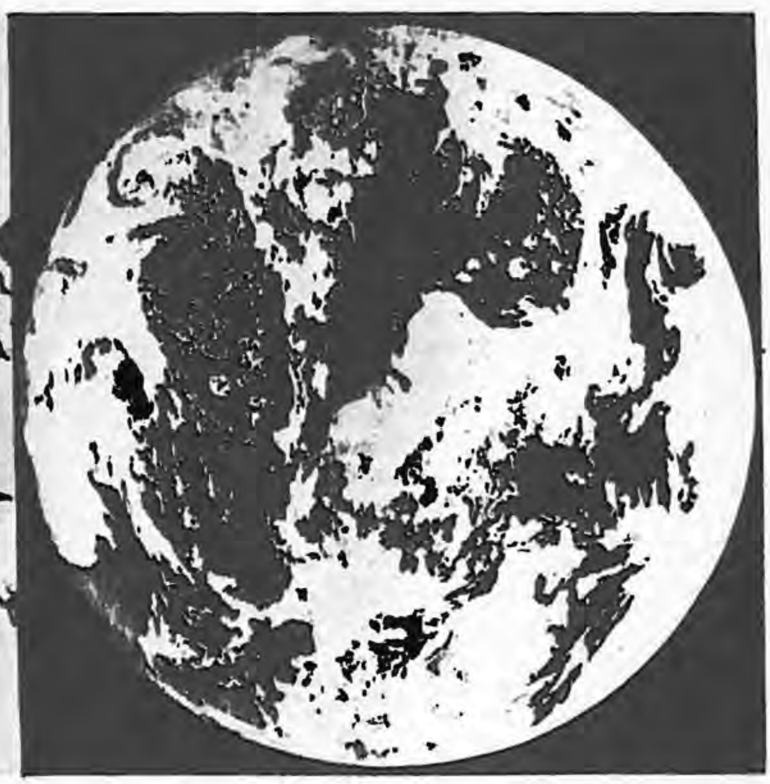
A model is a representation of a physical or social system. All models are merely approximations to reality. This is because simulations of complicated systems must necessarily be limited in scope. For example, a model of the atmosphere cannot possibly simulate the whole range of behavior of such an exceedingly variable system, from the smallest molecular motion to the largest hurricane. For this reason, models are designed with limited space and time scales in mind. So long as they are not stretched beyond their designated limits, models can serve as useful tools for understanding the workings of a system.

Before a model can be constructed, careful attention must be given to selecting the important factors which define the system. In the case of the atmosphere, there are five factors which define what we call "the weather." These are: pressure, temperature, density, humidity, and wind velocity. Often it is desirable to define the factors of a system in symbolic form and to summarize the relationships among them by means of equations. For example, $P=DRT$ is an equation pertaining to the atmosphere. P is the pressure, D is the density, R is a constant for air, and T is the temperature. This equation informs us that the pressure, density, and temperature of the air are all interdependent.

When the system's factors are expressed in equation form, we have a mathematical model. If the factors change with time, such a model can be used as a predictive tool. This is accomplished by including the time rate of change of the factors in the equations of the model. The equations are solved to get future predicted values of the factors. For example, we know that the pressure, density, humidity, temperature, and wind velocity all change with time because "the weather" changes from day to day. The rate of change of these factors is expressed in the atmospheric model equations. Starting with today's measurements of these factors, these equations are solved to predict tomorrow's weather. High-speed computers make it possible to solve the weather equations for a period of 24 hours in a fraction of that time. It has been estimated that it would require 64,000 people working simultaneously at desk calculators to duplicate this feat!

Another advantage of a mathematical model is that it can synthesize all the effects of the separate factors of a system more efficiently





than the human mind can. This is essential if the interactions of the system's components are so numerous and complex that cause-effect relationships tend to be blurred. The atmosphere is such a system. It is usually impossible to pinpoint a single cause for any observed weather phenomenon. Instead, several weather factors usually change simultaneously, interacting with one another to produce the observed effect. Models that incorporate most of these interactions can be used to check the relative importance of each factor in the modeled phenomenon.

Although mathematical models are powerful tools, we should keep in mind their limited scope. A weather forecast model for the entire United States will imperfectly simulate the smaller scale weather of Wisconsin. Models designed for short-term forecasting will give poor results if used for extended forecasts of many days. We must also remember that even a perfect mathematical model cannot express the full impact of a system on human beings: atmospheric models will never capture the aesthetic appeal of a rainbow or a small child's delight at playing in freshly-fallen snow.

However, we should continually strive to broaden our models in order to include as many related human factors as possible. For example, it is conceivable that a weather forecast model could be used in conjunction with a model that predicts agricultural yield for different weather conditions. This would extend the predictive capability of a weather model into another sphere, while still leaving room for human interpretation and implementation. Models such as this could be of great assistance in the planning of the future needs of a society.

Because of the staggering potential of mathematical models, it is imperative that there be democratic control of the applications of these models. Such popular control is sadly lacking in the case of the Army Mathematics Research Center. AMRC applies mathematical models to imperial needs -- to predict the path of a missile, to coordinate the intricate weaponry of the electronic battlefield, and to plan strategies for controlling Third World peoples. In other hands, modeling could be used to plan a good distribution of state health care and to map out an efficient public transportation system for a metropolitan area -- in other words, people's mathematics applied to people's real needs.

Chapter 1

COUNTER-INSURGENCY

Military research in this country, including AMRC research, is dictated by United States' foreign and military policy. During the past twenty years, the military policy has been based on two cornerstones: the strategies of "massive retaliation" and of "limited response."

The "massive retaliation" strategy was formulated during the Cold War years of Eisenhower's Administration. It required the US to maintain an arsenal of nuclear weapons and conventional bombers sufficiently large so that any country opposing US interests or contemplating attack is threatened with total destruction of its homeland. The policy had defensive aims in preventing an attack on the US by the Soviet Union.

It also has had an offensive aspect. It has been used to threaten countries, specifically China and the Soviet Union, which might object to US actions in other parts of the world. Such threats have been made either overtly or implicity during US intervention in the Greek revolution just after World War II, over the islands of Quemoy and Matsu off the Chinese coast in the late fifties, and recently during the Indochina War. However, such a strategy is only effective against an established nation with an industrial sector to protect. A country must have something to lose before it will fear "massive retaliation."

The unexpected success of the Cuban Revolution and other events, however, convinced military planners that guerrilla movements in the undeveloped countries, in addition to the USSR, posed a threat to United States

interests. Strategists saw that a new strategy was required, developed it under the Kennedy Administration, and called it "limited response." Its purpose was to prevent, or at least control, the development of guerrilla movements opposed to free enterprise and to US investment in their countries.

Initially, the strategists hoped, early intervention with local police equipped and trained by the United States would be sufficient to crush the insurgency. This would avoid the necessity of sending in US troops with all the economic and political problems such an action would cause. Also, there would be a strong propaganda effort to convince potential supporters of insurgents that an "American-type society" was better than what guerrillas could offer.

If this proved unsuccessful, the US would intervene with conventional World War II-type weapons: infantry and bombers. But the application would not be simple, for in a guerrilla war, there are no front lines. This fact required some modification of the "limited response" strategy, and it is here that AMRC has aided the Army.

To deal with the difficulty of finding the guerrillas, surveillance techniques were developed including night-vision instruments and specially equipped observation aircraft. Military planners also had to deal with the expense involved in fighting a guerrilla war, since they depended on 10 soldiers for each guerrilla in the field. The "limited response" capability was extended to include what is now known as the automated or electronic battlefield, where most notably in Indochina, electronic devices are used to spot guerrilla movements and then to guide bombers to their targets.

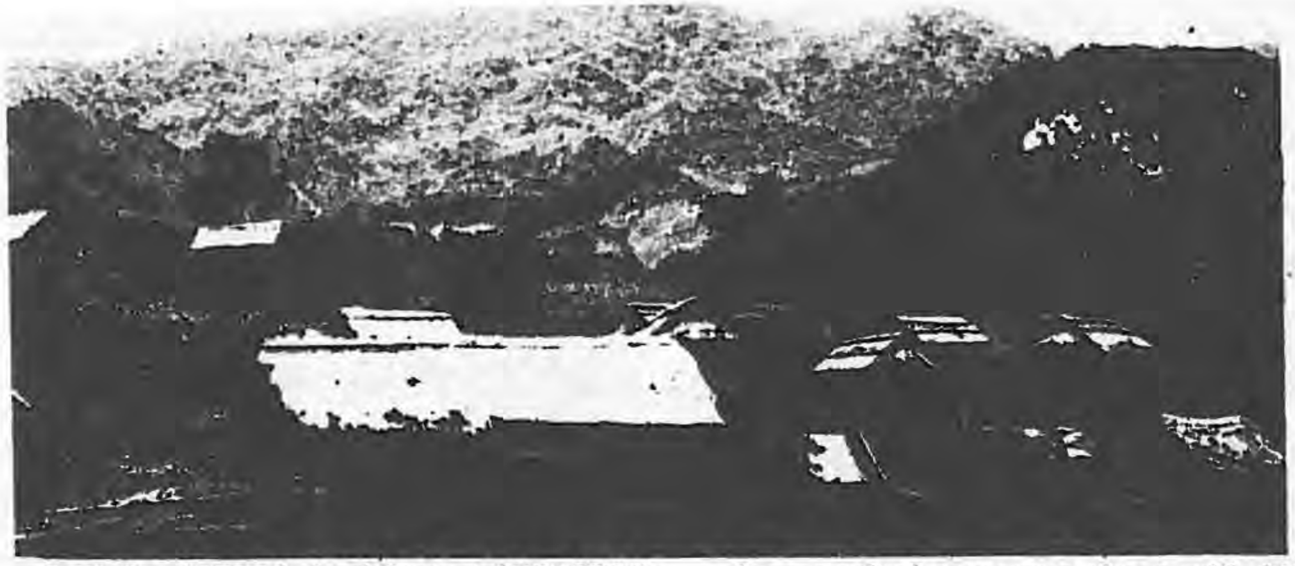
The strategy of "limited response" is not limited in the amount of firepower used. In cases such as Indochina, where the guerrillas control large areas, bombing is carried out so indiscriminately that it is in fact an attack against the entire population - and reaches the same level of destruction as that called for under the "massive retaliation" strategy. "Limited response" is selective in its primary goal: not the unconditional surrender of an established government but the control of a guerrilla insurrection. Today, the modified "limited response" strategy is often termed one of "counter-insurgency".

This section concentrates on the aid AMRC has given the Army in creating a "limited response" capability. Preventing insurgent groups from driving the US from their countries requires different strategies as well as different weapons. Here we examine four projects on which AMRC consulted: Project MICHIGAN; a special project on bomb shelters; the Strategy & Tactics Analysis Group (STAG); and the Research Analysis Corporation (RAC).

PROJECT MICHIGAN

Once a guerrilla army is in the field, a major military problem facing the defenders of the status quo is to find the guerrilla units, their supply depots, and their equipment. Developing the technology for surveillance of guerrilla actions and for determining targets to be destroyed was the primary task assigned Project MICHIGAN, located at the Willow Run Laboratory under the University of Michigan. This Project developed radar techniques for terrain mapping for selecting targets to be bombed; this radar technology became one component of the automated battlefield in Indochina.*

* This automation is possible through the use of sensors which are able to detect sounds, smells, heat, the presense of metal, and more by sending out a signal and receiving a response. One kind of sensor system is radar, which first sends out beams (radiation) and then records them after they reflect off some object. The distance between the radar equipment and the target is deduced from the time it takes the beams to hit and return.



Initially, AMRC helped Project MICHIGAN in two areas: first, in developing a mathematical model to determine the limitation of radar systems and to chose the best design; and second, in solving a model of a maser-- a modern electronic device which enhances the ability of radar to detect small objects.*

The atmosphere distorts a radar beam by bending it before its return to the aircraft, thereby causing inaccurate information concerning the target's location. AMRC helped analyze this effect so that the system could be made more accurate. Further assistance to radar surveillance was given by AMRC in the form of mathematics helpful in deciding which routes would be flown to observe enemy troops.

By 1962, Project MICHIGAN had begun work perfecting a different technique of surveillance, which also received AMRC's help. This technique, called "infrared detection," finds targets by detecting the heat radiating from them. Because different types of objects emit different infrared waves, this technique is useful in detecting camouflaged troops or trucks with warm engines hidden in the jungle. It is especially useful at night, when ordinary visual spotting of targets is ineffectual.

One particular problem with infrared detection is that of distinguishing the signals emitted by the intended target from those emitted from other objects. Richard L. Legault, a member of Project MICHIGAN who consulted numerous times with AMRC, was interested in finding ways to distinguish the signals caused by people from signals caused by all other objects, especially trees. AMRC also gave important help to the design of infrared detection systems by finding mathematical means to develop methods of transmitting the data over wires, to and from the computer which selects the targets.

*A maser increases the radar's target detection ability by amplifying its radiation into intensely concentrated beams. A maser concentrates the radiation in the same way that a laser produces a concentrated beam of light. Just as a laser beam could bounce off a reflector placed on the moon by astronauts, so can the maser's radiation be reflected from small objects and detected by radar.

THE "BOMB SHELTER PROBLEM"

Once a target has been sighted ("acquired" in Army jargon), plans are made to destroy that target. In Indochina, this presented particular difficulties. Recall that it was during 1965 that the bulk of US ground troops were sent to Vietnam. At the end of 1965, AMRC received a call from the Army Research Office requesting a hurry-up project - the "bomb shelter project" in the AMRC Reports. The Center was asked to find the probability of destroying an underground target by explosions around the target, and quickly submitted a report on this problem to the Army.

It seems likely, given the time at which this project was done, that it had to do with destroying National Liberation Front underground fortifications; and unlikely that it pertained to missile warfare, since seldom is a large number of missiles directed at one small underground target.

WAR GAMES

To "search and destroy" guerrilla targets is very difficult, demonstrated by the United States' experience in Indochina. The Army would like to minimize the problems in two ways: first, by preventing the guerrilla movements from growing to a point of decisive military strength; and second, if this cannot be prevented, by finding new strategies to fight the guerrillas. These efforts are part of the job of the Army Strategy and Tactics Analysis Group (STAG) and the Research Analysis Corporation (RAC).

STRATEGY and TACTICS ANALYSIS GROUP

STAG is an Army group which plans battle tactics and strategies at all levels. One of the main tools used in such planning is war games. These "games" are sets of mathematical equations representing a combat situation. The military strategist makes a decision; the decision is then represented by placing values in the equations. The answers, which are often found by computer, predict what would be the combat results in a real war given the strategist's decisions. AMRC helped STAG prepare equations which will simulate, as correctly as possible, what really happens in combat. These are called "models" of war.

AMRC's help began in 1960 and has continued through 1972, according to the Center's latest written report. The aid may well be continuing today. Assistance has focused on increasingly sophisticated combat situations, including guerrilla warfare, as the Army's work has progressed over the years. The mathematical problems in finding equations to represent the complexities of combat are very intricate and require AMRC's expertise.

The first models were for conventional warfare of the type fought in World War II. But as the US has become more concerned with its strategy of "limited response", the interest in models has also shifted in that direction.

A basic war model is the Lanchester model. This is described in this chapter to give a sense of what is required in such models. AMRC was involved in attempts to improve the Lanchester model in October 1972. Some of its aid has helped David R. Howes of STAG to develop his computer model of guerrilla warfare, which he called "GUEVARA".

This kind of research makes it possible for the Army to plan the manipulation of whole countries in order to defeat guerrilla armies or to prevent their development. It is in this effort that the Army uses AMRC's current work on population studies and economic models (equations which show how the economy of a country works and enable predictions of what will happen if certain changes are introduced).

Allowing the Army to get involved in such planning also risks new Indochinas, since the Army will want to implement the theories it develops from such models in actual situations. Planning the suppression of indigenous political movements which the Army thinks might take to the field in opposition to current governments is anti-democratic, since no such movement or guerrilla army could exist without the support of the people.

RESEARCH ANALYSIS CORPORATION

The Research Analysis Corporation's work is especially devoted to answering the following types of questions about combat systems: What does a change in the military situation do to the combat effectiveness of a system? At what level do increases in technical performance yield diminishing returns in combat effectiveness? What trade-offs can be made to reduce cost, but maintain the same level of combat effectiveness? AMRC has helped RAC develop the mathematical tools needed to answer such questions. The mathematics often requires mathematical models of warfare like those used by STAG. The particular examples referred to are the Carmonette model, used for individual men, vehicles and weapons, and the Theaterspiel model, used for combat studies of division-sized units. Although AMRC's reports give only brief attention to the Center's help to RAC, we felt it was significant and include what sparse information there was.

Project MICHIGAN

I DESCRIPTION

Project MICHIGAN, established in 1953 under the Army, is part of a diversified program of research conducted at Willow Run Laboratories of the University of Michigan's Institute of Science and Technology in Ann Arbor. The Institute was established in order to make available to government and industry the resources of the University of Michigan, and to broaden the educational opportunities for students in the scientific and engineering disciplines.

PURPOSE

The mission of the Project is: (1) to supplement the functions of the military in-house laboratories in the research and development of equipment for surveillance, target detection, target location, and data transmission; (2) to make maximum use of the techniques and equipment developed by the military labs and to emphasize their ultimate use in the combat surveillance system; and (3) to engage in such research and development as may be found necessary to fill gaps in the existing programs leading to combat surveillance.

Project MICHIGAN is carried out by a full-time Willow Run Laboratories staff of specialists in the fields of physics, engineering, mathematics, psychology, and related areas; by members of the teaching faculty; by graduate students; and by other research groups and laboratories of the University of Michigan.

PROGRAMS

The Project emphasizes basic and applied research in radiometry, radar, infrared, acoustics, seismics, optics, vision, information processing, information or data-links, information display, control and guidance for aerial platforms, i.e. airplanes, helicopters, etc., and systems concepts. Particular attention is given to (1) high-resolution sensory and location techniques, i.e. techniques that enable one to pick out an object from the background that is very small or partially hidden, and (2) the evaluation of systems and equipment by simulation and analysis, and by laboratory and field tests.

Project MICHIGAN and the Institute of Science and Technology are most famous for their involvement in two programs: (1) the Joint Thai/US Aerial Reconnaissance Laboratory in Thailand, headed by George Zissis, where infrared counter-insurgency surveillance techniques were tested and further developed by Michigan research staff in the field in Thailand for Vietnam and elsewhere; and (2) the seismic and acoustic research and development, headed by D. E. Willis, which became an integral part of the electronic battlefield sensor system developed for Indochina.

The electronic battlefield with remote sensors as envisioned in Army R&D (January-February 1972). Judging from the conical hats on the guerrillas, this is intended to represent Indochina.

II EARLY CONTACT BETWEEN AMRC AND PROJECT MICHIGAN

AMRC lists scattered contacts with Project MICHIGAN starting in 1957. In that year, AMRC attempted to get R. M. Thrall to join its staff. He is a mathematician in operations research at the University of Michigan and a chairman of the Army Mathematics Steering Committee's Subcommittee on In-Service Education and Training. At the time of AMRC's offer to join its staff, Thrall was doing research for Project MICHIGAN on "Evaluating Surveillance Systems." Thrall was also conducting, with others, a large-scale experiment which was an evaluation of the interpretation of intelligence data by experienced Army officers. The object of the experiments was to formulate and test modeling techniques which could be used to design better battle-area surveillance and intelligence systems. Thrall turned down AMRC's offer to work with it. However, he did become the official liaison between Project MICHIGAN and AMRC for the entire duration of their contacts.

III INFLUENCIAL EVENTS

Prior to 1960, there was little contact between AMRC and Project MICHIGAN. However, at the same time, various military, national and world factors were to bring about a change in the extent of this contact. In 1958 Henry Kissinger's study group emphasized the need for counter-insurgency warfare capabilities for the military. In 1959 General Maxwell D. Taylor outlined this same need in his book, The Uncertain Trumpet. The Cuban Revolution in 1958-59 gave additional support to arguments in favor of developing counter-insurgency warfare techniques. Then in 1961 two men came to power in government who were very receptive to this same idea: John F. Kennedy, who established the Green Berets, and Robert McNamara, the creator of the elctronic battlefield.

The emphasis on counter-insurgency warfare was concurrent with and complementary to the growing significance given to military electronics. Involved specifically in the latter were General Arthur Trudeau, Chief of Research and Development, Department of the Army, and J. A. Boyd, Director of Project MICHIGAN. In 1959 and 1960, these two men worked together on the 3rd and 4th National Conventions of the Professional Group on Military Electronics. This group, started in 1955, was a professional group of military electronic engineers within the Institute of Radio Engineers (IRE). It was organized to serve the needs of both military and civilian engineers who specialized in the field of military electronics. To this end, the group aided other Professional Groups of the IRE in their liaison with and services to the military to create newer and better military electronic systems.

General Trudeau's involvement as a Convention Advisor implies that he was very interested in getting professional people such as engineers and applied mathematicians working much more closely with the military. It also shows he was aware that engineering advances do not occur in isolation from fundamental research, for example, research in mathematics. This awareness led General

Trudeau to make efforts to increase the contact between Project MICHIGAN and AMRC. At his request, on April 20, 1960 AMRC's Bueckner, Hunter and R. E. Langer, Director of AMRC, went to Project MICHIGAN for briefings. AMRC's responsiveness to General Trudeau's request is an indication of the degree of accountability to which the Army holds AMRC. The briefings foreshadow great involvement between AMRC and Project MICHIGAN.

IV AMRC CONSULTATIONS WITH PROJECT MICHIGAN

Following the "Trudeau briefings," intense collaboration began between AMRC and Project MICHIGAN. On July 5-6, 1961 two days of meetings were held at AMRC. Present were R. M. Thrall, W. M. Brown, R. Scott, and J. Riordan from Project MICHIGAN, and a large representation from the AMRC staff including Anselone, Bueckner, Wilcox, Nohel, Zitron, Kay, Harris, and Brenner. At these meetings, Project MICHIGAN presented 8 problems for the consideration of AMRC. These 8 problems divide into 4 problem areas. We will discuss these four, plus another area which was presented at a later date. The five problem areas indicate those which we are able to decipher from the information we presently have, and are only a part of the collaboration between AMRC and Project MICHIGAN. The chart below indicates the names of these problem areas, and to the best of our knowledge, the years during which they were pursued.

THE FIRST PROBLEM AREA: Radar Surveillance

1 Consutaltations and People Involved

The first problem area concerns a radar system being developed by Project MICHIGAN. There were a number of consultations concerning this area. The first of these was the July 1961 meeting previously mentioned, in which three of the 8 problems presented by Project MICHIGAN had to do with the radar project. These three problems were:

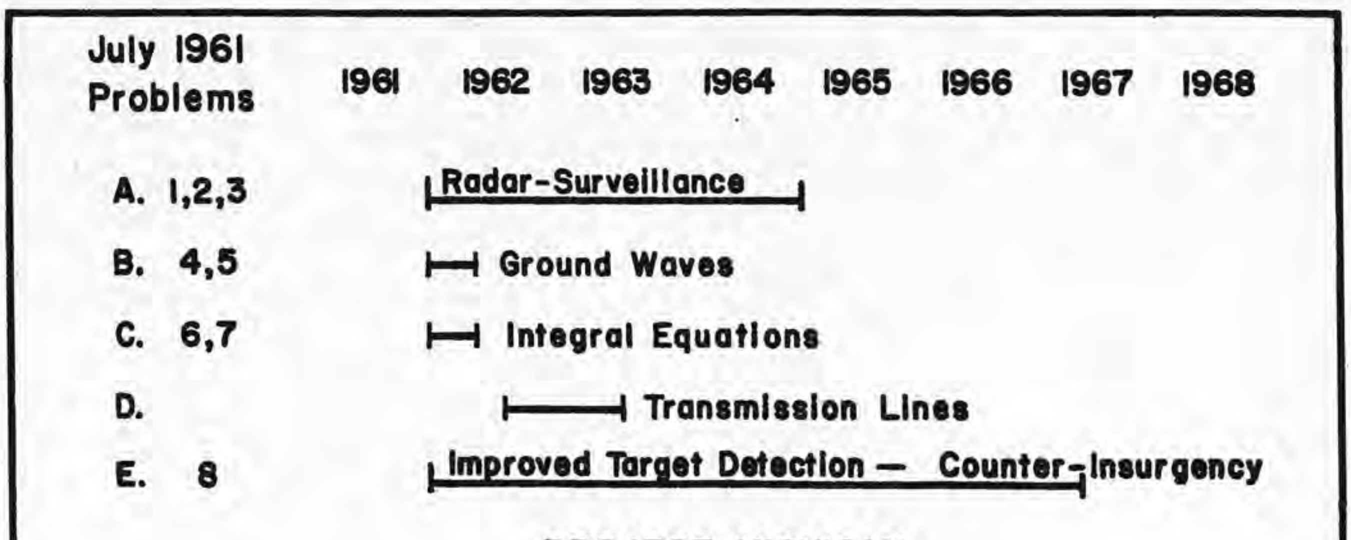
(1) Find a set of equations for analyzing the best means of picking out an object in a surveillance photograph from its background;
(2) Estimate how much radar beams are bent when passing through the atmosphere;
(3) Find a concise description of the solution obtained from a mathematical model of a maser. (A maser is an electronic device that emits radar waves in a narrow, coherent, very intense beam.) (See footnote)

The problems stated in AMRC's technical language are:

(1) Find a mathematical approach to filtering of a complex random process, in which the presence of noise, which is optimum with respect to the modulus of the process;

(2) Estimate the effect of atmospheric transmission of radar signals as a function of pressure, temperature, etc.;

(3) Determine the characteristic of the solution of a set of non-linear differential equations which describe the behavior of a maser.



PROJECT MICHIGAN
PROBLEM AREAS

Other consultations followed within a month. A Semi-Annual Report tells us that:

> "on August 10, 1961, Dr. Brenner traveled to the Project for further consultations with Mr. C. Palermo on the [above] problem 1, in which classified information is involved.... It is expected that this contact will continue." (25 October 1961 Semi-Annual)

This quote indicates that AMRC consults on problems which involve classified material. AMRC Reports never mention the contact again, implying that continuing contacts were never reported.

Another consultation took place on November 16-17, 1961. As part of an AMRC team of four sent to Project MICHIGAN, Anselone and Bueckner

> "discussed a problem on reconnaissance route selection, and remarked its relation to the maximization of a certain utility function which takes into account the values of bits of information and the risks due to loss of information and equipment by enemy action. This makes the problem one in decision theory." (25 April 1962 Semi-Annual)

On that same date, according to the Report just cited, "Dr. Zelen discussed statistical decision theory as applied to information processing."

On March 16, 1962 as one of AMRC's members sent to Project MICHIGAN, Fleichman consulted on a system of non-linear differential equations related to the ruby maser.

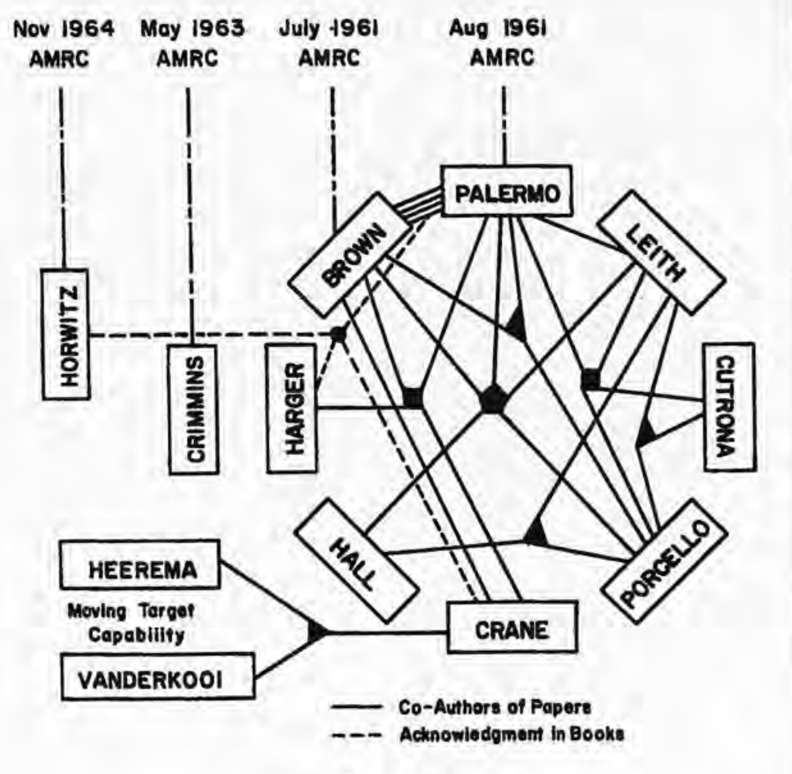
During the same visit, Gurland and Zelen "conferred also on the analysis of data to be collected from a terrain profile measurement system" (25 April 1962 Semi-Annual Report).

On May 9-10, 1963 Greville, Noble and Wilcox of AMRC went to Project MICHIGAN. Among the people at the Project with whom they consulted was T. Crimmins (25 October 1963 Semi-Annual Report).

On November 19, 1964 Harold Horwitz was among four Project MICHIGAN men who came to AMRC to consult on problems. This consultation is a good example of the amount of coordination and planning between the two staffs. The problems discussed at the meeting had previously been assembled by AMRC's Greville, the official liaison to the Project at that time, in a visit to Project MICHIGAN on October 21, 1964. Upon his return, Greville distributed a summary of the problems to the AMRC staff for their consideration before Project MICHIGAN's November visit (20 January 1964 Quarterly Report).

Although it does not seem obvious to the non-specialist, all of the above consultations and the Project MICHIGAN people involved have one thing in common: they are all working on a coherent high-resolution, side-looking, combat surveillance radar. These people include W. M. Brown, Head of the Radar Laboratory of the Institute of Science and Technology, C. J. Palermo, Assistant Head of the same Radar Laboratory, T. Crimmins, H. Horwitz, and many others. Seeing the connections among these men and knowing the research on which they collaborated, helps us to put together a picture of the radar system. The diagram below demonstrates some of the working relationships between these individuals.

The work by these people on the radar project began in 1954, and a test system was operational in 1959. The increased need for high-resolution surveillance under the new military program of flexible response necessitated further perfection of the radar system.



Project MICHIGAN
Radar Project Connections

2 The Radar System

The system developed is a terrain-mapping radar for surveillance. The radar is airborne (via plane) and produces a picture of the ground below. The data, or picture, is processed by equipment on the ground. During the early 1960's, we know the picture was stored on film in the air and then processed on the ground. Now there is reason to believe that this has been fit into the electronic battlefield system with more sophisticated remote-control aircraft for surveillance, and more instantaneous relay of information.

In addition to developing this radar system for terrain mapping, Project MICHIGAN also refined the system so that moving targets could be picked out on the ground. This is shown by a paper entitled, "Memorandum of Project MICHIGAN's MTI (Moving Target Indication) Capability of an Airborne Coherent Radar," by C. E. Heerema, R. B. Crane, and L. R. Van Derdooi, 1963 (see diagram). This was the type of capability needed to provide intelligence for the bombing of North and South Vietnam and Laos. This radar work was being done jointly for the Army and for the Wright Patterson Air Force Base, Air Force Avionics Laboratory.

3 AMRC's Part in the Radar System Project

AMRC's part in Project MICHIGAN's radar project consisted of helping with the mathematical modeling of the various parts of the radar system involved in obtaining high-resolution (Problem 1). They did this in several ways:

(1) AMRC helped with the mathematical modeling of the data-analysis system which Project MICHIGAN used to determine the performance limitations of the system and to choose the best design for high resolution;
(2) AMRC helped with the problem of refraction (bending) of the radar beam as it passed through the atmosphere (Problem 2). The effect of the bending is important for high resolution for it introduces errors. Researchers approaching this problem have put into a computer a mathematical model of the atmosphere between the airplane and the ground, so that when analyzing the data, corrections for this bending can be calculated automatically. The bending calculations can also be related to the help AMRC gave on the mathematical analysis of terrain-profile data;
(3) AMRC also helped with problems modeling the performance of a maser (Problem 3). The maser is important to give radar high resolution because it produces a strong signal relative to the background.

In addition to its help in the area of high resolution, AMRC helped with the mathematical decision theory used to decide reconnaissance routes.

THE SECOND PROBLEM AREA: Ground Waves

The second problem area pursued jointly by AMRC and Project MICHIGAN is "Ground Waves." Two problems, the 4th and 5th, presented by Project MICHIGAN at the July 1961 meeting, delineated this area. These problems were:

(4) Determine the disturbance in the field of a low frequency ground wave due to the location of a boss, or mountain, in the field;
(5) Determine a practical method for computing the phase of a low-frequency ground wave for wide ranges of the parameters, considering the earth as inhomogeneous and spherical earth and the atmosphere as variable.

On November 16-17, 1961 at Project MICHIGAN, Wilcox of AMRC

> "cited literature on the solution of a problem of the differentiation of radiation, and showed how the solution can be used in a situation which featured a mountain near a transmitter. Literature was cited on the effect of variable atmosphere on low-frequency groundwaves."
> (25 April 1962 Semi-Annual Report)

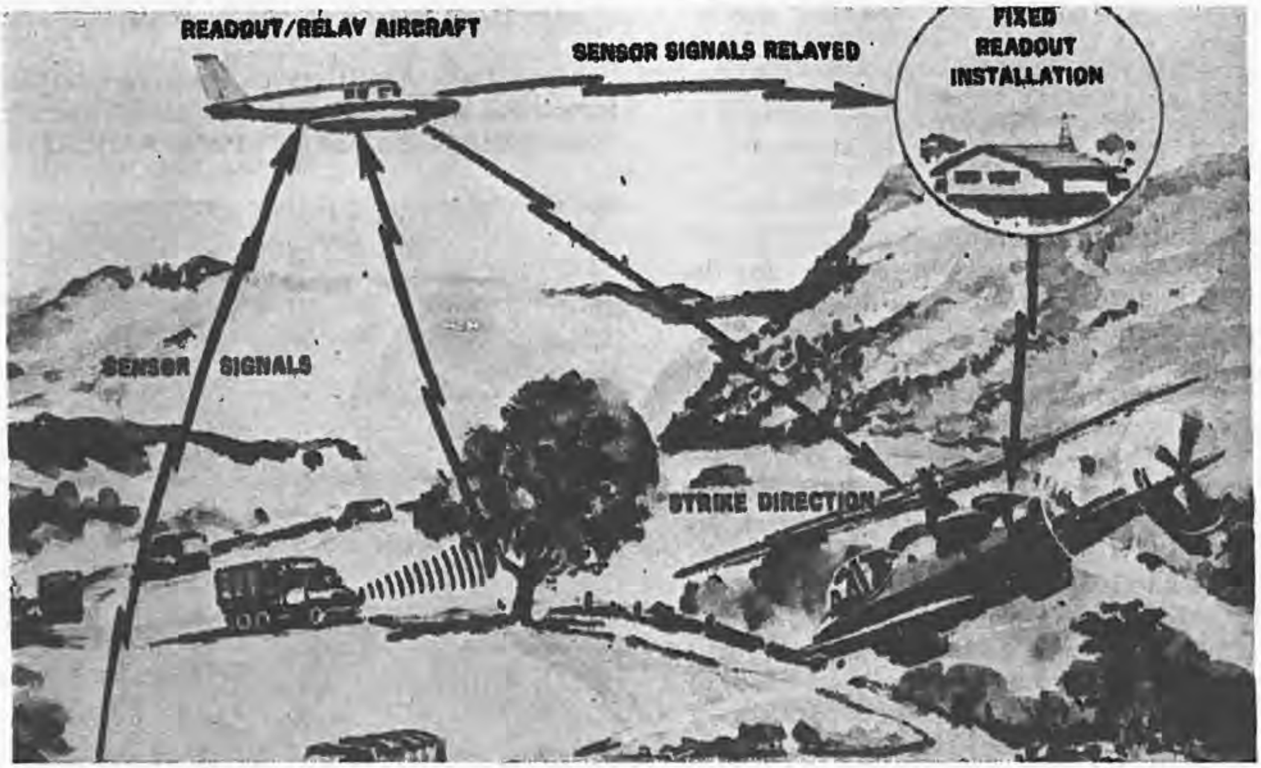
Although we are not certain of additional specifics of this problem area, we know it was R. Scott who was involved in the Project, because in 1966 he wrote a Project MICHIGAN report on the "Phase of the Height-Gain Function of the Low Radio Frequency Ground Wave," in which he discussed the problem of ground-wave propagation over a spherical earth.

THE THIRD PROBLEM AREA: Integral Equations

The third problem area has to do with the minimization of integrals. This area is suggested by the 6th and 7th problems presented by Project MICHIGAN at the July 1961 meeting. They appear to be problems which were not worked on extensively; the only information we have shows that on November 16-17, 1961 AMRC's Bueckner proposed a method for solving one of the integral equations (25 April 1962 Semi-Annual Report). The two problems were:

(6) To determine a method for minimizing an integral which involves a function and the convolution of that function with itself;
(7) To find a function f(x) which minimizes the integral: $\int_A\int [G(r)f(x)f(y)-1]^2 dA$

where G(r) is a given function of $r^2=x^2+y^2$ and A is a given area.



AIR-SUPPORT SYSTEM: "The ground tactical application depicted above consists of sensors in the ground and in trees sending out signals to a read-out relay aircraft as well as to fixed read-out installations, followed by air strikes against the enemy." (Army R&D January-February 1972)

THE FOURTH PROBLEM AREA: Transmission Lines

In 1962, a new identifiable problem area emerges: Transmission Lines. There were several consultations on this topic.

On March 16, 1962, as one of an AMRC team of five sent to Project MICHIGAN, C. Wilcox

> "consulted on an analysis of coupled transmission lines. He described work he had done on the problem prior to the meeting. In this work he had developed a method which is applicable for arbitrary inductance and capacitance, and hence for strong coupling. This [work] answered two questions that had been raised by the Project."
> (25 April 1962 Semi-Annual Report)

Noting that Wilcox had done work previous to the consulting implies that he had been briefed on the topic prior to the meeting (possibly during Project MICHIGAN's two day visit January 29-30, 1962), and had worked on the problem between the January and March meetings.

Other consultations with Wilcox follow. On February 19, 1963, Wilcox and others met with Project MICHIGAN at AMRC. On May 9-10, 1963, Wilcox, Greville and Noble returned to Project MICHIGAN. At this consultation Wilcox

> "reported at length upon his solution of a coupled transmission line problem. This solution was posed at an earlier meeting by Dr. Holland-Moritz of the Project. Its formulation and solution are set forth in MRC Technical Summary Report #376."
> (25 October 1962 Semi-Annual Report)

Wilcox published this same report in the math journal SIAM Review 6, 148 (1964) under the title, "Electric wave propagation on nonuniform coupled transmission lines." This journal publication resulting from the "Wilcox meetings" is an example of how mathematical results of consultations on military problems can be presented in the open scientific literature as abstract mathematical problems.

As previously mentioned, the work by AMRC's Wilcox was in response to a problem presented by Holland-Moritz of Project MICHIGAN. Holland-Moritz worked in the Electronic Information Processing Group, Radio Science Laboratory of the Institute of Science and Technology, Ann Arbor, and dealt with infrared data processing. He was working with others on a digital data-transmission and data correlator system. This system sends a picture via telephone line; in this case, the picture is an image of infrared surveillance information. Work on this system began in 1959 for the Electronic Warfare Division, Air Force Avionics Laboratory at the Wright-Patterson Air Force Base. AMRC, via Wilcox, helped Holland-Moritz with the mathematics for optimizing the performance of such a system in a practical environment (2-wire telephone lines) where often several types of impulse noise may be mixed with Gaussian noise. In other words, AMRC helped get the best resolution for the transmitted picture. The system was more equipment for electronic surveillance.

THE FIFTH PROBLEM AREA: Improved Target Detection - Counter-Insurgency

The problem area of "Improved Target Detection - Counterinsurgency" is suggested by the 8th problem presented by Project MICHIGAN in its July 1961 meeting with AMRC. The problem was:

> (8) To determine the effect on optimum filtering techniques of the fact that only a portion of a signal is actually processed. (A spectral filter may be thought of as a window through which signals pass to the detector. A desirable filter is one which is highly transparent to "target signals" and relatively opaque to "background signals.")

After 1963, AMRC gives less complete information about the problems discussed at its consultation sessions with Project MICHIGAN.

Therefore, the information obtainable for this problem area is different than that of other areas. Only the dates and names of the participants of the consultations are available and not the topics discussed. Nevertheless, we are able to clearly decipher the problem area by studying the context of the Project MICHIGAN people most directly involved: J. Riordan and R. R. Legault.

1 Riordan and Legault

Improved Target Detection - Counter-insurgency is Riordan's problem area. This can be concluded by noting that he is the only person of those present at the July 1961 meeting who has not yet been connected to one of the 8 problem areas.

Riordan worked with Legault at the Infrared and Optical Sensor Laboratory, Institute of Science and Technology. They consulted with AMRC on the following dates:

July 5-6, 1961:
Riordan at AMRC.
May 9-10, 1963:
Riordan and Legault at the Project.
October 17, 1963:
Riordan and Legault at AMRC.
November 19, 1964:
Riordan and Legault at AMRC.
December 8, 1964:
Riordan telephoned AMRC's Greenspan.
March 30-31, 1967:
Legault at the Project.

Except for Thrall, who was the liaison between AMRC and Project MICHIGAN, Riordan and Legault are mentioned as having consulted with AMRC more times than anyone else.

Riordan and Legault also published together. In June 1964, they published an article in "Applied Optics" under the title "An Algorithm for Optimizing a Spectral Filter." This is the same topic Riordan presented to AMRC in July 1961 as a problem. The article presented the results of an investigation of the existence and computability of an optimal spectral filter for infrared detectors. It is included in a September 1964 Institute and Technology Report entitled "Studies in Spectral Discrimination." The report was done under Air Force contract AF 33-657-10974.

2 The 29-month Program: Counter-insurgency Reconnaissance

Under the same Air Force contract, Legault and others were involved in a 29-month program of reconnaissance research from March 1963 to July 1965. Descriptions of the applications of this research are secret. However, a short general description of the program can be found in the abstracts of two reports written by Legault, classified as secret. The reports are entitled "Unusual Reconnaissance Concepts." In the abstract of one secret report, Legault wrote:

> "A 29-month program of research to create new reconnaissance subsystem concepts has been carried out. Initially, the role of reconnaissance in limited warfare was studied, and it was concluded that new techniques and equipment were required. This led to studies of spectral discrimination, a dual-antenna airborne MTI [Moving Target Indication] system, and a spectral photographic technique for detecting targets under a foliage canopy." AD-369 331 (our emphasis added)

Legault and Riordan published mathematics on the topic of spectral discrimination, as seen in the article referred to earlier. The abstract of the other secret report reads:

> "Part 1 [of this report] 'Counter-insurgency Reconaissance' deals with several reconnaissance problems. Current people-detection capabilities of various sensors are discussed, and a listing of possible equipment is presented. Foliage-penetration, MTI [Moving Target Indication], and hologram-radar techniques [techniques for making a 3-dimensional radar picture] are summarized and related to the problem of detecting people. There is a discussion of the theory of spectral discrimination and of possible methods of implementing it." AD-370 833
> (emphasis added)

From these abstracts we can conclude that Legault's program was testing present reconnaissance equipment and techniques to see how they would perform under counter-insurgency conditions. He was researching what equipment and techniques could be made applicable, and what new things had to be developed. The abstracts also indicate that the new equipment was to be used to detect people. Clearly, the theme of the 29-month program is counter-insurgency in tropical regions, for example, in Indochina.

3 AMRC's Involvement

Of the five problem areas, the duration of the involvement between AMRC and Project MICHIGAN is the longest in this one: Improved Target Detection - Counter-insurgency. AMRC's help with this reconnaissance project came through its consultations with Riordan and Legault. Four of the consulting dates between these two men and AMRC correspond to the time of the 29-month project. Perhaps the volatile nature of the contents of these four consultations is the reason AMRC chose to publish only the names of the participants and dates of the consultations, and not the problem areas discussed.

Besides the four consultations mentioned above, Legault consulted with AMRC on March 30-31, 1967 after the 29-month program had been completed. After 1967, reports which he wrote for the Institute of Science and Technology indicate that Legault continued in the area of counter-insurgency research. The application of the research in these reports readily applies to US activities in Indochina. The reports are:

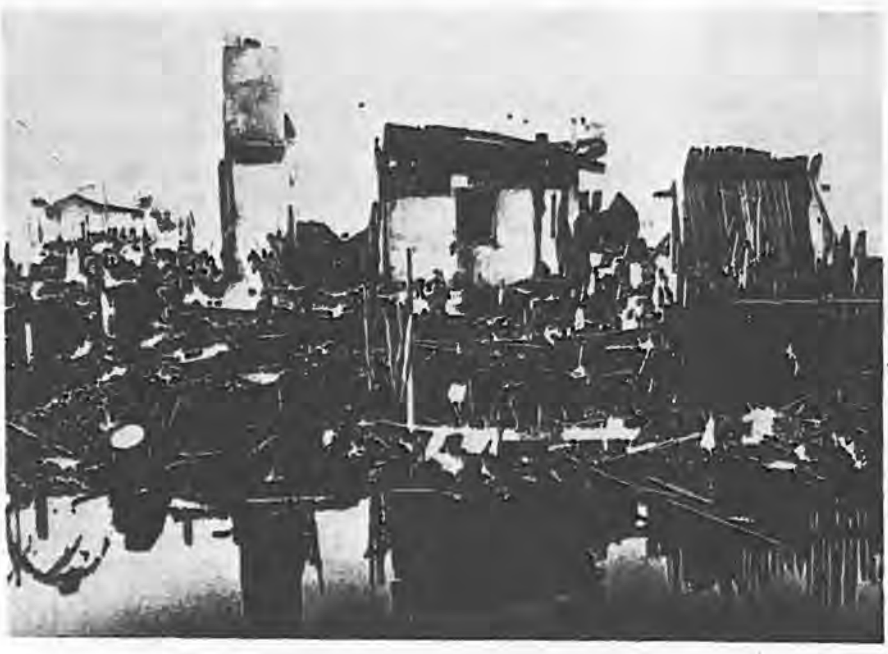
(1) "Air-to-Surface Missile Technology 1975 to 1980" AD-390 734 (1968);

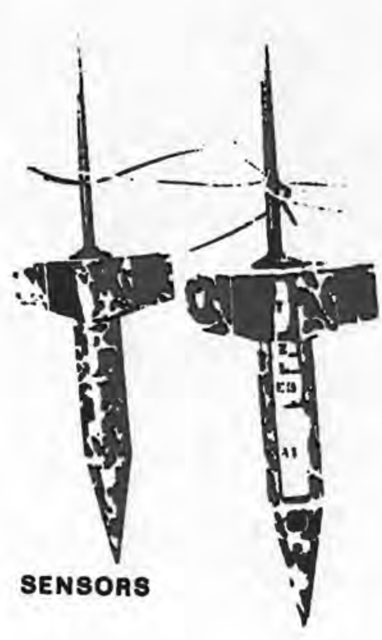
(2) "On the Detection of Concealed Handguns" AD-500 586L (1969);

(3) "Night Sensors for Truck Interdiction" AD-510 185 (1970).

V CONCLUSION

AMRC reports after 1967 do not mention further contact with Project MICHIGAN. It is possible that AMRC stopped listing Project MICHIGAN contact after University of Wisconsin protest against AMRC began. Most likely, however, the Army's push to get the surveillance hardware designed, out of Project MICHIGAN and into operation to form the backbone of the military program of "flexible response," had passed the mathematical analysis and design stage into the final engineering and implementation stage. AMRC had done its job, helping Project MICHIGAN meet its mission of research and development of systems and components for military surveillance, by providing in-depth mathematical help on several extended projects and, no doubt, on several rapid projects over a period of at least seven years (1960-67), through twenty documented consultations and countless other consulting contacts that were never mentioned.





SENSORS

AMRC CONSULTING WITH PROJECT MICHIGAN

Date	AMRC	Proj MICHIGAN	Subject	Place
1957	Householder	--	--	Proj MICH
1957	--	Thrall	AMRC position	--
1959	--	--	--	Proj MICH
1960	--	--	--	Proj MICH
April 20 1960	Bueckner, Hunter, Langer	--	"Trudeau Visit" briefings	Proj MICH
July 5-6 1961	Anselone, Brenner, Bueckner, Harris, Kay, Nohel, Wilcox, Zitron & others	Brown, Riordan, Scott, Thrall	8 specific problems in 4 problem areas	AMRC
August 10 1961	Brenner	Palermo	July 1961 problem #1	Proj MICH
November 16-17 1961	Anselone, Bueckner, Wilcox, Zelen	--	Integral equations, diffraction of radar, reconnaissance route selection, computer programming, decision theory	Proj MICH
January 29-30 1962	--	Thrall & others	--	AMRC
March 16 1962	Anselone, Fleishman, Gurland, Wilcox, Zelen	--	Ruby maser, transmission lines, computer programming, terrain data analysis, satellite orbits	Proj MICH
November 8, 1962	several staff	Thrall & 5 others	Consultations	AMRC
February 19 1963	Anselone, Fleming, Greville, Noble, Rall, Wertz, Wilcox, Wouk, Zelen	Thrall & others	Consultations on several problems	AMRC
March 25 1963	Wertz		--	Proj MICH
May 9-10 1963	Greville, Noble, Wilcox	Crimmins, Holland-Moritz, Legault, Riordan, Thrall	Transmission lines, integral equations, maximizing an integral	Proj MICH
October 17 1963	--	Legault, Riordan, Thrall	Consultations	AMRC
December 4 1963	Harris & others	3 staff	5 Proj MICH problems	AMRC
October 21 1964	Greville	--	Assemble 7 Proj MICH problems for AMRC staff staff preview	Proj MICH
November 19 1964	11 AMRC staff	Horwitz, Legault, Riordan, Thrall	Technical discussions of 7 October problems	AMRC
December 8 1964	Greenspan	Riordan	Parabolic equation	Phoned AMRC
February 15 1967	Mann	Jebe	Advice on paper	Wrote AMRC
March 30-31 1967	Harris	Thrall, Legault	Problems of Army	Proj MICH

The "Bomb Shelter Problem"

This problem was dictated by the Army in response to their need to predict the survivability of underground bomb shelters in the event of attack. Mathematical models were needed for the solution of the problem, so AMRC was called in. According to the Center's Reports to the Army, this problem was the permanent staff's major work during the latter part of 1965.

In preparing the mathematical predictive models, AMRC personnel consulted with Army scientists on the practical aspects of the problem. In our report we describe the kinds of work these Army scientists were concentrating on.

The problem was first given to AMRC on October 5, 1965 when "Mr. George Fellers of the Special Projects Planning Office, Office of the Chief of Engineers, Department of the Army, Washington D.C. called Professor Rosser concerning a bomb shelter problem" (20 January 1966 Quarterly Report). This contact illustrates that AMRC does not only pursue work that catches its fancy as it claims, but is at the call of the Army. Further contacts occurred on October 7, 11, 15, 22 and on December 2 of the same year. The solution was submitted, apparently rather rapidly, by 5 January 1966.

Following his call, Fellers visited AMRC on October 11 to give Rosser, Harris, Cheng and Karreman the details of the problem. A Colonel Roberts sent a letter with further information on October 15. On October 22, Fellers made arrangements for a second visit which took place December 2. This series of contacts demonstrates that, if circumstances warrant, consulting occurs at AMRC as well as at the various Army installations.

A Marine watches the bombing of a Vietnamese village.

Taking part in this second meeting at AMRC were Rosser, Harris and Karreman of AMRC and Fellers, Jesse Kirkland of the Engineering Waterways Experiment Station (see section on this base), and First Lt. Walter Moore (of the Protective Structures Branch, Army Corps of Engineers, Omaha, Nebraska). We looked for published papers to give us clues concerning the work of these Army men. Fellers and Moore had no published papers listed (in TAB), but we were able to trace Kirkland's field of expertise. In 1966 he published "The Elastic Response of Buried Cylinders, Critical Literature Review and Pilot Study" (AD-633 673). In it he describes tests done under static and dynamic loading conditions in a Small Blast Load Generator. Dynamic strains are external explosions; static strains are internal structural strains, for example those simply caused by the pressure of the upper part of the cylinder upon the base. The fact that these tests were performed in a "small blast load generator" suggests that the work was about shelters protecting against conventional weapons rather than against atomic weapons.

Three other men, Gayle E. Albritton, Albert F. Dorris, and T. E. Kennedy were listed as co-authors with Kirkland on this 1966 paper. Examining their work provides additional insight into the nature of the project. Albritton has eleven papers listed dealing with explosions in cylinders buried in sand and with the response of concrete beams to blasts. This second area may well be related to nuclear attack studies. Dorris had one paper of his own, entitled "Response of Horizontally Oriented Buried Cylinders to Static and Dynamic Loading" (AD-621 340). Tunnels used by the Indochinese people could be modeled by a horizontal cylinder. A paper by Kennedy entitled "Dynamic Test of a Model Flexible Arch-Type Protective Structure; Report 1 Pilot Test" (AD-651 349) seems likely to relate to the bomb shelter problem and to be a tunnel analysis.

The results of AMRC's work on the bomb shelter problem were published by Rosser, Harris and Karreman in a paper entitled. "The Probability of Survival of a Subterranean Target under Intensive Attack" (TSR #653). The model described in this paper simulates a finite number of explosions occurring in a circle around the target, and attempts to predict the probability of destruction of the target.

We believe this model was used for predicting the effects of mounting attacks on underground guerrilla fortifications in Indochina, not in planning for a hypothetical nuclear war. There seems to be no mathematical reason why this model could not have been used to develop conventional bombing strategies. Although the report used the word "missiles" to describe the source of the explosions, we know that when the Army commissioned this rush job in 1965, it was much more concerned with destroying Laotian caves and Vietnamese tunnels than it was with defensive measures for nuclear attack.

TOOLS FOR GUERRILLA WARFARE

The Army's concern with this problem continued to grow. Army R&D Newsmagazine (May 1967) described a US Army Research Office "review of the present state of research on detection, destruction and denial of Vietcong tunnels and underground installations." By 1969, the Army was so determined to develop methods of destroying tunnels that it built "Vietcong"-like tunnels in Puerto Rico (Army R&D May 1969). This effort was under the direction of Waterways Experimental Station, the home base of Jesse Kirkland, one of the Army scientists who explained the bomb shelter problem to AMRC.

TUNNEL COMPLEX BUILT IN PUERTO RICO duplicates "those of the Vietcong, including storage rooms such as this one discovered by U.S. troops." It was constructed by hand using "Vietcong-type tools and according to Vietcong Specifications and construction techniques," as part of a WES program to find new means of detecting mines, booby traps and tunnels "such are complicated warfare in Vietnam."

(Army R&D May 1969)

It is interesting to note that although AMRC's report on the "bomb shelter problem" was listed in the Center's first Quarterly Report of 1966, it was not until 15 November 1966 that Fellers wrote Rosser giving permission for it to be released as an unclassified report (30 January 1967 Semi-Annual Report). Apparently, the first draft of the report too clearly indicated the real use of the mathematics and had to be revised to make this more obscure. This TSR #653 is dated December 1966, one year after the work was actually done.

Demonstrations against AMRC in 1968 led to the formation of the Kleene Committee to investigate UW military research. The head of this committee, Stephen Kleene, was hardly unbiased since he had served as Acting Director of AMRC from 1966-67. Rosser's version of this project appeared in a 1969 letter to Kleene. To pacify his critics, Rosser wrote:

> "The report in question is #653, 'The probability of survival of a subterranean target under intensive attack.' Naturally this is a question to which the Army has been paying attention for years. With the international situation what it has been, the Army would have been derelict in its duty of it had ignored the question. In the course of its studies, the Army came up against a mathematical problem with which it could not cope. This problem was presented to the MRC. As I have stated before about such problems, no one at the MRC was under any compulsion to work on the problem. However, three of us got very interested and decided to have a go at it. The Army gave us very little information beyond the statement of the mathematical problem. They did not say whether they hoped to build a subterranean shelter that would survive an attack, or to plan an intensive attack that would demolish a subterranean shelter of an enemy. We did not ask. The answer probably would have been top secret, whereas the mathematical problem was not classified at all. The Army also gave us some limits for the resistance of the target and the intensity of the attack saying that they needed a solution of the mathematical problem that would be valid within the stated limits. They stated that the values given for these limits were not classified.
>
> "In due course, we solved the problem, and wrote a draft of Report #653, giving some numerical examples within the stated limits. We must by chance have picked some numerical examples close to those involved in the Army's own studies. At any rate, the Army said that publication of the Report with those numerical examples might be a hazard to the safety of the country. We hurriedly collected and burned all pieces of paper with those numerical examples on them. We chose some new numbers, suitable to the survival of anthills at which rocks are being thrown; and rewrote Report #653 with numerical examples based on the anthill numbers. The Army had no reservations about this, the Report was produced and distributed, and was later published in the customary fashion in the open literature. It is freely available to everyone including even the armies of Russia, Israel, Egypt, et al. I don't see how publication could be more open."

Strategy & Tactics Analysis Group (STAG)

Contacts between AMRC and STAG have taken place periodically from 1960 to the end of 1972. These consultations have been primarily with one STAG person, Dr. R. Howes, and to a lesser extent with H. Maisel, Chief of the Land Warfare Division, and Dr. A. W. DeQuoy.

It seems that AMRC first offered its assistance on 12 September 1960 when

> "a problem concerning evaluation of an unfamiliar integral encountered in a target analysis problem was submitted by Dr. Howes The integral was shown to be a transformed incomplete Gamma function."
>
> (25 October 1960 Semi-Annual Report)

(The incomplete Gamma function is an important tool in the "bomb-shelter problem.") The incomplete Gamma function is used to compute probabilities. Thus we assume they were trying the build a mathematical model to assess the probability that a target would be hit under some conditions. There is a strong possibility that the work of STAG and that of Project MICHIGAN was coordinated in the early 60's, as suggested by the following consultation involving AMRC.

On June 4-5, 1963, Dr. T. N. E. Greville of AMRC's Permanent Staff spoke at the Ninth Conference of Army Mathematicians at Watervliet Arsenal. While there, he took the opportunity to consult with H. Maisel of STAG, H. W. Doss of the Institute of Science and Technology associated with the University of Michigan (where Project MICHIGAN was carried out), and D. P. Flemming of the Canadian Armament R&D Establishment, Quebec. While the AMRC reports give no indication of what was discussed, we can look at the published Department of Defense reports of Doss and Flemming to get a clue; Maisel apparently published no papers.

Hodge W. Doss published a paper in 1964 with Project MICHIGAN (see earlier section on Project MICHIGAN). His area of expertise is direction finding and position locating. The automated war required a computer method for guiding the bombers to their targets; apparently it was in this aspect of its development that he was involved and that AMRC staff discussed with him. A co-worker of Doss' at Project MICHIGAN, R. M. Thrall, ackowledged in his 1959 paper entitled: "A Model for Evaluating the Output of Intelligence Systems" (AD-215 126) that Mr. H. Doss had "provided much help in the design and conduct of the experiment..." The model

referred to is used to simulate combat.

Flemming's work involved shock waves and the computer simulation of guns and rockets.

Shortly after the June contact, on August 5 and 6, 1963,

> "This agency was visited by T. N. E. Greville at the invitation of Colonel De Quoy to discuss means for closer liason between STAG and MRC. The contacts were mainly with Mr. H. Maisel, Chief, Land Warfare Division and Mr. J. A. Albertini. Further meetings are planned. There were also consultations on problems related to 'the interaction between decision-making processes in opposing military groups' and to 'the assesing of the effect of concentrated but inaccurate fire on a dispersed target.' "
>
> (25 October 1963 Semi-Annual Report)

These are problems directly related to the Lanchester theory.

LINE-OF-SIGHT TERRAIN STUDIES

John A. Albertini's field of expertise is seen by looking at an October 1962 paper he published with Paul F. Dunn, "Mathematical Model for Topographical Line of Sight" (AD-289 315). The abstract is instructive:

> "The topographical characteristics of a military theater of operations directly influence the performance of communications equipment, target aquisition systems, and flat-trajectory weapons. Consequently, any realistic simulation of combat operations must include simulation of the line-of-sight constraints. Current attempts to computerize land-combat war games are handicapped by inadequate terrain representations and by the difficulties encountered in adapting the play of the line of sight to automation...."

The fact that they are concerned about the line of sight indicates that these are not

(continues on page 26 after box)

An example of a warfare model:

The idea of mathematically representing combat to aid in making strategic decisions was first suggested by F.W. Lanchester around the time of the First World War. Lanchester formulated a battle between two forces in terms of equations which described the rate at which each side's strength decreased. He was especially concerned with air combat. Today, Army researchers have modified Lanchester's equations and assumptions to use them as a means of predicting the outcomes of other combat situations such as ambushes or guerrilla warfare. Primary efforts have been devoted to the problem of using the equations to determine, from the initial condition of the armies, which side will ultimately win.

Lanchester himself dealt with two situations. In the first instance, each side knows only the general location of the opposition forces; and as units on either side are destroyed, the remaining forces then distribute their fire uniformly over the whole battlefield. In the second situation, each side knows the exact location of each opposing unit; and as units on either side are destroyed, the fire is concentrated on the surviving units.

Actual Battles

These simple cases worked on by Lanchester have now been expanded to make the modeling more realistic. He assumed that opposing units had the same firepower, and to modify the equations, introduced different weapons such as tanks versus rifles.

But the outcomes of actual battles are determined by factors more complex than the numbers of troops and weapons. Model builders today incorporate human variables which introduce elements of probability, in contrast with Lanchester's original elements of certainty, that one side will defeat the other.

Troop morale and training is an important factor. Whereas Lanchester's equations described attrition resulting from hostile fire only, today's equations are formulated to include desertion and surrender which also cause attrition. Retreat and advancement of forces could be predicted on the basis of the attrition they suffered; observed casualty

Lanchester's Theory of Combat

rates and theoretically "acceptable" rates would be compared to determine whether a force should advance or retreat.

Equations could be modified by allowing each side to add reinforcements during the fighting. Lanchester assumed that the size of the forces was fixed during the battle.

An additional factor to be considered is the role of the military decision-maker in influencing the course of events. Essentially, depending on the factors taken into consideration, a war game played with opposing forces of the same relative strengths could have an infinite number of outcomes.

Counter-Insurgency Planning

Serious counter-insurgency modeling began in the early sixties by S. J. Deitchman, and was continued by M. B. Schaffer of the RAND Corporation. Their mathematical models were based on Mao Tse-Tung's three phases of guerrilla warfare, which are summarized by Schaffer:

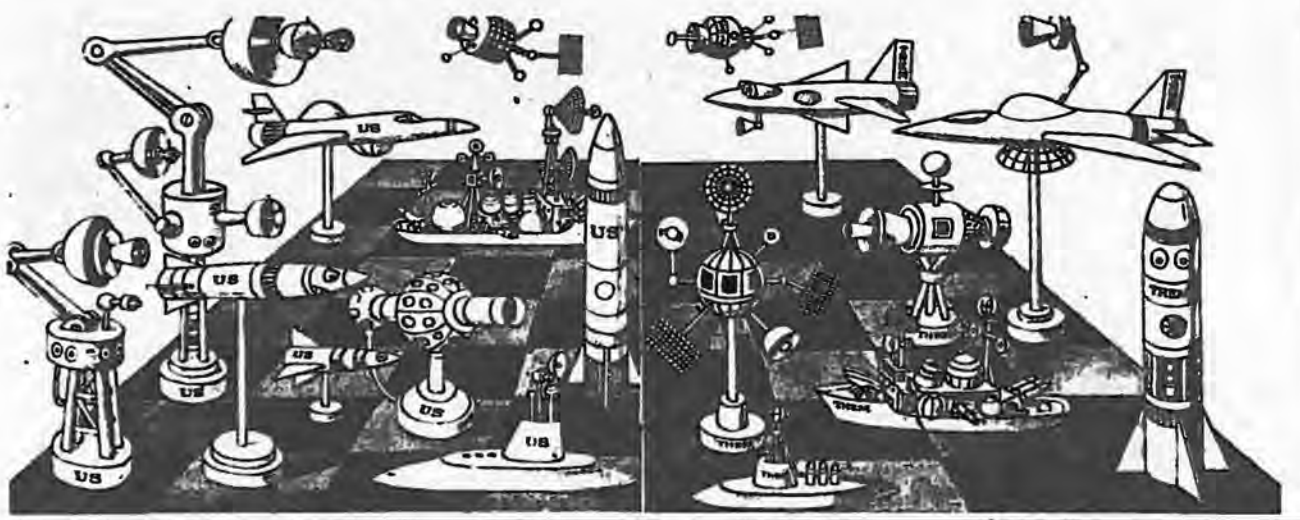
> "The first two phases of insurgency are characterized by small-force ground-yielding operations by the insurgents but overall military superiority on the part of the counterinsurgents. In phase II the insurgent operations become increasingly military; however, they continue to be basically small-force guerrilla activity which cause the defense to fragment and the engagements to be localized and relatively isolated. In phase III the insurgents take the strategic offensive and operate with larger, more conventional forces."
>
> Lanchester's Models of Guerrilla Engagements

To model guerrilla warfare, Schaffer extended the basic Lanchester equations to include the effects of battlefield desertions, capture of prisoners, supporting weapons, and changes in weapon efficiency over time (as could be caused by rusting or extended use). Schaffer's equations represent three kinds of combat -- skirmish, ambush and siege -- which occur in "phase II" of Mao's strategy.

Skirmish is a battle in which surprise is not a factor. An ambush involves an element of surprise and, because of this, a smaller force could defeat a larger one. Siege involves an attack on a fortified position such as a strategic hamlet in Indochina. Here, timing the use of supporting weapons such as artillery or aircraft is critical. If a preliminary "softening-up" is undertaken, then the element of surprise is lost.

Equations aid the planner in balancing some advantages against others. But as Schaffer points out, these equations cannot predict the outcome in guerrilla warfare because they do not take into account political, sociological, economic or moral factors. They do help in estimating casualty rates on both sides, demonstrated by the emphasis on "enemy body-counts" during the Indochina War.

Recent modifications in these equations now take into account intelligence about the opposing force, command efficiency, and search and reconnaissance to pin-point the enemy's location.



artillery or missile problems, but infantry. Thus there is a possibility that the simulations that they were working on were for guerrilla warfare. Note that J. F. Kennedy was in office by this time and had ordered the beginning work on "flexible response", in other words, counter-insurgency. If they can build realistic computer simulations, then they can predict the response in any given situation in the armed stage of a guerrilla war. This is an integral part of planning tactics and strategy. The two problems mentioned in this report fit in. The interaction of decision-making in two opposing groups could be guerrilla vs. anti-guerrilla tactics. The "dispersed target" might well be a guerrilla unit. It would not involve missiles because of the phrase "concentrated fire"- if one has only a thousand missiles, how can they be concentrated on one target? Also, the fire is called "inaccurate". This might be an attempt to assess the effectiveness of concentrating rifle fire into a forest to try to hit a guerrilla band, possibly from heliocopter gun ships.

COUNTER-INSURGENCY MODELS

The remaining contacts at STAG were with David R. Howes who works on computer models of guerrilla warfare, including the Lanchester model. The first consultation is described in AMRC's 1968 Annual Report:

> "A COMBAT EFFECTIVENESS PROBLEM. March 21, 1968. In response to a detailed request for assistance with a problem concerning measures of effectiveness which was received from Dr. David R. Howes, U.S. Army Strategy and Tactics Analysis Group (STAG), Bethesda, Maryland on March 6, 1968 Professor J. B. Rosser wrote to Dr. Howes to suggest a meeting between STAG personnel and Professor Bernard Harris. A preliminary study of the problem indicated that a solution technique could be provided.
>
> "April 4, 1968, et seq. An exchange of correspondence began, resulting in an appointment for Dr. Howes to visit MRC on April 26, 1968.
>
> "April 26, 1968. Dr. Howes consulted with an MRC group consisting of Professors M. Fox, B. Harris, G. Kimeldorf, and J. B. Rosser regarding the estimation of a parameter measuring relative combat effectiveness in a computer simulation of war games. The solution to this problem for the special case considered which had been worked out at MRC in the interim was presented by the MRC group. It seemed that it dealt adequately with the problem."

"Effectiveness" in Howes' work is probably the factor of combat effectiveness used in models such as the Lanchester equations of combat.

In 1969, Howes wrote Rosser:

> "Dear Mr. Rosser:
>
> Following our telephone conversation on 23 December, I discussed your Center's draft of orientation lectures on mathematical programming with Colonel Carpenter, our Commanding Officer. Colonel Carpenter was most encouraged to hear that this series is close to realization. He hopes that STAG can avail its personnel to these lectures at the earliest date, since the maintenance and operation of large programming models has become a STAG responsibility.
>
> While STAG can look to other sources for instruction in various technical aspects of the operation of computerized programming models, it is only by means of a series such as yours that STAG personnel can be brought to appreciate the concepts and theories which underlie the computer models.
>
> I hope that you will be able to give early attention to your draft."
>
> -quoted in Mathematics for Death

Howes' only paper in the Defense Department's indexes appeared in 1971. It was entitled: "GUEVARA, A Computerized Guerrilla Warfare Model" (AD-863 983L); the "L" attached to the code means that access to this paper is limited to those with the proper security clearance.

In 1971, Howes' consultations with AMRC continued when "Prof. J. B. Rosser furnished Dr. David R. Howes of STAG an approximating function for a certain integral" (27 April 1971 Semi-Annual Report).

"A FORCE-STRUCTURE PROBLEM"

According to the 3 May 1972 Semi-Annual Report:

> "Dr. Stephen M. Robinson consulted with Mr. David R. Howes at STAG, Md. on March 13, 1972. He presented a new method for formulating and solving an optimal delaying action problem discussed by representatives of US-STAG at the 1971 Army Numerical Analysis Conference. He also pointed out possible applications of a ratio-game model to an optimal weapons allocation system. Work on the latter subject is continuing."

Robinson had published a paper on the subject of ratio games in 1971 entitled, "Computational Solution of Ratio Games by Iterative Linear Programming" (TSR #1140). In an interview 27 March 1973, Robinson elaborated on his consultation at STAG:

> "I did some work, for example, with the Strategy and Tactics Analysis Group in Bethesda, Maryland which was very interesting to me and gave me some new insights on a mathematical area that I hadn't thought of before....
>
> "When I went to Bethesda, for example, on this most recent consultation, I had my clearance sent ahead, and they had a big guarded area, and I went into it and got a name badge and all that kind of stuff that they do. But the whole time I was there, we never talked about anything classified.
>
> "We talked about this problem which is a force structure problem, a problem having to do with rational mutual disarmament. That is, how two opposing sides agree on certain cuts in force structure in a stable way: that is, in a way that would not tempt one side to take advantage of the other."

This problem Robinson described could have been one of two potential disarmament problems facing the American military in early 1972: the Strategic Arms Limitation Treaty (SALT) with the Soviet Union, or the withdrawal of American forces from Vietnam. In both cases, the United States was seeking means to reduce its forces without losing face. Given Howes' previous work on the GUEVARA model, American strategy for Vietnam would seem to be the probable area for this disarmament study's application.

In his interview, Robinson also said that his consultation with STAG was not immediately fruitful:

> __QUESTION__: "Are the results of the research published?"
>
> __ROBINSON__: "If there are any results, they would be published. In this particular case, I was not able to come up with anything that I thought would make a proper paper. I do have some material that I'm still not quite satisfied with.
>
> I intend to talk with some other people, in fact probably in June, about some of the stuff in here....I hope that if somebody can show me how to be a little smarter than I have about some of this stuff, I'll be able to publish it. But at the moment, I'm not satisfied with the results. I don't think it's a good enough piece of work."
>
> __QUESTION__: "Has the Army been able to use the work even though you're not satisfied with it?"
>
> __ROBINSON__: "I don't know of any such use. That is, nobody that I was associated with then, that I talked with, has told me that they were using it. Nobody has told me that they weren't using it either, so I don't know whether they have or not.
>
> I would say that it wasn't very impressive work, and I don't think that it would be awfully useful. If it were useful, then of course, they would be welcome to use it."

LANCHESTER MODELS AT STAG

Despite Robinson's claims of ineptitude, Howes consulted AMRC again in 1972. According to the 20 October 1972 Semi-Annual Report:

> "On 2 April 1972 Professor Louis B. Rall, Associate Director, returned material sent to him by Dr. David R. Howes, U.S. Army Strategy and Tactics Analysis Group, Bethesda, Maryland, concerning dynamic Lanchester equations. Since the problem of obtaining oscillations in a Lanchester model seemed to be fairly difficult, Professor Rall suggested using a Volterra model for the attrition rates and cited two references that might be of interest in this connection."
>
> (20 October 1972 Semi-Annual Report)

This work on the Lanchester warfare models described above is an attempt to make the models apply to the more complicated situation where the probabilities of various outcomes of the combat change according to the progress of the fighting. The "Volterra model" referred to is an alternative type of equation that might be used in the Lanchester theory. It is interesting to note that John Nohel of the UW Mathematics Department has now, and has had for some time, a Defense Department grant to study these Volterra equations in their abstract form. Nohel, it should be noted, works occasionally for AMRC.

The 20 October 1972 AMRC Semi-Annual Report further states that "On 5 April 1972 MRC TSR Nos. 1140, 1142 and 1158 were mailed to Dr. David R. Howes, US Army Strategy and Tactics Analysis Group, Bethesda, Maryland, at his request." No. 1140 is Robinson's paper on linear programming, mentioned above. No. 1158 was written by Fred Brauer of the UW Mathematics Department on the "Predator-Prey problem." The predator-prey type of equation offers a way of predicting when and with how much effort a predator can destroy a prey. Howes would be interested in using this type of equation in place of those in his current warfare model to see if it gets better results. The prey would be the guerrillas, and the predator the US.

The predator-prey problem occurs in ecology as well as in Howes' studies on guerrilla warfare. For this reason, the Technical Summary Report written on the predator-prey equations includes a note that it will be published in the "open literature"; the other two reports sent to Howes contain no such remark. The ecologists however will have to wait about two years for the AMRC report to appear in the journals, while STAG received a copy immediately.

The third paper sent to Howes, No. 1142, was also written by Stephen Robinson. This paper concerns the Von Neumann economic model, a mathematical description of the functioning of an economic system. The fact that Howes requested information on economic models suggests that the economy of a country in which a guerrilla war occurs is a factor in the warfare models currently being constructed. In other words, the US is determined to manipulate the economy of whole countries in order to defeat guerrilla movements. This concern with economic modeling is a new direction in AMRC's research, as we describe in Chapter 10.

AMRC CONSULTING WITH STRATEGY & TACTICS ANALYSIS GROUP

Date	AMRC	STAG	Subject
September 12 1960	--	Howes	Target analysis problem
June 4-5 1963	Greville	Maisel	Coordination with Project MICHIGAN
August 5-6 1963	Greville	de Quoy, Maisel, Albertini	War gaming, model of concentrated but inaccurate fire
March 6 1968	Rosser	Howes	Model of combat effectiveness
April 14 1968	--	Howes	Model of combat effectiveness
April 26 1968	Fox, Harris, Kimeldorf, Rosser	Howes	Model of combat effectiveness
March 15-18 1970	Karreman	--	Mathematical programming
1971	Rosser	Howes	Approximation for an integral
March 13 1971	Robinson	Howes	Optimal delaying action
April 2 1972	Rall	Howes	Lanchester model of combat

Research Analysis Corporation (RAC)

The Research Analysis Corporation (RAC) is an independent "nonprofit" research organization working solely for the Army, doing the same kinds of research that the RAND Corporation does for the Air Force. It is one of the four major organizations doing social, behavioral, and operations research for counter-insurgency programs. The others are RAND, Special Operations Research Office (Center for Research in Social Systems) and the Human Resources Research Office.

In a 1969 report to NSF, the Research Analysis Corporation describes itself as a Federal Contract Research Center studying three major topics for the Army:

(1) Operational systems, to "analyze existing organizational structures and systems, and develop and test concepts";

(2) Technological systems to "....research methodology development and exploitation of new research techniques" where "....technical means are analyzed as they relate to governmental objectives"; and

(3) Economic, Political and Social Sciences where "strategic interests are assessed, trends are projected and implications developed to assist in governmental planning and policy development, Defense forces, weapons systems, manpower and materiel are analyzed in cost effectiveness studies."

RAC is organized into eight different departments. Three examples will suffice:

> "The Science and Engineering Department focuses on the possible application of new technology to combat. RAC has offered improvements in airmobile operations, such as those being conducted in Vietnam today. One of the studies undertaken by this Department, i.e. the laboratory of actual combat conditions, has analyzed the combination of helicopter and weapons and has made recommendations for improved airborne artillery.
>
> "The Combat Analysis Department is primarily concerned with military combat and the battlefield employment of conventional armed forces, including the air defense of the United States."
>
> "What is the best way to conduct military, political, and economic operations in areas controlled or threatened directly by enemy insurgent action? The Unconventional Warfare Department conducts studies into ways of preventing insurgencies before they develop and into methods of controlling them should prevention fail."
>
> (above quotes from Army R&D June 1967)

The Research Analysis Corporation's special competence is in "large-scale operations research and systems analysis." This is

The computer that "proves" the war is being won. Data collected for the "Hamlet Evaluation System" is analyzed to "see who loves us." Optimistic results on the "my-wife-is-not-trying-to-poison-me-therefore-she-loves-me" pattern are reliably produced each and every month. J. P. Griffiths, Vietnam, Inc.

mathematical and computer techniques which allow the planning of supplies for an entire army, planning the stationing of troops around the world, analyzing the cost of a weapons system, or planning a strategy against a guerrilla or conventional army. All of these efforts require the relating of various factors in the practical situation, and then computing the correct balance of factors so that each factor is maximized for the Army's purpose. This is called a "trade-off" in which each factor may be slightly lower than its highest value so that other factors can be closer to their highest values. For example, in guerrilla warfare planning, the factor of democracy may be lowered in the plan so that the factor of control over the guerrilla troops' movements may be increased. Thus, these models built by RAC with the help of AMRC are used to manipulate people in order to win the Army's goals.

AMRC'S ASSISTANCE

Balancing the various factors to obtain the maximum strength of each is a very difficult mathematical problem. AMRC has helped in this work which involves the "mathematical programming problem." This entails the use of computers to find the maximum value of a given function. Essentially, the "function" is a formula set up to describe a practical situation. Thus, finding the maximum value gives an indication of the best solution to the practical problem, the best way to distribute troops or the best way to fire into a clump of trees to kill any guerrilla troops hiding there.

Finding a way to let the computer solve such problems means that calculations can be done faster, and therefore more factors influencing the situation can be taken into account in the formula. It was to deal with such problems that the first series of consultations took place between AMRC and RAC.

"Operations Research Office sent its Mr. Nicholas Smith to the MRC on 3 February to give a briefing on existing problems and to confer with various members of the MRC" (25 April 1961 Semi-Annual Report).

Smith's briefing apparently paid off for RAC a few months later. On 1 September 1961, its name was changed from the Operations Research Office to the Research Analysis Corporation, possibly as part of Kennedy's reorganization of US military planning to prepare for "limited warfare" rather than "massive retaliation." The consultations with Smith continued later that year, as described in the 25 April 1962 Semi-Annual Report:

> "November 13-14 1961. On these days the MRC was visited by Dr. Nicholas Smith and Mr. Anthony Fiacco for consultation with Drs. Anselone, Bruckner, Brauer, Buck, Gurland, Wilcox and Zelen of the MRC. The central topic was the approximate solution of high-speed computer methods of non-linear, non-stochastic programming. This involves the minimization of a certain utility function of many variables in a region determined by inequalities. Various modifications of the utility function and of the classical gradient methods were discussed."
>
> (25 April 1962 Semi-Annual)

Subsequently, Langer received a letter from RAC President Frank A. Parker which said, in part:

> "Not only was the MRC staff generous of their time, they were also generous of their ideas. This group, together with Dr. Smith and Mr. Fiacco, have worked out a very promising line of research in the solution of nonlinear, nonconvex, static programming problems. This meeting, held in response to our request at a time when present lines of research on this problem appeared unfruitful, has revitalized this work and shown that the US Army Mathematics Research Center is responsive to the needs of our organization."

The success of the consultation was further shown in the sequence of papers that Fiacco published over the next few years, giving the results which were obtained on the mathematical programming problem.

AMRC's remaining two reported contacts with RAC involved work on mathematical simulations of warfare. 20-21 December 1964, Professor Karreman of AMRC's Permanent Staff, who still holds this position, toured several Army centers to consult. "He stopped at the Research Analysis Corp. to assist them with a statistical analysis problem and a simulations-model problem" (20 January 1965 Quarterly Report).

The final contact occurred on 14 July 1966, when "Dr. Joseph O. Harrison Jr., Research Analysis Corporation, McLean, Virginia wrote Professor Rosser requesting replacements of damaged MRC reports and Orientation Lecture Series" (18 October 1966 Quarterly Report). While we cannot determine exactly which reports were desired from this, it does indicate that the reports were useful to Harrison. His area of work is indicated by the following abstract of a September 1964 report he wrote with Mary Francis Barrett, entitled: "Computer-Aided Information Systems for Gaming" (AD-623 091). The abstract notes:

> "Scientific war games have been under development by military operations research groups since about 1960, and business games by industrial operations research groups since 1956. From an information system point of view, these games may be divided into three types: computer simulations, digital man-machine games, and continuous variable man-machine games. Computer simulations, or completely automated games (i.e. Carmonette AD-257 012) are always rigid, usually stochastic and generally very detailed. Since they are not limited by the decision-making speed of human beings, they may be executed rapidly, permitting repeated plays with large-scale variations of input conditions and change factors.
>
> "Digital man-machine games, or partly mechanized games (i.e. Theaterspiel) employ digital computers for book-keeping, computing, and transmission of data, but use the people for decision making. In digital man-machine games both speed of execution and level of detail are sacrificed in the interests of human participation. Continuous variable man-machine games employ people for decision making and electronic analog computers for computation. The human decisions are introduced continuously as the game proceeds rather than periodically."

The usefulness of this work to the Army is described in Army R&D of September-October 1970:

> "Research Analysis Corp. had developed a computerized combat simulation called "CARMONETTE" III. Individual men, units, vehicles and weapons in this simulation interact in a highly realistic battlefield environment guided only by generalized orders of the type given to platoon leaders. This method was chosen as a foundation on which to graft highly complex surveillance, detection, target acquisition, and communications routines. These include radar and night-vision (infrared) systems. The simulation, in effect, provides an indication of when increased technical performance reaches a point of diminishing returns in terms of combat effectiveness."

ARMY WAR GAMES in 1953. The game board represents southern France.

Large-scale operations research and systems analysis, balanced variable factors for maximum efficiency in computerized war games, complex techniques to search and destroy -- these are the services which the Research Analysis Corporation and AMRC provide for the Army.

AMRC CONSULTING WITH RESEARCH ANALYSIS CORPORATION

Date	AMRC	RAC	Subject
February 3 1961	--	Smith	Existing problems
November 13-14 1961	Anselone, Buckner, Brauer, Buck, Gurland, Wilcox, Zelen	Smith, Fiacco	Computer programming
December 20-22 1964	Karreman	--	Statistical analysis, simulation models
July 14 1966	Rosser	Harrison	Request for AMRC reports

Chapter 2

CHEMICAL & BIOLOGICAL WARFARE

The Army Mathematics Research Center has played an active role in the development of biological and chemical weaponry. Beginning in the late 1950's and continuing throughout the 1960's, AMRC had numerous contacts with Edgewood Arsenal and Fort Detrick, the two major Army bases working on chemical and biological warfare. AMRC provided valuable mathematical assistance, particularly in the formulation and development of models to describe the behavior of biological and chemical agents with respect to such factors as storage characteristics, pathogencity or toxicity(capacity to cause illness or death), and dissemination.

US planes spraying Vietnam cropland with herbicides.

HISTORICAL BACKGROUND

The use of chemical weapons during the First World War provoked widespread international opposition and led to the convening of the 1925 Geneva Conference which prohibits the use of asphyxiating, poisonous, or other gases, and of bacteriological methods of warfare. This Protocol, ratified eventually by 44 nations, remains the most important international treaty restricting chemical and biological warfare. The United States was one of the original signatories of the treaty, but the Senate Foreign Relations Committee refused to ratify it in 1926.

Despite the failure of the US to ratify the Protocol, the official military policy until the mid-1960's was that chemical and biological agents would never be used by American forces except in retaliation for a chemical or biological attack. About 1966, however, an important change in policy occurred, and the military became free to use biological and chemical weapons on a first-strike basis during conventional warfare (see Chemical and Biological Warfare by Seymour M. Hersh). Much of the CBW research done in the US today is concerned with offensive measures.

In 1961, plant-killing defoliants and herbicides were approved for use in Indochina and have been employed extensively since then to destroy thousands of acres of croplands and jungle, causing many toxic effects in people and in animals. In addition, riot-control gases have been used often against Liberation forces.

SPECIFIC USES

In order to understand AMRC's role in chemical and biological weapons research, it is necessary to have some appreciation of the complex mathematical, meteorological and biochemical factors involved in the use of such weapons. The use of biological agents, in particular, involves problems of a mathematical nature. For example, accurate dissemination of the biological agents presents an important problem.

Early forms of delivery systems which were considered included contamination of food or water sources, or the use of prevailing wind currents or insects (vectors) to convey the disease. Such methods, however, are difficult to control accurately and hence have been eliminated from serious consideration. Present research largely centers around the use of aerosols to disseminate the germs. An aerosol consists of airborne solid particles and liquid droplets, and may be dispersed by bombs, shells, sprays or mines.

Mathematics is very important in helping predict the effects of aerosol dispersal of biological or chemical agents; predictably, many of the contacts between AMRC and Edgewood or Detrick were concerned with problems directly related to aerosols.

The use of aerosols, besides giving a more accurate method of dispersal, can enhance the virulence of certain pathogens by introducing them to victims through an unorthodox route. For example, a disease normally transmitted through the mouth, when introduced into the respiratory tract, might bypass normal bodily defense mechanisms and thereby produce infection more effectively. Factors to be considered in a mathematical model of aerosol dissemination might include:

(1) Particle size, which can affect the rate at which germs fall to the ground, or effectiveness at entering the upper respiratory tract;

(2) Infectivity and virulence, which may be affected by physical and thermal stresses during the production of the aerosol, oxygen in the atmosphere, ultraviolet irradiation from the sun, and humidity;

(3) Meteorological & terrain conditions; and

(4) Particle concentration.

(see John Cookson and Judith Nottingham's A Survey of Chemical and Biological Warfare)

Methods to predict the spread of diseases must also be intensively studied in order to prevent infection of one's own troops. Very complex stochastic models, taking into account such factors as infectivity, attenuation, spatial distribution of susceptible and infected individuals and their movement in the habitat, and random mutations of the bacterium or virus are necessary to describe the phenomenon of an epidemic. An example of such a model is one presented by J. Neyman and Elizabeth L. Scott at a 1963 Symposium conducted by AMRC and published in Stochastic Models in Medicine and Biology, edited by John Gurland of AMRC. Those attending the conference included representatives from Fort Detrick and Edgewood Arsenal.

Fort Detrick
Edgewood Arsenal
Dugway Proving Ground

Nerve gas arsenal, Hermiston, Oregon.

Before describing some of the specific consultations between Army personnel and AMRC mathematicians working on the development of CBW, we will describe briefly the Army installations involved.

Edgewood Arsenal, located 16 miles northeast of Baltimore, Maryland, is the main center for chemical weapons research and development and serves as the management center for all chemicals and munitions. Edgewood also conducts research on biological agents.

Fort Detrick, located near Frederick, Maryland, controls the procurement, testing, research, and development of all biological munitions and products. Emphasized are offensive agents, including anthrax, Q-fever, pneumonic plague, brucellosis, and encephalitis, although vaccines and other defensive measures are also under consideration. Aerobiology comprises a large portion of the research. Facilities include the newest computers, electron microscopes, and a large variety of cloud chambers to measure the dissemination and virulence of possible germ warfare agents. In 1969, President Nixon closed Detrick, and its functions have been moved to Edgewood and elsewhere.

Dugway Proving Ground, located near the Great Salt Lake in Utah, is the major Army testing ground for the chemical and biological munitions developed at Edgewood and Detrick.

AMRC CONTACTS

Following is a sampling of important contacts between AMRC and the researchers at Edgewood, Detrick, and Dugway.

In April 1959, AMRC's Bueckner and van der Corput met with Detrick's K. L. Calder to discuss a problem with the inversion of a certain Laplace transform, a technique for solving differential equations and useful in stochastic models. Bueckner sent results to Calder in July, and in December further discussions were held (25 April 1960 Semi-Annual Report). Calder's research uses stochastic models to predict the effects of dissemination of toxic chemicals or biologically active particles over a target area. Scanning the titles from some of his published papers gives a clear indication of the importance of mathematical models in predicting the effectiveness of such weapons. Listed in the TAB's Index was a 1969 paper by Calder entitled: "A Time-Dependent Stochastic Model for Multiple Biological Bomblet Attack of Finite-Area Targets" (AD-854 133). Clearly, this paper deals with biological warfare. Cited as references in this study were several earlier papers by Calder, published during the period of contact with Bueckner. They include:

"A Mathematical Model for Casualty Effects in the Attack of Area Targets with Randomly Dispersed Antipersonnel CW or BW Munitions" (1957);

"A General Method for Estimating Casualty Effects in Attacks of Area Targets with Randomly Dispersed CW or BW Munitions" (1959);

"Probability Distributions of Dosage and Casualty Effects in Attacks of Large-Area Targets with Randomly Dispersed Munitions" (1961).

Sheep dead in Utah's Skull Valley from Dugway's nerve gas test on 13 March 1968. 4,000 sheep were killed outright, another 2,000 put to death to end their suffering.
photo: New York Times Magazine, 25 August 1968

Other important contacts occurred in December 1959 and in January 1960, when AMRC's Hunter met with Ira DeArmon and M. A. Rhian of Fort Detrick to discuss the problems in extrapolating animal diseases to humans (25 April 1960 Semi-Annual Report). This consultation revealed the need for more data before inferences for humans could be made. Research work published by Rhian between 1962 and 1964 included studies of allergenic agents (substances which stimulate an allergic response) and of anthrax (a deadly disease bacterium which can affect both animals and human beings). DeArmon also published a number of papers dealing with anthrax during the period 1959-62.

DISEASE DISSEMINATION

The Army's interest in methods of dispersing disease continued to grow. An important contribution came from AMRC's Zelen, who in October 1962 consulted with S. N. Metcalf and B. Haines of Fort Detrick, and later submitted to them a detailed report on "Design of an Experiment to Evaulate Aerosol and Storage Characteristics of Viral Slurry" (25 April 1963 Semi-Annual Report). Aerosols containing viruses would be made from viral slurries and therefore knowledge of the storage characteristics of such slurries is essential to ensure that the virus remains infective if these weapons are stock-piled. The importance of aerosols in the offensive dissemination of biological and chemical agents cannot be overemphasized, since this is the form in which the active agent enters or contacts the body.

In addition to his interest in viruses, Haines published during the 1960's many papers dealing with the deadly anthrax bacterium. Some of his reports are secret and hence unavailable to us, but the short descriptions in the TAB's Index reveal that they deal with biological warfare and utilize mathematical models.

During his October 1962 visit to Detrick, Zelen also gave aid to Army researchers working on chemical warfare. The AMRC Report reveals that Zelen discussed a computer simulation of a chemical weapons system with DeArmon and R. Greeenstone (25 April 1963 Semi-Annual Report). Greenstone had just published a study on this topic in 1961.

The Semi-Annual Report indicates that the two men represented the Army Chemical Center at Edgewood Arsenal. Two years earlier, DeArmon was listed in an AMRC Report as an Army researcher working at Fort Detrick. This suggests that the two bases were working closely together long before Detrick was officially closed and its functions transfered to Edgewood and elsewhere.

Aerosols are also important for distributing chemical weapons, as R. O. Pennsyle's work at Edgewood shows; his papers include one entitled: "Mathematical Models for Measuring the Dissemination of Aerosol Particles in Toxic Chemicals" (AD-845 313), 1969. AMRC's J. B. Rosser gave assistance to Pennsyle in 1966 (19 April 1966 Quarterly Report).

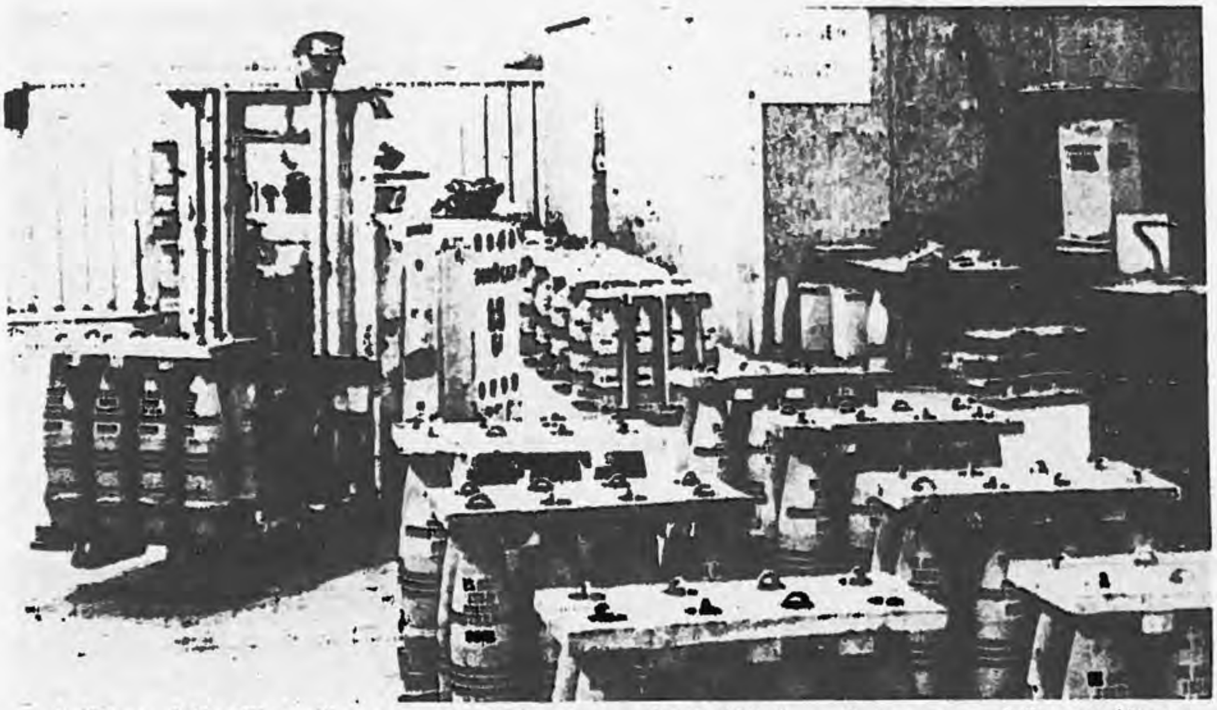
Work on aerosols continued throughout the late 1960's. Don Shearer of Dugway Proving Ground called AMRC's Louis B. Rall in May 1968 to request assistance with partial differential equations for describing the diffusion of aerosols in the atmosphere. Rall suggested a visit to AMRC (Supplement to the 1968 Annual Report).

FURTHER AMRC ASSISTANCE

AMRC not only gave assistance in solving specific mathematical problems of Army CBW researchers, but gave more general help as well to Edgewood Arsenal and Fort Detrick. Statistics have been applied to several facets of the operations: the costs, planning of experiments, and analysis of the results. In 1959, AMRC's Hunter and Steel participated in the Fifth Conference in Design of Experiments at Detrick (25 April 1960 Semi-Annual Report). Hunter was again involved in 1960 in an Edgewood course on the applications of statistics to the physical sciences (25 October 1960 Semi-Annual Report). More recently, in 1968, Karreman of AMRC sent reports to Edgewood's J. C. Richards about economic modeling problems (26 April 1968 Quarterly Report). In 1969, Karreman was at Detrick discussing computational methods for the design of biostatistical experiments (30 October 1969 Semi-Annual Report).

These selected instances of consultation between the Army Mathematics Research Center and the Army's CBW establishment should give some indication of the Center's involvement in chemical and biological warfare research and development. AMRC's own descriptions of these contacts, including more than the specific math involved, make it obvious that the AMRC staff clearly understood, and understand now, the nature and application of the mathematical assistance they provide.

Vietnamese women and children emerging from a hole after US troops used smoke and tear gas.



Artillery shells filled with a nerve gas that can cause death within four minutes are carefully moved by a worker at the Newport Chemical Plant near Terre Haute, Indiana. This plant is the major supply center for nerve gas in the United States.

AMRC CONSULTING WITH EGDEWOOD ARSENAL

Date	AMRC	Edgewood	Subject
1959	Bueckner, Kanger, Wilcox	—	—
December 1959	Hunter	Silver	Application of statistics
December 1959	Hunter	Rhian, De Armon	Extrapolations of animal disease to humans
April 1960	Hunter, Anselone, Lieberstein	—	Review contract reports
May 1960	Hunter	—	Course in application of statistics
January 1961	Anselone, Bueckner	Mendelsohn	Computer use
February 1961	Hunter, Knitter	Mendelsohn, Ellner, Ready	Life expentancy of chemical items
February 1961	—	M. Cutler	—
October 1961	Gurland, Zelen	—	Math sessions of chemical corps
December 1965	Rosser	Pennsyle	Correspondence
November 1967	Karreman	Gibby, Richards	Arsenals and private industry
February 1968	Karreman	Richards	Economic modeling
October 1969	Karreman	—	Use of computers

AMRC CONSULTING WITH FORT DETRICK

Date	AMRC	Detrick	Subject
1958	staff	--	Statistical matters
1959	staff	--	Statistical matters
April-Dec 1959	Bueckner, Van der Corput	Calder	Laplace transform
November 1959	Hunter, Steel	--	Design of experiments
January 1960	Hunter	Rhian, De Armon	Animal deseases (quantal response curves)
April 1960	Hunter	--	Detection of aerosol
December 1960	Bueckner	Maloney, Calder	--
November 1961	Buck	Maloney	Information retrieval
April 1962	Gurland, Zelen	Maloney, Foster, Wadley	Biological assays
October 1962	Zelen	Greenstone, De Armon	Computer simulation of chemical weapons system
October 1962	Zelen	Haines, Metcalf	Aerosol and storage characteristics of viral slurries
March 1963	Anselone, Bueckner	Richetta	Light scattering, solution of integral equation
August 1963	Anselone	Richetta	Light scattering, solution of integral equation
August 1969	Karreman	--	Computational methods for design of biostatistical experiments
1970	Noble, Yohe	Jacobs, Frederer	Sampling, quality control

Chapter 3

MISSILES

AMRC has consulted with the Army on two aspects of its missiles program: artillery rockets and the Anti-Ballistic Missile system. These two kinds of rockets were at one time important to US foreign policies, but are today little more than expensive memorials to discarded military strategies.

ARTILLERY ROCKETS

An artillery rocket can propel nuclear or conventional warheads at troops and cities between a few miles and a few hundred miles away. During the 1950's, the Army developed a large arsenal of rockets for artillery use: Redstone, Pershing, Sargeant, Little John, Honest John and Lance. The smaller rockets in this group can be launched from a truck or other vehicles which can move around with the infantry; the larger missiles are less mobile but have a longer range.

The large nuclear-tipped artillery rockets were developed under President Eisenhower in order to combat the Russian Army in the event of European war. The bulk of these missiles were deployed with the US Army in Germany, in close proximity to Soviet troops, and many remain there today. Military planners, after preparing themselves for a limited nuclear war with the Soviet Union, concluded in 1961 that such a war would be absurd. They realized that neither United States' nor Soviet armies, with their accompanying civilians, would survive the rockets' nuclear blasts, and decided that an initial European-scaled war would expand into global nuclear war.
Since America would then have depended on the Air Force's ICBMs and the Navy's submarine-launched missiles, the Army's artillery rockets were seen as second priority and a waste of funds. Since Kennedy, Presidents have reduced expenditures on these rockets to a trickle.

The Army still possesses artillery rockets, and continues some research on missile technology, although success has been limited by the insufficient funds. For example, the Army has been developing the Lance, a mobile and accurate missile, but after more than a decade of work, the Lance still has technical problems. While waiting for the Lance to operate correctly, the Army in Germany deploys old rockets like the Sargeant which has not been in production since 1964.

A Lance rocket (left) mounted on its mobile launcher being tested in the jungles of the Panama Canal Zone. A multiple rocket launcher (right) from World War II, included in an article, "The Case for a Multiple Rocket Launcher System" (Army, November 1970).

The Army's missile men also try to obtain funds for an occassional new rocket system which they have designed. In 1971 for example, a Multiple Array Rocket System (MARS) was proposed. The rockets in MARS would be cheap and unguided, little different from those giving off "the rocket's red glare" during the War of 1812, but the Army's new design would concentrate a high volume of these rockets on a single target. The MARS, however, was not considered useful enough in fighting guerrilla armies, the Army's foremost responsibility, and was therefore not given any funds.

THE ANTI-BALLISTIC MISSILE SYSTEM

The ABM is the second Army missile program to which Army Math has contributed. Since the beginning of ABM development in 1956, the program has been stuck in the research phase because the system looked both too expensive and too unreliable. The technical problems were superseded by political considerations:

> "The official (i.e. Department of Defense) perception of the nature of the threat posed to U.S. cities and strategic forces changed in 1967. Prior to that date, it was assumed that the major threat to the U.S. came from the possibility of a Soviet attack on U.S. cities. The possibility of a Communist Chinese attack began to appear following their successful testing of a thermonuclear device in May 1966....On September 18, 1967, the Johnson Administration announced plans to deploy the Sentinel ABM system. The system was explicitly 'anti-Chinese'."
>
> Why ABM?, 1969
> by J. J. Holst & W. Schneider

The book Why ABM? was written by the Hudson Institute where Herman Kahn and other scientists think about thermonuclear wars for the Defense Department. These planners provide a scenario where the ABM would be needed aginst the Chinese:

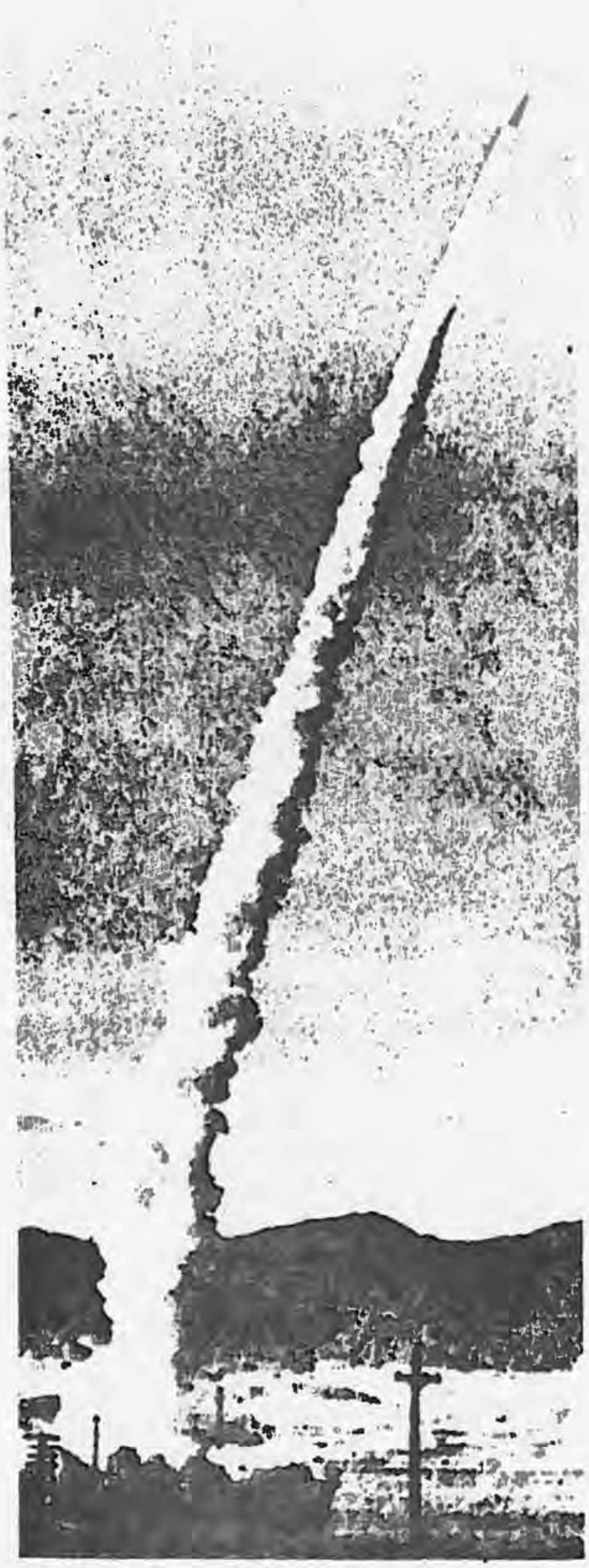
> "Let us assume that at the height of a grave crisis between Red China and the United States, a few Chinese missile-carrying submarines lay off our West Coast....Let us further assume that the United States was in some turmoil at this time, with very small but very verbal groups condemning our defense of the government in country X. Regardless of the righteousness of our cause, if our cities within range of these submarine-based missiles were undefended, the President would be faced with a very difficult decision." -Why ABM?

In 1969, "country X" obviously equaled Vietnam, so the American military felt the need for an ABM system in order to continue intervening in wars along China's borders. As the Hudson Institute says:

> "Although the probability of a Chinese nuclear attack against the United States is low, the probability of a United States - Chinese crisis is not and one should probably not look 'uncovered' in crucial dealings with a tough bargaining opponent." -Why ABM?

President Nixon likewise has said that his form of the ABM system, Safeguard, was necessary for a "credible foreign policy in the Pacific area" -(31 January 1970 press conference).

Nixon has also promised that Safeguard could deter an attack by the Soviet Union,



Sprint ABM seconds after take-off in test interception of incoming missile at White Sands Missile (Army 1967)

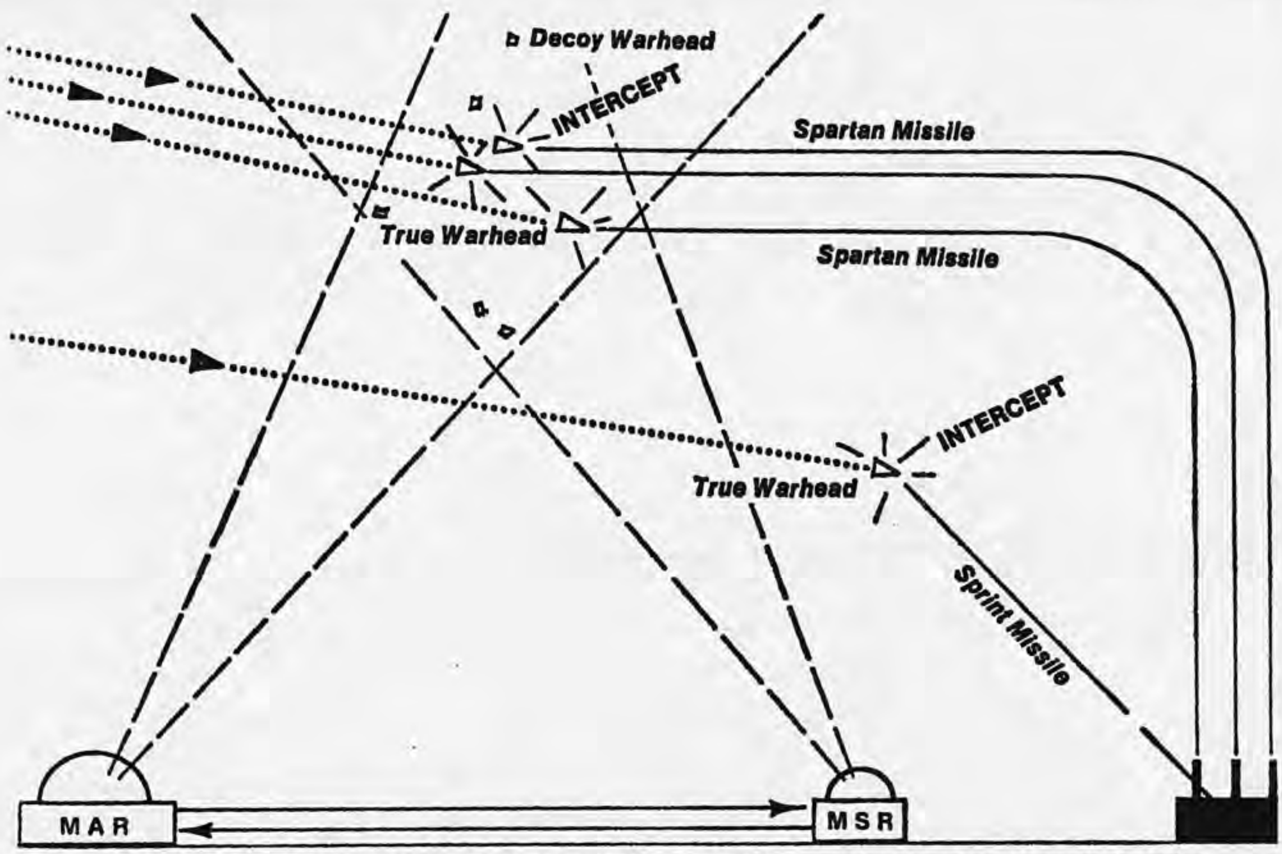


DIAGRAM OF THE ABM SYSTEM. The Spartan and Sprint missiles intercept the incoming warheads under the guidance of the multifunctional array radar (MAR) and the missile site radar (MSR). (Army 1967)

but this claim has been challenged by many scientists:

> "The protection offered by SAFEGUARD for the MINUTEMAN force is negligible. Even if SAFEGUARD functions perfectly, it offers significant protection to MINUTEMAN only over a very narrow band of threats; if the threat continues to grow as rapidly as it is at present, SAFEGUARD is obsolete before deployed; if the threat levels off, SAFEGUARD is not needed. For SAFEGUARD to have any significant effectiveness at all in protecting MINUTEMAN, the Soviets would have to "tailor" their threat to correspond to it."
>
> Petition signed by Jerome B. Wiesner and Herbert F. York, among others

Whatever the ABM's capabilities would be against a Russian attack, Nixon's talk about the menacing Soviet missiles did scare up just enough votes in Congress to win approval for Safeguard. Construction began on two ABM sites in 1969, and on two additional sites the following year, bringing enormous profits to AT&T and the other corporations building Safeguard.

The windfall for America's missile men began to dry up after only two years. Although the Army's Ballistic Missile Defense Agency complained about insufficient funds in 1971, its budget was further reduced the next year. When Nixon signed the Strategic Arms Limitation Treaty (SALT) in May 1972, the Army was then permitted only two ABM installations, one already under construction in North Dakota, and a second one planned for the Washington, D.C. region.

The SALT agreement does not limit China's nuclear weapons, which were the original motivation for building the ABM, but events in Indochina have forced Nixon to repress his paranoia about the Chinese people. When Nixon and Kissinger decided that détente with China and the Soviet Union was the only way to avoid total defeat in Indochina, ABM deployment with its implicit threat of nuclear war had to be reduced. ABM construction has halted everywhere, except at the lone site in North Dakota, and the program has receded back to the research phase.

AMRC contributed to research on the ABM artillery rockets, and to other aspects of the Army's missile program through consulting with White Sands Missile Range.

White Sands Missile Range (WSMR)

White Sands Missile Range was established by the Army on 8 July 1945, converting 7,000 square miles of southern New Mexico's Tularosa Basin into America's busiest missile range. Over the mountains and desert where the Mescalero Apaches once hunted, the Army now fires thousands of missiles each year - over 29,000 from 1958-70. Officially, White Sands' job, or "mission" as the military calls its work, is to:

> "Operate a national missile range for support of all approved missile and related test programs, independently test and evaluate Army missile and rocket systems, and engineer and develop range instrumentation systems for gathering test data."
>
> (NSF Directory of Federal R&D Installations, 1970)

"WHITE SANDS MISSILE PARK has 32 missiles, making it the "world's first and largest outdoor missile museum." (Army R&D December 1967).

The impact of White Sands' research, however, reaches beyond missiles. In tracing the impact of AMRC consulting at White Sands, we found, for example, scientists contributing to the Army's chemical warfare systems and the acoustic sensors used in the electronic battlefield. This diversity has evolved from the various laboratories at White Sands which use rockets as a research tool. The Atmospheric Sciences Lab (ASL) measures the temperature, pressure, and winds of the upper atmosphere with instruments carried aloft by missiles fired at White Sands. These atmospheric studies could be of use in weather forecasting. The Army Digest (February 1971), however, informs its readers that:

> "Weather forecasts are only a minor part of this group's total mission....At least 95% of their work supports research, development, test and evaluation efforts of the Army. And this 95%....looks like the table of contents in a hairy-chested men's adventure magazine."

This table of contents for atmospheric research covers all "Army functions on which atmospheric conditions have significant impact" which, according to Army R&D, September 1972, includes electromagnetic and acoustical sensors for the electronic battlefield, sound-ranging, chemical and biological warfare, cannons, unguided rockets, guided missiles, nuclear weapons, communications, and troop movements in the air and on the ground.

Out of this long list, we will discuss two projects on which AMRC has consulted: unguided rockets and acoustical sound ranging. We shall also document AMRC's extensive consultation with William L. Shepherd, a White Sands mathematician who has helped develop the Anti-Ballistic Missile System.

ARTILLERY ROCKETS

Two types of rockets serve Army artillery: large expensive missiles such as the Honest John which are capable of delivering nuclear and conventional warheads over greater distances than cannons or mortars are able to do, and light cheap rockets massed on a helicopter or on a tank which concentrate high volumes or explosives on single targets. The Army's rockets in both cases are often "unguided" since no corrections are made in their flight path after launching. As opposed to "guided missiles" which are steered to their targets during flight, the unguided rockets are cheaper, more dependable, and immune to enemy "jamming" to which guided missiles are vunerable.


HONEST JOHN, an Army unguided artillery rocket

In order to hit a target, an unguided rocket must be launched at the correct angle, taking into account not only the mechanics of flight but the winds encountered en route. For researchers at the Atmospheric Sciences Lab, "the problems are how to aim cannons and rockets to compensate for atmospheric deflection, drag and weathercocking" (Army R&D September 1972)

In order to solve t[illegible] problems, the ASL scientists construct[illegible] ematical models of the interaction between [illegible] unguided rocket and the atmosphere. As part of this model building, ASL gathers atmospheric data such as winds aloft, pressure and humidity with sensor instrumented rockets. (Other means for atmospheric measurements using radar are being designed for the Air Force by the Electrical Engineering Department of the University of Wisconsin.)

The atmospheric data, together with general mathematical expressions for flight paths, atmospheric conditions, and target locations, must be solved to find the launch angle corresponding to each intended target. Rapid computer solutions to these equations are mandatory since, if too much time is taken solving the equations, the winds could change and blow the rocket off course.

A special mathematical method for the computer solution of these equations is called Runge-Kutta. In 1967, L. D. Duncan of ASL received the following letter from AMRC Director J. B. Rosser. This letter, dated November 3, appeared in Mathematics for Death:

"Dr. Louis D. Duncan
Atmospheric Sciences Laboratory
U.S. Army Electronics Command
White Sands Missile Range
New Mexico 88002

Dear Dr. Duncan,

It was nice to see you again and have a chance to hear of the new developments in unguided rocket ballistics. I should like to add a few more words to the discussion we were having about Runge-Kutta just as I was leaving. It may be some time before I can get around to writing up in generality the version of the predictor-corrector methods which corresponds to my treatment of Runge-Kutta. However, if you would like to try it I suggest you indicate approximately what order of accuracy you think you would be interested in. I will work out a set of coefficients for that order with a few more detailed suggestions as to how to try this out....

Sincerely,
J. Barkley Rosser"

Rosser was carrying out one of the prime functions of AMRC: the tailoring of known mathematical techniques to Army needs. These techniques are often specialized to the point of being useless for any application other than that of the military. Note also that Duncan received the variation Runge-Kutta before Rosser could "get around to writing up in generality" the technique for distribution to the public. These two AMRC services to the Army are not available to the civilians who get Army Math's research from its Technical Summary Reports.

The Army's application of Rosser's version of Runge-Kutta is clearly suggested by the titles of Duncan's publications in this period:

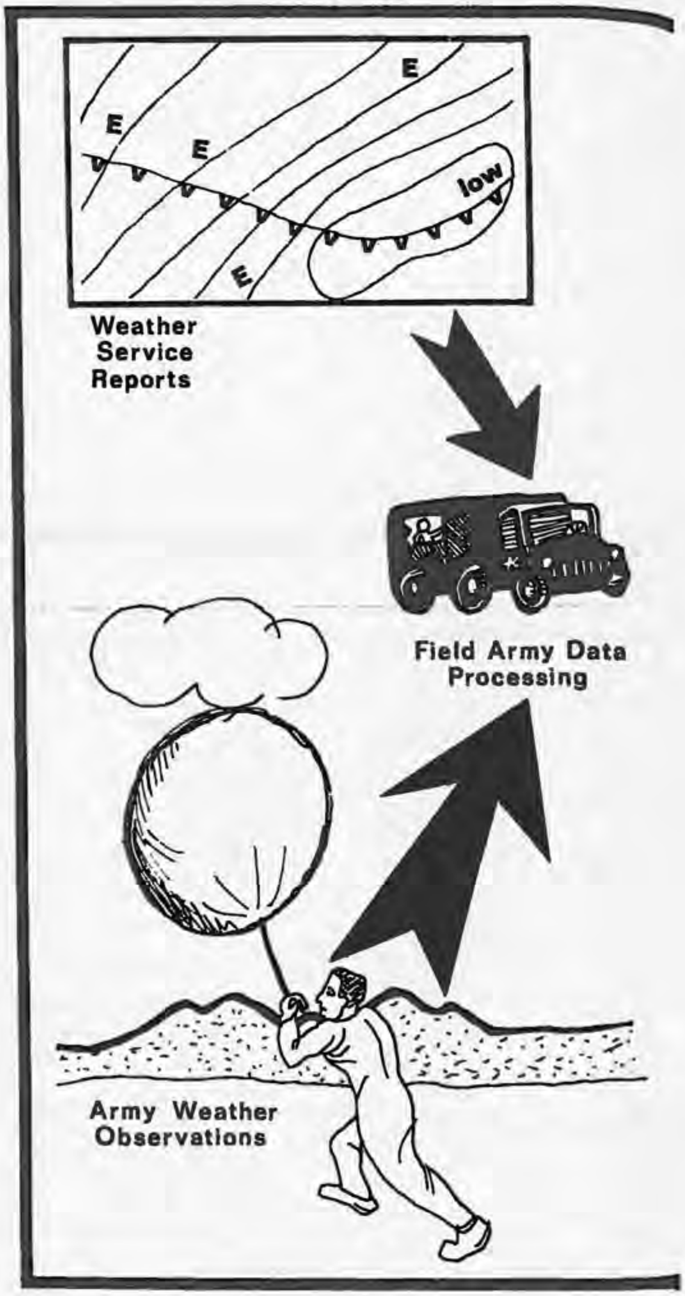
1966: "Techniques for Computing Launcher Settings for Unguided Rockets"(AD-642 855) and "Basic Considerations in the Development of an Unguided Rocket Trajectory Simulation Model" (AD-642 856);

1969: "A Rapidly Converging Iterative Technique for Computing Wind-Compensating Launcher Settings for Unguided Rockets" (AD-693 853).

The dates on these papers should not be taken too literally because of the Army's publications policy. In order for Duncan to publish his 1969 report, a better method had to be developed to aim unguided rockets; then the resulting obsolete technique which Duncan had earlier developed was declassified and discarded into the open literature. Such publications are trotted out from time to time, as examples of contributions in the "public interest."

AMRC gave aid to the development of unguided missile systems on at least two other occasions. In November 1966, Louis Rall of AMRC called ASL's Willis Webb in response to Webb's request for assistance with an unguided ballastics problem. Rall replied that "consulting would be available whenever required" (30 January 1967 Semi-Annual Report). Earlier in September 1961, Captain Dowling, Lieutenant Hendel, and William Shepherd of White Sands consulted with eight AMRC mathematicians on "the rapid computation of frequency predictions of impact points of unguided missiles directed at a specific target if the missile's power is cut off at particular points in flight" (25 October 1961 Quarterly Report).

WHITE SANDS MATHEMATICIANS Willis Webb (left) and William Sheppard (right) at the 1972 Army Science Conference.



We cannot say specifically where the Army used this research by Duncan, Webb, and Shepherd. Their mathematical techniques are possibly part of the present launching systems for the Army's artillery rockets. More certain is that Duncan's computer routines will find a place in the Automatic Meterological System (AMS) currently being built by the Atmospheric Sciences Lab:

> "The AMS is visualized as an integrated tactical meterological system for field Army use. This system embraces automatic observations, analysis, computation of application data, dissemination and display of atmos-

AUTOMATIC METEROLOGICAL SYSTEM

(Army R&D September 1972)

> pheric information in the scale, detail and format, accuracy and timeliness required by each supported Army operational element.... The first-generation AMS, to support artillery, is scheduled for completion in fiscal year 1975." (Army R&D September 1972)

This slab of bureaucratic prose is the vision which Duncan has been working towards: a system of weather instruments and battlefield computers which will automatically aim and fire unguided rockets such as Honest John toward targets selected by artillery commanders. Programmed into that AMS computer will be many mathematical techniques, perhaps including Rosser's version of Runga-Kutta. The Automatic Meterological System is an example of the kind of technological warfare which Army Math has made possible.

ACOUSTICAL SOUND-RANGING

The second project at the Atmospheric Sciences Laboratory which received AMRC support is "sound-ranging and acoustics - the problem of how to correct microphone data for atmospheric refraction and distortion" (Army R&D September 1972). Acoustic sound-ranging is a technique for identifying the source of sounds. Sounds "heard" by widely-spaced microphones are fed into computers programmed to recognize particular types of sounds and to locate their source. This sensor system is used at White Sands to track rockets during flight, and in Southeast Asia to locate people and guerrilla artillery.

Wind and changing air temperatures, however, deflect sound, and these atmospheric effects must be taken into account by the sound-ranging computer in order for the results to be accurate. An ASL mathematician, Robert P. Lee, attacked this problem in a 1972 study called "Artillery Sound Ranging Computed Simulations" (AD-745 887) in which "a new type of field test is described to measure statistically the effect of wind and temperature fields on atmospheric sound-ranging" (US Government R&D Reports).

AMRC Director J. B. Rosser assisted this research in 1970 by sending Lee "transforms of digitized time series" (2 November 1970 Semi-Annual Report). The mathematics described by this jargon is an important part of Lee's work on acoustical sensors. The sound picked up by the microphones is stored in the computer memory as a "digitized time series" (which means a sequence of numbers measuring how powerful the sound is at different moments in time). The computer then "transforms" the sound's power into the different pitches comprising the sound. The pitch, in turn, determines how much the sound's path of travel is bent by wind and air temperature. From the pattern of pitch in a sound, the computer can also discriminate between a rocket and the wind, or between a person and the rustle of the leaves. Without this advanced mathematics provided by AMRC, sound-ranging technology would locate the guerrillas less accurately, and would accordingly be less useful to the Army's electronic battlefield.

"TEST VERSION OF MULTI-FUNCTION ARRAY RADAR (MAR), under development at White Sands Missile Range (WSMR), New Mexico, is expected to provide for defense against long range ballistic missiles. Large dome contains MAR receiver equipment and smaller domes house the transmitters." (Army R&D September 1964)

THE ANTI-BALLISTIC MISSILE SYSTEM

The ABM system combines four pieces of military hardware: radar for tracking an incoming rocket, computers for predicting the Inter-Continental Ballistic Missile's future path, guided missiles for intercepting the ICBM, and a nuclear warhead for its final destruction. White Sands has contributed to all four segments of the ABM system.

The ABM missiles, the Sprint and the Spartan, were first tested at White Sands. Because of the 1963 Nuclear Test Ban Treaty, the ABM's nuclear warhead cannot be tested in the atmosphere, so the Atmospheric Sciences Lab has been working on a computerized model for the warhead's explosion in the upper atmosphere. Many models of radar for the ABM have been tested at White Sands, and computer programs for tracking ballistics have been written there. AMRC contributed to the ABM by consulting on White Sands research on radar and computer programs for missile tracking.

AMRC entanglement with the ABM came through William L. Shepherd on the Instrumentation Development Directorate at White Sands. Six times between 1961 and 1967, Shepherd and a co-worker, Thomas Bellows, contacted AMRC, mobilizing fifteen mathematicians to answer their questions.

Throughout this long series of discussions, Shepherd and his AMRC collaborators were developing the mathematics needed to track the ICBM accurately with radar. This goal is seen most clearly in the consultation on 17 October 1963 between Shepherd and Prof. Karreman at AMRC. According to AMRC's 25 October 1963 Semi-Annual Report, the two cooperated on "the solution of a mathematical system formulating a ballistic missile tracking program with the use of more than one radar station."

The nature of Shepherd's "ballistic missile tracking program" is suggested by two of his reports:

1962: "Velocities Necessary for an Aircraft Simulating an ICBM" (AD-276 422);
1963: "Three-Dimensional Motion for an Aircraft Simulating an ICBM" (AD-422 454).

These papers show how an airplane carrying a radio beacon can simulate an ICBM with respect to a radar station tracking the airborne beacon. According to the abstract for the 1963 paper, "The angular position and angular rates of the ICBM with respect to the tracking radar determine the aircraft position and velocity required to simulate the ICBM." Since it is cheaper and easier to simulate an ICBM than to actually fire one, the ABM radar can be tested by the beacon-carrying aircraft flying as Shepherd's method directs them. According to Army R&D, an ABM radar was installed for testing at White Sands in 1964 (see photograph).

Shepherd's remaining consultations with AMRC also have possible applications to the ABM. In 1961 for example, Shepherd talked with seven AMRC mathematicians about the "tracking of a satellite by means of the Doppler frequency shift of a reflected pulsed radar beam" (2 October 1961 Semi-Annual). This pulsed-beam radar technique would later be incorporated in the ABM radars tested at White Sands.

Another series of AMRC consultations between Shepherd and Bellows also involved subjects crucial to radar research. According to AMRC Reports (30 January 1967 and 21 April 1967), the mathematicians discussed "the spectrum of modulated waves" and "the analysis of electromagnetic waves." Since radar depends on electromagnetic waves such as radio waves, these mathematical techniques might likely apply in studying errors in radar tracking stations, an important theme in Shepherd's research and that of his agency, the Instrumentation Development Directorate. For instance, the IDD published a report on "Refraction Error Analysis of the Distance Measuring Equipment of the Integrated Trajectory System at WSMR" (AD-476 909). Because refraction - bending of the path of travel by the atmosphere - is dependent on the wave's frequency spectrum, this study would not only require a spectrum analysis of the radar waves, but would be important to the ABM system, which cannot afford errors in its tracking system.

By concentrating on radar and missile tracking research from 1961-67, Shepherd, White Sands and AMRC all helped make the ABM system attractive to Presidents Johnson and Nixon. In this way, mathematical technology helped accelerate the arms race.

AMRC CONSULTING WITH WHITE SANDS MISSILE RANGE

Date	AMRC	White Sands	Subject
June 1961	N. Draper	—	Course on statistical methods
September 1961	Anselone, Brauer, Bueckner, Greenspan, Morre, Saltzer, Wilcox	Dowling, Hendel, Shepherd	Unguided missiles, satellite tracking
April 1962	Wilcox, Fleishman	Shepherd	Missile impact points
October 1963	Karreman	Shepherd	Ballistic missile tracking
early 1964	Greenspan, Greville, Karreman, Noble, Rall	Shepherd	Functional approximations
November 1966	Rosser	Webb	Unguided rockets
December 1966	Greville	Shepherd, Bellows	Wave spectrum
January 1967	Greville, Halton, Harris, Noble, Zaremba	Bellows	Electromagnetic spectrum
February 1968	Karreman	Jones	Air defenses
late 1970	Rosser	Lee	Time series

Chapter 4

CONVENTIONAL WEAPONS

These weapons need little introduction to anyone who has watched battle films from Indochina. Despite the new helicopters and advanced electronics which the Army uses to move the troops and find the guerrillas, it still does its killing with mortars, machine guns, and hand grenades. Even these traditional weapons, however, are being studied by Army researchers in search of possible improvements.

Research on conventional weapons is the specialty of three bases, Picatinny Arsenal, the Ballistics Research Laboratories, and Watervliet Arsenal, all three of which have consulted heavily with AMRC.

While all three bases design artillery and explosives, they have divided the research between them. Watervliet concentrates on the properties of the metals from which artillery is built. Picatinny works on non-metallic materials such as plastics. And Ballistics Research Laboratories studies the motion of artillery shells within guns, during flight and upon arrival at the target.

Also described in the following chapter is Waterways Experimental Station, a center for researching the environments the Army faces in combat. Among the accomplishments of Waterways is a new tire for use on the swamps and beaches of Indochina.

The fact that AMRC's research on conventional weapons was described in exceptional detail in a few Annual Reports of the late 60's demonstrates the possibility that the Army considered these well-known weapons to be less controversial than research on the electronic battlefield or chemical warfare. The reports on Picatinny's research in particular illustrate clearly a mathematical model and its usefulness to the Army.

Picatinny Arsenal

Picatinny Arsenal in Dover, New Jersey, designs and develops small nuclear and conventional munitions such as artillery and mortar ammunition, mines, grenades, propellants, rocket and missile warhead sections, impact and inertial fuses, and arming devices. For this work, Picatinny specializes in the technology of solid and liquid propellants and the dynamics of non-metallic materials which might go into weapons.

Through consultations, AMRC has helped Picatinny on four problem areas:

(1) the properties of some new plastics involved in ballistic missile defenses (1959-60);

(2) the design of explosive shells (1963);

(3) the reliability of electronic components such as transistors when used in missiles (1966-67); and

(4) a mathematical model for allocating the development and production of munitions between Army arsenals and private industry (1967-69). In this last case, AMRC's own words describe mathematical modeling, its usefulness to the Army, and the contributions to modeling technology which Army Math is making.

All four of these applications are described frankly in AMRC reports. We present them in order of their occurrence so that the sophistication of the Army's applications for mathematics may be seen growing under AMRC's tutelage.

PLASTICS

In August 1959, Lieberstein of the AMRC staff visited Picatinny to consult on plastics involved in missile defense systems:

> "There was considerable discussion of experiments and computations to determine stress-strain curves applicable to explosive loading of a new class of reinforced plastics

> encountered in problems connected with ballistic missile counter-measures. There was consultation on a project in which the impact of extremely high velocity pellets upon plastic plates showed peculiar shock progressing at supersonic speed into the material....There has been follow-up correspondence. Dr. Lieberstein sent suggestions from the MRC on an experimental design."
>
> (25 April 1960 Semi-Annual Report)

In October, the Picatinny staff paid a return visit. The 25 April 1960 Semi-Annual Report says, "Members of this Arsenal visited Dr. Lieberstein and the UW Chemistry Department in October, 1959 to discuss experiments on a visco-elastic fluid model to determine certain structural properties of chemical compounds." This consultation continued into 1960 with one more trip by Lieberstein to Picatinny, and a follow-up letter one month later. The subject of this last correspondence is not reported by AMRC.

SHELLS

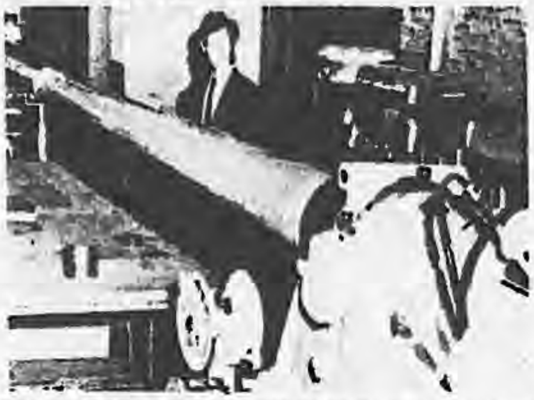
A Picatinny mathematician visited AMRC on March 7, 1963 to discuss shells which means, in Picatinny's work, the outer casing for artillery projectiles, fuel tanks, and missiles.

"Mr. Benson of Picatinny visited the MRC for the discussion of problems including:
(1) the motion of a liquid filled shell;
(2) the constrained buckling of thin shells;
(3) the motion of a spring in a centrifugal shell; and
(4) a detached shock problem.
MRC participants in the discussions were Drs. Noble, Papadopoulos, Narasimhan, Saini, Manohan, Datta and Wilcox."
(25 April 1963 Semi-Annual Report)

These four mathematical topics are helpful in developing munitions, and could fit into Picatinny's work in a number of ways: the "liquid-filled shell" mentioned first could be the fuel tank in a missile being developed at Picatinny; the "spring" in the third case might belong to the fuse in an artillery shell; and the "shock problem" mentioned last, certainly related to explosions, might well relate to the "buckling of thin shells" in item two.

MISSILE RELIABILITY

In 1966, the Army Research Office telephoned permanent staff member Louis Rall to ask for assistance on a "reliability" problem at Picatinny. Reliability theory is a statistical technique used in various weapons testing to predict how long a weapon will last before it breaks down. During September 1966 and again in July 1967, Bernard Harris of the permanent staff went to Picatinny to work with A. Bulfinch on this technique as applied to electronic parts in missiles. This consulting is described in AMRC's 1967 Annual Report:



PICATINNY ARSENAL ENGINEER looks over 75 foot gun adapted for testing projectile mechanism failures inside the tube.

"A statistical reliability problem. Work began on this problem in Fiscal Year 1967. The problem is that of estimating the reliability of electronic components for use in missiles.

"Known characteristics of the missile flights are used to determine the stresses to which these components will be subjected in flight. The reliability estimates can be employed in selecting the best of several designs, in determining if the quality of a delivered batch of components is acceptable, or in determining deterioration of stored components. With regard to the first suggested application, selecting the best from several designs of a component by running a large number of firings for each design is hopelessly expensive. However, the resistance of a component to known degrees of acceleration can be determined by laboratory tests. What is required is a statistical procedure for combining accelerometer data from a reasonable number of firings with laboratory data to provide a basis for selecting or rejecting a given design of a component.

"After about a year of work, Professor Bernard Harris, with the help of a visitor, Professor J. D. Church, devised two statistical models which can be applied to this problem. Not only do they not require flight testing of the components, but they can be used with fairly small sample sizes and so will substantially reduce the expense of laboratory experimentation.

"July 25-27, 1967. Professors Harris and Church consulted at Picatinny Arsenal with Mr. A. Bulfinch concerning this reliability problem and reported on the progress of investigation in connection with this problem. An asymptotic solution of this problem had been obtained by Professors Harris and Church, and was issued as MRC Technical Summary Report No. 814, the estimation of reliability from stress-strength relationships. This was enough for Mr. Bulfinch and his co-workers at Picatinny Arsenal to benefit considerably."

This AMRC Report #814 contains the only details of the research by Harris and Church which have been made public. This paper is another example of AMRC's "pure research" which is really a generalized presentation of the work they did to solve an Army problem.

WEAPONS MANUFACTURING

Picatinny's next problem was allocating its resources for development, engineering and production of munitions between the Army's arsenals and private industry. AMRC's involvement with this problem began on November 30-December 1, 1967 when Herman Karreman of the permanent staff consulted with Jerome Selman from Picatinny. The details of this problem are given in AMRC's 1968 Annual Report:

"A resource allocation problem of the Army Munitions Command. Work began on this problem in Fiscal Year 1968. A Headquarters group of the US Army Munitions Command (MUCOM) located at Picatinny Arsenal, asked its Operations Research (OR) Group, located at Edgewood Arsenal, to construct a mathematical model for the allocation of development, engineering, and production of large items (or items procured in large quantity) by arsenals and/or private industries....

"Prof. Karreman of MRC had a number of meetings in Fiscal Year 1968 with Messrs. Gibby, Richards and Selman. In addition to discussing various points with them, he supplied them with published materials concerning a pilot study he had made twelve years ago of the procurement of manganese, one member of a group of 'strategic' materials.... There seems to be the feeling that the methods employed in the manganese study can be applied with advantage to these particular problems of MUCOM....

"Major attention is to be given to the problem of determining how the munitions requirements of the Army over the next 10 to 15 years can best be met, taking due account of the international political situations that might occur during these years (peace, cold war, limited war, etc.).

"As a first step, the spectrum of possible future political configurations has been fragmented into six different groups and the requirements for each of these groups determined. Next, the probabilities of transition of each political configuration in a future period of time into those of the next time period have been estimated. Thus, these various political situations are seen as elements of a Markoff chain.

"The various ways in which these future requirements can be met by existing and possibly new plants as well as by drawing on inventories has then to be formulated mathematically. The limiting factors in this instance are the future capacities of the plants and the quantities that will be stored for use in emergency situations.

"Then the costs associated with each of these activities have to be assembled and from these the total cost function can be constructed. The latter will be highly nonlinear due to the various economies of scale; in addition it will contain the probabilities of transition of the political situations in the course of time.

"The problem is to determine what set of future activities will produce the minimum total cost during the entire period covered by the study. To that end a recursive technique known as dynamic programming will be employed.

"This will produce what is called an 'optimal policy' for each possible combination of plant capacities and quantity stored at the start of the period under study. A search will then be made for ergodic properties that might be inherent in the system, as a guide for future policy decisions.

"Prof. Karreman visited Edgewood Arsenal again March 20-21 and June 26-27 to help with the construction of appropriate mathematical models and with the application of dynamic programming techniques to obtain numerical results. The mathematical formulation is complete. The necessary costing data is being assembled. The writing of a computer program to compute actual numerical results is underway. Prof. Karreman will continue his personel involvement with the project."

AMRC has probably given the public a frank portrait of this particular Army application for mathematical modeling because the problem seems mundane. Our evidence, however, suggests that the Army applies similar models in making policy decisions for areas such as the optimum strategy for guerrilla warfare (see section on the Strategy & Tactics Analysis Group).

AMRC CONSULTING WITH PICATINNY ARSENAL

Date	AMRC	Picatinny	Subject
August 1959	Lieberstein	—	Models of plastic
October 1959	Lieberstein & Chemistry Dept members	—	Models of plastic
April 1960	Lieberstein	Davis	Models of plastic
May 1960	Lieberstein	Davis, Dinkle	Models of plastic
February 1961	Hunter	—	Statistical consultations
March 1963	Datta, Manohar, Narasimhan, Noble, Papadapoulos, Saini, Wilcox	Benson	Explosive shells
June 1963	Noble, Sarafyan	Cox	Differential equations
September 1966	Harris	Bulfinch	Missile reliability
July 1967	Harris, Church	Bulfinch	Missile reliability

Ballistics Research Laboratories (BRL)

The Ballistics Research Laboratories located on Aberdeen Proving Grounds in Maryland is "the Army's basic and applied research center for the problems of greater firepower." According to a survey of this base in Army Research and Development Newsmagazine (August 1965), BRL does not design artillery itself. Instead, it evaluates the guns developed at other arsenals such as Watervliet and Picatinny, and does research on ballistics and other sciences which can be applied to explosives, cannons, rockets, and mortars.

To fulfill these obligations, BRL has long been adept at a wide range of scientific techniques including wind tunnels, electronic computers and damage assessment. During World War II, the world's first continuous-flow supersonic wind tunnel was built at BRL by the German aerodynamicist Theodor von Karmen. Later in the War, Vanevar Bush built his ENIAC, the first all-electronic computer at BRL, to calculate firing tables for artillery.

Less advertised are the breakthroughs achieved in BRL's Terminal Ballistics Laboratory which, according to Army R&D August 1965:

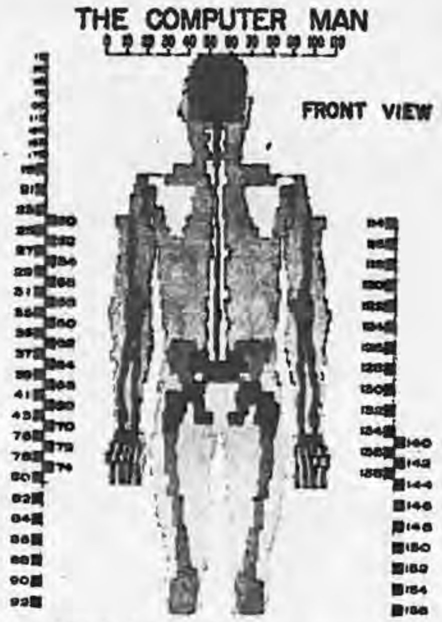
> "conducts research in terminal effects of conventional and special weapons upon material and personnel targets. Included in current studies are such phenomena as penetration, fragmentation, blast, radiation, wound ballistics...." (Army R&D August 1965)

One such study is described as "a mathematical description of man's vunerability to terminal ballistic effects....to measure effectiveness of various weapons." Mathematics certainly reached new heights of callousness in this project on "wound ballistics" which reduces people struck by artillery blasts to:

> "....Shapeless Rocks
> Retaining only Satan's Mathematical Holiness,
> Length, Bredth and Highth."

When William Blake wrote this line in the eighteenth century, he envisioned mathematic's potential for carnage which is today increasingly visible at Army installations such as BRL and AMRC.

This mathematical study of human vulnerability is only a small corner in the pattern of BRL mathematical research. AMRC, while



"FRONT VIEW OF MAN as programmed for the Ballistics Research Laboratory. Each block has been assigned a value corresponding to the vulnerability of the respective anatomical area, resulting in a mathematical description of man's vulnerability to terminal ballistic effects. This description is coupled with terminal ballistics data to measure effectiveness of various weapons." (Army R&D August 1965) not directly involved in wound ballistics, has consulted with BRL in three areas:

(1) a mathematical study of "non-steady flows" probably connected with gas dynamics in such situations as wind tunnels or cannon barrels (1960);

(2) attempts to increase artillery accuracy and effectiveness (1966-68); and

(3) studies on projectiles moving in a gun barrel (1968 and 1972). Since our evidence in this last case in the most conclusive, we present this one before the two earlier consultations where AMRC's reports are less explicit.

ARTILLERY SHELLS

Alexander Elder from BRL came to AMRC for consultations first in 1968 and again in 1972. These conversations are most clearly described in AMRC's 20 October 1972 Semi-Annual Report:

"Dr. A. S. Elder of the Ballistics Research Laboratory of Aberdeen Proving Ground consulted on 29 June at MRC with Professor J. Barkley Rosser on two problems. The first problem is to get an improved theory of the motion of a sabot-projectile assembly in the barrel of a gun. There is especial interest in devising suitable scaling laws. Prof. Rosser said that he had been entirely out of touch with such problems for over 20 years, and did not think anyone else at MRC had ever even thought about them. So no competence exists at MRC.... Prof. Rosser undertook to see if there is a person or group in the Engineering School at the University of Wisconsin that seems to have capability and might be interested in having a contract to work with the matter."

Rosser's part here as matchmaker for the Engineering School and BRL is a natural one for him, although not as renowned as his go-between role for the Mathematics Department and the Army. The dialogue continues:

"the other problem was that of getting efficient computational procedures for Bessel functions of various orders in regions of the complex plane. Professor Rosser said that MRC has a well tested multiple precision computer routine with which the Bessel function's coefficients could doubtless be computed. Dr. Elder said he would try to find time to get back to the problem, and then ask for active cooperation from MRC. Prof. Rosser suggested that perhaps he could come to MRC as a Research Resident for the purpose."

The Bessel functions referred to in this report are some of the most important mathematical functions used to describe physical situations. They are applicable when the situation involves symmetry around an axis. Thus, they could be applied to describe heat transfer in a gun muzzle or the flow of air through a wind tunnel. The probable use which Elder has for Bessel functions is indicated by the title of a report he wrote in 1971: "Stress Analysis of 176 mm. Projectile" (AD-730 308).

Elder's first consultation with AMRC likewise concerns the mathematics of cylindrical objects which could be applied to gun barrels and cannon shells:

"On August 27-28, 1968, Mr. A. S. Elder of the Ballistic Research Laboratory, Aberdeen Proving Ground, visited MRC to consult with Prof. Noble about two mathematical problems which he had encountered at BRL. One problem was to determine the distribution of stresses inside a semi-infinite cylindor with specified stresses on the circular end, and either no stresses or specified displacement on the curved surface. The other problem was equations arising in propagation of waves in a visco-elastic medium.

"Both of these are very difficult problems of the sort that engage the attention of the leading applied mathematicians of the world. No single known method will solve either problem. One must experiment with combinations of methods, together with judicious use of computers." (1968 Annual Report)

ARTILLERY TACTICS

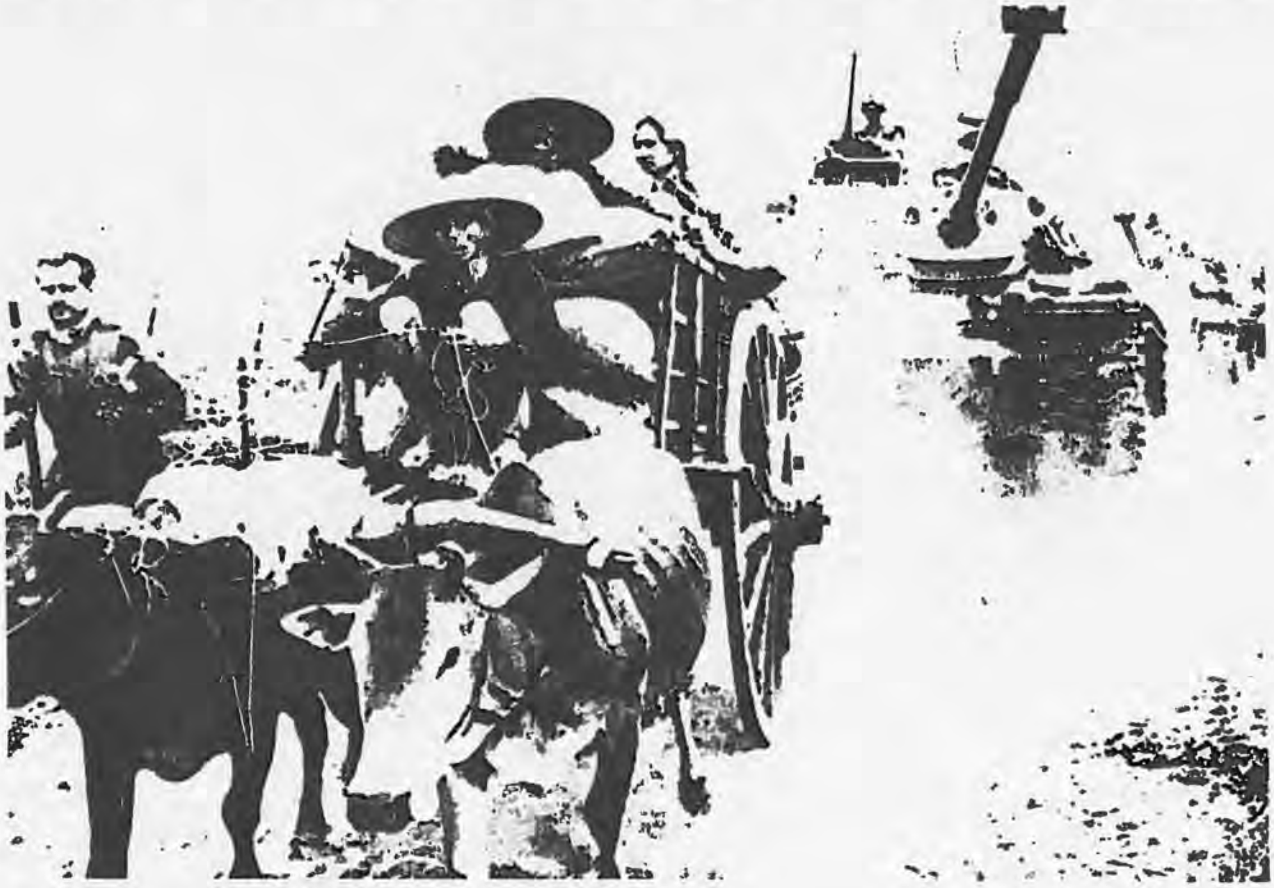
From 1966-68, three mathematicians working on artillery problems at BRL, Aivir Clemins, William J. Sacco, and W. C. Taylor, consulted extensively with AMRC. Clemins spent a two-week residency at AMRC in June 1966, working with Greenspan on some of the mathematics involved.

In 1967-68, BRL's primary contact at AMRC was Bernard Harris. In June 1967, Harris helped an Army committee meeting at BRL prepare the "Joint Effectiveness Manual/ Surface to Surface Committee" (20 July 1967 Quarterly Report). On 3 November 1967, while lecturing at BRL on the "theory of random graphs," Harris also consulted with Mr. W. C. Taylor and Mr. W. J. Sacco" (26 January 1968 Quarterly Report). A letter from Harris to Sacco dated 13 March 1968 told of the "progress of a probability problem posed by Mr. Sacco" (26 April 1968 Quarterly Report).

The AMRC Reports do not tell us explicity what Clemins, Sacco, and Taylor were working on, and their publications during this period range widely from weapons allocation to new designs for artillery shells. The BRL project which most likely required AMRC's help was a series of three reports published by Sacco: AD-634 599 (1966), AD-645 813 (1967) and AD-809 133 (1969), all dealing with "a weapon-target allocation problem of current interest in weapons evaluation studies," in the words of the papers' abstracts. According to the government's summaries of these three papers, Sacco takes the "kill probabilities" caused by different artillery shells landing on various targets, and then seeks through three different mathematical techniques the tactics which an artillery commander could use to kill the most for the least money. In military jargon, this is called "the optimization of cost-efficiency."

GAS DYNAMICS

The first AMRC-BRL contact came in 1959 over a problem of "one-dimensional non-steady flows." The statement of the problem indicates that it might apply either to BRL's wind tunnels or to the gases flowing within a cannon barrel. This problem was brought



to AMRC in October 1959 by C. Masaitis of BRL. Anselone and Bueckner of the AMRC Permanent Staff studied the problem and "some results were conveyed to Dr. Masaitis orally in January 1960" (25 April 1960 Semi-Annual Report). These results were later printed in their abstract mathematical form in TSR #171 in July 1960. Anselone visited BRL on the 20th of April 1960 to continue work in the same area with John Giese of BRL. Later, during the summer of 1960, Masaitis spent a two-months' residency at AMRC to do further research in this area.

In all, Ballistics Research Laboratories has consulted AMRC twelve times, with six BRL and seven AMRC staff members taking part.

AMRC CONSULTING WITH BALLISTICS RESEARCH LABORATORY

Date	AMRC	BRL	Subject
October 1959-January 1960	Anselone, Bueckner	Masaitis*	One-dimensional non-steady flows
April 1960	Anselone	Giese	One-dimensional non-steady flows
December 1962	Stewartson	—	Consultation and lecture
June 1963	Young	Giese	Review research memoir
March 1964	—	Giese	Review of manuscript
November 1964	—	Giese	Evaluation of two BRL papers
December 1964	Greenspan	—	Cost-effectiveness study
November 1965	Papadopoulos	Giese	BRL report evaluation
April 1966	Rall	Giese	Consulting
June 1966	Greenspan	Clemins	Spent two week residency to study artillery problems
November 1967	Harris	Sacco, Taylor	Artillery efficiency
March 1968	Harris	Sacco	Probability problem
1968, 1972	—	Elder	Mathematics of cylindrical objects

* Masaitis also spent a two month residency at AMRC in summer 1960

Watervliet Arsenal

Watervliet Arsenal near Albany, New York, develops traditional weapons such as mortars and cannons, as well as doing research on the engineering of the materials used in such weapons. Watervliet concentrates on the properties of metals, while Picatinny Arsenal specializes on other materials such as plastics, as we describe in the preceding chapter.

AMRC has aided Watervliet on two problems: the stresses which firing heat puts on a cannon (1960), and the stress properties of composite materials such as fiberglass (1966-68). AMRC aid for this later project went beyond the usual brief consulting visits. Watervliet researcher Moayyed A. Hussain worked on this problem during a six-month residency at AMRC. This example reveals the lack of substance in two rationalizations which AMRC's Director J. Barkley Rosser often makes for his Center. His first claim is that: "It quite explicity states in the MRC contract that MRC is not to work on the military applications themselves" (quoted in Mathematics for Death). This statement is contradicted by the evidence of a Watervliet researcher spending six months at AMRC working on a problem for that Arsenal.

Rosser's additional claim that AMRC's research is "beneficial to all" since "foreign scientists return home with ideas developed here" (5 October 1968 Capital Times) is also misleading. Hussain is an Indian national, but he has conveyed AMRC's ideas only to the US Army. For an additional example of a foreign national working for the Army, see the following section on Waterways Experiment Station.

We have the most evidence on Hussain's research because of his residency, but will first present the earlier 1960 consultation which is more closely tied to Watervliet's work on cannons.

RIFLE BARRELS WHICH FAILED during testing at Watervliet Arsenal. The rifles were tested either by actually firing rounds (RDS) of ammunition or by pressuring the barrels with a hydraulic fluid. (Army R&D March 1971)

CANNON FATIGUE

AMRC's first contact with Watervliet was established during a trip to the base by permanent staff member Bueckner in February 1960. Bueckner discussed, with a group under Robert E. Weigle, problems in "thermal stress"; this probably refers to the heat which develops in a weapon during its firing. We deduce this from Weigle's only non-classified publication during the period 1960-64, entitled "Experimental Technique for Predicting Fatigue Failure of Cannon Breech Mechanisms" (AD-462 090). This paper discussed a statistical technique for deciding which cannon breeches will fail from tests on a small sample. Predictably, thermal stresses are a primary cause of fatigue in cannons.

THE RESEARCH OF M. A. HUSSAIN

Hussain spent six months during 1966-67 on the AMRC staff and consulted four times with Professor Ben Noble of the permanent staff. Hussain and Noble were seeking a mathematical theory of composite materials (building materials such as fiberglass composed of fibers embedded in metal or plastic). Mentioned indirectly in the 1969 Annual Report, a reference to Hussain appears in a description of other research:

> "Extensive work was done by George Eason ....on the behavior of materials in which the strain and torsional characteristics are different in different directions. This is what one encounters with laminated materials, and materials in which great strength is achieved by embedding glass fibers or boron whiskers or such things. Such composite materials show much promise and are being extensively studied, for example at Watervliet Arsenal, where Dr. Hussain has worked in the past with Prof. Noble on theoretical studies of such materials."

Direct references to Hussain's work in AMRC Reports are typically more cryptic and even misleading. During Hussain's research residency in 1966-67, he co-authored with Ben Noble "Angle of Contact for Smooth Elastic Inclusion" (TSR #735). According to the AMRC Semi-Annual Report of 7 April 1967, "The results apply to numerous problems involving the pivoting of one object on a shaft of different material."

The 1968 and 1969 Annual Reports give us more information on this relationship. The 1968 Report says:

> "Dr. Moayyed A. Hussain of Watervliet Arsenal, Watervliet N.Y., visited MRC on August 24-25, October 23-25, 1967 and April 8, 1968 for consultation with Professor Ben Noble. In addition, Professor Noble visited Watervliet Arsenal on June 14, 1968 for consultation with Dr. Hussain and Mr. C. Y. Cho."

These consultations enabled Hussain to publish many analyses of composite materials such as one in 1969 entitled: "Effect of a Fiber in a close Distance from the Free Surface of a Semi-Infinite Matrix" (AD-690 184).

A disposable fiberglass 81 mm. rocket launcher developed by the Organic Composites Group at Watervliet Arsenal. (Army R&D January-February 1973)

Hussain's studies are only a part of Watervliet's program with composite materials. Watervliet reported in 1969, for example, that steel tubes wrapped in fiberglass had better elastic properties at less weight, and in 1970, a Watervliet "Review of the Influence of Non-Metallic Inclusions on the Mechanical Properties of Steel" concluded that fibers embedded in steel could prevent metal fatigue. We have not yet found exactly how Watervliet is using composite materials in weapons. Beyond reasonable doubt, however, it is apparent that mortars and cannons are the ultimate application of Hussain's research; over one-third of Watervliet's publications each year are concerned with these weapons. One example, published in 1965, is "Stress Fields in Mortar Baseplates on Elastic Foundations" by Hussain and M. A. Sadowski (AD-471 309).

AMRC CONSULTING WITH WATERVLIET ARSENAL

Date	AMRC	Watervliet	Subject
February 1960	Bueckner	Weigle	Thermal stress
1966-67	--	Hussain	6 mos. research residency
August 1967	Noble	Hussain	Elasticity
October 1967	Noble	Hussain	Elasticity problems
April 1968	Noble	Hussain	Elasticity problems
June 1968	Noble	Hussain, Cho	Elasticity problems

Waterways Experiment Station (WES)

A crucial task for Army research is preparing the military to operate in the extremes of climate and geography found in the Third World. Fort Clayton in the Panama Canal Zone tests Army equipment in rain forests. Fort Gila in Arizona tests in the desert. The Natick Laboratories in Massachusetts prepare the Army for the mountains; the Coastal Engineering Laboratories in Maryland, for the seacoast. The Cold Regions Research and Engineering Laboratories in New Hampshire design Army vehicles for the Artic tundra. Waterways Experiment Station in Mississippi studies transportation in swamps.

This environmental research is directed specifically towards meeting the needs of either United States forces or its client armies fighting in the Third World. For example, Army Research and Development News Magazine (October 1965) boasts that techniques developed at the Cold Regions Lab, where AMRC consulted five times, have been used in Korea, the Himalayan Mountains, and even Thailand.

"Aerial view of the U.S. Army Engineers Waterways Experiment Station, Vickburg, Mississippi. The complex is the largest and most diverse research, testing, and development facility by the Army Corps of Engineers." (Army R&D July-August 1967)

The Waterways Experiment Station (WES), located at Vickburg on the Mississippi River, is an Army Corps of Engineers center for environmental research with which AMRC has had extensive contact. The Waterways Lab develops the technology for the canals, river channels, and dams which the Army Corps of Engineers is constantly building in the US, frequently at great cost to the environment. However, this technology can also be applied directly in war. According to an article on WES in Army R&D (July-August 1967), "Research for the Army Material Command concerning cross-country mobility involves the impact of the environment on military operations."

"Schematic and internal view of experimental wheel." (Army R&D August-September 1969)

Tires

This problem of cross-country mobility, related to the escalating Vietnam War, was one of the most serious problems WES dealt with in 1963. Army vehicles, originally designed for use in Europe, did not work well in the tropics. To meet the requirements of guerrilla warfare in an area where there were no good roads, vehicles had to be equipped to move across rugged terrain. The easiest way to get at this problem was by improving the tires so that the vehicles would not sink so easily into wet soil or sand. According to Army R&D News Magazine, studying the properties of tires was a major effort at WES. The research was under the direction of Dean R. Freitag, whose specialization was pneumatic tires on soft soils.

AMRC offered its services in this effort during the last part of 1963. T. N. E. Greville and Ben Noble visited Waterways on September 16-19, at which time Greville gave a series of orientation lectures on "The Planning and Analysis of Scientific Experiments," which were intended to teach the use of statistical techniques in testing. Noble and Greville also consulted with a number of other Waterways researchers; several of these received additional information at a later date. For example,

> "In follow-up correspondence of September 24, 25, 26 and October 4, Dr. Noble gave the following: to Mr. J. L. Macrae a critique of a report of the 'load-flow method of estimating the depth of shrinkage of a towed wheel in dry sand,' with suggestions for substantial simplifications of formulas;.... and to Mr. D. R. Freitag of the Mobility Section, lengthy comments on 'a method to characterize the pressure over an elliptical area'...."
>
> (25 October 1963 Semi-Annual Report)

STAR WHEELS for deep mud and swamps are being tested on this howitzer.

Blast Wave Theory

AMRC has also collaborated with WES in a second area of research to the extent that an AMRC staff member took a permanent position at Waterways. Akira Sakurai ended his AMRC appointment on 31 March 1964; the 15 April 1964 Quarterly Report states that:

> "After considerable enthusiastic negotiations with the U.S. Army Waterways Experiment Station, we were able to arrange for one of our visiting members, Dr. Akira Sakurai, to accept a WES appointment at the conclusion of his MRC appointment. To the best of our recollection this is the first time an MRC visiting member has subsequently joined the staff of an Army installation."

Before working at AMRC, Sakurai worked at the Tokyo Electrical Engineering College, Japan. Sakurai's list of publications in the fields of gas dynamics and magnetohydrodynamics gives an indication of why the Army wanted him. While at AMRC, he published a paper in September 1964 entitled "Blast Wave Theory" (TSR #497), which gives a method for finding an approximate solution to an idealized model of blast wave propagation. At Waterways, Sakurai worked with J. M. Pinkston on the analysis of shock waves induced in water by an explosion above the water. Pinkston's own research dealt with the effects of explosions on underwater shelters and storage areas. At this time, the Army was considering the possibility of using a nuclear weapon detonated offshore to create high waves. These waves would be a "clean" weapon to destroy coastal areas by flooding. As Army R&D (July-August 1967) explained,

> "Nuclear weapons effects research is conducted by mathematical analysis, small-scale high-explosive tests, special laboratory tests and full-scale nuclear tests. Efforts are concerned chiefly with blast-resistant structures and underwater shock effects."

The same theory could be applied to conventional weapons; the first report by Sakurai and Pinkston, published in June 1966 (AD-814 396) dealt with the shock waves caused by the explosion of TNT above the water's surface.

AMRC has claimed that the presence of foreign nationals on their staff shows that their work should not be considered secret military research. Yet Sakurai publishes restricted reports for the Army. His presence on the AMRC staff proves only that it is not citizenship that matters, but rather a person's politics and his commitment to the goals of the US Army.

AMRC CONSULTING WITH WATERWAYS EXPERIMENT STATION

Date	AMRC	WES	Subject
January 1961	Ostrowski	Campbell	Vortex problem
March 1963	five staff	Newman	Power spectral analysis
June-Sept 1963	Howe, Greville	Newman	Shock waves
September 1963	Noble, Greville	Macrae McNulty Freitag Simmons	Wheels in sand Boundary value problem Wheel research Tides
November 1963	Noble	—	Heat exchangers
January 1964	Wertz	—	Wave analysis
November 1964	Wertz	Hanes	Electronics, humidity measurements
September 1966	Cryer	Oswalt	Partial-differential equations

Additional AMRC-Army Contacts

The following chart indicates additional AMRC consultations to those described in the four previous chapters. The extensiveness of the Army Mathematics Research Center's consulting, with both military and corporate enterprises, is evident. Also clear is the fact that a small number of Center personnel, the Permanent Staff, have been primarily involved in these consultations.

AIR FORCE CAMBRIDGE RESEARCH LABORATORY
- 1966 September — Rosser

ADJUTANT GENERAL'S OFFICE
- 1959 October — Hunter

ADVANCED MATERIAL CONCEPTS AGENCY
- 1971 January — staff
- 1971 May — Rosser

AIR DEFENSE TRAINING CENTER
- 1968 February — Karreman

ARGONNE NATIONAL LABORATORIES
- Prior to 1959 April — Langer

ARMY RESEARCH OFFICE
- 1961 February — staff
- 1962 October — Greenspan
- 1963 — staff
- 1963 August — Greville
- 1963 October — staff
- 1964 February — Noble, Rall, Rosser
- 1966 February — Harris
- 1966 July — staff
- 1966 July — Rall
- 1966 September — Rosser

AUTOMOTIVE CENTER (Warren, Michigan)
- 1963 November — staff

AVIATION AND SUPPLY MATERIAL
- 1963 July — staff

COLLINS RADIO COMPANY
- 1963 July — staff

CORPS OF ENGINEERS

Beach Erosion Board
- 1963 June — Anselone, Krueger, Langer, Moore, Noble, Rall, Wilcox, Wouk

Omaha District
- 1966 January — Rall
- 1966 January — Thompson

DEPARTMENT OF DEFENSE COMPUTER INSTITUTE
- 1968 January — Rosser

HARRY DIAMOND LABORATORIES
- Prior to 1959 April — Langer
- 1962 March — Zelen
- 1962 April — Papadopoulos, Seth
- 1962 December — Zelen
- 1963 April-May — Rall
- 1966 September — Rosser
- 1966 November — Rall
- 1967 May — Rall

DREXEL INSTITUTE OF TECHNOLOGY
- 1961 — staff

DUKE UNIVERSITY
- 1963 March — Howe, Langer
- 1966 August — Rall

(continued on next page)

FORT BELVOIR	
Prior to 1959 April	staff
1959 February	Anselone, Buchal, Bueckner
1960 December	Bueckner
1961 May	Bueckner
1961 June	Bueckner
1961 August	Bueckner
1961 October	Bueckner
1962 February	Zitron
1967 April	Rall
1967 April	Noble
1967 May	staff

FORT BRAGG	
1958 May	Langer
1961 December	Anselone
1966 November	Ostrowski, Rall

FORT EUSTIS	
1957 November	Langer
1963 October	Greville

FORT KNOX (Medical Research Lab)	
1966 November	Rosser

FORT LEE	
1964 March	Karreman
1967 February	Hu, Karreman, Ritter, Rosen
1967 April	Harris, Karreman
1970 October	Harris

FORT MONMOUTH	
1958	staff
1959	Buchal, Bueckner, Kanwal, Milne-Thomson
1959	Bueckner
1959 November	Lieberstein
1959 (2 times)	Hunter
1960 April	Lieberstein
1960 May	Lieberstein
1961 January	Anselone, Bueckner, Moore
1961 February	Hunter
1961 August	Knitter
1961 October	Gurland, Zelen
1961 November	Zelen
1962 February	Knitter
1962 October	Weinstein
1963 March	Zelen
1963 June	staff
1966 March	Greville
1971 April	Rosser

FORT RILEY	
1971	staff

FORT SILL	
early 1959	staff
1959 June	Bueckner, Lieberstein
1960 March	staff
1960 May	Anselone, Bueckner, Hunter

FRANKFORD ARSENAL	
1968 February	Rosser

IBM	
1964 March	Karreman

MAP SERVICE	
1960 August	Kopal
1963 April	staff
1964 October	Cline, Greville, Noble, Rosser, Steward, Wilcox
1965 May	staff
1966 February	Noble
1966 July	Karreman
1967 February	Hu, Karreman
1967 August	Rall
1970 October	Harris

MATERIAL COMMAND	
1970 October	Karreman

MINISTRY OF DEFENSE, WESTERN GERMANY	
1961 April	staff

MINNEAPOLIS HONEYWELL CORPORATION	
1961 March	staff
1967-68	staff

MOTOROLA, INC. Military Electronics Division	
1963 May	Gurland

MUNITIONS COMMAND	
1963 August	staff
1964 November	Greenspan, Noble, Papadopoulos, Rall
1964 November	Karreman

NATICK LABORATORIES	
1970 March	staff
1970	Spence

NATIONAL BUREAU OF STANDARDS	
1959	Langer

NORAD	
1968 February	Karreman

OAK RIDGE NATIONAL LABORATORY	
1959	Langer

OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE

1968 February	Karreman

OFFICE OF THE CHIEF OF ENGINEERS

1966 February	Rosser

OFFICE OF THE CHIEF OF RESEARCH AND DEVELOPMENT

1966 August	Rosser
1966 September	Rosser
1966 September	Greenspan
1968 March	Rosser
1968 March	Rall

OFFICE OF THE CHIEF OF STAFF

1967 October	Greville
1968 January	staff
1970 January	Hu

OFFICE OF THE SURGEON GENERAL

1960 March	Wilcox
1960 April	Bueckner
1960 May	Bueckner, Wilcox
1960 May	Hunter
1960 June	Bueckner
1960 July	Kopal
1960 August	staff

PENTAGON

Prior to 1960 April	Bueckner, Langer, Wilcox
1960 April	staff

PERSONNEL OFFICE (U.S. ARMY)

1962 March	Anselone, Gurland, Reinhardt, Zelen
1964 June	Greenspan

PRESIDIO (Monterey, California)

1966 August	Rall

PROTECTIVE STRUCTURES BRANCH (U.S. ARMY)

1966 December	Rosser

QUARTERMASTER RESEARCH AND DEVELOPMENT LABORATORY

1959 September	Bueckner

QUARTERMASTER RESEARCH AND ENGINEERING COMMAND

1960 Movember	Bueckner
1961 November	staff

RAND CORPORATION

1959	Langer

REDSTONE ARSENAL

1961 April	Hunter
1967 April	Swan
1967 April	Greenspan
1967 April	Wynn
1972 February	staff

RESEARCH AND DEVELOPMENT GROUP (U.S. ARMY) Europe

1966 August	Rall
1966 August	Rosser
1966 September	Rosser
early 1971	staff

ROCK ISLAND ARSENAL

1958 March	Langer
1958 September	Heteyi
1959 June	Lieberstein
1963 March	Greville
1963 October	Papadopoulos, Noble

SPRINGFIELD ARMORY

1962 January	staff

SUPPLY AND MAINTENANCE COMMAND

1963 February	Greville

TAG RESEARCH AND DEVELOPMENT COMMAND

1961 February	staff
1961 April	staff
1961 April-June	Anselone, Bueckner, Gurland, Saunders

TANK AUTOMOTIVE COMMAND

1963	Greville
early 1971	staff

TOPOGRAPHIC STATION

1972 April	Yohe
1972	Rosser

TRANSPORT MATERIAL COMMAND

1961 June	staff
1961 August	Saunders
1961 December	staff
1962 January	Zelen

WATER DYNAMIC BRANCH U.S. ARMY ENGINEERING DISTRICT

1964 October	Wertz

WATERTOWN ARSENAL

1960 March	Bueckner

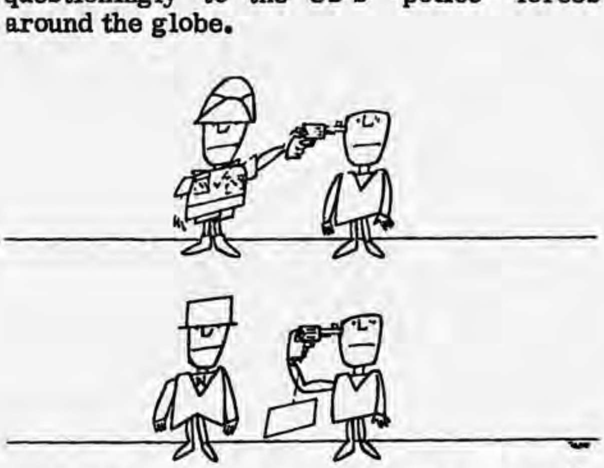
WESTPOINT MILITARY ACADEMY

1961 February	Hunter
1961 March	staff
1961 June	staff
1961 June	Kemperman

Chapter 5

POLITICAL CLIMATE FOR MILITARY RESEARCH

The pattern of consulting exposed by the preceding evidence makes sense only when we recognize that the Army's main function since the Second World War has been to protect the United States' expanding economic empire. AMRC's advisory work and contacts with Army installations show in microcosm the perversion of the research network in this country; its readiness to respond unquestioningly to the US's "police" forces around the globe.



THE COLONIALIST GAME - OLD AND NEW

Science for the People opposes a very real United States empire. It is unfortunate that in our society, with its mass media, so many facts sound untrue or clichéd when they actually are not. Often one must travel to the Philippines, South America, Africa, South Korea and of course to Southeast Asia to discover that there is nothing at all unreal about US imperialism, and the aggressive warfare and "special operations" which the US must carry out in its defense.

We mean by "imperialism" the efforts of the corporate, military and administrative elites to maintain control over the economic resources of other countries, whether these be measured as labor, commodities, land or other natural resources. Through its control, the US secures large sources of raw materials and cheap labor, expanding markets for American products, and outlets for surplus US investment funds. The material profits from this domination go primarily to the highly industrialized western consumer societies, and to a lesser degree to those dictatorships and "nationalist" governments which have sold their countries to the West. These nationalists, who receive much of their advanced education and military training in American programs here and abroad are, in effect, just one more arm of the US empire-building effort. The indigenous economies, cultures and peoples of the Third World are the victims of this imperialism.

THE ARMY: One Protector of the US Empire

The Army's role in the United States empire is described by the Douglas Aircraft Company in a 1965 report prepared for the Army Research Office. Although classified at first, sections from "Pax Americana" (later retitled "Strategic Alignments and Military Objectives") leaked out through the Senate Foreign Relations Committee. This is one comment from its General Conclusions:

"While the United States is not an imperialist nation, she exhibits many of the characteristics of past imperiums and in fact has acquired imperial responsibilities.

"The Army will be the major military instrument in the continuation of US leadership whether at home of abroad.

"Probably the most important future role of the Army will be in the role of nation-building (that is, pacification and civic action) and in keeping secure the frontiers of the US imperium. Relevent here is the Army's past and present role in the Philippines, Taiwan, Europe, South Korea, Thailand, and now South Vietnam."

It is this Pax Americana which Nixon seeks to secure through his policies. What Douglas Aircraft calls "nationbuilding" is identical to Nixon's favorite euphemism "building for peace". The past and ongoing Army Math service to the military must be seen in the light of the United States' evolving imperialist policy, the latest expression being the Nixon Doctrine. This chapter examines the development of this policy since the Korean War and its implications for science and the research network in this country.

EVOLUTION OF U.S. POLICY

"Around the globe, East and West, the rigid bipolar world of the 1940's and 1950's has given way to the fluidity of a new era of multi-national diplomacy....It is an increasingly heterogeneous and complex world, and the dangers of local conflict are magnified. But so, too, are the opportunities for creative diplomacy."

Richard Nixon, 1971
in U.S. Foreign Policy for the 1970's - Building for Peace, page xi.

US military policy underwent distinctive transformations in the aftermath of the Korean War. There was a growing assumption that American soldiers would never again need to undergo the rigors of conventional warfare: the infantry maneuvers, tank and artillery command, and so forth. The advent of nuclear weaponry and the doctrine of "massive retaliation" dominated US defense strategies throughout the 1950's. Although Korea had introduced the example of "limited warfare," such episodes were considered by the Eisenhower-Dulles administration to be secondary conflicts, important only as possible tripwires into World War III. Eisenhower was afraid that intervention in local wars, on enemy terms and terrain, would prove financially ruinous.

But by the late fifties, and especially after events in Cuba and Algeria, criticism of this policy was widespread. Maxwell Taylor called "massive retaliation" a dead-end as a dominant strategic concept. In a 1961 report for the Rockefeller Brothers' Fund, Henry Kissinger wrote: "Our mobile forces must be tailored to the gamut of possible limited wars, which may range from conflicts involving several countries to minor police actions" (Prospect for America - The Rockefeller Panel Reports, 1961, pages 111-112).

BIG-BOY
hamburgers

THE KENNEDY DOCTRINE

The real shift in military policy occurred under Kennedy. On an earlier visit to Indochina, he had seen the French floundering against the Viet Minh, and subsequently studied both Mao Tse-Tung and Che Guevara. Under him, the strategy of "flexible response" became the official Pentagon doctrine. He established the Special Group on Counter-Insurgency to coordinate all such military operations. Within each branch of the Armed Forces he established "special forces" for conventional warfare: Army Special Forces (Green Berets), Air Force Special Operations Forces, and Navy Sea/Air/Land Teams (SEALS). These forces could operate as irregular units in guerrilla fighting, commando raids, or in intelligence gathering.

Thus the first serious provisions were made for limited wars: wars which aim for bargained termination rather than the total subjugation of enemy nations; wars which use less than all of our resources, leaving our civilian sectors relatively intact, if inflationary; and wars which by suppressing indigenous rebellions maintain a political status quo favorable to the expansion of US economic markets.

The Kennedy demonology still painted a Red Menace, but diffused it throughout the Third World with less obvious connections to Moscow or Peking. Our struggle was no longer neck to neck with Soviet "aggressors" but against any people who might set the example of local control and self-sufficiency apart from the United States empire. The domino theory of McNamara could not tolerate another Cuba.

The new policy of "limited war" received its embarassing initiation at the Bay of Pigs, but its purpose was more fully carried out in the Dominican Republic, where the US occupation in 1965 set the course toward the "election" of Balaguer, returning the island to an orderly and profitable dictatorship remindful of Trujillo's reign. Johnson's hope that Vietnam might similarly succumb was shattered, but through his efforts the technology of "limited warfare" reached new levels in the electronic battlefield. It is this technological advance which has made the Nixon Doctrine possible.

THE NIXON DOCTRINE

> "America has always had a belief in a purpose larger than itself. Two centures ago our mission was to be a unique exemplar of free government. Two decades ago it was to take up a worldwide burden of securing the common defense....Today we must work with other nations to build an enduring structure of peace."

Nixon is the first President to openly admit that democratic government is not the ideal the US should hold out to other nations. If this dream was not shattered in the Dominican Republic, then US support of military dictatorships in Indochina, Greece, Brazil, South Korea, the Philippines and many other places should have by now opened the groggiest eyes.

Four conditions lie behind the Nixon Doctrine:

(1) The bankruptcy of our political and ideological influence in the world. If the US can't sell "the American Way of Life" to an entire people, it can at least sell or give to its dictators the military technology and advice which keeps them in power, and keeps their society "stable" for the economic development of US-based industry and the opening of fresh, cheap labor supplies.

(2) The decline of our economic power as indicated by the fall of the dollar on the world exchange. Hence, more reliance is being placed upon the initiative of the local entrepreneur. Again in Nixon's words:

"This new sharing requires a more subtle form of leadership. Before, we often acted as if our role was primarily one of drawing up and selling American blueprints. Now, we must evoke the ideas of others and together consider programs that meet common needs. We will concentrate more on getting other countries engaged with us in the formulation of policies; they will be less involved in trying to influence American decisions and more involved in devising their own approaches....

"For only in this manner will they think of their fate as truly as their own."

(3) The decay of commitment to United States policies, evidenced abroad by the corruption and weakening among Armed Forces personnel and at home by the loss of a political mandate for those excursions, such as in Indochina, which make the reality of the US empire visible to the public.

(4) The development of a sophisticated war technology which can support a puppet regime without an obvious US presence or the politically irritating loss of American lives. On the surface, the Nixon Doctrine tells the public: "the best way to prevent insurgency is to meet economic and social imperatives; the best way to control it is a determined security effort by the country itself" (Nixon's Building for Peace, page 149). Indeed, these imperatives are met by buying off puppet regimes like those of Thieu, Lon Nol, Park, and Balaguer, and placing before such small elites the economic and social goals obtainable by the few under capitalism. Add to these circles of dictatorship the wealthy classes which will bite at the carrot of individual affluence, and to those a well-equipped military police to step on the popular resistance of the people as a whole, and you have met the social and economic imperatives of United States imperialism.

NEW WAR TECHNOLOGY

But again, behind all this is the presence of the new war technology, which is different from that of great power conflict. Even the US military brass has no illusions about transforming the Ukraine into an automated battlefield. What US military advisors and their clientele need to know ranges from the science of electro-optical devices and laser range finders to analyses of those rural village customs in Laos which might hinder "economic development", from East Asian precipitation averages to the mathematics of supply and personnel routing.

The necessary research implied by this scope cannot be done only within the Defense Department's research centers, even with a few think-tanks such as RAND tacked on. Building up a world weather control system, for example, from information run through a giant Illiac IV computer is an activity which might be controlled by the DOD's Advanced Research Projects Agency,* but it also must draw on all corners of academia, if only for the accumulation of data. The technology of "limited warfare" and social control demands an equally sophisticated research and development complex comprising universities, industries and private research organizations along with the already enormous strictly military research network.

*ARPA is an organization of eminent civilian scientists which was established in 1958 under the Director of Defense Research and Engineering. As overall coordinator of high-priority military research programs, ARPA first concentrated on problems of nuclear test detection and ballistic missile warfare. In recent years, its emphasis has turned towards counter-insurgency, computer technology, human behavior and social science research.

RESEARCH ON THAILAND

One example will demonstrate the operation of the US war research system. Right now, Thailand's military operates complex "flying laboratories" for aerial surveillance of insurgent movements. Thai E-47 airplanes are equipped with infrared detection devices and other surveillance instruments, and are now operable with a minimum of US advisory help. What are some of the facts which have made possible this particular bulwark of the Nixon Doctrine?

1) Since 1954, several scientists at the University of Michigan have specialized in the applications of infrared surveillance techniques to ground warfare. In 1967, R. Scott of Michigan took the M-33 target acquisition computer and designed it to guide pilots so that improved infrared imagery could be obtained.

2) In 1964, under DOD Project AMPIRT* (ARPA Multiband Photographic and Infrared Reconnaissance Test), Project MICHIGAN and the Cornell Aeronautics Laboratories received a joint $2-3,000,000 grant from the Advanced Research Projects Agency to study applications of infrared reconnaissance technology to counter-insurgency surveillance in Southeast Asia.

3) In 1966, University of Michigan scientists took four field trips to Thailand in order to test surveillance equipment and techniques.

4) In 1967, the University received a $1,000,000 contract under DOD Project Agile.** Professor Joseph Morgan of Michigan led a team of university scientists which used knowledge gained from Project AMPIRT to outfit the C-47 planes.

*AMPIRT's goal was "to study the use of multiband aerial photographic and full spectrum infrared sensors in detecting target clues in a counterinsurgency environment." M. Klare's War Without End, pg. 174

**Project Agile is "A broad program of applied research and development through which ARPA examines problems of multiservice and multigovernment interest and application in the fields of counter-insurgency and limited conflict. It provides friendly nations of the developing areas with better ways of organizing their own resources to counter insurgent threats....Agile's systems R&D is intended to provide a basis of knowledge, techniques and technology from which to draw 'blueprints' for deterring insurgency in its early stages."

Director of Defense Research & Engineering John Foster, 1968, quoted in Michael Klare's War Without End, 1972, pg. 215

5) Meanwhile, at least 30 Thai officers were receiving training in surveillance techniques on the Ann Arbor campus and at the Thai-US Research & Development Center in Bangkok.

6) Industries such as Bendix Corporation of Ann Arbor, Texas Instruments of Dallas, HRB-Singer of State College, Pa., and the Aerojet General Division of General Tire & Rubber Co. carried on their manufacturing of actual detection systems, drawing on Michigan's research.

7) The Michigan team derived ongoing benefits from working under DOD sponsorshop, receiving among other things the assistance of AMRC. Since the late 1950's, the Army Mathematics Research Center has been constantly and often informally advising the MICHIGAN effort, as we document in Chapter 1. Many contacts were made prior to 1960, and from 1960-67 advice was offered on at least 20 different occasions. This total of 20 contacts is listed in AMRC's Semi-Annual Reports which serve only as indicators and not as summaries of the Center's work. The actual number was undoubtedly larger, supplemented by correspondence which has escaped the records.

THE MILITARY IN THE UNIVERSITY

Military dominance of academia is not limited to Michigan's Willow Run Laboratories which harbored Project MICHIGAN, or to Wisconsin's Army Mathematics Research Center. It is an overriding policy which shapes the entire intellectual community, with a few notable exceptions, to its ends. Continuing with our example of Thailand, we see that research coordination does not cease with an organization like the Thailand Study Group, put together at ARPA's request by the Jason Division of the Institute of Defense Analysis. Such groups secretly review the state of counter-insurgency research as it relates to Thailand, but broader efforts are required to move overall research in directions favorable to the military.

For one example, in 1966 the Academic Advisory Committee on Thailand (AACT) was founded by two Michigan professors who had returned from a research mission sponsored by the Agency for International Development (AID) in Thailand. Their goal was to determine the research needs of the US Operations Mission in Thailand (USOM).

SURVEILLANCE RESEARCH: From the University to Industry to the Army

"On April 19, 1960 at the Washington, D.C. National Airport, the United States Army unveiled a new type of combat-surveillance radar system which is designated as the AN/UPD-1 (XPM-1)....

"This combat-surveillance radar system represents a dividend from a continuing research program in radar at the Institute of Science and Technology at the University of Michigan. This radar research is part of Project MICHIGAN....(emphasis added)

"The AN/UPD-1 system is a good example of how a team effort of a university and industry can provide experimental models of new devices for early tactical evaluation. In less than ten months from the first successful demonstration with a breadboard system, a sub-contract was in force and work was under way on the construction of the experimental system....

"The airborne portion of the system was subcontracted to Texas Instruments Inc. of Dallas, who in turn subcontracted to General Precision Labs and Kaerfott Inc. for Doppler inertial systems. The ground vans containing the radar-data handling and processing equipment were fabricated by the Institute of Science and Technology at the University of Michigan."

Selected from "A High-Resolution Radar Combat-Surveillance System" by L. J. Cutrona, W. E. Vivian, E. N. Leith and G. O. Hall, in the Transactions of the Professional Group on Military Electronics of the Institute of Radio Engineers, April 1961.

Their report, entitled "Suggestions on the Elaboration of a University Role in USOM" led to the formation of a "secretariat" founded in September 1966 at UCLA and paid for by AID. This administrative home base began to coordinate AACT members as they tapped academic sources to keep an ongoing supply of relevent information going to the US Command in Bangkok. Under the facade of academic neutrality, AACT members arranged USOM-relevant conferences. For example, in 1970 they persuaded the Association of Asian Studies to include a panel on the problems of northern Thailand within their April meeting.

National clearing-houses like the National Science Foundation also serve the military by keeping inventories on pertinent research. During 1965 House hearings, the Director of the Pentagon's Special Operations Research Office, Dr. Theodore Vallence, was asked how government-sponsored organizations such as SORO work with the universities. He replied that several governmental and semi-governmental agancies keep inventories on the research activities of university personnel. The large clearing-houses included, in his opinion, the National Science Foundation and the Roper Institute in Williamstown, Mass. These institutes, to remain up to date on their studies, pick through the literature while most of the coordination is done "through normal intercourse among people in the scientific world: by attending meetings, corresponding, through publications, and so on."

The connections should be evident between United States' military policy and the broad rěsearch system tailored to its requirements. Scientists today are as necessary and as responsible for sophisticated counter-insurgency weaponry as were WW II nuclear physicists for the development of the atomic bomb; they have only become more inconspicuously specialized and sheltered within research networks held together by military coordination. Institutes such as the Army Mathematics Research Center are not merely centers for "basic research" - they are integral links in the Defense Department's overall coordination of in-house, industrial and university military research.

PART II
HOW AMRC WORKS

Chapter 6

AMRC'S CONTRACT WITH THE ARMY

Most, if not all, of the operations of AMRC are a clear reflection of the contract between the United States Army Research Office - Durham, North Carolina and the University of Wisconsin Board of Regents. First signed in 1956 and extended yearly since then, this contract defines what the Army expects of its Mathematics Research Center. Over the years, the only changes have been minor rewordings which did not greatly affect the functioning of the Center. The text of the contract we present is "Modification P010 to contract DA-31-124-ARO-D-462" which has been in effect since June 1973.

In the following chapter, we describe AMRC and its relation to its contract. In the first section we present the overall setting within which AMRC operates. In the second section we describe the key AMRC staff positions. In the third section we discuss the overall guidance of AMRC's programs by the Army Mathematics Steering Committee. In the last section we outline the framework of AMRC's operation, using statements and data from AMRC's reports, and show, using the words of the contract, that all these operations fulfill contractual obligations to the Army set forth in the contract.

I OVERALL SETTING

AT THE UNIVERSITY

AMRC's setting considerably influences the functioning of the Center. The Army has realized from the outset that a university setting is essential for the kind of mathematics research center it needs, where close scientific contact between Army research and development personnel and other scientists, primarily academic ones, is possible. Additionally, only by providing a stimulating university environment can the Army draw the top researchers in the desired fields of applied mathematics to such a center. These researchers would not work in the more controlled environment of an Army base or laboratory where the options, and the publishing so important for the esteem of their scientific peers, are more restricted. These researchers, however, eagerly come to the University of Wisconsin to do the same research for the Army. What the Army expects from its partnership with the University is outlined in the objectives of the Army-University contract in which the University agrees to fulfill the objectives and scope, utilizing its best efforts, personnel, and facilities.

AMRC is a "sanctum sanctorum of a bunch of scientific mercenaries."
- Donald Armstrong, father of Karl

OBJECTIVES

The contract states that the objectives are:

A. TO PROVIDE A GROUP OF HIGHLY QUALIFIED MATHEMATICIANS WHICH WILL CONDUCT MATHEMATICAL RESEARCH IN THE AREAS CITED IN (1)-(5) OF PARAGRAPH A BELOW. THE EMPHASIS IN THIS RESEARCH IS TO BE ON LONG RANGE INVESTIGATIONS WITH THE INTENTION OF DISCOVERING MATHEMATICAL TECHNIQUES THAT MAY HAVE APPLICATION TO THE SCIENTIFIC AND TECHNICAL NEEDS OF THE ARMY. THE RESEARCH IS TO SUPPLEMENT (NOT REPLACE) THAT OF EXISTING ARMY FACILITIES.

B. TO PROVIDE FOR THE ARMY A SOURCE OF ADVICE AND ASSISTANCE ON MATHEMATICAL TECHNIQUES, MATHEMATICAL PROGRAMS AND MATHEMATICAL PROBLEMS.

C. TO PROVIDE A CENTER FOR STIMULATING SCIENTIFIC CONTACT AND COOPERATION BETWEEN ARMY SCIENTIFIC PERSONNEL AND OTHER SCIENTISTS.

D. TO INCREASE THE RESERVOIR OF MATHEMATICIANS THAT MAY BE CALLED UPON BY THE GOVERNMENT FOR ASSISTANCE IN THE EVENT OF NATIONAL EMERGENCY BY ACQUAINTING MATHEMATICIANS WITH PROBLEM AREAS RELEVANT TO ARMY NEEDS.
(P-I/A-1/OBJECTIVES)

This notation follows each contract quote so that it can be seen in the context of the full contract which follows at the end of this chapter: P=Paragraph, A=Article.

II PERSONNEL

The University of Wisconsin must provide the personnel to fulfill these objectives. AMRC operates with a Resident Director and a staff of permanent members, visiting researchers, students, programmers and clerical help. The Director and a minimum of four key staff members, known as the Permanent Staff, must have full faculty status with tenure. AMRC's primary functions are performed by its 8-10 Permanent Staff and the Director.

DIRECTOR

The Director, chosen by the University, must be approved by the Army, with the advice of the Army Mathematics Steering Committee (AMSC). In the words of the contract, the University must:

APPOINT A DIRECTOR OF THE PROGRAM WHO WILL, IN COORDINATION WITH THE AMSC, FORMULATE POLICIES FOR THE PROGRAM AND RESEARCH GUIDELINES FOR THE PERSONNEL....THE DIRECTOR WILL HAVE FULL FACULTY STATUS WITH CORRESPONDING RIGHTS AND PRIVILEGES. (P-I/A-1/SCOPE-E)

THAT APPROVAL WILL BE OBTAINED FROM THE CONTRACTING OFFICER TO CHANGE THE DIRECTOR,
(P-VI/A-6, c/ADMINISTRATIVE CONTROL)

THE SHOOTING GAME !!

The University has provided directors for AMRC with histories of high-level military involvement. The former Director, J. Barkley Rosser, who just retired in 1973, has been Chief of the Theoretic Ballistics Section of the Allegheny Ballistics Laboratory (1944-46); consultant at the Applied Physics Laboratory of Johns Hopkins University (1945-63); Director of the "Focus Project" for the Institute for Defense Analysis (1959-63); and consultant for the National Security Agency (1965-71). In addition, he helped set up the Institute for Defense Analysis Center at Cornell University, and received a Presidential certificate of merit for rocket work in 1948 and a certificate of commendation from the Secretary of the Navy in 1960 for his work on the Polaris missile. With this background, it is not surprising that C. W. Clark, Major General, Director of Army Research wrote to University of Wisconsin President Fred H. Harrington on 24 May 1963 stating:

> "Your selection of Professor Rosser delighted me, since his background and qualifications are ideal for the position. In addition, his nomination received the unanimous approval of the Army Mathematics Steering Committee."

PERMANENT STAFF

In addition to providing the Director, the University is also required to:

> APPOINT KEY SCIENTISTS AS REQUIRED WHO WILL AID THE DIRECTOR IN FULFILLING THE OBJECTIVES AND SCOPE OF THE PROGRAM.... THIS GROUP WILL INCLUDE AT LEAST ONE (1) EXPERT OF RECOGNIZED COMPETENCE TO PERFORM RESEARCH IN EACH OF THE FOLLOWING FOUR (4) FIELDS:
>
> (1) NUMERICAL ANALYSIS AND OTHER AREAS OF COMPUTER SCIENCES, INCLUDING THE EXTENSION OF THE SCIENTIFIC USEFULNESS OF HIGH SPEED COMPUTERS;
> (2) STATISTICS AND PROBABILITY;
> (3) APPLIED MATHEMATICS AND ANALYSIS;
> (4) MATHEMATICAL TECHNIQUES OF OPERATIONS RESEARCH. (P-I/A-1/SCOPE-F)

If we look at the Permanent Staff members and compare their fields with the areas numbered above, we find:

(1) C. W. R. deBoor, T. N. E. Greville, T. C. Hu, Louis Rall, I. J. Schoenberg;
(2) B. Harris;
(3) B. Noble, I. J. Schoenberg;
(4) T. C. Hu, H. E. Karreman.

Many of the Permanent Staff also have past connections with the military, although not to the extent of the Director. For example, T. N. E. Greville was, in the US Army Quartermasters Corps, Deputy Chief Mathematician (1958-60) and Chief Mathematician (1960-61). B. Harris was a mathematician at the National Security Agency (1952-58). And H. E. Karreman received the Lanchester Prize in operations research (1960). This prize is named after the creator of a mathematical model for military tactics, explained in the previous section on STAG.

In addition to appointing Permanent Staff, the University must:

> APPOINT ALL OTHER PERSONNEL REQUIRED FOR THE OPERATION OF THE PROGRAM. (P-I/A-1/SCOPE-G)

AMRC's staff is filled out by visiting mathematicians, assistant professors, post-doctoral fellows, computer programmers and a staff of secretaries.

III GUIDANCE

AMRC is a one-of-a-kind mathematics research center. With so much invested in a single institution, the Army cannot leave it to random development and must supervise its operation. The contract designates the Army Mathematics Steering Committee (AMSC) to provide this supervision. The AMSC was established by the Department of the Army to assist the Chief of Research and Development and other top-level Army staff in the planning, coordination and supervision of the mathematics research interests of the Army. It is a committee formed from Army in-house laboratories and other Army research and development agencies. Since 1958, its Chairman has been Dr. Ivan R. Hershner, a Lt. Colonel in the Army, a mathematician, and Chief of the Physical Sciences Division, Office of the Chief of Research & Development. The contract outlines the AMSC supervision of Army Math as follows:

> ....THE CONTRACTOR AGREES TO COORDINATE WITH THE AMSC ON MAJOR POLICY MATTERS CONCERNING THE PROGRAM. SUCH COORDINATION WILL BE MADE WITH THE CHAIRMAN OF THE AMSC BY THE DIRECTOR, REPRESENTING THE CONTRACTOR. THE DIRECTOR WILL BE RESPONSIBLE FOR MAINTAINING THE EMPHASIS TOWARD HIGHLY APPLICABLE MATHEMATICAL RESEARCH, AS DESCRIBED IN ARTICLE 1. HE WILL BE RESPONSIBLE FOR MAINTAINING LIAISON BETWEEN CONTRACTOR PERSONNEL AND ARMY SCIENTIFIC PERSONNEL, THEREBY KEEPING THE STAFF OF THE PROGRAM COGNIZANT OF ARMY MATHEMATICAL PROBLEMS. BOTH COORDINATION AND LIAISON WILL BE ACCOMPLISHED IN ACCORDANCE WITH THE PROCEDURES ESTABLISHED BY THE AMSC AND THE CONTRACTING OFFICER....
>
> (P-V/A-5/TECHNICAL SUPERVISION)

The Director of AMRC, as outlined above, is responsible for developing the program of research carried on by Army Math's staff in coordination with the AMSC. The Director achieves this coordination by meeting twice a year with the AMSC and by frequent contact with the chairman and other committee members. Many of the more visible programs and services developed at AMRC at the request of the Steering Committee are the 10 (soon to be 11) orientation lectures, the yearly symposia in the spring, the yearly advanced seminars in the fall, and several special seminars held over the years.

IV WHAT AMRC DOES

The programs carried out by AMRC fall into several categories: research, consulting, training, providing technical services, and working with academic scientists.

RESEARCH

In an interview on 27 March 1973, AMRC's Stephen Robinson named the areas of research being pursued at the Center: applied mathematics, statistics, operations research, computer science, systems programming, numerical analysis, and a summer program in mathematical economics.

U.S. ARMY MATHEMATICS STEERING Committee members and invited guests gathered recently at the U.S. Army Air Mobility R&D Laboratory, Ames Research Center, Moffett Field, Calif., for the 34th semiannual meeting. Pictured (l. to r.) are Dr. Fred Frishman, OCRD; Dr. Ivan Hershner Jr., OCRD; Dr. G. Thomas Sicilia, Office of the Deputy Chief of Staff for Personnel; Prof. H. Solomon, George Washington University; Prof. Robert M. Thrall, Rice University; Douglas B. Tang, Walter Reed Army Institute of Research; Prof. J. B. Rosser, director, Mathematics Research Center, University of Wisconsin; Joseph M. Kirshner, Harry Diamond Laboratories; Dr. John D. Hwang, Army Air Mobility R&D Laboratory (AMRDL); Dr. Walter Pressman, Electronics Command; Lawrence A. Gambino, Army Engineer Topographic Laboratories; Dr. Norman P. Coleman, Army Weapons Command; Miss Alexandra Tolstoy, Combat Developments Command; Dr. Alan S. Galbraith, Army Research Office—Durham (ARO-D), N.C.; George L. Kinnett, AMRDL; Dr. John H. Giese, Aberdeen Proving Ground; Dr. Walter D. Foster, Fort Detrick; Gerard T. Dobrindt, Army Test and Evaluation Command; Dr. Ronald P. Uhlig, Army Materiel Command (AMC); Dr. Badrig M. Kurkjian, AMC; Sidney Sobelman, Office of the Deputy Chief of Staff for Military Operations; COL. Lothrop Mittenthal, commander of the Army Research Office.

The contract states that the objective of the Center is to do mathematical research that is relevant to the Army, with emphasis on long-range investigations. The contract also prescribes the areas in which research is to be conducted, stating that the Center is to:

> FORMULATE AND CARRY OUT A PROGRAM OF RESEARCH IN THE FOLLOWING AREAS:
> (1) NUMERICAL ANALYSIS AND OTHER AREAS OF COMPUTER SCIENCES, INCLUDING THE EXTENSION OF THE SCIENTIFIC USEFULNESS OF HIGH SPEED COMPUTERS;
> (2) STATISTICS AND PROBABILITY;
> (3) APPLIED MATHEMATICS AND ANALYSIS;
> (4) MATHEMATICAL TECHNIQUES OF OPERATIONS RESEARCH;
> (5) OTHER AREAS OF MATHEMATICAL RESEARCH ALSO HAVING POTENTIAL RELATIONSHIP TO AN ARMY FUNCTION OR OPERATION.
> (P-I/A-1/SCOPE-A)

We see that this list exactly overlaps Stephen Robinson's list. The contract further states that:

> ....IT IS EXPECTED THAT APPROXIMATELY HALF THE EFFORT UNDER THE CONTRACT WILL BE DEVOTED TO A RESEARCH PROGRAM AIMED AT ADVANCING MATHEMATICS IN THE AREAS CITED IN (1)-(5) OF PARAGRAPH A ABOVE AND TO THE REQUIREMENTS OF OTHER PARAGRAPHS OF THIS ARTICLE, AND THAT THE REMAINING EFFORT WILL BE DEVOTED TO BASIC RESEARCH IN MATHEMATICAL AND CLOSELY RELATED AREAS WITH SPECIAL EMPHASIS ON THE AREAS CITED IN (1)-(5) OF PARAGRAPH A ABOVE. (P-I/A-1/SCOPE-B)

The contract therefore directs all of AMRC's work into areas which the Army can use. Half the time, AMRC must solve specific Army problems, either immediate or long-range, and the remainder of the time, AMRC's research must have "special emphasis" on the four areas of mathematics which the Army needs.

The problem of knowing what areas of research have relevance to Army problems is not left to guess work. As noted under the description of guidance, Army Math's Director is in direct communication with the AMSC which formulates Army mathematical problems. In addition, the Permanent Staff is also contractually involved in the process:

> HE [THE DIRECTOR] WILL BE RESPONSIBLE ALSO FOR MAINTAINING LIAISON BETWEEN CONTRACTOR PERSONNEL AND ARMY SCIENTIFIC PERSONNEL, THEREBY KEEPING THE STAFF OF THE PROGRAM COGNIZANT OF ARMY MATHEMATICAL PROBLEMS.
> (P-V/A-5/TECHNICAL SUPERVISION)

A 1970 proposal submitted to the National Science Foundation by J. B. Rosser states:

> "Clearly the permanent staff of MRC has to have the competence to determine the areas of research most needed to fill gaps in the Army's need and to bring in competent visitors to help with such research, to assign priorities for consultative interaction (including the proportion of time to be spent thereon), to devise the most effective procedures for dissemination of information about interdisciplinary mathematics, and so on. Indeed, they do have such competence, and the Director delegates to them the primary responsibility for making such decisions."

Liaison is maintained at several levels. Eight AMRC staff members have served on the following AMSC Subcommittees: Numerical Analysis and Computers, In-Service Educational Opportunities and Training, Operations Research, Applied Mathematics and Analysis, and Statistics and Probability.

Army Math staff also attend Army conferences where Army problems are discussed as illustrated in the photograph below:

ARMY MATHEMATICIANS DISCUSS R&D APPLICATIONS at a conference at Redstone Arsenal sponsored by the Army Mathematics Steering Committee on behalf of the Office of the Chief of Army Research and Development. On the far left is University of Wisconsin Prof. Lawrence C. Young -- on the far right Prof. J. Barkley Rosser.

Army Math's third and probably most important way of understanding Army problems is through consulting with Army researchers on specific problems.

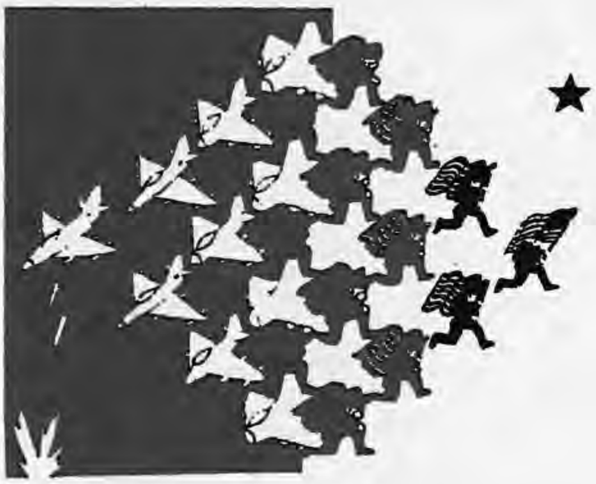
With all this input, the Director and Permanent Staff of AMRC have a good grasp of mathematical problems arising in Army programs, and can plan and influence the Center's research. Concerning the research performed by other staff, J. B. Rosser says he handles this by inviting mathematicians to join the staff whose work has the possibility of applying to military problems. An example of staff choice is presented in the 24 April 1968 Semi-Annual Report:

"One of the leading experts in the area of error computing codes, Professor H. B. Mann, is a permanent staff member of MRC, so that there will always be some research going on in this area. Upon discovering that the Electronics Command at Ft. Monmouth had a special interest in the area, a three year intensification of effort was initiated in the fall of 1965, when Dr. Ray-Chaudhuri, an expert from IBM, was appointed as a visitor to MRC for a year. On April 11, 1966, Drs. Mann and Ray-Chaudhuri presented an Orientation Lecture Series on Error Correcting Codes at Ft. Monmouth."

Here, a person possessing the talents necessary to help AMRC's staff with one of its research problems was brought to the Center as a visitor. Such visitors, often highly paid, play a very important role in the research conducted at AMRC.

An example of a long-range research effort is presented in the same Semi-Annual Report:

"Spline functions were originally developed for use in the design of ships. Otherwise, they were considered mathematical curiosities, and research on them had never proceeded in an organized manner. In 1965, Professors I. J. Schoenberg and T. N. E. Greville discovered that spline functions could be used for much improved methods of approximation.



As a result, a special study was set up in the fall of 1966 to see if spline functions could be useful in other areas of Army relevance. The study has been so successful that it has been expended to a three year program."

J. B. Rosser's 1971 proposal to the National Science Foundation says of spline functions:

"By means of orientation lectures, advanced seminars, and symposia, these results have been made known to mathematicians at Army laboratories, who are finding the spline function methods of much value. At a meeting of Army mathematicians at Redstone Arsenal in May of this year, a considerable number of the papers presented involved spline functions in some way."

CONSULTING

This aspect of AMRC's work is explored in Part 1 of this report. Army Math is the conduit through which abstract mathematics is transformed into practical military applications.

The first objective stated in the contract deals with consulting.

The scope section of the contract also directs AMRC to:

FURNISH ADVIDE TO ARMY SCIENTISTS AND ADMINISTRATORS CONCERNING MATHEMATICAL PROGRAMS, MATHEMATICAL TECHNIQUES AND MATHEMATICAL PROBLEMS AND THE EMPLOYMENT OF MATHEMATICAL PERSONNEL. (P-I/A-1/SCOPE-C)

The Director and Permanent Staff are directed by the contract to furnish advisory services to Army activities.

* Spline functions in their simplest form are a series of straight lines pieced together in order to approximate a curved line. Using sufficient tiny straight lines, the spline function normally can duplicate curved lines with a great deal of accuracy. Because the straight lines in a spline function are manipulated by the computer more easily than complex curves, the Army has found many applications for this technique in its computer models. For instance, spline functions have been used to approximate missile paths and to predict their impact point - techniques used for both missiles guidance systems and the Anti-Ballistic Missile system.

TRAINING

AMRC's training function happens at a number of different levels. We might categorize these by the types of people for whom each set of programs is designed: (a) Army personnel; (b) a combination of Army, academic and industrial personnel; and (c) the reservoir of scientists familiar with Army-related mathematics.

(a) In the first category we find two major programs: the Research Residency and the Orientation Lectures. The Research Residency program initially suggested by AMRC and subsequently approved by the Steering Committee, conforms with the requirement outlined in the contract stating that AMRC must:

> PROVIDE OPPORTUNITIES FOR EDUCATION OR RESEARCH TO PERSONNEL APPROVED BY THE AMSC COMPATIBLE WITH THE RESEARCH INTERESTS AND CAPABILITIES OF THE SCIENTIFIC STAFF OF THE PROGRAM. (P-I/A-1/SCOPE-H)

AMRC describes the program as:

> "an important in-service educational opportunity for extending one's competency in an applied mathematical field. These are available to civil service employees as well as to uniformed members of the Army."
> (AMRC's In-Service Educational Opportunities offered by the MRC, May 1971)

Thus, when a problem posed by the Army seems especially difficult or appears time consuming, AMRC invites the Army researcher to spend time at the Center to work on the problem. For example, in June 1972, A. S. Elder of the Ballistics Research Lab asked Rosser about a problem which would involve the use of AMRC's computer techniques. Rosser explained that it would take time to learn these techniques, and suggested that perhaps Elder could come to MRC as a Research Resident for that purpose (20 October 1972, Semi-Annual Report). Eight Army personnel have been trained at AMRC under this program.

The second program, the Orientation Lectures, was initiated by AMRC at the suggestion of the Army Mathematics Steering Committee. This program requires AMRC staff to visit various Army bases and to present lectures requested by the installation. Occasionally a base will request a lecture series even before AMRC has finished its preparation. The lecture series ordinarily extends over the mornings and afternoons of two or three consecutive days.

> "Their objectives are to present or emphasize facts and viewpoints which should be more widely known or understood. Their aim is the exposition of ideas, not the development of techniques. Therefore, they are not more technical than the subject may require, and are directed at users of mathematics as well as at mathematicians. When appropriate, discussion and problem periods are included."
> (AMRC's In-Service Educational Opportunities offered by the MRC, May 1971)

The fact that these Orientation Lectures have been given several times at different bases indicates their value to the Army.

In addition to the two mentioned above, it appears that other programs may be developing. Recently, Karreman of AMRC's Permanent Staff "consulted with the Civil Schools Branch, Office of Personnel Operations, about the possibility of training Army officers in mathematical programming and management science at the University of Wisconsin" (17 April 1970 Semi-Annual Report).

(b) The programs designed for mixtures of Army, academic and industrial personnel include the Advanced Seminars and Special Requested Seminars. The Advanced Seminars are meetings lasting a few days which occur once a year. The topics of discussion change from year to year.

Police block demonstrators from entering AMRC "Symposium on Population Dynamics."
Photo: Daily Cardinal, 26 June 1972

"The purpose of the Advanced Seminars conducted by the MRC is to provide Army personnel with an opportunity for training in a particular field of current interest on a higher level than afforded by the Orientation Lecture Series....

"A seminar will be devoted to a segment of mathematical, computational, or statistical theory -- generally one in which there have been important modern developments that may have relevance to Army interests. Its purpose will be to present an up-to-date survey of the state of a field, extending up to the frontier of current research. In addition to recently developed methods which have proven their merit in application, some attention will be given to new concepts of potential utility...."

(AMRC's In-Service Educational Opportunities offered by the MRC, May 1971)

Not only does AMRC help the Army with its mathematical problems using current techniques, it also attempts to find new techniques itself, or to look at those advanced by other mathematicians and assess which ones might be useful to the Army.

The latest two Advanced Seminars were "Waves on Beaches" in 1971 and "Mathematical Programming" in 1972.

Besides the Advanced Seminars, there are also Special Requested Seminars. One example is the Conference on Differential Games held in June 1968. This conference was requested by F. G. Dressel, Army Research Office-Durham on 28 June 1967. Herman Karreman was placed in charge of arrangements for this Army conference held here in Madison.

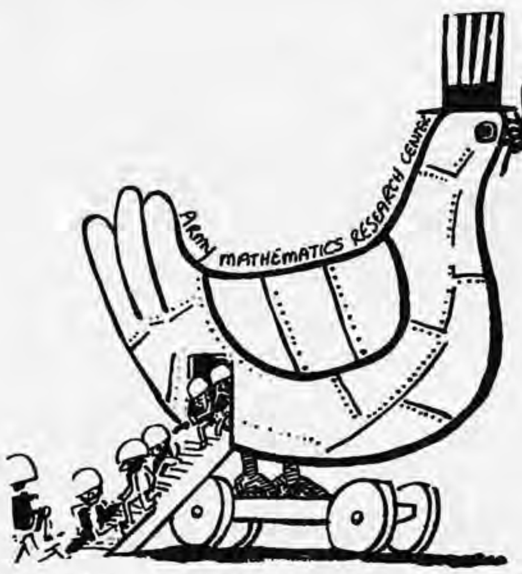
(c) The third category of programs relates to the creation of a reservoir of mathematicians who are familiar with Army problems. The AMRC accomplishes this in a number of ways which reflect its contractual agreement with the Army to:

CONDUCT SYMPOSIA AND SIMILAR ADVANCED EDUCATIONAL ACTIVITIES IN THE MATHEMATICAL AREAS CITED IN (1)-(5) OF PARAGRAPH A ABOVE,.... (P-I/A-1/SCOPE-D)

and to

FOSTER A WIDER INTEREST IN THE MATHEMATICAL AREAS CITED IN (1)-(5) OF PARAGRAPH A ABOVE BY OFFERING MATHEMATICIANS EMPLOYMENT TO DO RESEARCH IN THOSE AREAS. (P-I/A-1/SCOPE-I)

To these ends, AMRC has an active graduate and post-doctoral research program. J. B. Rosser writes in a letter:



TROJAN "PEACE DOVE" MADE IN U.S.A.

"Holders of our fellowships are brought into contact with actual Army problems. Several in the past have in their Ph.D. thesis derived solutions for specific problems of concern to Army laboratories. A holder of one of our fellowships has spent the past summer at Fort Detrick working on some of the problems encountered there."

In addition, AMRC has a very active program for visiting staff and for part-time appointments of University of Wisconsin academic staff. Between 1970 and 1972, 65 mathematicians worked as visitors on the AMRC staff: 21 from foreign institutions, 31 from US universities and 4 from corporations.

PROVIDING TECHNICAL SERVICES

Technical Studies

AMRC staff regularly evaluate research proposals sent to them for that purpose by the Army Research Office and other agencies. The purpose is to estimate whether or not certain proposals seem to be scientifically valid, and whether or not the work would be useful enough to the Army to warrant the expenditures of funds. AMRC staff evaluate 10-15 proposals yearly. They must according to the contract:

....PROVIDE FOR THE ARMY A SOURCE OF ADVICE AND ASSISTANCE ON...MATHEMATICAL PROGRAMS.... (P-I/A-1/OBJECTIVES-C)

Recruiting

AMRC helps to fill vacancies at various Army installations and institutions. This is part of their responsibility as outlined in the contract to:

> FURNISH ADVICE TO ARMY SCIENTISTS AND ADMINISTRATORS CONCERNING...THE EMPLOYMENT OF MATHEMATICAL PERSONNEL. (P-I/A-1/SCOPE-D)

Several examples of this are:

> "April 6. Dr. Rall wrote Mrs. R. S. Gannon, U.S. Military Academy, West Point, New York, offering assistance with recruitment of professional personnel in mathematics or statistics for the Research and Instructional Departments of the Academy."
> (20 July 1967 Quarterly Report)

> "September 28. In response to a letter of September 22, 1967, Edward J. Ross, Jr., U.S. Army Natick Laboratories, Natick, Massachusetts, Professor Rosser circulated information concerning positions at Natick Laboratories to interested MRC staff and MRC fellows. (25 October 1967 Quarterly Report)

> "After considerable enthusiastic negotiations with the U.S. Army Waterways Experiment Station, we were able to arrange for one of our visiting members, Dr. Akira Sakurai, to accept a WES appointment at the conclusion of his MRC appointment. To the best of our recollection, this is the first time an MRC visiting member has subsequently joined the staff of an Army installation."
> (15 April 1964 Quarterly Report)

WORKING WITH ACADEMIC SCIENTISTS

AMRC has aided the Army in obtaining the use of University of Wisconsin facilities outside the Center itself.

> "December 7, 1964, Professor Rosser answered an inquiry from Dr. R. H. Brown Director, Math Analysis, USAEC-USAEL, Ft. Monmouth, regarding avaliability of University of Wisconsin computer time for a USAEC program."
> (20 January 1965 Quarterly Report)

> "The U.S. Army Correctional Training Facility, Fort Riley, Kansas, was advised upon their request to contact the University of Wisconsin Computing Center to arrange, if possible, time on a UWCC machine or another 1108 to complete their study for the Vice Chief of Staff as soon as possible."
> (5 November 1971 Semi-Annual Report)

But the facilities are not the most important item. The main function that AMRC performs is providing easy access the the academic scientists. In a letter to President Fred in 1955, I. R. Hershner stressed the importance of being near an educational institution with the "easy contact with scientists in other fields." As discussed earlier, this is one of the main reasons for locating the Army's Mathematics Research Center on a university campus. It helps AMRC complete one of its contract's objectives, which is to:

> PROVIDE A CENTER FOR STIMULATING SCIENTIFIC CONTACT AND COOPERATION BETWEEN ARMY SCIENTIFIC PERSONNEL AND OTHER SCIENTISTS. (P-I/A-1/OBJECTIVES-C)

One example of this contact occurred on 9 June 1961 when E. H. Wissler working on an Army contract visited AMRC

> "for consultation on the determination and computation of heat transfers and temperature relations in sets of cylinders to simulate the human body. The conferences were with Drs. Anselone, Bueckner and Saunders of the MRC and Drs. C. Castello and A. Skoda of the Cardiovascular Research Department, University of Wisconsin. Future conferences are likely to eventuate as Professor Wissler's model is progressively developed."
> (25 October 1961 Semi-Annual Report)

A second example has already been described in an earlier section on Ballistics Research Laboratories, when A. S. Elder of BRL came to Rosser with a problem on 29 June 1972. Rosser sought someone in UW's School of

Engineering who would be interested in having a contract to work with BRL on Elder's problem. We do not know if he found anyone.

The liaison between Army scientific personnel and other scientists is created in five ways:

(1) the visiting staff positions for mathematicians from other academic institutions;
(2) the joint appointments of the permanent staff of AMRC with UW academic departments, such as mathematics, statistics, computer science, and economics;
(3) the part-time appointments of UW faculty to AMRC;
(4) the arrangement for joint AMRC-Math Department seminars;
(5) the Advanced Seminars and Symposia.

These Advanced Seminars and Symposia provide important liaison with scientists across the country who would not normally come into contact with AMRC. The Advanced Seminars have been described under our section on "Training" in this chapter.

> "The Symposia conducted by the MRC provide Army personnel with an opportunity for training and increase in scientific competence on the highest possible level, by discussion of the latest results of research in an important field, and by contact with the expert persons doing that research."
> (AMRC's In-Service Educational Opportunities offered by the MRC, May 1971)

It would be far more difficult to assemble the array of scholars attending a seminar or symposium were it held on a military base where the connection with the Army is more obvious. It is at such conferences and meetings that many informal ties and contacts are made and continued. This meets one of Hershner's original objectives of the Center, to make possible "fresh scientific contact between Army research and development personnel and other scientists."

The topics discussed at the Advanced Seminars and Symposia allow AMRC to keep abreast with latest research in fields important to the Army. These topics are chosen more than a year in advance, and are discussed (and most likely decided upon) by the AMSC Subcommittee on In-Service Educational Opportunities and Training (30 January 1967 Quarterly Report).

The most recent Symposium as of this writing was on "Non-linear Elasticity" held 16-18 April 1973. The previous Symposium held in June 1972 was on "Population Dynamics," the study of changes in population. AMRC also held in the same summer a special program in mathematical economics. A continuation of this summer program was held in the summer of 1973. In a following chapter on Army Math's current status and future directions, we describe the Army's increasing interest in population dynamics and economic modeling.

In summary, the entire operation of the Army Mathematics Research Center, with all of its programs of research, consulting, training, providing technical services, and working with academic scientists, is a clear reflection of what the Army desires and expects AMRC to be.

AMRC's current contract with the Army

June 29, 1973
Modification P010

PARAGRAPH I. Article 1 of Title I, entitled Scope of the Work, is deleted in its entirety and the following Article is substituted in lieu thereof:

"Article 1. Scope of the Work. The Contractor, as an independent contractor and not as an agent of the Government, shall conduct a program of unclassified basic research to be entitled "INTERDISCIPLINARY RESEARCH IN THE MATHEMATICAL SCIENCES." Utilizing its best efforts, personnel and facilities, the Contractor agrees to fulfill the objectives and scope contained herein. The objectives and the scope hereunder shall include:

OBJECTIVES:

A. To provide a group of highly qualified mathematicians which will conduct mathematical research in the areas cited in (1)-(5) of Paragraph A below. The emphasis in this research is to be on long-range investigations with the intention of discovering mathematical techniques that may have application to the scientific and technical needs of the Army. The research is to supplement (not replace) that of existing Army facilities.

B. To provide for the Army a source of advice and assistance on mathematical techniques, mathematical programs and mathematical problems.

C. To provide a center for stimulating scientific contact and cooperation between Army scientific personnel and other scientists.

D. To increase the reservoir of mathematicians that may be called upon by the Government for assistance in the event of national emergency by acquainting mathematicians with problem areas relevant to Army needs.

SCOPE:

A. Formulate and carry out a program of research in the following areas:
(1) Numerical Analysis and other areas of computer sciences, including the extension of the scientific usefulness of high speed computers;
(2) Statistics and probability;
(3) Applied mathematics and analysis;
(4) Mathematical techniques of operations research;
(5) Other areas of mathematical research also having potential relationship to an Army function or operation.

B. Perform research in the areas cited in (1)-(5) of Paragraph A above and conduct basic research in mathematics, including research in problem areas suggested by the Army Mathematics Steering Committee (hereinafter referred to as AMSC; this Committee has been established by the Department of the Army to assist the Chief of Research and Development and other Army staff elements in the planning, coordination and supervision of the mathematics research interests of the Army). It is expected that approximately half the effort under the contract will be devoted to a research program aimed at advancing mathematics in the areas cited in (1)-(5) of Paragraph A above and to the requirements of other paragraphs of this Article, and that the remaining effort will be devoted to basic research in mathematical and closely related areas with special emphasis on the areas cited in (1)-(5) of Paragraph A above.

C. Furnish advice to Army scientists and administrators concerning mathematical programs, mathematical techniques and mathematical problems and the employment of mathematical personnel.

D. Conduct sympoia and similar advanced educational activities in the mathematical areas cited in (1)-(5) of Paragraph A above and, then appropriate, afford Contractor personnel the opportunity of obtaining academic degrees.

E. Appoint a Director of the program who will, in coordination with the AMSC, formulate policies for the program and research guidelines for the personnel. The Director will implement said policies and research guidelines. He will be responsible for the dissemination of the results of the research activities carried out under the program, and will perform all other duties necessary for the successful fulfillment of the program objectives and scope. The Director will have full faculty status with corresponding rights and priviledges.

F. Appoint key scientists as required who will aid the Director in fulfilling the objectives and scope of the program. These scientists will have full faculty status with corresponding rights and priviledges. This group will include at least one(1)expert of recognized competence to perform research in each of the following four(4)fields:

(1) Numerical analysis and other areas of computer sciences, including the extension of the scientific usefulness of high speed computers;

(2) Statistics and probability;

(3) Applied mathematics and analysis;

(4) Mathematical techniques of operations research.

G. Appoint all other personnel required for the operation of the program.

H. Provide opportunities for education or research to personnel approved by the AMSC compatible with the research interests and capabilities of the scientific staff of the program.

I. Foster a wider interest in the mathematical areas cited in (1)-(5) of Paragraph A above by offering mathematicians employment to do research in those areas.

J. Perform additional work under the general supervision of the Director and with the approval of the AMSC to further the general objectives and scope of this contract."

PARAGRAPH II. Article 2 of Title I, entitled Time of Performance, is deleted in its entirety and the following Article substituted in lieu thereof:

"Article 2. Time of Performance. The period of the contract performance shall begin on 1 July 1966 and continue through 30 June 1976. The negotiations between the Government and the Contractor for the operation of the program contemplate a continuing endeavor; services under this contract shall continue through 30 June 1976. The contractor, prior to 31 December of each calendar year, shall submit its proposal to the Contracting Officer for the continuation of the contract work for an additional year beyond the contract term, and the Government shall have the option of accepting the Contractor's proposal and adding an additional year to the contract term as well as adding an additional increment of funds to the estimate and limitation of cost, as hereinafter provided. The contents of the Article shall not in any way be construed to obligate the Government to provide additional contract funds to reimburse the Contractor for performance of research effort beyond the period specified in Article 4 of Title I, entitled Cost of Performance."

PARAGRAPH III. Article 3 of Title I, entitled Personnel to be Utilized, is deleted in its entirety and the following Article substituted in lieu thereof:

"Article 3. Personnel to be Utilized. The research performed under this contract will be under the supervision of the Director of the program. The Contractor, prior to 31 December of each calendar year, will submit, together with its contract continuation proposal, an Exhibit A. On Exhibit A will be listed, to the best of the Contractor's knowledge and ability, the salaried personnel who will be utilized in the conduct of the program for the year beginning 1 July of the same calendar year and the rate of compensation and appointment period planned for each. Any changes made in the personnel listed in Exhibit A will be reported in subsequent semiannual reports. It is understood and agreed that all personnel being reimbursed by the Contractor will be under the exclusive supervision of the Contractor during the period of their employment."

PARAGRAPH IV. Article 4 of Title I, entitled Cost of Performance, as amended is further amended to incorporate an increase of $1,290,000.00 for continuation of the research effort during the period 1 July 1973 through 30 June 1974, as reflected in Exhibit A. The Article is amended by deleting the words and figures "Nine Million Three Hundred Eightly-One Thousand Five Hundred Fifty-Nine Dollars and Fifty-Two Cents ($9,381,559.52), and substituting in lieu thereof the words and figures "Ten Million Six Hundred Seventy-One Thousand Five Hundred Fifty-Nine Dollars and Fifty-Two Cents ($10,671,559.52).This amount has been obligated by the Government to reimburse the Contractor for the performance period 1 July 1966 through 30 June 1974. Reimbursement will be made in accordance with Clause 39 of Title II. Such estimated cost may be increased only in the manner provided in this contract.

PARAGRAPH V. Article 5 of Title I, entitled Technical Supervision, is deleted in its entirety and the following Article substituted in lieu thereof:

"Article 5. Technical Supervision. The AMSC is designated as the Technical Supervisor. The Contractor agrees to coordinate with the AMSC on major policy matters concerning the program.

Such coordination will be made with the Chairman of the AMSC by the Director, representing the Contractor. The Director will be responsible for maintaining the emphasis toward highly applicable mathematical research, as described in Article 1. He will be responsible also for maintaining liaison between Contractor personnel and Army scientific personnel, thereby keeping the staff of the program cognizant of Army mathematical problems. Both coordination and liaison will be accomplished in accordance with the procedures established by the AMSC and the Contracting Officer. The AMSC may request the Contractor to make changes that are within the technical scope of the contract, provided that such requests do no change the estimate of cost or time of performance. Any request emanating from the AMSC which may change the estimate of cost or time of performance (as such items are expressed contractually in this instrument) must be furnished the Contractor through the Contracting Officer, and over his signature, and is not binding on the Government unless so furnished. A copy of all communications pertaining to the technical aspects of the contract between AMSC and the Contractor shall be furnished to the Contracting Officer."

PARAGRAPH VI. Article 6 of Title I, entitled Administrative Control, is deleted in its entirety and the following Article is substituted in lieu thereof:

"Article 6. Administrative Control. All contractual administration will be carried out by the Contracting Officer, U.S. Army Research Office, Durham, North Carolina 27706. Communications pertaining to administrative matters will be addressed to the Contracting Officer, Attention: RDRD-L. The Contractor agrees:

a. to bear primary responsibility for the conduct of the research and to exercise judgement towards attaining the stated research objectives within the limits of the contract's terms and conditions.

b. that the Director will be continuously responsible for the conduct of the research program and will be closely involved with the research efforts.

c. that approval will be obtained from the Contracting Officer to change the Director, or to continue the research work during a continuous period in excess of three months without the participation of an approved Director.

d. to advise the Contracting Officer if the Director will, or plans to, devote substantially less effort to the work than specified in the attached budget.

e. to obtain the Contracting Officer's approval to change:

i) the methodology of experiment when such is stated in the contract as a specific objective,

ii) the stated objectives of the research effort, or

iii) the phenomenon or phenomena under study.

No changes in or deviations from the contractual provisions, including the "Scope of Work", "Estimated Cost" and "Period of Performance" clauses set forth herein, shall be effected without a supplemental agreement executed by the Contracting Officer authorizing said changes. All administrative matters, including requests for approval of i) foreign travel; ii) significant deviations from the categories of Exhibit A; iii) the purchase of non-expendable equipment with a unit acquisition cost of $1000.00 or more; iv) any changes to the estimated cost or period of performance of this contract; and v) all other matters which require prior approval, shall be addressed to the Contracting Officer."

PARAGRAPH VII. Article 7 of Title I, entitled Overhead Rate, as previously amended is further amended to incorporate a provisional overhead rate of 56% applicable to direct research salaries and wages chargeable to contract, including sick leave, holiday and vacation allowances, but excluding other fringe benefits, for the period 1 July 1973 through 30 June 1974.

PARAGRAPH VIII. Article 8 of Title I, entitled Reports and Publications, is deleted in its entirety and the following Article substituted in lieu thereof:

"Article 8. Reports and Publications.

A. The Contractor will prepare for distribution a semiannual report on the activities of the program. This report is to be distributed to the University and Army personnel who are directly concerned with the administration of the program. It will include a summary of all the work performed during the period covered by the report, a list of personnel changes, and a description of the projected activites of the program for the ensuing six (6) month period. In addition to the semiannual report, a technical summary report may be prepared upon the completion of each research project. A technical report may be prepared on any project at the discretion of the Director. Reports of this nature will be distributed in accordance with instructions from the Chairman, AMSC. Special reports may be required by the AMSC, and if such reports are required, the Contractor will prepare same in accordance with instructions from the Chairman, AMSC.

B. The Contractor shall submit narrative quarterly reports in letter form (in two (2) copies) to the Contracting Officer and fifty (50) copies to the Chairman, AMSC. Such reports shall include statements of funds expended and committed, consultants employed by the Contractor and consulting services individually rendered by Contractor personnel with the amount of time devoted thereto.

C. Publications in recognized scientific journals of scientific papers resulting from research performed by personnel of the program is encouraged. Papers resulting from research performed may be presented at scientific meetings and submitted to journals for publication without prior clearance, but a copy will be given to the Director. Moreover, if the Director judges that such a presentation or publication will enhance the accomplishment of the objectives of the program, the program may assume various extra costs of such presentation or publication, to include but not be limited to travel, secretarial services, reproduction, mailing, page charges, and purchase of reprints. Simultaneously with each acceptance by a publisher, one (1) copy of the accepted manuscript or typescript will be sent to the Chairman, AMSC, with the name of the journal and the approximate date of publication. The paper should include a credit line to read as follows: "Sponsored by the United States Army under Contract No. DA-31-124-ARO-D-462". Manuscripts prepared as Technical Summary Reports will be reviewed by designated representatives of the AMSC and approved prior to printing and distribution. Press releases, presentations at scientific meetings, and papers should not discuss the overall Army program or the source of Army interest in the particular research area involved. Copies of press releases shall be submitted to the Chairman, AMSC, as far in advance of the contemplated release date as possible."

PARAGRAPH IX. Article 10 of Title I, entitled Government Furnished Property, is deleted in its entirety and the following Article substituted in lieu thereof:

"Article 10. Government Furnished Property. It is contemplated that the Contractor will require various items of office equipment which shall include, but not be limited to, furniture and fixtures, typewriters, adding machines, calculators, and duplicating equipment. With respect to any item of equipment having an acquisition cost of less than $1000.00, the transfer of title to the equipment will be in accordance with the Government Property Clause of the General Provisions."

ADDENDUM TO EXHIBIT A
Estimated Cost of Performance

1. Salaries		
a. Research Staff	453,800.00	
b. Assistants	12,900.00	
c. Computing Staff	57,000.00	
d. Secretarial Staff	78,500.00	
e. Student Help	4,400.00	
		606,600.00
2. Fringe Benefits		
a. Academic Staff @ 15.3% of Items 1a, 1b, and 1c	80,126.00	
b. Classified Staff @ 20.0% of Item 1d	15,700.00	
		95,826.00
3. Fellowships		
a. Stipends	43,000.00	
b. Tuition and Fees	23,900.00	
		66,900.00
4. Computing Services		50,000.00
5. Materials, Services and Supplies		84,178.00
6. Equipment		900.00
7. Communications and Shipping		10,100.00
8. Consultants		14,500.00
9. Travel		21,300.00
TOTAL DIRECT COSTS		950,304.00
INDIRECT COSTS @ 56% of Salaries		339,696.00
TOTAL ESTIMATED COST		1,290,000.00

Chapter 7

AMRC'S CLAIMS REFUTED

AMRC has been defended in many ways by its staff and by University officials. Some of the more flagrant "rationalizations" are considered in this chapter, and their incongruity with the facts is explained.

Noble Denies Project MICHIGAN Consulting

Permanent Staff members of AMRC have periodically denied that they have consulted with Army scientists. For example, Ben Noble wrote the letter printed below concerning a debate between himself and another mathematics professor, Anatole Beck. Full details on the extensive work that AMRC did with Project MICHIGAN are described in Chapter 1, and clearly disagree with Noble's letter. The report "around 1965-66" to which Noble referred, is actually the 1967 AMRC Annual Report.

UNIVERSITY OF WISCONSIN-MADISON
MADISON 53706

MATHEMATICS RESEARCH CENTER — 610 WALNUT STREET

September 18, 1972

TO: Budget Committee of Mathematics Department

FROM: Ben Noble

My attention has been drawn to what was apparently a very misleading report in a Mathematics Department budget committee meeting by Anatole Beck of a conversation I had with him on Wednesday, September 14. He made two statements to me:

(a) In an MRC annual report around 1965-66, there was mention of "Project Michigan" in the table of contents, but the relevant pages had been cut out of the report.

(b) His belief was that "Project Michigan" was evaluated by MRC.

I responded as follows:

Statement (b) is completely false – MRC is not set up to do this kind of thing, and never has done it.

It is true that MRC was approached by "Project Michigan" for help in connection with advice on certain purely mathematical problems. The problems turned out to be far more specific than MRC is set up or expected to handle, and contact between MRC and "Project Michigan" ceased almost as soon as it began. I made two points to Anatole, which he apparently refrained entirely from reporting:

(i) Visitors and myself (with no security clearance) were involved in the conversations, so secrecy was <u>NOT</u> involved.

(ii) Furthermore, MRC did <u>NOT</u> get involved in "Project Michigan" -- exactly the opposite of what Anatole seemed to be trying to get his auditors to believe.

It is sad that Anatole feels called upon to try to suggest that our "Project Michigan" involvement is to the discredit of MRC. In fact, as I had carefully explained to him, <u>it is very much to the credit of MRC</u> that it operated throughout in the traditions of an independent university institution.

Ben Noble

Noble's statement that "contact between AMRC and 'Project MICHIGAN' ceased almost as soon as it began" is a conscious lie. In actuality, the contacts between these two military research centers extended from 1960 to 1967, and Noble himself consulted with Project MICHIGAN on 19 February 1963 and 9-10 May 1963, according to AMRC's own reports. On the second occasion, Noble traveled to Michigan in order to consult on problems such as " transmission lines". Noble wrote this letter to the Budget Committee of the Mathematics Department, a standing committee of UW which is a state agency. So, in fact, he has lied about AMRC's work to officials of the State of Wisconsin.

Noble's letter was used again during a debate over AMRC in a public meeting of the UW Mathematics Department on 26 April 1973. These false claims used by AMRC's Permanent Staff casts doubt on their other statements concerning the nature of Army Math research.

Humanitarian Overtones to AMRC

At the 26 April Math Department meeting, AMRC's Acting Director R. C. Buck claimed a new direction for the Center's research.

"Many projects carried on by the Army have strong humanitarian overtones. These projects depend strongly on applied mathematics. The future of the MRC is going to expand more and more in these areas."

27 April 1973 Capital Times

As an example, Buck mentioned research on pattern recognition techniques to help the blind.

It is too soon to determine whether Buck's "humanitarian overtone" policy is serious or just a publicity front to disarm the Center's critics. J. B. Rosser, AMRC's Director until 1 July 1973, has made claims similar to Buck's in the past, but the Center continued its work for the Army without significant change. Given the other misleading statements made by the Permanent Staff, one must doubt the reality of AMRC's Humanitarian Overtones policy.

Even if Buck's humanitarian projects materialize, they will still be merely "overtones" to the Army's weapons research. This is clearly demonstrated by Buck's one concrete example of his new policy, pattern recognition for the blind. Computers have been programmed in the past several years to recognize objects or to read on behalf of the blind. These pattern recognition techniques were first developed by Defense Department researchers to enable automated warfare devices to recognize targets, especially from the air. For example, William J. Sacco of the Ballistics Research Laboratories (see Chapter 4) published a report in February 1969 entitled: "An Application of Pattern Recognition to Radiometric Target Detection" (AD-684 904), whose abstract says:

> "Classical detection theory is used to provide a framework for the study of the potential of passive detection of metallic targets by millimeter wave radiometry [i.e. infrared sensors]. The target is assumed to be embedded in a foliage environment."

Ideología en la ciencia

Because of such applications to the electronic battlefield, the Defense Department has always been the foremost patron of pattern recognition research in universities, sponsoring massive programs in this area at MIT and Stanford, and smaller programs elsewhere. AMRC has contributed to the military's pattern recognition research in the consultations with Project MICHIGAN (see Chapter 1). The techniques developed at Project MICHIGAN to detect targets from sensor data have occasionally been adapted to help the blind. Under the guise of charity for the blind, AMRC's new policy would thus continue the kind of mathematics research which the Army needs to perfect the electronic battlefield.

A weapons-builder like AMRC giving help to the blind is not only an old form of hypocrisy, but a shoddy form of public service. The real needs of the blind in this project are secondary to the needs of the Army. As a result, AMRC has overlooked all the immediate problems of blind people in order to program pattern recognizing computers which only a minority of blind people (plus the Army) will ever have access to. A genuine Peoples' Mathematics Research Center as discussed in the last section of our report would direct its research program to meet the problems of the blind and others in need of technological services, leaving the "overtones" to the military. In order to really help people, a math research center would have to go talk to people about their problems. AMRC has no mechanism to do this, but rather takes its guidance from the Army.

Classified Research at AMRC

"At the Center, no classified research is done. In fact no classified work is done on the campus by any MRC staff. Secrecy of any kind would be a hindrance."

J. B. Rosser in a 1969 letter
to UW Dean Stephen Kleene

AMRC personnel back up this claim by saying that everything they do is published in the Technical Summary Reports which are theoretically avaliable to everyone ("even the Russians" as Rosser often says). In reality, those unclassified publications from the Permanent Staff are often stripped-down facades for the actual mathematical efforts to solve classified problems through consultations and correspondence with military personnel. However, the reports of the visiting mathematicians are often exactly what they are presented to be: mathematical research in areas of interest to the Army, usually not arising from consultations with military personnel.

How AMRC can write unclassified reports on classified research was explained by Stephen Robinson, the Center's Assistant Director, during the 27 March 1973 interview with People's Video. Robinson was asked: "Is there ever any problem with something developing in the course of the consultation that is classified and can't be published?" and he answered:

> "The only reason why any classification would be involved is that sometimes a problem will be motivated by a development or physical problem having to do with something which is classified. And it may well be that the person who has proposed the problem will want to show the consultant where the problem comes from, and exactly how the problem arose in the course of this development or engineering situation or whatever it is, in order that the mathematician may be able to help him to formulate the problem in a better way.
>
> "In that case, the mathematician would have to look at this material which is classified, and that's where a requirement for a clearance would arise. But the clearance would not be involved in the mathematics of the problem, that is, the clearance would apply to the fact that this problem arose in the development of something which might be classified.
>
> "But the mathematical aspects of the problem would not be classified. So, I don't believe that this would interfere with the publication of the mathematical problem which is what the consultant would actually be working on. The classification would apply to the particular physical realization of the problem that happened in that case.
>
> "But the mathematics isn't classified. You can't classify mathematics, and so I would say that this sort of thing could be published."

To permit the AMRC Permanent Staff to fully examine the mathematical problems which arise in the course of Army classified work, they must have security clearances. This fact was verified in the recent interview with Robinson, who told of his need for a security clearance on two different occasions: first, for an Army Science Conference in June 1972, during which the background of some problems involved developmental work -- the session was therefore classified; and second, for consultations with STAG, described in Chapter 1.

Another illustration of the AMRC security process is provided by a requisition initiated by Permanent Staff member Louis Rall in early 1968. Rall requested funds to buy a Special Mosler Class 3 Security Filing Cabinet, because he considered it an essential item under the new security regulations imposed by the Defense Department on 1 March 1968. George F. Iverson, Director of Business Services - UW Administration, recommended on 12 January 1968 that Rall's filing cabinet be purchased out of the President's Special Capital Fund #K44-4078. This security filing cabinet cost $231.00, as the following letters indicate:

"Mathematics Research Center - U.S. Army
The University of Wisconsin
Madison, Wisconsin 53706

December 12, 1967

Mr. Len Van Ess, Director
Financial Research Administration
442-A Administration Building
Campus
Re: Contract No. DA-31-124-ARO-D-462

Dear Mr. Van Ess:

According to new security regulations, we shall need additional protection for classified documents after March 1, 1968. Consequently, I ask permission to purchase a Mosler Class 3 Security Filing Cabinet #7110-687-89. The estimated cost is $231.00. I attach a copy of the approval of the Defense Supply Agency.

Sincerely,
(signed)
Louis B. Rall
Assistant Director AMRC"

"Mathematics Research Center - U.S. Army
The University of Wisconsin
Madison, Wisconsin 53706

January 3, 1968

Mr. Len Van Ess, Director
Research Administration - Financial
442-A Administration Building

Re: Contract No. DA-31-ARO-D-462

Dear Mr. Van Ess:

I should appreciate your early approval of my request dated December 12, 1967 for an approved container for classified documents (Mosler Class 3 Security Filing Cabinet #7110-687-89) which will be required on March 1, 1968 under the new security regulations to be in effect during that time. Since the operation of the Mathematics Research Center is a continuing one, and from time to time it is essential for performance under subject contract for us to have the facility for storage of classified documents, I feel that approval of our request is essential. I call your attention to the security endorsement of the contract dated May 19, 1967. Approval for purchase of this container has already been obtained from the Defense Supply Agency.

Sincerely,
(signed)
Louis B. Rall
Assistant Director AMRC"

AMRC's Permanent Staff clearly sees the need for security clearances and classified information in order to continue their work for the Army.

Under these circumstances, whether the final report of AMRC's research is classified makes little difference. The real question is whether the research is done to solve Army problems. The mathematics done for the Army can always be generalized to the point where it need not be classified, and on this level of abstract mathematics, secrecy can be a hindrance to the Army, as Rosser wrote to Kleene. The Army would be hurt if the militarily useful mathematics in its abstract form was prevented from wide circulation among non-military mathematicians who might unwittingly contribute to its more rapid development.

The distinction between "good" unclassified research and "bad" classified research has thus lost any meaning.

Consumers of AMRC's Research

"Who are the consumers of MRC research results? Everyone who has technological problems."

J. B. Rosser in the 1969 letter to Kleene

Who has technological problems today? Since AMRC aims only to help selected scientists, Rosser, with the tunnel vision of a technocrat, apparently imagines that only other scientists have technological problems. Yet there are others: people facing hunger, pollution, inflation and unemployment; Indochinese doctors who must remove plastic pellets from the victims of US anti-personnel weapons; those persons "on file" with the local police or in data banks kept by the military for domestic surveillance; small farmers whose land, livestock and family have been sprayed with chemical defoliants such as 2,4,5-T; and everyone eating foods processed with harmful chemicals for the sake of profit.

These people could all benefit from technology and even portions of AMRC's research, yet now are the victims of US technological developments. This situation has stemmed from science in this country in general and AMRC research in particular because the discoveries are not available to everyone, as Rosser claims, but to elites who use them for their own purposes. As an example, the principal "consumers" of Army Math's work are:

(1) the Army, which defines the Center's work in the first place, as we have documented in Chapter 6, and as a recent issue of Army R&D of January-February 1973 points out: the Army Mathematics Steering Committee "assists in developing the scientific program of the Mathematics Research Center at the University of Wisconsin."

(2) the research staff which studies past military research in order to produce more of the same;

(3) many of the 300 AMRC alumni who began successful careers investigating militarily useful problems and now maintain contacts made while working at the Center;

(4) university scientists from around the country who are briefed at specialized conferences; and

(5) corporate personnel who adeptly fit research conclusions into their highly sophisticated and exploitative marketing and profit-making schema.

Last September at AMRC's Seminar on Mathematical Programming, more than 20 corporations were represented besides the universities and military institutions. Among these corporations were: World Bank, IBM Research Center, RAND, Shell, Continental Oil, Bell Telephone Labs, and Oscar Mayer -- enterprises that have figured prominently in domestic and foreign economic exploitation.

Effect of Funding on AMRC

"I don't believe that the type of research program we have and the areas in which we work would be any different if, for example, the entire contract were to be assumed by the National Science Foudation or the Department of Health, Education & Welfare or anything else."

Stephen Robinson, 27 March 1973
interview with People's Video

This long-standing claim that AMRC is unaffected by its Army funds was completely refuted by staff member J. Ben Rosen in an interview which he gave the Cardinal on leaving the Center for a new job:

> "The influence of the source of funds is felt by the selection of people appointed to the MRC. They are chosen keeping in mind research for military application and not for, say, ecology. The research in both these fields may be the same, but not generally."
>
> Daily Cardinal, 11 May 1971

The Army funds have been such a great stigma for the Center that, in 1971, an application was made to the National Science Foundation (NSF) for sufficient funds to cover AMRC's entire operation. In a 1972 interview, Robinson admitted that the NSF application was made "to get the radicals off our backs."

Eventually, Army Math's proposition was turned down, presumably because NSF could not afford the Center's $1,400,000 annual budget. Nonetheless, the Center's willingness to apply for NSF funds has occasionally been taken as proof of AMRC's independence from the Army. An inspection of its proposal to NSF shows otherwise.

First, the funding request left the AMRC contract with the Army intact, with the same principles of Army assistance and the same coordination by the Army Research Office through the Army Mathematics Steering Committee. Further, the Permanent Staff would have remained unchanged under the proposed NSF grant, and thus their partiality for Army work would not be hindered.

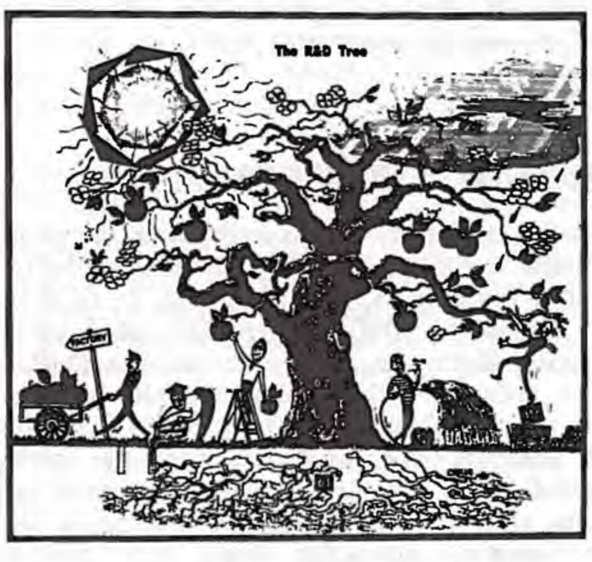
So the request itself was simply a political cosmetic, designed with no purpose beyond deception, and the continued protection of the Army's work force in academia.

PART III
AMRC'S RELATIONSHIP WITH THE UW

Chapter 8

AMRC's Early History

The creation of the Army Math Research Center, from the time the Army recognized its need for such an enterprise until AMRC actually began operating as part of the University of Wisconsin, was an astonishingly rapid process. The 1954 idea became reality on 2 April 1956, demonstrating the ability of the military to muster up enthusiasm among the academic community and to provide continuing support for its development.



THE ARMY SYSTEM OF SCIENTIFIC RESEARCH as conceived by Army Research and Development News Magazine.

BEGINNINGS

The Army in 1954, faced with problems in mathematics, formed the ad hoc Army Mathematics Advisory Panel for the Chief of Research & Development to study the possibilities for Army-supported research in this field. UW math professor Rudolph E. Langer participated in this panel with adequate credentials, having been Regional Councillor for the Office of Ordnance Research for several years and a member of the Scientific Advisory Board of the Rock Island Arsenal.

A year later, in early 1955, the Panel recommended the establishment of an Army-oriented Math Center. The Army's Chief of R&D approved the proposal, and the ad hoc Advisory Group on the Army Math Center was appointed to negotiate a contract for the Center by January 1956.

In June 1955, the chairman of this Advisory Group, Lt. Col. Ivan R. Hershner Jr., wrote to the University of Wisconsin among 44 other educational and research institutions asking President Edwin B. Fred for a statement proposing the Center's operation at UW. It is worth knowing some of the specifics required of the Center's host, for they demonstrate the attitudes that the University willingly complied with in order to compete for the Center's site. Most fundamentally, the Army memorandum indicates the prerequisite mutual education process demanded of the Center's community and the Army. As military needs catalyzed involvement of academic personnel, so in turn would the Center expand the potential and actual resources available for military application.

The key objective, Hershner wrote, was

> "to provide a nucleus of highly qualified mathematicians responsive to the Army, who will carry on investigations slanted towards general problems having Army relevance and who can be called upon for advice on specific problems which may be outside the specific capabilities of regular Army mathematics facilities. The goal of the Center should be the discovery, if possible, of techniques having direct applications to the Army's needs" and "responsive to the needs of all Army agencies."

"Fresh scientific contact between Army research and development personnel and other scientists" would be possible. Military and civilian Army personnel, studying and researching at the Center, could simultaneously educate "academic mathematicians with respect to the interests of the Army" and request studies of math useful in certain activities. A reservoir of mathematicians would be created, "of vital significance in the event of hostilities."

Hershner stressed the importance of being near an educational institution, with the "easy contact with scientists in other fields." The staff would split their time between programmatic research and that of their own interests, "which it is assumed will also be in the Army's interest." The majority would be nontenured personnel on loan from educational institutions and Army agencies, and young scientists with limited knowledge beyond their formal training. Students earning degrees might be employed. Academic personnel would become familiar with Army problems and return, along with Army personnel, to their regular positions "scientifically advanced."

RESEARCH AREAS

Research would cover four principle areas: (1) numerical analysis including engineering physics of high speed computers; (2) statistics and probability; (3) applied math and analysis; and (4) operations research including linear and non-linear programming, game theory, decision theory, information theory and optimization problems.

The Center, operating as a distinct unit with resident Director and staff, would be guided by a non-resident steering group of representatives from the technical services and other Army R&D agencies. Through a contract, the Center would be funded by Army research funds, at an estimated annual cost of $800,000. One-quarter of this would rent a large digital computer, essential to the Center since the Army had invested in this field with expectations of large payoffs. Congress had already appropriated $400,000 for the Fiscal Year ending 1 July 1956, and the Army hoped to increase expenditures to $600,000 in FY '57 and $800,000 in FY '58.

The Center's sponsoring institution would have to qualify for facility clearance, the Director for Top Secret security clearance, and other key personnel for Secret security clearance, to ensure "adequate contact with all important Army scientific work." The memorandum ended with the wish that the Center be located in an area "providing lesser likelihood of interruption of operation in the event of hostilities."

UNIVERSITY RESPONSE

President Fred quickly formed a group of nine to discuss the proposal, including Vice President A. W. Peterson, Dean Mark H. Ingraham, and mathematics professors Langer, Hammer, Korevaar and MacDuffee. After meeting with Hershner July 18, and later with the University Administrative Committee and the Board of Regents, the group agreed to vie for the Center. Peterson was frank in stating that the Army hoped that the Center's research work would lead to information which would have to be classified. In writing to Fred, Peterson added: "the Army representatives had assured our faculty group that while the principal purpose of the Center would be to serve the Army, the University would have control over the staff and the work of the Center in a manner which would make it attrative to us."

Edwin B. Fred, UW President during AMRC's early years.

On 1 August 1955, President Fred sent back his proposal to Hershner, stating "We should be happy to have the Army locate it [the Center] at this University." Here are some excerpts illustrating what won the Army over.

> "At the request of the Army, we would establish and operate here a Mathematics Center conforming in its objectives, philosophy and scope with the outlines of your memorandum....The University administration, as well as the faculty, is devoted to productive scholarship, to the end that we operate here in a stimulating research-centered atmosphere."

The University would supply space for the Center's staff and equipment "as near to the campus as possible, in order to effect an actual integration of the Center both from the scientific and social aspects, into the structure of the University." In addition to seeking out the best director and corps of mathematicians for faculty appointments, the University would also invite larger numbers of scholars to spend resident periods at the Center. Since the Center staff would be faculty, they would be welcomed as an additional resource for graduate studies.

"To make the Center a dynamic institution of high quality," Fred pointed out the qualifications of the whole University, and of the Mathematics Department in particular. The University already operated several institutions comparable to the proposed Center: an Enzyme Research Institute, Cancer Research Center, National Agricultural Center for Advanced Study, and Naval Research Laboratory. With "considerable knowledge of and interest in Army problems," the University also conducted a large Army ROTC program, and held 21 Army research contracts in 15 departments amounting to more than $4,750,000.

Although in the Math Department "interest in and knowledge of Army problems are rather potentialities than actualities," Fred emphasized that "there would be no reluctance on the part of the mathematicians here to develop an interest in Army problems." Not only would the department look favorably upon the location of the Army Mathematics Center here, but "it would cooperate with the Center's staff, and in every way accept it into the existing mathematical fraternity." Although only Langer had had any wide opportunity to understand Army problems, other professors had been connected with other government agencies (Hammer with the Los Alamos Lab), math students had gone into direct or indirect service of the Armed Forces in such laboratories as RAND, Sandia, Los Alamos, Oak Ridge, GE and Westinghouse. In a related area, the Department of Electrical Engineering was interested in high speed computers, and was soon to finish a large digital one of its own design, the WISC.

Fred wrote that there was a total student body of 15,000 with 3,000 in the graduate schools. The Math Department had 5,000 students, 50 graduate students, and 70 staff of which one-half were teaching assistants. This might partially explain the emphasis given to encouraging math graduate studies through the Center.

He assured Hershner that the University had facility clearance, and that several mathematics faculty had Secret Security clearance; and that it would be easy for the Center staff to visit any Army installation and for installation personnel to visit the Center.

Fred further sought to land the contract by pointing out Madison's reputation as being "America's best place to live" according to LIFE, and by stressing its ideal climate: "delightful in spring; often cool and generally moderate, relatively speaking, in summer; invigorating during a long fall, cold but not excessively so, and generally bright in winter." He ends by stating that Madison is in a good "dispersal" location, being both outside the regions of conspicuous industrial and military targets of the Atlantic Coast and Mid-West, and the seat of an active Air Force fighter base, so as to "enjoy exceptional protection against operational interruptions in the event of hostilities."

SELECTION OF UW AS THE SITE

University research support comes from a number of sources: the instructional budget; state and federal appropriations, grants and contracts; and private sources, notably the Wisconsin Alumni Research Foundation. To house Army Math, WARF came to the rescue.

In his August 1955 proposal, Fred had suggested only makeshift space for the Center. September 22, WARF voted to help the University prepare a suitable location for the Center if it were chosen as the site. From $850,000 it had granted in August for University improvements, WARF now granted nearly half ($300,000 for physics improvements and $100,000 contingency funds) plus an additional $400,000 for an enlarged Sterling Hall addition -- for both physics and the Mathematics Research Center. Subtracting the cost of the physics improvements, the cost of Army Math was thus estimated at $500,000.

A week later on September 30, Vice President Peterson, Dean Ingraham and Langer, armed with a welcoming letter from Governor Walter Kohler, appeared before the Army Mathematics Advisory Panel in Washington, representing one of four institutions still under consideration for the site. Their efforts were amply rewarded, for on November 16, Fred was notified that the University had been chosen for the Center site. The importance and national significance of this event was described in a confirming letter from L. Gen. James M. Gavin, Chief of Army R&D:

> "The decision to establish a Mathematics Research Center at the University of Wisconsin was made on the basis of a study conducted by representatives of all Army activities having an interest in mathematics and by outstanding representatives of the mathematics community. The Mathematics Research Center represents a forward looking research undertaking by the Army and I wish to express my appreciation for your willingness to establish the Center at your institution. It is anticipated that the Center will provide the mathematics complement to the support of long range research."

25 November 1955, it was announced that Langer would be Director. Basic personnel would include: (1) an Associate Director; (2) leaders in the four principal fields; (3) a junior staff of assistant professors at the post-doctoral level; (4) a small research engineering staff; and (5) a changing staff of research assistants from the graduate school population. Expectations were that a large number of visitors from the regional agencies and educational and research institutions would spend from a week to two years studying particular problems. "An advisory staff of key people in Army installations will recommend Center programming and will aid in screening Army programs which are submitted for Center research."

Langer noted, "The Center should handle only problems beyond the range of present installations and problems with a broad scientific interest." It was time to discard the traditional trial and error method of development in favor of an approach based upon mathematical calculations. The Army expected the Center to be extremely useful in this area.

Fred hailed the location of the Center as a "tribute to our mathematical competence and a salute to this state which has supported a strong program in this basic field of mankind's knowledge." A month later, Dean C. A. Elvehjem said that the prospective Center "had done as much for the morale of our faculty as anything that has happened since the completion of the Memorial Library."

December 10, after a building committee was appointed, the University Board of Regents approved the Army's establishment and support of the Center, and authorized plans for the addition to Sterling. The following year, in October 1956, the Regents granted that final plans be laid for the addition. Soon after, construction began.

STAFFING PROBLEMS

From the very beginning of implementation of the contract, problems centering around staffing the Center arose, with the Army taking a rather hard line in demanding that the contract be rigidly followed, even if the University had to bend some policies. In an April 3rd letter to Colonel Cullion of the Army Mathematics Steering Committee at Durham, N.C., UW President Fred hesitated in signing the contract and questioned the budgeted salary of Dr. Langer, the Director of the new Center. Fred pointed out that a salary of $17,500 was second only to that of the President himself, and above the present Administration salary bracket. This was therefore not in accordance with wage and salary Article 35 (b) of the proposed contract. In reply, the Army pointed out that during the negotiations, the established salary level of $17,500 had not been in conflict with Article 35 (b) of the proposed contract, and suggested that perhaps the Director's position called for "establishment of a new job category." Despite these differences, however, the contract was signed on 25 April 1956.

The next group of problems associated with staffing the Center were those of the recruitment of the staff. Four major problems appeared to be causing mathematicians to hesitate about leaving their current positions and joining the MRC staff. Langer lists them as follows:

(1) salary - most could not afford to accept;

(2) time available for research - the requirement that 50% of the individual's own research be devoted to programmatic work of the Center was more stringent than other positions offered by industry or agencies such as RAND;

(3) consulting - usually faculty members render consulting services for fees. MRC required that these be almost eliminated and forbade acceptance of fees from government agencies; and

(4) length of contract - since the Army first envisioned short extensions of the contract, job security was in doubt to those who joined the staff.

The Army became increasingly impatient with the University's inability to bring in big-name mathematicians to join the MRC staff, and coldly rejected a proposal that the Center be staffed with visiting personnel and younger mathematicians who were highly competent but had not had time to become famous in their field. By July 1956, President Fred apparently began having second thoughts about AMRC, and mentioned the possibility of reconsidering whether UW should continue with plans for the new Center. The Army also seemed to have second thoughts, as Colonal C. Medinnis, Commander of the Chicago Ordnance District, ended a letter setting up a meeting to discuss the matter by stating: "It appears to our mutual advantage to settle this matter as soon as possible to the complete accord of the University and the Government or agree to abandon the project at the University of Wisconsin."

The University must have felt that AMRC was too big a plum to lose, both in terms of money and prestige, and the Army felt the need was too critical to start over elsewhere, so differences were worked out in a series of meetings from late 1956-early 1957. To overcome the four major problems encountered in recruiting, the Army agreed to a contract with a longer extension to create staff job security, to lessen restrictions on outside consulting, and to change the requirement of programmatic research so that 50% of AMRC's work as a whole would be programmatic instead of 50% of each individual's research. The University was directed to increase salaries to enable AMRC to be competitive. But competitive salaries would have been higher than the UW's salary policies would permit, so to side-step this problem, the University called on the Wisconsin Alumni Research Foundation and set up the following plan:

(1) To offer nominees, for key positions in AMRC, University faculty positions with tenure as required by the contract at prevailing salaries;

(2) To offer nominees, simultaneously, immediate leaves of absence for the duration of their AMRC position, to permit acceptance of appointments from WARF. WARF could pay any salary without regard for University salary policies. For its efforts, WARF would receive 4% of the salaries and wages which it administered.

The above changes solved the recruitment problem, so by April 1960, Director Langer in his Semi-Annual Report was able to say,

> "I believe that the AMRC has made its way, and that it is well along the way toward filling those needs of the Army that it was designed to fill....It has been, and appears to be increasingly helpful to other Army activities...."

"Distinguished mathematician, Dr. Rudolph E. Langer, takes center among friends during activities in his honor. Left to right are University of Wisconsin President F. H. Harrington, Director of Army Research Brig. Gen. Walter E. Lotz, Prof. Langer, J. Barkley Rosser, Director of Mathematics Research Center - United States Army, and Dr. S. C. Kleene, toastmaster." (Army R&D, June 1964)

R. E. Langer was Director until December 1963, through which time he guided the research and Army problem-solving efforts of AMRC that are recorded elsewhere in our report.

On 1 December 1963, J. Barkley Rosser became AMRC's Director and has continued at that post to the present day. The following letter describes the Army's joy in his appointment:

"Department of the Army - Office of the Chief of Research and Development
Army Research Office - Washington 25 D.C.

24 May 1963

President Fred Harvey Harrington
University of Wisconsin
Madison 6, Wisconsin

Dear President Harrington:

I have been informed that the Commanding Officer of the Chicago Procurement District wrote you on 14 May 1963 approving your nomination of Professor J. Barkley Rosser as Director of the Math Research Center, U.S. Army, following the contemplated retirement of Professor Rudolph E. Langer.

Your selection of Professor Rosser delighted me, since his background and qualifications are ideal for the position. In addition, his nomination received the unanimous approval of the Army Mathematics Steering Committee.

Thus, I offer my sincere congratulations on this outstanding appointment. I am sure that Professor Rosser will be able to increase the fine support that the Center is now giving to many Army agencies, and that he will be a worthy successor to Professor Langer.

Please express my sincere good wishes to all concerned.

Sincerely,
(signed)
Chester W. Clark
Major General GS
Director of Army Research"

Rosser plans to retire 30 June 1973. R. C. Buck of the UW Mathematics Department then will become Acting Director, due to the Center's difficulty in finding a permanent Director. Buck has been a part-time staff member at AMRC during six of the past twelve years.

AMRC'S PERMANENT STAFF

Selected Biographies

To describe the backgrounds of AMRC's Permanent Staff members, we include these backgrounds and mathematical specialties.

J. Barkley Rosser

JOHN BARKLEY ROSSER

BACKGROUND:

1936-63	Mathematics Department, Cornell University
1944-46	Chief of the Theoretical Ballistics Section, Allegheny Ballistics Lab.
1948	Presidential Certificate of Merit Award for work on rockets
1949-50	Director of Research, Institute of Numerical Analysis
1955-58	Member of the Stewart Committee for the Monitoring of Space Satellites
1959-61	Director, Focus Project, Institute for Defense Analysis
1960	Received Secretary of Navy's Recommendation for work on the Polaris Submarine missiles
1960-62	Chairman, Mathematics Division, National Research Council
1961-62	Chairman, Mathematics Department, Cornell University
1963-73	Director, AMRC
1964-66	Member of the Space Technology Panel of the President's Science Advisory Committee
1964-71	Periodic consultations for the National Academy of Sciences
1965-69	Periodic consultations for the National Security Agency
1968-69	Member of the ad-hoc advisory committee to President Pusey of Harvard University
1969-70	Consulted for the National Research Council

SPECIALITIES:

Logic, numerical analysis, ballistics mathematics.

LOUIS B. RALL

BACKGROUND:

1951-53	US Army
1956-57	Mathematician, Shell Development Company
1957-60	Professor, Lamar State College
1962-	Professor AMRC
1970-	Associate Director of AMRC

SPECIALITIES:

Numerical Analysis, integral equations, functional analysis, applications of Newton's method and the Kantorevich Theorem.

STEPHEN ROBINSON

BACKGROUND:

1962	B.A. University of Wisconsin-Madison
1962	Commissioned as Army Second Lt. from ROTC
1963	M.S. New York University
1963-64	Stanford University
1965	US Army. First Lt. at Headquarters U.S. Army J.F.K. Center for Special Warfare. Fort Bragg, North Carolina
1966	US Army. Captain at Presidio, Monterey, California
1966-68	US Army. Vietnam
1969	Appointed to the administrative staff of AMRC
1969-71	Attended University of Wisconsin-Madison Graduate School
1971	Appointed to the research staff of AMRC
1971	Ph. D. University of Wisconsin-Madison
1971	Assistant Director of AMRC

SPECIALITIES:

Linear programming, game theory, optimization.

ROBERT CREI

BACKGROUND:

1947-49	Assistant Professor of Mathematics, Brown University
1950-54	Associate Professor of Mathematics, University of Wisconsin-Madison
1954-	Professor of Mathematics, University of Wisconsin-Madison
1957-	Periodically held one third time appointments to AMRC
1958-59	Visiting Professor, Stanford University (Guggenheim Fellow)
1959-60	Member of the staff, Project Focus, Institute for Defense Analysis
1961-64	Mathematics Division, National Research Council
1963-	National Security Agency Advisory Board
1965-70	Mathematics Advisory Panel, National Science Foundation
1973-	Acting Director, AMRC

SPECIALITIES:

Complex variables, algebraic analysis, number theory, approximation theory, mathematics education, history of mathematics.

BERNARD HARRIS

BACKGROUND:

1952-58	Mathematician, National Security Agency
1958-63	Professor of Mathematics, University of Nebraska
1963-	Professor AMRC
1966-	Professor of Statistics, University of Wisconsin-Madison

SPECIALITIES:

Computer statistics, communication theory, combinatorics.

TE CHIANG HU

BACKGROUND:

1960-66	Research Mathematician, IBM Research Center
1964	Consultant to the RAND Corporation
1966-68	Associate Professor of Computer Science and AMRC, University of Wisconsin-Madison
1968-	Professor of Computer Science and AMRC, University of Wisconsin-Madison
1968-	Office of Emergency Preparedness

SPECIALITIES:

Network theory, operations research, computer combinatorial mathematics, discrete optimization.

HERMAN F. KARREMAN

BACKGROUND:

1954-56	Research Associate, National Bureau of Economic Research
1956-63	Econometric Research Program, Princeton
1963-	Professor AMRC
1965-	Professor, School of Business, University of Wisconsin-Madison
1968-	Professor, School of Engineering, University of Wisconsin-Madison

SPECIALITIES:

Operations research, stochastic processes, mathematical economics.

BENJAMIN NOBLE

BACKGROUND:

-62	Professor of Mathematics, Royal College of Science and Technology, Glasgow, Scotland
1962-	Professor AMRC

SPECIALITIES:

Integral equations, numerical analysis, mathematics of fluids.

ISAAC J. SCHOENBERG

BACKGROUND:

1926	Ph.D. University of Jassey, Roumania
1930-31	Fellow, University of Chicago
1931-32	Research Fellow, University of Chicago
1932-33	Harvard University
1933-35	Member, Institute for Advanced Study
1935-36	Acting Assistant Professor of Mathematics, Swarthmore College
1936-37	Instructor of Mathematics, Colby College
1937-41	Assistant Professor of Mathematics, Colby College
1941-46	University of Pennsylvania
1943-46	Ballistics Research Laboratory, Aberdeen Proving Grounds
1946-48	Associate Professor, University of Pennsylvania
1948-65	Professor of Mathematics, University of Pennsylvania
1965-	Professor AMRC

SPECIALITIES:

Diophantine approximations, total positivity, distance geometry, integral transforms, approximation theory, spline functions.

THOMAS NALL EDEN GREVILLE

BACKGROUND:

1933-37	Actuarial Assistant, Acacia Mutual Life Insurance Co.
1937-40	Instructor of Mathematics, University of Michigan
1940-46	Actuarial Mathematician, US Bureau of Census
1946-52	US Public Health Service
1952-58	Statistical Consultant, Int. Coop. Admin.
1954-58	Assistant Chief Actuary, US Social Service Administration
1958-60	Deputy Chief Mathematician, US Arm. Om. Corp.
1960-61	Chief Mathematician, US. Arm. Om. Corp.
1961-62	Vice-President, S.A. Miller Company
1962-63	Visiting Professor, University of Michigan
1963-	Professor AMRC
1964-	Professor in the School of Business, University of Wisconsin-Madison
1971-72	Visiting Professor, Federal University of Pernambuco, Brazil

SPECIALITIES:

Actuarial mathematics, matrices, approximation and interpolation.

Salaries

The following salary figures are from the State of Wisconsin Budget Summaries for 1972-73. The section printed here is a list of the official salaries - those reported to the State of Wisconsin - paid to the Permanent Staff of AMRC. Such a reporting is required by law since the University is a state agency, and therefore all its reports are public documents.

The figures apparently do not include funds the Permanent Staff received from WARF (see previous chapter) since Exhibit A of the contract reports Rosser's salary as $45,000, while he is listed here as receiving only $33,500 for the nine-month academic year.

Notice that the Permanent Staff receive higher salaries than the average UW Mathematics professors. For example, the average salary for a full professor in the Mathematics Department is $20,700, with 70 of the Math faculty in this bracket.

The codes used by the State in this summary are as follows:

Before the salary figures:

- A Annual
- C Academic Year

After the salary figures:

- LV leave without pay
- * total salary

MATHEMATICS RESEARCH CENTER

-PERMANENT STAFF-

ROSSER, J BARKLEY	DIRECTOR	C	33,500*
	ALSO COMPUTER SCI AND MATHEMATICS		NO SALARY
RALL, LOUIS B	ASSOCIATE DIRECTOR	A	27,800*
	ALSO MATHEMATICS		NO SALARY
ROBINSON, STEPHEN M	ASSISTANT DIRECTOR	A	15,800*
YOHE, JAMES M	ASSISTANT DIRECTOR	A	16,600*
GREVILLE, THOMAS N E	PROFESSOR	A	32,800*
	ALSO SCHOOL OF BUSINESS		NO SALARY
HARRIS, BERNARD	PROFESSOR	A	28,000*
	ALSO STATISTICS		NO SALARY
HU, TE CHIANG	PROFESSOR	A	19,346
	ALSO COMPUTER SCI		7,254
		A	26,600*
KARREMAN, HERMAN F	PROFESSOR	A	25,000*
	ALSO SCHOOL OF BUSINESS AND INDUSTRIAL ENGINEERING		NO SALARY
NOBLE, BENJAMIN	PROFESSOR	A	34,400LV*
	ALSO COMPUTER SCI AND MATHEMATICS		NO SALARY
SCHOENBERG, ISAAC J	PROFESSOR	A	38,400*
	ALSO MATHEMATICS		NO SALARY
STEWART, WARREN E	PROFESSOR	C	22,450*
	ALSO CHEMICAL ENGINEERING		NO SALARY

Chapter 9

UW Protection of AMRC

ADMINISTRATION

Ever since the University of Wisconsin helped establish AMRC, it has been deeply involved in the functioning of the Center and in protecting it from criticism. Examples of these activities can be seen at all levels of the University heirarchy.

President John Weaver has attempted to protect AMRC's work and other University research projects by claiming that UW does only "pure research." In response to a reporter's question of whether or not the UW does military research, Weaver was quoted in the 12 February 1973 Capital Times as saying: "The University of Wisconsin is not engaged in weaponry or the applied research of the sort you speak of." As shown in previous chapters, AMRC's Permanent Staff who are University faculty have done just what Weaver denies. Either Weaver is unaware of AMRC's activities as part of the University he heads, or he is intentionally misleading the public.

Donald E. Percy, currently a Vice President of UW, began his career at Wisconsin on 1 December 1963 as Assistant Director of AMRC. According to the 22 January 1964 Quarterly Report, Percy was "formerly with the Institute for Defense Analysis and with the Office of the Secretary of Defense." Percy was AMRC Assistant Director until 1965 when he became Dean of Letters and Science, the College under which AMRC is placed in the University structure.

Percy still maintained contact with the Center in this capacity since Deans of Letters and Science regularly receive AMRC reports to keep them abreast of the Center's activities. The fact that Percy was subsequently promoted to the University Vice-Presidency means that AMRC can now count on having a friend at the highest levels of decision making within the University.

Donald E. Percy, formerly AMRC Assistant Director and now UW Vice President.

Edwin H. Young, now the Chancellor of the University's Madison campus, has received AMRC's reports to the Army, now as Chancellor and earlier during his term as Letters and Science Dean. Last summer in 1972 he went to Toronto, Canada to testify at the extradition hearing for Karleton Armstrong, who allegedly bombed AMRC in 1970. Young knows what is going on at the Center because of the regular reports he receives, but still

Edwin Young, Chancellor of UW's Madison campus.

gave misleading testimony concerning AMRC activities. When asked if the charges made by students about AMRC's work for the Army had any basis, Young replied: "No basis, as far as I know of, of any classified or secret work done on campus." Thus while he must have known of the Center's involvement with Project MICHIGAN, for example, he tried to give the impression that no such work went on by emphasizing the word "secret". When asked if the AMRC contract with the Army required AMRC to give technical assistance to the Army, Young answered: "No. There was a period of time when one of the conditions was that some of the mathematicians might go off and consult if the Army requires. That has been removed from the contract." Then questioned if AMRC still does any consulting, Young replied: "They may or may not as anybody else may." This testimony is intentionally misleading and not in line with what Young must know to be the facts.

Stephen Kleene, the current Dean of the College of Letters and Science, has had an even closer association with AMRC. Kleene has for many years been a faculty member in the Mathematics Department, and has worked part-time at AMRC during the the academic years 1963-64 and 1964-65. He was Acting Director of AMRC during Rosser's leave of absence in 1966-67, during which time he wrote the famous 1967 Annual Report, which had its section dealing with contacts with Army installations deleted because it contained such sensitive material.

Even though Kleene has been so intimately involved in University military research, he was appointed by the University in 1969 to head a faculty committee to investigate the students' claims that military research and especially secret research were being done on campus. His appointment ensured that no serious investigation of AMRC or any faculty member doing military research would occur. In fact, his committee only requested a statement from each professor explaining what research he was doing. Since the letters were not investigated, all sorts of evasions were possible and even encouraged by this situation.

On 5 November 1969, Kleene wrote a short paper entitled: "A Dove's Defense of MRC" which was released like a press statement with the intention of giving the impression of faculty support for AMRC during the time that students were demonstrating against the Center. Kleene claimed that the University was "neutral" and therefore it could not deny its facilities to AMRC, but he made no offer to give equal University support to those opposing the work of the Army. He attempted to obscure the nature of the Center's work by saying: "Participation on the MRC does not make them [the staff] supporters of the Government (whatever it is at the moment) on matters of policy." He concluded with: "Those of us who can should help the Army to receive the best scientific advice it can get on how to carry out as <u>successfully and economically</u> as possible whatever tasks it has now or might have in the future" (emphasis added).

Stephen Kleene, formerly Acting Director of AMRC and now Dean of the College of Letters and Science.

MARSHALL COMMITTEE

The Marshall Committee, chaired by W. Robert Marshall of Mechanical Engineering, was recently appointed as a faculty committee

to oversee AMRC. But a quick perusal of the committee's personnel gives no reason to expect that changes will be initiated by this group. Three faculty members have worked for AMRC: George E. P. Box (Statistics) from 1967-68, Olvi L. Mangasarian (Computer Science) from 1967-71, and T. C. Hu (currently on AMRC's staff) from 1966 to the present. Two other members, E. Robert Marshall (Mechanical Engineering) and Joseph Hirschfelder (Chemistry) were on an earlier Ad Hoc Committee which supposedly was created to oversee AMRC for the faculty, but which in fact accepted the Army's guidance of the Center.

Additional members are John A. Nohel (Mathematics), William S. Bicknell (Business), Robert Borchers (Physics), Alan Ek (Forestry), Vincent C. Rideout (Electrical Engineering), and Daniel F. Shea (Mathematics). Shea is currently involved in a joint Math Department-AMRC seminar, and was a spokesman for the pro-AMRC forces at the recent Math Department meeting held on 26 April 1973 to discuss the censoring of AMRC. Mathematics faculty voted by a ratio of 3-1 to continue their involvement with the Center.

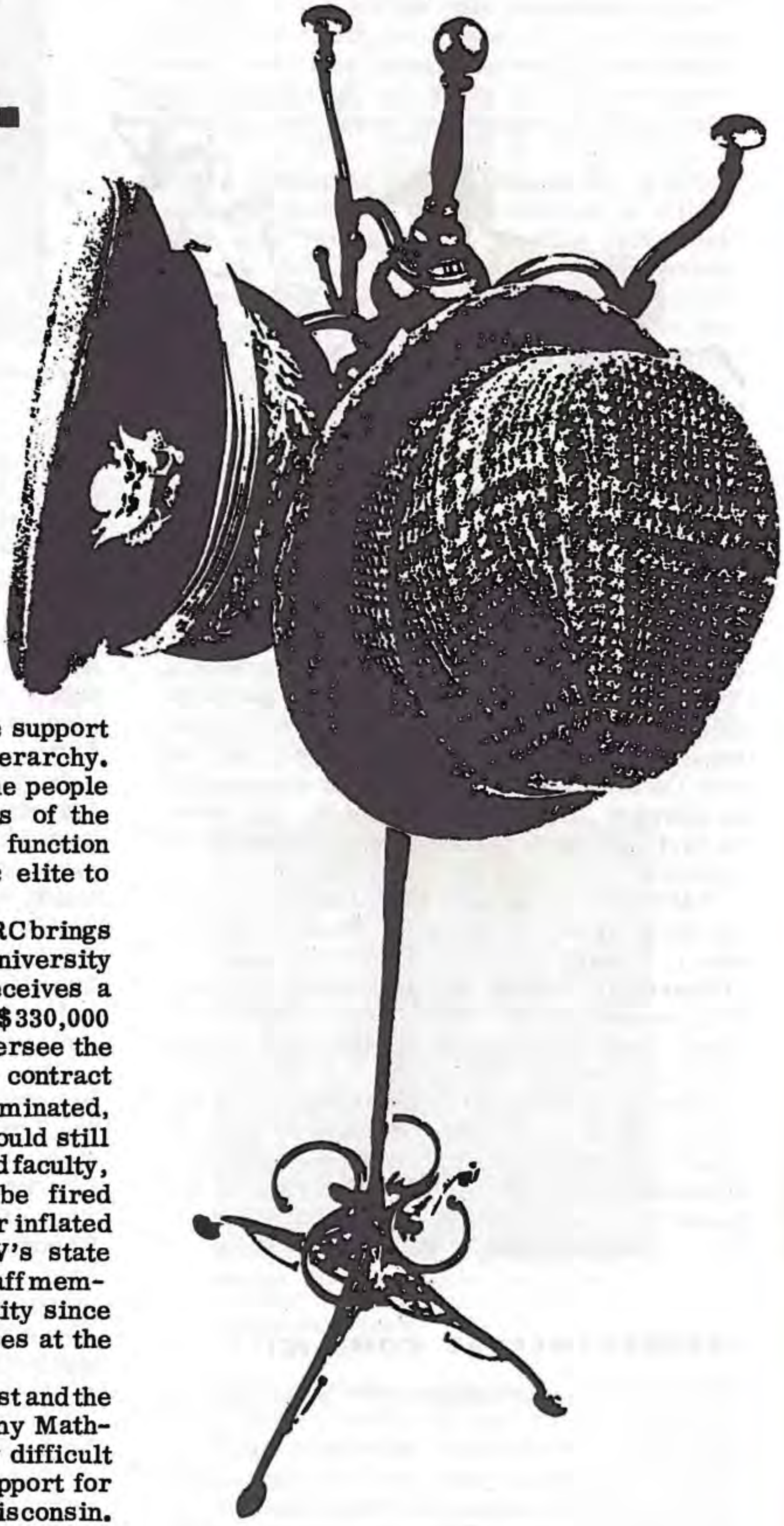
DEPAPARTMENTAL COMPLICITY

The Marshall Committee members, with the exception of Ek and Borchers, come from departments which have had faculty members on the AMRC staff part- and full-time. They include: Mathematics, Statistics, Economics, Computer Science, Chemistry, Engineering, Business, Commerce and the Medical School. These selected departments have therefore derived concrete financial benefits from the Army Mathematics Research Center's existence, since faculty employed by the Center receive salaries from AMRC rather than from the departmental budgets. The more faculty holding joint UW-AMRC appointments, the more staff the University departments can hire within the budget limits set by the State.

In the case of the Statistics Department, for example, not only have several faculty worked for the Center, as Permanent Staff member Bernard Harris does at the moment, but it was created by a former AMRC staff member, the George Box mentioned above. After being brought to the University to work for AMRC, Box was appointed first chairman of the department, with the task of developing a discipline distinct from mathematics.

The Mathematics Department, however, has enjoyed an unparalleled relationship with the Army Mathematics Research Center. Almost half of its current tenured faculty (32 out ot the total 68) have worked at some time for the Center. Prior to the current Chairman, Michael Bleicher, the five earlier ones worked at AMRC: R. C. Buck, L. C. Young, H. Schneider, J. Nohel and W. Wasow. The presence of the Center has drastically altered the direction of the Math Department's research, increasing its emphasis on applied mathematics of the kind that AMRC best uses. Army Math's first director Langer often complained that UW Mathematics was not concentrated sufficiently on applied work; this is now no longer the case.

What you wear to work makes no difference.



CONCLUSION

There are two main reasons for the support given to AMRC by the University hierarchy. The first is ideological. Some of the people mentioned above support the goals of the Army and believe that it is a proper function of the University and the scientific elite to advance those goals.

The second reason is money. AMRC brings at least $1,400,000 each year to the University of Wisconsin, from which UW receives a management fee of no less than $330,000 (56% of the salaries involved) to oversee the Center. In the event that the Army contract and its financial support were terminated, AMRC Permanent Staff members would still have to be paid since they are tenured faculty, and persons with tenure cannot be fired according to University policy. Their inflated salaries would then come from UW's state instructional budget. Few of these staff members have proven their teaching ability since they rarely, if ever, teach any classes at the University.

Given the University's self interest and the depth of its involvement in the Army Mathematics Research Center, it is very difficult to expect anything but continued support for the Center from the University of Wisconsin.

Chapter 10

FUTURE DIRECTIONS

The Army Mathematics Research Center is expanding the scope of its research to include investigations in broader areas. This shift parallels the increasing interest of the military in political and social sciences. The motivation behind this interest was outlined by former Chairman of the Joint Chiefs of Staff Maxwell D. Taylor, in an interview with Bill Moyers shown on Public Television in Madison, 17 March 1973:

> "We ought to take time out now and take a deep breath and look at what we learned in Vietnam, and then try to project our present threats and problems into the future and ask ourselves what kind of threat are we likely to face which might require the use of military strength.... The problems that might cause a nuclear or major war are still there but I would say diminished in intensity, whereas I see endless increase in the field of limited problems [for example limited war] arising from all sorts of things to include population growth, which happens to be one of my hobbies at this time."

According to Taylor, the burdens of excess population cause weak governments to collapse, create discontent in populations, endanger "democratic" government, and intensify

> "the competition that's going to arise between the industrial nations fighting for the diminishing supplies and raw materials on which they depend. The easiest example of the economic pressures which could lead to military operations is in the case of oil....If indeed access to oil, for example, would be shut off, that would be a situation which might very readily lead to military operations. Meanwhile, many minerals are going to become scarce in the coming decade, so that this whole globe is going to be grasping for solutions to the depletions of these stocks."

The military is very interested in anticipating possible future conflict situations and maintaining control in those areas in which it is already involved. As Taylor confirmed in the interview, military commitment follows the flag and wherever the flag is put, the commitment will escalate.

ECONOMIC MODELING

Today, AMRC still works for the Army. Its changes in policy correspond to the world political and economic situation. AMRC's Assistant Director Stephen Robinson, in a recent interview with People's Video on 27 March 1973, talked about diminishing resources and the future:

> "We're using up a lot of resources. Some of these are non-renewable resources. I don't think we've done very much thinking about the consequences of this. Now part of the effort here [at AMRC] is to take a look at what might happen in the future, when we keep on with this growth pattern that we're in now. We keep on using up these resources -- what's going to happen? The preliminary studies that were done at MIT tend to indicate that some rather unpleasant things might happen. We'd like to find out if that's true. And if so, are there policies we can follow that will tend to avoid this?" *

* The "MIT study" refers to The Limits to Growth, published in 1972, describing a global model designed by the MIT Project Team headed by Dennis L. Meadows. Present trends in world population, industrialization, pollution, food production and resource depletion are analyzed, with the conclusion that unless enormous changes occur, sudden and uncontrollable declines in population and industrial capacity will result.

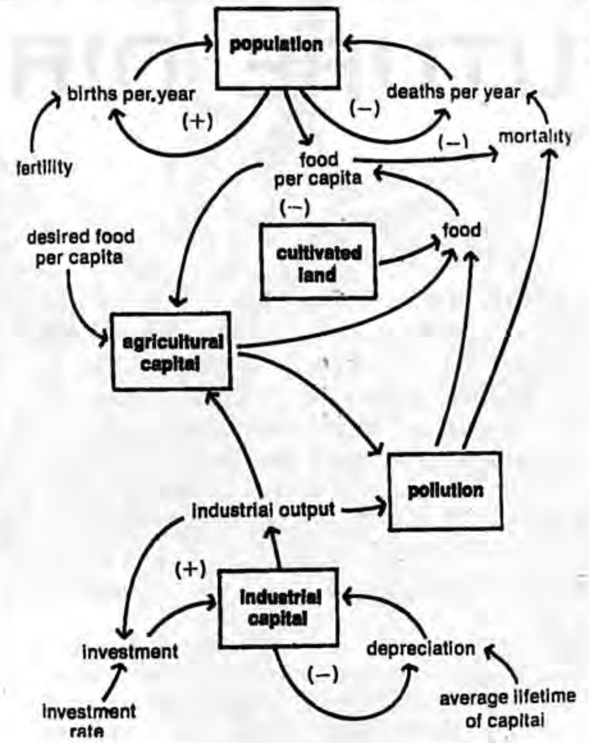
Stephen M. Robinson, AMRC's Assistant Director.

The effort Robinson talks about is a new program in economic modeling, coordinated by himself and H. R. Day of the UW Economics Department, who was also a member of Robinson's Ph.D. thesis committee. The 20 October 1972 Semi-Annual Report briefly describes the 1972 summer cast of characters: B. E. Easton and Lynn McLinden; J. P. Aubin of Paris, interested in competetive equilibrium, B. P. Stignum of Northwestern University, in dynamic stochastic processes; and D. G. Tarr of Ohio State University, interested in oligopoly models. All but Tarr will be back for the 1973 summer program.

An economic model is a system of equations which attempts to describe the relationships between factors in a country's economy such as the availability of raw materials, industrial and agricultural production, trade and foreign investment. Such models have not been successful because of the extremely complex relations among the factors. The rewards from developing the simple models which now exist, and so increasing their predictive abilities for our military policy makers, makes a large investment in research worthwhile.

POPULATION DYNAMICS

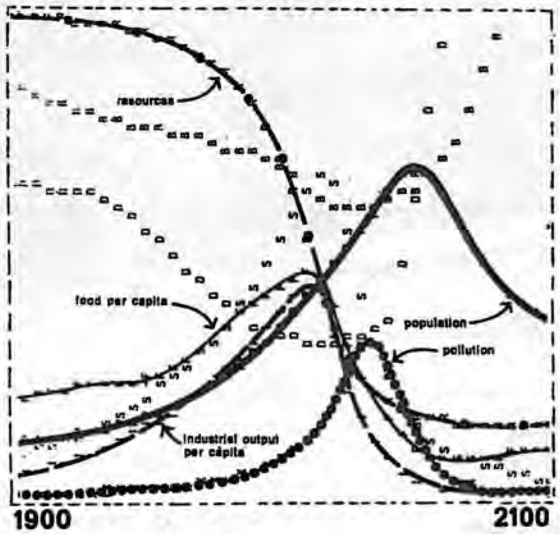
Held in June 1972, at the same time as the summer program in economic modeling, was AMRC's Symposium on "Population Dynamics." As Maxwell Taylor noted in his interview, this is an important subject for military planners. In line with this, AMRC consultations with the military planners of the Strategy and Tactics Analysis Group (STAG) have been on the upswing during the past few years (see Chapter 1). An example of STAG's work is the paper written in 1971 by David R. Howes, entitled: "GUEVARA, A Computerized Guerrilla Warfare Model." This work which AMRC and STAG collaborated on clearly falls into the area which might be called social science modeling.



A major purpose of The Limits to Growth and its world model is to determine which behavior will occur when the world system's limits are reached. In this model, population (total number of people) and industrial capital (factories and machines) are the central factors, with agricultural capital (tractors, irrigation ditches, fertilizer, etc.), cultivated land and pollution affecting them. Positive feedbacks (+) are birth and investment, generating population and capital; negative feedbacks (—) are death and depreciation regulating this growth. Each arrow indicates a causal relationship, immediate or delayed, large or small, positive or negative, depending on the assumptions being tested in the model.

- summarized from The Limits to Growth, pages 92-98

In order to obtain the information needed for these more complex social models, AMRC is attempting to expand its influence into other University departments. We have already mentioned that Economics and Demography faculty have cooperated with AMRC. In addition, there were held during the 1973 spring semester joint seminars of personnel from AMRC and various departments, including



This model showing "overshoot and collapse", takes into account eight variables in predicting the world's most likely behavior as its limits are reached. It is called "standard" because it assumes that there will be no major changes in the physical, economic or social relationships that have operated for the past 100 years. Food, industrial output and population grow until diminishing resources force a slowdown in industrial growth. Population and pollution continue increasing after industrialization drops, until finally famine causes a population decline. (B=birth rate, D=death rate, S=services per person)

- summarized from The Limits to Growth, pages 122-126

Mathematics, Computer Sciences, and the Social Systems Research Institute. The joint work undertaken by AMRC and these additional academic departments tends to give AMRC a more respectable appearance. Increased respectability enables AMRC to entice more academicians to contribute towards AMRC's work for the Army, under the guise of continuing normal scholarly research.

These inter-departmental seminars are merely local versions of the yearly symposia and seminars which AMRC holds. Their purpose is the same: to collect as much information as possible, in the hope that some of it might be useful to the Army.

As the Army Math Research Center expands its work into seemingly more abstract and less technical weapons research, spokesmen will claim that the Center is doing work which is of benefit to all citizens rather than solely helping the Army. AMRC staff will claim that their discoveries have "good uses" as well as Army applications. While there may be some truth in their theoretical statements, in practice it will not be true. The work will be tailored to the Army's needs.

Meanwhile, AMRC is still doing the technical consulting described in Part 1 of this report. Its spring Symposium, held from 16-18 April 1973, was on "Non-Linear Elasticity," the mathematical study of the bending properties of materials, including metals and plastics. In attendance was Sam Li Pu of Watervliet, a co-worker of M. A. Hussain. As we describe in Chapter 4, Hussain worked with AMRC Permanent Staff member Ben Noble during a six-month AMRC Research Residency from 1966-67; his work with Noble continued through 1969.

During the summer of 1973, Ben Noble plans to write an orientation lecture series on the finite element method in conjunction with the Symposium on that subject which is scheduled for the spring of 1974. These orientation lectures, as we describe in Chapter 6, are designed to teach Army scientists the fundamentals in particular areas.

Also on the agenda is an Advanced Seminar on "Generalized Inverses and Applications" planned for the fall of 1973, with Professor M. Z. Nashed of Georgia Tech. as program chairman. This seminar topic, and the one noted above, are both concerned with techniques for finding solutions for models.

The areas of research currently being pursued at AMRC have been outlined by Assistant Director Robinson, described in Chapter 6 under the Center's contract with the Army. With the addition of the mathematical economics program and work in differential equations which are important for modeling, the research areas are still those required by the contract.

In the future, we can expect an increasing diversity in AMRC's research activities, as United States' foreign policy and military needs grow, and require the designing of systems for social control beyond the development of new weaponry. AMRC can be expected to try to sell this new research as beneficial to all since it deals with "social problems." But as long as this research is directed toward the needs of the military instead of the needs of the people, it cannot be said that AMRC is serving the public. AMRC's newest research for social and economic manipulation can only be stopped by political action from people opped to the imperialists' use of science.

PART IV

an alternative:

A People's Math Research Center

How often do you see TV advertisements describing products you really need? How often does the federal or state government propose health, housing, and employment programs which will reach you and genuinely improve your life? You are left to your own devices in one crisis after another: deciding whether to sell your farm to a realty speculator or wait until the Highway Department confiscates it five years later; organizing a neighborhood recycling project which can't begin to save the last stands of wilderness areas; wishing you could stop the unrestricted expansion of the tourist industry which is drowning your town; wondering why the Board of Education continues to consolidate community schools into one unmanageable, impersonel system.

All these plagues on our lives are the issues scientists could be helping to cure, yet when they pay any attention at all to these problems, their remedies often make the disease worse. In the past decade, concentrated scientific resources have gone into putting men on the moon and setting the world record in Indochina for tons of bombs dropped in a single war, while only sporadic attempts have been devoted to eradicating hunger, acute poverty and pollution. And now, crucial programs for food, education and housing are being terminated.

Most people now regard science and technology either as a pointless spectacle or as an oppressive tool in the hands of the military, government, and big business. The only way most of us can benefit from science is to purchase its products, both goods and services, at inflated and unjust prices.

In facing the reality of the Army Mathematics Research Center, we confront this central dilemma: how can powerful technology be transformed from a means of oppression into a force for molding society and our environments as people really wish?

Removing AMRC will solve only a small part of the problem. As Louis Rall of AMRC told another mathematician, "If your research was funded by NSF instead of AMRC , the Army would still get your work, perhaps a bit more slowly." As long as giant government and corporate institutions maintain their monopoly over the distribution of science in our society, the face of technology will not change.

Breaking this monopoly requires major surgery to destroy the coercive control these institutions hold over the world's technological and human resources and the creation of a new system of science which people control in order to fulfill their needs. Two essential steps in this process are the abolition of the Army Mathematics Research Center, and the creation of a People's Mathematics Research Center.

This Center will function as a coordinating point for people who wish to organize against repressive government and corporate policies; for people wholly neglected by any research developments who want to begin to implement programs towards significant improvements in their lives and who now have no access to any useful research facilities; and for mathematicians who are dedicated to creating a categorically different breed of science which will challenge the existing nature of research and those who control it.

A PMRC would use many of the same mathematical techniques as AMRC does, but the ends of this research would serve the majority of the people in this country rather than the Army. It would make mathematical resources avaliable to everyone, rather than solely to the scientific establishment. And above all, it would begin to bring segments of today's research under popular control.

These principles would guide the development and operation of a PMRC. There are several more specific questions which are more difficult to answer:

(1) For whom will the Center work?
(2) What will the Center do?
(3) How will the Center be controlled?
(4) Who will staff the Center?
(5) How will the Center be funded?

For whom will the Center work?

First, it must work for the general public, giving priority to those who do not now have access to mathematical technology. This standard would eliminate any PMRC services to the military and to corporations sufficiently powerful to organize their own mathematicians. Further, those with enough resources to hire their own scientific consultants would remain lowest on PMRC's list of those deserving help.

Secondly, PMRC would concentrate on the problems of those citizens' groups which are able to articulate the needs of a large constituency: cooperatives, neighborhood organizations, civil rights and farmers' coalitions, and rank-and-file labor groups.

The crises of working conditions, land use, poverty in a hundred forms, cannot be tackled by individuals alone. Since we have reached a point in history when all persons are interconnected with one another, all problems must be defined on a community basis. Individual benefit must not be equated with private profit, but seen as necessarily dependent upon the well-being and improvement of the entire community. Otherwise, the few will gain at the expense of many others.

The function of a mathematical model is to take various separate aspects of a problem. . . .

And draw them together into a coherent whole.

However, it is often possible to reach more than one conclusion from avaliable data:

What will the Center do?

The personnel at the Center would have two primary jobs: to carry out projects, and to recruit new projects by conducting educational programs explaining the capabilities of the Center. The educational campaign can be conducted through the media, but more effort should be expended in personal appearances by staff members in meetings with citizen's groups.

A central function of the Center will be to inspire confidence in science. The bitterness and disullusionment many people feel today is entirely justified, given the predominant brand of research which threatens and invades our daily lives. A wholly new and responsive research Center would begin to break down the myth that all science, all planning, all technological innovations are ultimately harmful, and would reduce the suspicion and ignorance which so many of us have toward science in general.

Planning and scientific developments are not inherently useless or harmful. It is their sponsorship and control by an unrepresentative government and exploitative corporations which transforms potentially good research into the system of abuse and violence which we witness today. For example, mathematical modeling, which is AMRC's specialty, has been used routinely by the military for the past 2 years to solve questions of both policy and technology. Anthony Russo has described RAND Corporation models which successfully convinced the American generals in Vietnam that the strategy of "generating refugees" by search-and-destroy missions would damage the NLF (Ramparts April 1972). Yet the same technology, under different control, could be a powerful force in giving ordinary people greater control over their own lives.

How will the Center be controlled?

If the Center is to serve the people, then the policies of the Center must reflect the will of the public. Also, workers need control over their work to ensure that it has meaning. These two requirments imply that the Center must be directed by the public as well as by the people who work there. No structure for PMRC can guarantee popular control; indeed, any structure which PMRC develops must be flexible and open to alterations on the demand of people whose needs are not being met by a certain arrangement.

Experiences with local health clinics and other examples of community-organized pro-

grams have shown, however, that public control over the research can be achieved through a number of mechanisms. People should be engaged in numerous levels of any project which PMRC undertakes for them. They must participate in deciding the questions to be answered, the factors to be considered, and the options to be tested. As volunteers or as temporarily paid employees of PMRC, they could contribute to the mathematical phases of the work by collecting and interpreting data.

The public would further have jurisdiction over the hiring of the staff, and the firing when they deemed it essential to maintain the Center's integrity, and would certainly be an integral part of whatever process was set to implement research results. This community control over every phase of the Center's work would be the greatest safeguard that the Center would remain useful in meeting the public's critical needs, and keep the initial sharing-of-power process from reverting into lab researchers being isolated from the public.

All workers in the Center must be equally involved in the decision making if elitism in science is to be challenged. This implies that each worker would have one vote, with senior researchers being accorded no special privileges. In no case should the research staff be the final group deciding what work will be carried out. This would encourage an isolated island of professionals making decisions for a large population which can creatively make them itself. It has been that very abdication of control and concern by millions of people, and the extreme power held by "professionals" which has caused scientific research to reach the extreme irrelevance and misuse it has today.

The fight against elitism could be taken one step further by breaking up the specialization of jobs. This would mean that every staff member would do unpleasant jobs such as maintenance, secretarial and other rote tasks, as well as participating in the creative decision making processes.

When the number of projects outgrows the resources of the Center, decisions giving priority to certain areas of continuing and future research should be made through public meetings by those communities involved in the current and potential projects. This process would depend on a consensus concerning the overall goals towards which the Center is aiming. We have no illusions concerning the difficulty of reaching this kind of agreement in American society today, where so many parts of our lives show competition between antagonistic classes rather than a productive sharing of power. Decisions concerning PMRC priorities and project selection might well have to be reached by majority vote, depending on the one central guideline from which PMRC must operate: that projects should be denied to people having large resources for carrying out independent studies for themselves.

Mathematical Modeling applied to

To demonstrate what a mathematical model is and how it could be applied to a civilian problem, consider an example: the copper mines proposed for northern Wisconsin. Kennecott Copper and other mining companies have discovered copper deposits near Wausau, Ladysmith and Marinette, and are preparing to extract this wealth. They have been buying land from farmers in the area and obtaining permission from the county governments. Thus, residents of these areas are facing a very complicated question: should they welcome or oppose copper mines in their midst? Before a farmer sells land to Kennecott and before the county government gives the miners permission to begin, they need to know what effect the mine will have on the county. Will the mine bring industry and prosperity to the area, or only be a temporary boom, leaving behind unemployment and a blighted environment after only a few years of exploitation?

The answer to this question is immensely complicated, taking in the interaction of everything from the international copper market's fluctuations to the health of the local ecosystem. Each of these factor's is, by itself, a complicated problem whose behavior in the future is open to argument, but to imagine their cumulative effect on the people of northern Wisconsin is virtually impossible.

The copper companies, of course, have fed the residents a rosy picture of an economic boom growing from the mines, but the people know that Kennecott's view of the future is biased by visions of profit. Thus the Rusk County government hired a Duluth consulting firm to get an independent estimate of the economic effects of a mine. The individual farmer faced with an individual offer to sell to Kennecott however, has only his or her own intuition as a guide, and no one has yet predicted how long the mining benefits will last or what the mines will cost the environment.

In the same way the military mathematicians construct models for the Defense Department when it is faced with problems of this complexity, so other researchers could create models to take into account the various factors in the mining situation: unemployment, water pollution, tax incomes from the mine, and others. They could express the relationships between these variables as mathematical equations. These relationships

KENNECOTT'S OPEN-PIT COPPER MINE in Bingham, Utah.

in some cases are purely mathematical in nature - for example, the percentage of the payroll going to taxes. Other more complex relationships such as the amount of consumer spending resulting from a company's expenditures, have been discovered mathematically by economists and other scientists. And some crucial relationships are understood poorly or not at all in mathematical terms. Yet AMRC's staff and other mathematicians have devised statistical methods for handling these areas of ignorance. Finally, the model could include the constraints under which the process operates: the amount of copper in the ground, the maximization of corporate profit, the legal regulations on mine pollution, and many others.

After constructing this system of equations which will hopefully mimic the real-life problem, the mathematicians could solve the equations for future years of the mine's existence, getting predictions for the economic and environmental conditions in the area over this time. Since many equations would be needed to model this copper mine problem, a computer would be needed to solve the equations. The researchers could also predict the range of errors possible in the predictions.

With this information, the northern Wisconsin farmers and county governments could get some idea of what would happen to their lives if a copper mine were started. They could also have models made for different conditions under which the mine might operate: strict pollution regulations or none, private or cooperative ownership of the mine, and others. In this way, mathematical models could provide people with the information needed to make a rational decision about a complex issue.

Modeling of course has its problems. The system of equations which most accurately represents real-life situations is often too much for even the largest computer to solve. The greatest problem with models, however, is the "garbage in - garbage out" syndrome; models containing false assumptions about the problem will give false predictions. The best antidote to computer-generated nonsense is close cooperation between the model builders and the people using the model, so that everyone understands the assumptions and the limitations built into the model.

Who will staff the Center?

The full-time participant staff in the Center would be responsible for explaining the potential benefits from mathematical modeling, its ability to predict future social, economic and political events, to those persons who have never had any contact with scientific research and to those who are bitter and skeptical about planning and science in general. This staff should certainly be technically skilled, not only in mathematics, but in ecology, meterology, economics and other pertinent sciences. Most fundamentally, staff members must be in deep agreement with the goals of PMRC to ensure that it fulfills its purposes.

It would be impossible to hire scientists such as those who now work at AMRC, for they have shown their willingness to comply with the military and to contribute to the perversions of science described earlier in our report.

Given that scientists are for the most part trained in universities and thus accept the prevailing notion of "pure research", the Center must be very careful in chosing who is to work there, aware that there are a thousand ways for scientists to comply with repressive policies. Credentials must include much more than PhD diplomas; perhaps one criteria might be that researchers must have worked in some occupation considered helpful in judging what directions various communities might take, such as farming, particular industrial skills, and so on.

How will the Center be funded?

Money is the crucial factor for anyone opposing the structure of science in America because funding is the ultimate control over the direction of science. Since the military, other branches of government, corporations, and private foundations are the only institutions with enough wealth to fund scientific research over the long run, any large scale science project must depend on these groups for funds and unfortunately accept some degree of control along with the money. This reality explains much of the massive distortions which the $1,250,000 AMRC grant creates in the research and political thinking of the UW mathematicians working there.

Although a People's Math Center would not need the same inflated budgets that AMRC operates under, where staff receive 50% higher salaries than do comparable math professors in the University, a serious contradiction would still exist between the ideal of popular control and the interests of the institutions which could fund PMRC.

Science for the People holds that a People's Math Center in our present society would have enough strong political benefits to compensate for the stumbling block to complete popular control which funding institutions would impose. Therefore, we call for the establishment of PMRC at the present time. Given current political realities, we feel that the State of Wisconsin is the least objectionable source of funding: it is more susceptible to popular control than federal government, and has access to funds.

PMRC could be a powerful weapon in the struggle for liberation, not just in science, but in unlimited related areas of our lives. The very existence of the Center would constitute proof that the present scientific network, myriad government pilot projects, billions in subsidized university research, corporate planning systems, all absolutely fail to provide the advice and direction we need to improve our lives. It would provide not only proof, but concrete encouragement to millions who now see no research organization speaking for them.

Alternative research will bring the awareness that so many of us have been victimized by the violence of modern science, and give us the strength to oppose and replace the violence with justice.

Research Method

The Army Math Research Center is part of a large, complex Army research and development program, with a prescribed function to supply mathematical advice to all Army bases or centers in need of it. To further spell out the Center's role, our research has sought to integrate four variables: the AMRC staff members, their various visits and contacts with Army installations, the Army researchers they met with during these consultations, and the direction of the research at these military centers.

AMRC STAFF

We considered the specialities of the various staff members and looked up their AMRC publications, listed by the Center as Technical Summary Reports. Since the TSRs are sanitized of any military context by AMRC policy, other sources on the staff's work had to be consulted, ranging from Who's Who to individual publications in the open literature or under government index. The basic information on non-classified research under government sponsorship is found in the Government Report Indexes, published by the Department of Commerce.

In addition to the Government Reports Index, there are special indexes to all defense research, excluding reports classified as "Top Secret." These exist in two forms: the Technical Abstracts Bulletin (TABS), a DOD publication which has been classified, and therefore unavailable, since 1971; and the "Defense R&D" Indexes, reels of microfilm which so far cover the years 1960-69, published by the Defense Documentation Center.

In these government indexes, all research reports funded by the Department of Defense are given a catalogue number starting with "AD". Because the AD-number is the key to locating the research reports, they are cited with every Defense Department paper discussed in our report. From the AD number and the year of publication, the paper can be located either in TABS or the Government Reports Indexes. Selected entire reports can sometimes be obtained by sending the AD number and a small fee to: National Technical Information Service, 5285 Port Royal Rd, Springfield, Virginia 22151. Since NTIS belongs to the Department of Commerce, it neither distributes classified documents nor includes them in their index.

CONSULTATIONS

Some formal contacts with Army bases are listed by AMRC in their three Annual Reports to the Army, published for 1967, '68 and '69. They omit all reference to militarily sensitive consultation, such as that given to Project MICHIGAN in 1967. Therefore, we relied more heavily on the Center's Quarterly and Semi-Annual Reports which have been sent every year to the Army. These give better descriptions of both visits and written correspondence, but even they omit, as J. B. Rosser has stated, the assistance given over the telephone or at scientific meetings. These informal services occur constantly, and are too numerous to be listed in such reports.

Over the years, the reports have contained less and less information. It seems that in the early years, when the Center was striving to prove its usefulness to the Army, its reports go into more detail, even quoting compliments paid to the AMRC staff by their military clients. Now most of the aid goes undescribed, reducing the public's understanding of their assistance.

ARMY STAFF RESEARCHERS

AMRC's Semi-Annual Reports list the Army scientists and research directors advised.

At times, the problems which the Army scientists were working on are also noted by AMRC, but generally these projects must be pieced together from other sources. In addition to the Government Reports Indexes, TABS, and other scientific abstracts, we obtained a broader picture of Army research from Army Research and Development Newsmagazine, in which ongoing research projects and their scientists are placed in relation to military policy and missions. There are even special articles on Army projects and the various researchers who have received awards for their work.

ARMY RESEARCH DIRECTION

For understanding US military projects and policies, Army R&D is useful again, together with TABS and the Government Reports Indexes. In addition, we consulted the National Science Foundation's Directory of Federal R&D Installations (1970), in which thumbnail descriptions are given of the facilities, subject areas, and "missions" prescribed for each government-sponsored research center.

There is a large literature avaliable on US military strategy and techniques, but by far the most helpful is Michael Klare's 1972 War Without End - American Planning for the Next Vietnams. We used it to understand the enormous research networks of which AMRC is one small part, and to visualize its connection to the aggressive military imperatives which these networks aim to meet.

OBTAINING REPORTS AND DOCUMENTS

The source documents were obtained from various levels of the University of Wisconsin Administration. The Administration is required to release the documents to any member of the public by the Wisconsin Statute known as the "Open Information Law". Written requests and repeated telephone calls to obtain the reports were often required because of considerable stalling by the Administration. Once they understood that we would persist even to the extent of a law suit to obtain the documents, they turned the documents over to us.

There were four main types of information that we obtained:

(1) Reports written by AMRC for the Army,
(2) Financial data maintained by the University,
(3) The contract that governs the relationship between the University, AMRC, and the Army, and
(4) AMRC publications.

The AMRC is required by the contract to write Semi-annual and Quarterly Reports. The Semi-annual Report describes the work the Center has done and goes to the Army Mathematics Steering Committee in Washington D. C. (described in Chapter 5). The Quarterly Reports go both to the Army Mathematics Steering Committee and to the Army Research Office, Durham, N. C., where an Army officer oversees AMRC's expenditure of funds. During the years 1967-1969, Annual Reports also were published. These apparently were for public consumption as well as the use of the Steering Committee. It is the 1967 Annual Report which is famous in Madison because certain sections were deleted from the public edition as being too sensitive; these sections covered the work that AMRC did with Project Michigan and other military projects. Since copies of these Reports are submitted to various University offices, they are public documents under the law. Some copies were obtained from the Dean of Letters and Sciences, some from the Office of Research Administration, and the remaining older reports were found in the University Archives.

These older reports plus some historical information came from the files of the past three University Presidents, held by the Archives. Material in the Archives is indexed, and although there are some regulations governing the use of these materials, access is usually obtained if you are persistent. Archives material may be valuable in future investigations of this type and should be used.

Before releasing this material to us, the University anxiously checked it all for any relationships to Karl Armstrong, the man presently facing trial for the 1970 bombing of AMRC. UW Vice Presidents Taylor and Percy and Lawyer Donald Hansen of Chancellor Young's office examined the documents for legal implications related to the prosecution of Armstrong. (Donald Percy's first job at the University of Wisconsin was Administrative Director of AMRC.) Copies of all papers were also forwarded to the State Attorney's General office, for use in the Armstrong trial.

Copies of the 1967, '68, '69 Annual Reports were given to us by AMRC after several months of pressure. The 1967 Report did not contain the deleted section.

Access to the contract and to many letters concerning AMRC were obtained through the

Office of Research Administration of the UW. This office also holds records of money spent by AMRC from which it is possible to find salaries and travel records of the AMRC staff. All the records of this office are public documents, and therefore a valuable source for investigations similar to this one.

AMRC also supplied us with copies of its unsuccesful 1971 proposal for NSF funding of the Center, a list of its recent publications, and the In-Service Educational Opportunities Offered by the MRC, a 1971 publicity pamphlet describing its training programs for Army personnel.

These techniques may well have permitted only a glimpse at any secret research in which AMRC is involved. The information we have collected is only the most accessible, and admittedly, we have only scratched the surface. Where our evidence is incomplete, the whole story can best be uncovered, not by further research of this kind, but by forcing AMRC to make public its full records of Army consultation. Only the Permanent Staff or the Army scientists can give a full accounting of the Center's work. It is our hope that they will be compelled to do so very soon.

Bibliography

Books

Cleaver, Harry. Counterinsurgency Research in Thailand. East Palo Alto, California: Pacific Studies Center, 1970

Cookson, John & Nottingham, Judith. A Survey of Chemical and Biological Warfare. London, 1969 & N.Y. Monthly Review Press, 1971

Hersh, Seymour. Chemical and Biological Warfare. Doubleday, 1969

Hudson Institute. Why ABM? 1969

Klare, Michael. War Without End: American Planning for the Next Vietnams. N.Y.: Vintage, 1972

People's Information Committee. Mathematics for Death: The Army Mathematics Research Center Unmasked. 1970

Meadows, Dennis L. et al. The Limits to Growth. 1972

Nixon, Richard M. U.S. Foreign Policy for the 1970's - Building for Peace. 1971

National Science Foundation. Directory of Federal Research and Development Installations. Washington D.C.: Government Printing Office, 1970

Government Research Indexes

Defense Research and Development of the 1960's (unclassified). Cumulated citations and indexes to defense-generated technical information, Defense Documentation Center/Defense Supply Agency.

Government Reports Index & Government Reports Announcements. Bimonthly publications of the National Technical Information Service, Dept of Commerce

Technical Abstracts Bulletin. Defense Documentation Center abstracts of unclassified defense research (classified since 1 April 1971)

Army Mathematics Research Center Documents

AMRC Contract with the Army (#DA-31-124-ARO-D-462)

Amendment of Solicitation/Modification of Contract. Modification P009 to above contract, effective 27 November 1972, US Army Research Office - Durham, N.C.

In-Service Educational Opportunities offered by the MRC. A 1971 publicity publication from the Center.

Reports: Annual - published for 1967, 1968, 1969.
Semi-Annual.- published since 1956 for the Chairman of the Army Mathematics Steering Committee, Army Research Office, Washington D.C.
Quarterly - early ones sent to Chicago Ordnance District, Dept of the Army, Chicago; more recent ones to Army Research Office - Durham N.C.

Technical Summary Reports. Abstracts of the Center's research publications.

Periodicals

Army Magazine. Published monthly

Army Research and Development News Magazine. Published monthly or bimonthly by the Army.

Committee for Environmental Information. Chemical and Biological Warfare. Special Issue of Science & Citizen; vol 9, no 7, August-September 1967

Transactions of PGMIL of the Institute of Radio Engineers. National Conventions of the Professional Group on Military Electronics - Conference Proceedings. 1957-65

Transactions on Military Electronics. Published by the Institute of Electronic and Electrical Engineers; vol MIL-7, April 1964.

Transactions on Military Electronics. Published by the Institute of Radio Engineers; vol MIL-5, April 1961; vol MIL-6, April 1962; vol MIL-8, January 1965; vol MIL-9, July-October 1965 (In 1965, this was superseded by the IEEE Transactions on Aerospace and Electronic Systems)

Index