Letters to the Editor

Military Funding in Mathematics

This letter is a shortened version of a paper

Military funding in mathematics

Bill Thurston

originally submitted as an article to the *Notices*. I hope that the AMS will decide to start publishing opinion articles *per se*, as do the APS (American Physical Society) in *Physics Today* and the ACM (Association for Computing Machinery) in *CACM*.

The article was commissioned by a group of mathematicians concerned about increasing military funding in mathematics. The original group was Lipman Bers, Lucy Garnett, Linda Keen, Lee Mosher, Barbara Simons, Mike Shub, Jean Taylor and Bill Thurston; we are in touch with many more. This letter does not necessarily reflect the opinions of anyone but me.

We plan a mailing list, and possibly a telephone tree. For more information, write to Bill Thurston, Mathematics Department, Washington Road, Princeton, NJ 08544.

Resolutions on this subject will be introduced at the Council and the General Meeting in San Antonio in January. There will be two related panel discussions during the January meeting: one on military funding in mathematics, and one on Star Wars software reliability.

What is the right question?

In many discussions of funding of science and of mathematics, ethical considerations having to do with the wider society or the longer term are dismissed as extraneous, unprofessional, or political. Such an atmosphere does not do us justice. Human society works only because people regard the welfare of the wider society as an important goal, often above their own narrow interests. People vary widely in their conclusions, but I believe we are nearly unanimous in the starting point.

For the topic at hand, the question is not "how can we maximize the resources and influence of ourselves and mathematics?" but "how can we most benefit society, mathematics and ourselves?"

We mathematicians are the only people who are in a good position to evaluate our impact on society. It is our civic duty to do so *especially* when we disagree.

Although most people desire to act in the best interests of society, many do not think through clearly what this means.

When a moral comparison between alternatives is unclear, people follow the gentle or not-so-gentle pressure of the here and now, the pocketbook.

Relevance

The issue is timely and urgent. We all are aware of deserving mathematicians who are denied NSF support for their research because money is scarce. We know mathematicians who have recently turned to the military, and others who are resisting acceptance of military funding.

I have personally had to come to grips with the issues because I am seeking financing for computation at Princeton, so I can quit spending a large part of my time on computer systems administration, maintenance and programming. Repeatedly, people approach me with opportunities for military funding.

I have chosen not to take that route. More than one person has criticized me, on ethical grounds, for *not* accepting military funding.

The military and support of science

World War II was a high point for the US military. The country had a united spirit in fighting against an evil regime in Germany and an imperialist regime in Japan — almost everyone was involved. Aspects of the war are controversial in some circles, but the patriotic unity and spirit of our nation is not disputed.

After World War II, the ONR (Office of Naval Research), followed by the AFOSR (Air Force Office of Scientific Research) and the ARO (Army Research Office) began supporting basic research in mathematics and other sciences. Many mathematicians whom I respect praise the management

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Publication decisions are ultimately made by majority vote of the Editorial Committee, with ample provision for prior discussion by committee members, by mail or at meetings. Because of this discussion period, some letters may require as much as seven months before a final decision is made. Letters which have been, or may be, published elsewhere will be considered, but the Managing Editor of *Notices* should be informed of this fact when the letter is submitted.

The committee reserves the right to edit letters.

Notices does not ordinarily publish complaints about reviews of books or articles, although rebuttals and correspondence concerning reviews in *Bulletin of the American Mathematical Society* will be considered for publication.

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of funding during this period. I was too young to be involved, and I accept what people tell me.

The NSF was founded in the early 50s and began to replace the military agencies as a funding source. The military agencies gradually shifted toward applied rather than basic research.

When Sputnik was launched in 1957, science became a high national priority. More resources became available. The Advanced Research Project Agency, or ARPA (to which Defense was later prepended making it DARPA) was founded in 1958. In theory, DARPA is an agency which funds initiatives in areas of strategic interest to the US, rather than providing sustained or broad support for science. They have played a crucial role in the development of Computer Science as a discipline.

During the long and bitter war in Vietnam, the military presence on campus was curtailed, after much controversy. Finally, the Mansfield amendment was passed in 1969, ordering the military only to fund projects directly related to their mission; other scientific funding was supposed to go through the NSF. The trend has persisted until the present.

During the years of the Carter and Reagan administrations, the military budget has grown tremendously. The military is not the same organization it was after World War II. Our large military establishment has no definite mission against which performance is tested. Projects such as the MX missile have some kind of bureaucratic logic, but are hard to justify by any external criterion.

The effect of this huge influx of military money on science and engineering is documented in the pamphlet *Basic research: the key to economic competitiveness* by NSF director Erich Bloch: federal money for research and development has shifted from about 50 percent civilian and 50 percent military in 1980, to 28 percent civilian and 72 percent military in 1985. When the comparison is limited to research (excluding development), the percentages for military funding are smaller but the increase is similar. The thrust of this change has been away from basic research, and toward applied research.

Within the last two or three years, a new program in mathematics has arisen through DARPA. Its budget is now $10,000,000, quite a large chunk of the total Federal mathematics support. This program has evoked controversy, partly because it touches areas of mathematics which have not previously had military funding and partly because of criticisms of its management and narrow stated goals. It is defended and supported by our mathematical leadership on the grounds that if we cooperate with the program, we will eventually be able to straighten out its problems.

The SDI (Strategic Defense Initiative or "Star Wars") is another major potential source of military funds for mathematics. There is currently about a million dollars of SDI money in mathematics, but next year there may be much more. The Board on Mathematical Sciences recently organized a meeting between mathematicians and representatives from ISTO (Innovative Science and Technology Office), the arm of SDI funding research in universities, to investigate how mathematicians could help with SDI.

I won't take space to explain the dangerous and fraudulent nature of SDI, for in my experience mathematicians and scientists largely agree on this. SDI might not be politically viable after the end of the Reagan administration. Some scientists argue that although they regard SDI as stupid, they need not work against it, since it is unimportant and will die of its own weight.

But SDI has already had a large influence on the arms race. The Reagan administration has rejected the concept of a mutual verifiable ban on nuclear testing on the grounds that it would interfere with SDI research. In Iceland it has rejected a near-agreement for major mutual disarmament on the same grounds. *Newsweek* reports that Richard Perle (an influential DoD hawk) uses SDI as a monkey wrench in the arms control process. Whatever the ultimate outcome of the arms-control talks, and whatever opinion we have on the desirability of arms-control or of SDI, we cannot dismiss SDI as insignificant.

Generations

Those of us who came of age during the Vietnam war experienced a culture very different from that of people just a few years older. The generation gap was strong; it was "us" against "them." "They" were living in the past, sending "us" to fight in an immoral war. Many of us were involved in student demonstrations and student strikes. We were sprayed with tear gas, whether or not we protested. We had friends who were killed, others who refused induction and were convicted as felons, and others who served in Vietnam and survived with psychological scars that still dominate their lives.

But it is important for us of the Vietnam generation not to live in the past. Mathematics is a multigenerational and international enterprise. We need to recognize that others have been shaped by very different and sometimes very terrible experiences.

Many mathematicians who came of age during or after World War II but before the Vietnam war decry the current nature of the military, the SDI program, and perhaps the current DARPA program, and would like to see a return to the seemingly benign relationship between science and the military, as it was after World War II.

This is no longer the post World War II era and it is no longer the Vietnam era. We should re-examine the issue of military funding in light of the present and of what we hope for the future.

MILITARY SOCIETY AND ACADEMIC SOCIETY

There is a basic contradiction between the principles which govern a military force and the principles of the academic environment. Military action is coercive. It is an extreme recourse, which should only be used under great duress. A military force is governed by authority, for it must act in concert.

In contrast, an academic institution is a place for reflective thought, diverse views, and considered discussions, not for the exercise of authority or coercion. It protects people from political fashions. It serves a society as a source of new ideas and a source of criticism for old beliefs.

For the health of society, military institutions and academic institutions should be *separated.* If, as many say, military institutions are not healthy enough to meet their internal research needs, let's cure the sickness rather than spread the disease.

For purposes of discussion, we can divide military funding of science into two loose categories: true military research, and general research.

True military research is by its very nature secretive. Information which is freely exchanged in the international academic community does not give a competitive military advantage to a particular nation. True military research certainly does not belong in a university. Nevertheless, it is present. For example, senior faculty in some of the best computer science departments are working on a big project to design "intelligent" military vehicles.

Much of the research funded by the military on university campuses is not truly military research, but general research. Scientists on military grants often maintain that they are doing the same basic research they would be doing if their grant was from NSF. On the collective level this is clearly false: military funding priorities are very special.

It is a dangerous reversal of the proper relationship between military and civilian life when control of civilian enterprises is funneled through the military. This reversal has taken place in fields not far from mathematics. It is difficult for students in many fields to *avoid* working on military projects. In places like MIT, graduate students in physics routinely shuttle between summer jobs doing true military research at the affiliated military laboratories, and general research funded by the military on the campus. The reversed relationship has funneled too much of our scientific and engineering effort into military matters.

In computer science, the major departments are now the ones which have a good relation with DARPA. According to an ACM report *Imbalance between growth and funding in academic computing science* by Gries, Miller, Ritchie and Young, a survey showed that in the top four departments the NSF support per faculty member in 1985 averaged $31,000, while that from the Department of Defense averaged $279,000. Such a department is in effect owned by the military. During quiet periods, the military is usually wise enough not to pull as much as they might on the strings, but the strings are well in place, to be pulled at need and at will. The military funding has emphasized applied research at the expense of theoretical research. In important areas of research such as VLSI (very large scale integration, the technology used for today's most important computer chips), the influence is so strong that information exchange is primarily at military conferences, not in journals. The information is available only to insiders.

The setting of research priorities should be a civilian process. The reversal of roles in which the military took responsibility for scientific research may have been appropriate during and shortly after World War II, but it is inappropriate, inefficient and dangerous today.

MATHEMATICS DEPARTMENTS

Mathematicians are reluctant to concern themselves with grants of their colleagues.

Such an attitude makes sense only as long as grants are small in scale, and do not impinge on others. With the new funding, this is no longer the case. There are community issues within mathematics departments of immediate concern to mathematicians.

The typical military grant is large in comparison to other sources of funding within most departments, especially in this time of funding scarcity. The money has an impact on graduate students. A department has two choices: student support is either distributed among students in a wide pool, or it goes to students of the participants in the grant.

With the first approach, students are essentially forced to take military money in order to remain in the department. Students are in a position of disadvantage in presenting their case, and it is not right to trample over their scruples.

The second approach leads to inequity: students of those who accept military grants likely receive better funding than those who do not accept military grants.

An additional difficulty is that foreign students are not eligible for support on many military grants.

There is a similar problem regarding computer equipment, which is increasingly important to mathematicians. If equipment is pooled within a department, members of the department are forced to accept military money to use the equipment. If equipment is not pooled, mini-empires are created within departments, a commonplace and divisive phenomenon in some disciplines.

Should people who have scruples against military grants or who do not have research

interests in fields favored by military agencies be handicapped in attracting graduate students, in this time of a shortage of students? *Do we want this process to determine the direction of mathematics?*

MANAGEMENT

Military funding is frequently not managed for the good health of science. There are two reasons for this.

First, although the decision process varies among military agencies, it often involves much less expert and disinterested outside input than the process in the NSF. Thus, decisions are much more dependent on the integrity and quality of the program directors — which is variable. Personal relationships, rather than quality of research, may determine research grants. Researchers are tempted to say what the program administrator wants to hear. It is easy to invent proposals which are persuasive to people who don't quite know what is going on.

Second, the research funded by the military must be justified by military needs, not just scientific interest. At the 1986 mathematics chairman's day, Arthur Wouk of the ARO (Army Research Office), described the mission of the ARO program in mathematics: shock, blast, and penetration. His frankness is to be commended; it is not the ARO that sets these goals, but the army research labs and the generals. Some mathematical methods useful for understanding shock, blast, and penetration are of general interest, but this is a byproduct. Similar public statements can be found for the other military agencies.

The narrowing of goals stemming from mission-directed research saps the health of mathematics. The strength of mathematics comes from its diversity and its unity. Mathematicians study a tremendous range of interesting phenomena. As we go from one mathematical theory to another, we find connections which give us glimpses of one magnificent edifice which encompasses them all. Mission-directed research prevents us wandering where our interests lead. If one compares the tremendous intellectual breadth of research supported by the NSF mathematics division to that supported, with a comparable total budget, by the military agencies, it is clear that the ratio of ideas per dollar is far larger for the NSF.

WE LIVE IN A DEMOCRATIC COUNTRY

One rationalization for military research starts from the fact that we live in a democratic country. The train of thought continues: Democracy means individuals following the will of the majority. Since the general public and elected officials seek increased military power, it is our duty to go along; moreover we must explain our own research in military terms so they will listen to us.

In fact, the few bits of preference we communicate on election day are but a small part of democracy. The real workings of democracy are the discussions and actions of many people; elections are the guarantee and catalyst for this process.

For instance, military contractors often say their work is chosen through a democratic process for the good of the country. But the defense contractors all have strong lobbying efforts in Washington. Military projects are in fact born and nurtured in a coalition of lobbyists from industry, lobbyists from the Pentagon, and politicians. The military contractors have a large input to and a large responsibility for the choice of their work.

The combined mathematical societies, through the Joint Policy Board on Mathematics (JPBM) and its representative Ken Hoffman, have been sponsoring a strong effort in the Pentagon and in Congress to persuade them to increase Federal support, and in particular, military support, for research in mathematics. Their effort has been effective. The JPBM has solicited grants from DARPA for funding of mathematics awareness week. Ken Hoffman has defended DARPA against criticisms within the mathematical community. The JPBM and the Board on Mathematical Sciences selects and solicits mathematicians to testify before Congress and speak to the press: they explain that we need to present a simple message, spoken with one voice.

It is disingenuous to say our actions are merely in obedience to a democratic decision; these actions *are* the democratic process. Let us use this process to express our actual knowledge and our real beliefs.

THEOREMS AND BOMBS: THE EFFECTS OF MILITARY FUNDING

Many say that the act of accepting military funding is irrelevant to society at large: its only practical effect is to channel money away from bombs into better uses.

Money is one aspect of the research which is rather negligible to the military. The entire Federal mathematics research budget is about 1/5000 the size of the military budget, comparable in cost to a single fighter plane.

What difference, then, does military funding make? Strong effects are clearly visible: effects in technology, in politics, in the international order, and in culture. I will discuss these in turn.

Technology. In dismissing the relevance of their work to the real world, pure mathematicians forget that the development of mathematical knowledge is an informal process not measured merely by theorems. Progress in mathematics is mainly the clarification and compression of thinking and the sharpening of concepts and analytical tools. The accompanying logical lattice of

formally stated and established theorems is significant, but as new and sharper concepts replace old, mathematicians can often quickly reconstruct proofs for theorems which were once difficult.

Mathematics is a universal subject precisely *because* it is abstract. The fields of mathematics are intellectually closely related. Although human limitations lead individuals to specialize, still, mathematicians have in common a powerful and general-purpose way of thinking.

Recently, through circumstance, I have spent time with computer scientists. I find myself talking and thinking about computer science problems, and analyzing them with modes of thought sometimes foreign to the culture of computer science. I enjoy this. My experience would be similar if I were to spend time with physicists, biologists, economists, chemists, engineers ... — or with weapons makers. My theorems are not the commodity which I have to offer them, but rather expertise in mathematical modes of thinking.

When the military funds academic research, the most important *technological* commodity they buy is access to the intellect and intellectual environment of the researchers.

Politics. Military funding of scientific research by respected scientists and in respected academic institutions has a political effect, independent of its technological effect.

First, the funding undercuts potentially strong opposition by scientists to military projects. Some people argue that mathematicians should oppose the DARPA program in mathematics on an institutional level, but not on an individual level; people should take grants from them, but register their opposition to the program as a whole. How many of the mathematicians currently receiving DARPA support are likely to publicly register such opposition? At the 1986 DARPA mathematics meeting at Boston University, the director of the DARPA mathematics program, Dr. Helena Wisniewski stressed the need for people with grants in the program to go out and support the program. This is natural; people with grants from the NSF go out and defend their program. It puts those who accept support in an awkward position if they believe the program itself is dubious.

Donald Hicks, recently resigned as undersecretary of defense for research and engineering, made an infamous public statement in which he said that he would like to see funds cut off from scientists receiving support from the DoD who speak out and "bite the hand that feeds them."

A second political effect of military funding arises from the high prestige of university research in the eyes of the public and Congress. This acts as a political lever. Ionson, the director of SDI's Office for Innovative Science and Technology, said, "It's probably something that's never been done, but this office is trying to sell something to Congress. If we can say that this fellow at MIT will get money to do such and such research, it's really something to sell." Scientists will never receive a large proportion of the defense budget, but they can make a large impression in the minds of Congress. Their research greases the way for far bigger expenditures on far more noxious projects. On a smaller scale, program directors in the military agencies cite distinguished participants, who are given freedom to ignore the program mission, in order to justify their entire programs.

Military funding of mathematics is like a portion of the military advertising budget. It is small in proportion to the total budget, but highly visible. Computer-generated pictures by mathematicians appear on their glossy brochures and postcards. Many people who would not even consider accepting direct payments to advertise in favor of higher military funding or SDI accept "advertising" money indirectly for their research. When you accept support, you should consider whether the product you advertise is a product you wish to promote.

The international order. Mathematics is a particularly international field. The military encroachment on US mathematics will drain this international spirit. Many foreign mathematicians already are inhibited from discussing international relations with Americans because of different understandings of the world; this effect will grow.

In every country, people like Edward Teller warn about the enemy's ominous military research. All military-funded research adds to the atmosphere of threat, because politicians can't tell true military research from military-funded general research. The atmosphere of threat is more important than military capability. France has enough military warheads to destroy the United States, yet this does not disturb us, because our relations are generally good.

Culture. There are marked cultural differences between academic disciplines. The cultural differences play a large part in the careers and political outlooks of members of the disciplines. I don't think I need to give examples since we have all seen them. Militarily-funded general research paves the way to a culture which accepts true military research, classified research, and weapons research.

People model behavior on the behavior and expectations of those with whom they associate. This is a very powerful force.

NEEDS

The needs of mathematics and of mathematicians for more resources are clear and not in dispute. We are facing a shortage of mathematicians in the very near future — we need better support for students and for postdocs. Also, we have large needs for wider summer support, along with new

needs for computer equipment and technical staff to support and maintain the equipment.

Being poor does not mean we should sell out.

WE ARE NOT POWERLESS

Some people say it is a political fact that people in our country are much more ready to vote for something if it is justified in military terms. It is much easier to get what we want if we pose it thus. We are not the ones to decide how money will be spent; we have to take what comes along, or be left behind. Ken Hoffman compares the situation to Dunkirk: the boats may look rather leaky, but if we are going to sit on the beach and wait for a troop carrier we will be left behind.

We are not under attack from a hostile force. We are also not powerless. We have a strong case, and an important product: we do not have to sell it for potential military applications. Mathematicians have traditionally been detached from politics and lobbying, but that does not mean we never can or will take action.

There is great power in truth and sincerity. The mathematics community has tremendous reserves of human potential energy. If we are lean and hungry, we are likely to use our energy. If we are honest, it is likely to be effective, for whether justified or not, the public and Congress hold scientists (including mathematicians) in a certain awe. Let us tell the NSF, tell Congress, and tell the public what mathematics is really about.

CONCLUSIONS

1. There has been opposition within the AMS to discussion of the wider issues associated with military funding, with the explanation that they are political issues. Democracy is political; the issues are professionally and ethically of great moment, and we need to have a general discussion in which all responsible points of view are considered.

2. Funding of basic research is an important societal need, and it should be met through civilian agencies. Academia should be separated from the military. Military funding of research in universities, and of mathematics in particular, is bad for our society, bad for the universities, and bad for mathematics.

The military pattern of funding has a large negative impact, since it attaches strong strings from the military to academia. Even in normal times, this channels the short supply of mathematicians into an intellectually limited range of topics, and distorts the debates on societal issues. In troubled times, the strings can be exercised to disastrous effect.

Individual funding by military grants has a negative impact on the rest of the community — an impact on dangerous technology, on politics and public relations, on international relations, and on the culture of mathematics itself.

3. We should resist the increasing role of the military in academia and in mathematics, and work to replace military funding by civilian funding.

3a. Those of us who believe military funding is wrong should reconcile our actions to our beliefs.

We should also discuss the issues, without rancor, with people who believe military funding is right, and with those who believe military funding is wrong but that acceptance of military funding is right. Many sincere and well-intentioned mathematicians have military grants; some of them work in fields or subcultures where they have little choice but to accept them. During the era of the Vietnam war, there was much name-calling concerning the question of the military on campus. We need to recognize the honesty and good will of those who accept military grants, while opposing their actions. It is up to the conscience of the individual what grants to accept.

3b. The AMS should take a position in the JPBM and instruct its agents not to promote military funding, and it should make a policy decision not to participate in military grants.

3c. The Board on Mathematical Sciences, an arm of the NRC and NAS, should stop acting as a marketing agent for military funding programs.

3d. When a consensus can be reached, the AMS should take the further step of advocating decreased military funding, taking particular care to find appropriate alternate funding for fields which have traditionally depended on military support.

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The Goal of Communicating

When trying to glean from papers the authors' motivations for doing the work, we often get an impression that the authors might be saying "so and so worked on this problem and I can generalize those results," in other words, the goal is one-upmanship. There is very little discussion of goals in the literature. Graduate students form their views of research in large part from the literature so this lack of guidance encourages the beginner to do motivationless research.

I would like to propose to those who might feel a lack of direction that they try to adopt as their primary research goal the discovery and communication of ideas that people need to know. Ideas that surprise. Ideas that are useful. Ideas that need to be communicated. Why they need to be communicated and to whom is up to the researcher to decide. This type of research requires a different approach. At least half the effort should be put into finding the right problem. Technical power in the proofs may turn out to be useful, but it is a secondary by-product, no more important than the results. There are