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SOVIET SCIENCE UNDER GORBACHEV*

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Gorbachev has exposed science to the same pressure for restructuring as all other sectors of Soviet society, as there has been an increasing recognition of poor scientific returns on a major investment. Some of the key problems of Soviet science are examined, in two basic categories: problems which are internal to Soviet science itself and problems of its relations with the outside world. The first category includes planning and funding difficulties, management style, and management-staff relations; the second, backwardness in key technologies and isolation from the world scientific community. The analysis of each of these areas of difficulty includes an account of current attempts at reform.

Keywords: Soviet Union, Gorbachev, science.

Science has experienced the trauma of *glasnost'* and *perestroika* no less than other areas of Soviet life. There has been a major public recognition of serious problems. Before Gorbachev came to power there was a considerable degree of public — and probably private as well — complacency about the performance of Soviet science. There was some degree of justification for such complacency, with Soviet scientists having achieved a number of spectacular successes in the nuclear and space fields and a respectable number of Nobel Prizes through the 1950s and 1960s. At the same time macro-level quantitative indicators, such as numbers of research personnel, funding as a percentage of national income, and the construction of 'big science' facilities, were impressive.

If there were problems in overall science and technology (S&T) performance, these were blamed on the production sector and its links with science (the notorious problem of *vnedrenie,* the implementation of research results in production), rather than on science itself. Further, if the science sector was unable to avoid the blame altogether, it was the applied sector which attracted the opprobrium, not the fundamental sector. This could be best seen in the very high status of the Academy of Sciences.

To a considerable extent this view of things was accepted by Western observers. There was a tendency to assume that Soviet scientific research, particularly in the fundamental sciences, was in reasonable shape. Thus the overwhelming bulk of detailed empirical research was in the areas of technology, innovation and *vnedrenie.*[1]

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With the coming of *glasnost'* the focus has been directed towards science, including fundamental science, as an area of significant difficulties. Criticism of the science sector has been a feature of Gorbachev's approach from the very earliest stages of his leadership. This has led to a response from some sections of the wider community which can only be characterised as a major anti-science and anti-intellectual campaign.[2] Scientists themselves have also not been slow to offer criticism of the performance of their own sector. One sometimes suspects that in doing so they are not always entirely objective — they are either settling scores with old enemies, putting in bids for increased resource allocation or simply trimming their sails to suit the tone of public debate. This might suggest that we should regard the new spirit of 'criticism and self-criticism' with a degree of caution. However there is, and has been for some time, good evidence that a problem does exist.

Of course, it would be a rare form of human endeavour that operated with no difficulties at all. The question we have to grapple with here is how serious are the problems of Soviet science. Perhaps the best, although by no means an easy, measure is the performance of Soviet science compared to world standards. Do Soviet scientists contribute a reasonable proportion of new discoveries? Can Soviet science rapidly replicate and further develop discoveries that are made abroad? Are Soviet scientists treated as equals by their Western colleagues? These are measures by which Soviet scientists themselves have become extremely self-critical recently. As far as some are concerned, the question is no longer whether there is a gap between Soviet and world science, but far more importantly whether the Soviet Union is in a position to even aspire to closing that gap. That is, has change in the world scientific community become so rapid that the Soviets are no longer even in the race?

This is not a question which I am able to answer with conclusive objective evidence. All I can do here is offer some scattered data on comparative Soviet performance, as well as some of the recent comments of Soviet scientists themselves. We can then go on to look at the possible reasons for any shortcomings we might find and evaluate how easily they might be overcome.

SOVIET EVALUATIONS OF PERFORMANCE

There have been two features of very recent statements from Soviet scientists about Soviet research performance. First, there is the extremely pessimistic tone, including declarations that something will have to be done very soon or it will be too late; second, there are the claims that there has been no improvement and possibly a decline over the five years of *perestroika.* One of the most authoritative statements comes from Gurii Marchuk, the president of the Academy of Sciences. After a period of apparently being reluctant to accept radical change in the Academy,[3] he has become increasingly outspoken over the last 12 months about

the difficulties faced by Soviet science. In a July 1989 article in the new science newspaper *Poisk* he stated that the gap with the West in such major fields as computer technology, quantum electronics, laser technology and biotechnology was not decreasing and that nothing that had been done over the last few years went more than half way in overcoming difficulties. He then went on to say most ominously:

> We have come to a dividing line, when backwardness could acquire a qualitatively irreversible character. . . . . Our situation is unique in the contemporary world: a crisis in science in a country with the combination of a deep scientific tradition, a tremendous store of knowledge and a large number of scientists.

His latter comment is in the context of comparing Soviet performance negatively with that even of developing nations.[4]

The *naukoved* (scientist of science) S.G. Kara-Murza was just as blunt in an article in the Academy's journal in early 1989. He noted the change in attitudes to scientific performance over the years of *perestroika.* He pointed out that at the *27th Party Congress* in 1986, although there had been considerable criticism of the science sector, the line had been that the Soviet Union possessed a great scientific capacity and it had only to learn how to use it correctly. Now the problem was discussed in very different terms. He stated bluntly that Soviet science could no longer be considered as part of world science. Shortages of up-to-date equipment meant that Soviet scientists were not even able to reproduce world scientific achievements much less do pioneering work themselves. Because of backwardness in communications technology Soviet scientists were unaware of work being done in other parts of the world and were unable to inform others on those rare occasions when they did make a discovery.[5]

The articles of Marchuk and Kara-Murza are perhaps the most blunt of recent times. However other leading scientists are perfectly prepared to back them up with statements that the lag between the Soviet Union and the rest of the world is increasing and that Soviet science is now too weak to be able to make any serious contribution to solving the Soviet Union's host of technical, economic and social problems.[6] It is noteworthy that all these statements stress the parlous state of fundamental science, the area in which the Soviet Union has traditionally maintained some pride in its performance.

WESTERN ANALYSES OF PERFORMANCE

Over the years some work has been done by Western analysts on the quality and effectiveness of Soviet research. It is recognised that the work is of a scattered and fragmentary nature, and that there are serious methodological problems involved in all the various approaches adopted. However, the high degree of agreement between the findings of all studies is striking, and it is an agreement which is not favourable to the Soviet

Union. There is some debate over some areas of work, and even general unanimity on Soviet excellence in particular fields. But the general impression is of a level of performance lagging considerably behind that in the West.

In the fundamental sciences the main methods used have been publication and citation analyses and records of the impressions of *émigrés* from the Soviet Union and of Western scientists familiar with the work of their Soviet counterparts, usually as a result of academic exchanges or collaborations.

Publication and citation analysis has been used perhaps least of all. Presumably this is because it is an excessively time-consuming job. But there are also considerable methodological problems involved. There are technical problems of the coverage of the citation indexes, but perhaps more importantly publication and citation practices are so culture specific that the results of this type of analysis require considerable interpretation. Perhaps most importantly there could well be a tendency for Western scientists to neglect Soviet publications for cultural or linguistic reasons that are in no way related to their quality. Furthermore classified research, which many consider to be among the Soviet Union's best, will not feature at all. Irvine and Martin recognise this in their study of high-energy physics, and so combine their citation and publication analysis with the more subjective peer evaluation approach. Their findings overall are of poor performance at Soviet accelerator facilities, including in terms of publication and citation results.[7] Narin, Frame and Carpenter, in a number of studies covering all the major natural science disciplines, found consistently low levels of citation of Soviet articles, even in areas in which the Soviets are generally acknowledged to do good work. The latter fact is enough to make the authors wary of drawing any conclusions from their data on the quality of Soviet research.[8]

Enormous programmes for interviewing Soviet *émigrés* have been undertaken in recent years, following the large-scale primarily Jewish emigration of the 1970s and 1980s. The Harvard-based project *Soviet R&D: information and insights from the third emigration* concentrated on *émigrés* with R&D experience and its results have now appeared.[9] While important caveats are expressed about the nature of the sample and reliance on essentially anecdotal information, the conclusion is reached that "despite the considerable strengths of the Soviet science system, the cost of its weaknesses have become so enormous that they can no longer be tolerated."[10]

Beyond responses to structured surveys *émigrés* have provided a considerable input into our understanding of Soviet science through their own writings. These accounts range from the damning to the respectful. The best example of the former is Mark Popovsky's book.[11] Although he makes no claims to a specific analysis of the quality of Soviet science, his picture of corruption and demoralisation hardly allows for either high quality or high productivity research. Most of his compatriots

publishing in the West, while not always as uncompromising and indeed at times concerned to point out to the West the underlying potential the Soviets have, nevertheless confirm his general picture.[12]

The final source of information we have are the impressions of knowledgeable Western scientists. Many of these are little more than throw-away lines in the Western popular science press. An example is Peter Smith's characterization of Soviet earth sciences as "mediocrity that looks suspiciously like the result of isolation and inbreeding", with papers that are "all too frequently vague, uninformative, impoverished in data and almost completely lacking in international outlook".[13] When a greater number of Western scientists are brought together to discuss Soviet science, as was done by the Scientific Affairs Division of NATO in September 1986, the conclusions are not surprisingly less black-and-white. Nevertheless the general picture of backwardness is confirmed, even in fields in which the Westerners felt it worthwhile and even essential to keep up with Soviet work or to work with Soviet scientists.[14]

By far the broadest surveys of Western scientists have been carried out under the auspices of the US National Academy of Sciences and based on questionnaires sent to American scientists going to the USSR on inter-Academy and science and technology exchanges, and to the hosts of Soviet exchange researchers. The so-called *Kaysen Report* is the most concerned with the fundamental sciences.[15] While the respondents were generally enthusiastic about the exchanges and about the scientific value of the co-operation in which they were involved, they still considered the USA to be ahead of the USSR in most scientific disciplines. Further, they tended to support the exchanges more for their political and cultural benefits than for purely scientific reasons.

It is in the area of reports from Western scientists with direct experience of Soviet research institutes that we have one of our most recent pieces of evidence. A group of US scientists visited the Institute of Solid State Physics in Chernogolovka in 1988, and returned with the impression that the Soviet Union was five to ten years behind in gallium arsenide research. While the Soviets had impressive achievements in the quality of their metal oxide semiconductor structures, there was debate on whether this was due to superior production techniques or simply careful selection of the best examples from large production runs.[16] The evidence here is not enough to tell us whether things have got worse under *perestroika*, but it does confirm a general lag.

It should be pointed out that most Western sources, although agreeing on a general Soviet lag, are aware that the picture is far from uniform. It is recognised that the Soviets do far better in some areas than others, and that in some they are catching up faster than in others. Thane Gustafson points out that Soviet pure science is strongest in fields that depend least on material support, including mathematics as the outstanding example.[17] It is considered that the Soviet educational system, while perhaps having other faults, does provide an excellent

grounding in mathematics and the theoretical aspects of various disciplines.[18] It has usuallly been assumed that defence-related work is of higher quality, because of its higher priority, tighter quality control, and better management, although a number of analysts are now questioning that assumption.[19]

Despite these qualifications all Western sources agree that in general Soviet fundamental research has lagged behind that of the West. Authoritative Soviet commentators are of the opinion that if anything the lag has increased over the period of *perestroika*. We must now turn our attention to what the reasons for this lag might be. There are two rough categories of explanations. There are those problems which are internal to Soviet science itself and the solution of which therefore depend on the Soviet Union alone. There are then problems of the Soviet Union's relationship with the outside world and the changes in that world over which the Soviet Union has no control. I cannot hope to deal with all the problems in either category in this paper. In the first I will concentrate on two major issues: science planning and funding, and management style and management-staff relations. In the second category we will look at Soviet backwardness in some key technologies on which modern scientific research has come to rely, particularly materials science and computing. The concern with computing will lead on to the problem of the isolation of Soviet scientists from the world scientific community.

PLANNING AND FUNDING

A major issue in any consideration of research performance is funding levels. If we are trying to explain relatively poor Soviet performance we might need to go no further than to point out that the USSR is trying to compete against the combined might of all the Western powers, including Japan.[20] Even when Western analysts determine that the Soviets devote a higher percentage of their national income than most Western countries to science, the actual amounts spent clearly diverge enormously.[21] Soviet funding faced increasing difficulties in the 1970s and 1980s as general economic performance declined. Despite a continuing bleak economic outlook Gorbachev's government has worked hard to increase science funding. The year 1989 saw a planned 20 percent increase in the science budget, including a 32.3 percent increase for fundamental science.[22] Even these increases, particularly after adjustment for what are now quite high levels of inflation, will do very little to narrow the funding gap.

Many analysts suggest that the funding gap is by no means the only explanation for poor Soviet performance, and indeed that the USSR gets quite a poor return on what are substantial investments. Many lay some of the blame at the door of the central planning system. Fortunately, we do not need to become involved here in a deep discussion of the advantages and disadvantages of central planning. There has in

fact never been as much genuine central planning of Soviet science as many outsiders might believe, while planning is now so much a feature of Western science that we cannot say that it is what sets Soviet science apart. It is true that Soviet institutes operate and are funded and equipped according to detailed yearly and five-year plans and even longer-term programmes. However institute managements have always had major opportunities for input into the compilation of plans and their adjustment during implementation. Indeed the fear has often been expressed that the traditional planning system has not ensured the degree of financial responsibility and discipline required for the efficient use of resources. Institutes have received guaranteed central funding for the same projects year after year with no outside bodies being willing or able to ensure that the projects are finished within a reasonable time, that the research being done is of good quality, or that the best quality researchers are receiving funds. These concerns have always led to one of two possible responses. The first is greater centralisation, in which central authorities try harder to enforce centralised allocation of funds and monitoring of performance. These efforts usually add to the information overload problems that are typical of central planning and so lead to greater *de facto* decentralisation and financial irresponsibility. The other typical response is decentralisation, in which institutes are made responsible for their financial health and are required to obtain enough funding for projects to cover costs.

This is very much the favoured approach at the moment. Institutes have been put on *khozraschet*, roughly translated as profit-and-loss accounting. The meaning and intent of the new approach are summed up in the September 1987 decree, *On transferring scientific organisations to full* ***khozraschet*** *and self-financing:*

> Proceed on the basis that scientific organisations like production enterprises are socialist commodity producers and their work must be based on the principles of full *khozraschet* and self-financing. They provide for their scientific-technical and social development with resources earned through the realisation of developments for users, and bear full responsibility for the results of their economic activity. . . . . In the absence of orders for research and developments and in the case of the prolonged fruitless work of a scientific organisation and the failure of its superior organisations to achieve effective work the scientific organisation ceases to operate.[23]

It is recognised that the approach can only be applied with anything like full rigour to applied research institutes, whose function is to produce research for interested customers on the basis of contracts. Fundamental research institutes are subject to the provisions of the decree, but the bulk of their contracts take the form of the *goszakaz (gosudarstvennyi zakaz,* state order). The *goszakaz* is the by now infamous concept introduced into industrial management to replace the traditional plan task. It is in fact an obligatory task given to the operational body by bureaucractic superiors and has little of the sense of a mutually voluntary

contract. This has meant that the bulk of fundamental research continues to be funded from the central state budget.[24]

The big change, in intention anyway, in the funding of fundamental research is not where the money comes from but how it is allocated. The intention is that funding be allocated to projects or programmes, rather than according to the old system of block funding for institutes. What seems to be meant here is that whereas in the past an institute received a lump sum based on the projects listed in its plan, with institute management having considerable flexibility in moving funds around, now funds will be allocated to a researcher or group of researchers to be disposed of only by them and only on their project. Further, funds will be allocated on a competitive basis. Essentially the Soviets are trying to introduce a Western-style research grant system. We are all aware of the disadvantages of the research grant system — the amount of time scientists have to devote to preparing grant applications, the pressure on scientists to devise marketable research, and the danger of conservative cliques getting control of the evaluation process. However there seems little doubt that such a system would introduce some much needed competition and discipline into Soviet research.

MANAGEMENT STYLE

Proponents of the research grant system must regard the last of its disadvantages just mentioned with great foreboding. One of the major reasons for introducing the system was to break the power of the scientific monopolies that dominate Soviet science. It is these monopolies which have been the subject of the most persistent and bitter criticism in the *glasnost'* era. We are not talking here of full-blown Lysenkoist type control of scientific disciplines, where ruthless operators used political patronage, bureaucratic bullying and ideological manipulation to destroy scientific rivals. It seems that since the fall of Lysenko in 1966 the political authorities have been reluctant to buy into scientific struggles. However we are talking about mini-Lysenkos who if not able to dominate whole disciplines as he did are at the very least able to dominate their own institutes. Russian science has always been very 'school' oriented, and that combined with the authoritarian culture typical of the Soviet Union has produced fertile ground for some pretty unsavoury science managers. It could be argued that the problem is compounded by the traditional Soviet expectation that research and administrative leaders be combined in the same person. We find that scientific recognition comes through the gaining of a senior administrative post, but while that post is occupied the appearance at least of scientific success must be maintained. This produces an incentive on the part of managers to appropriate the research of others and to prevent the emergence of rivals. The administrative position makes it possible to act according to the incentive. We thus find that plagiarism is not uncommon, while contributions by managers to an improbable

number of publications is rife. Recalcitrant researchers find their projects being closed down and laboratory equipment and records destroyed, themselves being demoted and dismissed, subject to ideological accusations and in some of the worst cases to imprisonment. Particularly under the traditional funding system, only the projects of those in good odour with the director would get into the plan or the director could use his discretionary powers to direct funds away from his enemies.[25]

As already suggested, the research grant system has been introduced at least partly in order to break the control of institute directors over funds, by giving project leaders direct control over their allocations. This of course will work only if the grant evaluation and allocation system is fair. It should surprise no one that reports are appearing that the system is in fact dominated by the monopolies of old.[26]

The other major attack on scientific monopolies has been the push for democratisation in Soviet science. The pressure within the Academy has been very strong for improvements in the procedures for election to the Academy and the introduction of the election of institute directors, Academic Councils and middle managers. After considerable resistance the Academy leadership has been forced to compromise, with elections now being allowed in institutes but with final confirmation remaining with Academy management. The new procedures, together with the introduction of compulsory retirement from management positions at age 65, has led to a considerable turnover of Academy management positions. However whether the new managers are any more democratic and open-minded than their predecessors remains to be seen.

MANAGEMENT-STAFF RELATIONS

The whole attack on management style assumes that there is a constituency for change in the institutes — that there are independent, creative researchers on the lookout for research grants and that institute staff, given the opportunity, will get rid of authoritarian managers. There is some evidence of such a constituency, but there is also some reason to believe that it is not overwhelming. In Soviet studies there is a useful if rather vague concept known as the social contract. The idea is that the Soviet population offers the government a minimum degree of political and economic commitment in return for the provision of a minimum degree of political and economic security. The standard of living might be low, but everyone is guaranteed a minimum standard and no one is required to work too hard. It is the commitment to the social contract on the part of significant numbers of the population that some observers use to explain the lack of enthusiasm for particularly the economic aspects of *perestroika* — people are not prepared to accept the reduced job security and increased productivity demands that *perestroika* entails.

It seems possible to apply the principle of the social contract to Soviet science. Soviet sociologists of science have for some time expressed disquiet about the number of so-called 'accidental' (*sluchainye*) people working in science, that is, people who have taken jobs in science not because they have any commitment to research or scientific knowledge but simply because it offers secure employment, there was nothing else on offer, etc.[27] It is felt that these people are particularly likely to be interested in a Soviet-style social contract. They are prepared to put up with dictatorial science managers as long as they provide them with a minimum degree of security and financial return and do not expect them to work too hard. The reports one comes across of extraordinarily non-productive activities in Soviet research institutes suggest that the latter part of the bargain at least is often being kept.[28]

Those who come to science with a genuine commitment to creative research find themselves in a difficult situation. First, many Soviet commentators complain, young people too often adopt a scientific career with unrealistic expectations of the creative freedom of the old-style lone scientist. They are not prepared for the very different style of even well-run modern-day 'big science'.[29] The disillusionment is even greater when the new science is not well run, when the chronic shortages of ancillary staff mean that young researchers tend to be little more than glorified laboratory technicians, and when dictatorial managers are able to deal brutally with anyone showing an independent mind.

There are three possible responses to this situation. First, one can simply give up and join the ranks of the 'accidental' people. Second, one can try to cope with the system while maintaining a research commitment. You help your manager out with his publications and research, but at the same time you expect him to provide you with the facilities and funding to do both his and your own research. This approach can of course only be adopted if the researcher's and manager's research interests are roughly compatible. The third response is to take the system on. We have already seen that managers are able and willing to deal roughly with those that adopt this approach. But of added interest is that there is evidence that such people are just as unpopular with their colleagues. Surveys show higher levels of job satisfaction, including satisfaction with management and collective endeavour, among 'accidental' people than among those with a true research commitment, and higher levels of on-the-job conflict among the latter.[30] It is often admitted in reports of victimisation of researchers that the victims were difficult characters who antagonised everyone in the institute. Sometimes it is clearly stated that the reason for their unpopularity was their expectation that their colleagues and subordinates work as hard as they did.[31]

The net result of all this is that there should be a large constituency in Soviet research institutes for the old system. The 'accidental' people and even the committed researchers who have learnt to operate within the system would have little reason to change it. The enthusiasm of the

campaign for democratisation within the Academy might suggest that the research community is not as unenterprising as this analysis might suggest. However it is a line of reasoning which is worth keeping in mind as *perestroika* of Soviet research management continues.

One could conclude this section of the paper by suggesting that the changes in the area of planning and funding, while perhaps representing movement in the right direction, do not address the major problem and cannot be successful until that problem is dealt with. That problem is management and management-staff relations. There appear to be high levels of demoralisation and cynicism in the Soviet science sector. They can be explained by any number of reasons: poor working and living conditions, a decline in relative wages, poor promotion prospects in recent years, and even an increasing popular anti-science mood.[32] However that highly dangerous paradox, simultaneously lax and brutal management, would seem to bear a major portion of the blame. It is certainly the issue which receives the most attention in recent Soviet commentaries. It is therefore a problem which has been recognised, and rational measures have been taken to deal with it. Whether they will be enough to overcome the interest of so many in the maintenance of the *status quo* is as uncertain at the level of the science sector as it is at the level of society as a whole.

TECHNOLOGICAL LAG

Science management is at least a problem that the Soviets can deal with themselves. While they show an increasing interest in Western science management techniques, their success or failure in the reform of their management does not depend on progress made in that area in the West. However there are a number of aspects of modern research in which the Soviet Union's relative position does not depend just upon itself. The extent and the nature of the lag (by "the nature of the lag" I mean whether it is irreversible or not) depends on Western performance as well. Here we will look at two aspects of these global features of Soviet science — their relative position in the technology which underlies modern research and their isolation from the international scientific community.

As we all know, modern 'big science' and even a lot of 'little science' require very high levels of technology, whether we are dealing with circumstances where the technology is driving the research or vice versa. There are now a very considerable number of things that one simply cannot do in science if one does not have the technology required to build and operate the apparatus. As the technology chains become longer nations without the technology early on in the chain find it increasingly difficult to keep up. Indeed the backwardness becomes self-reproducing — you need the technology to do the research which makes possible the advances in the technology. An example of an area in which the Soviets seem to find themselves in such a situation is in gallium arsenide

research. They have virtually no molecular beam epitaxy (MBE) machines, not because they do not know how to make them but because they do not have the technology required to build them.[33] If MBE machines are not available gallium arsenide research and technology are seriously affected. That in turn affects one's computer capacity, which then has serious negative consequences for research in all areas, including many of the areas of technology required to get their MBE machines on track. Another example which, although it does not deal with such a long chain, demonstrates well the negative effect technological backwardness has on Soviet research is accelerator physics. As Irvine and Martin describe, the Soviet Union's large accelerators have never produced the results hoped for because size was not enough to overcome technology based shortcomings in the construction of the machines.[34] Simon Kassel provides details on how inadequacies in surface materials and computer simulation capacity have held back Soviet pulsed power research (of the civilian variety anyway).[35]

The major difficulties appear to be in materials science and computing. Soviet backwardness in computing is well-known, although there is very considerable debate about the extent of the lag and their capacity to catch up. Marchuk suggested in April 1989 that the computer gap was not narrowing and in some fields was widening.[36] One very basic statistic should be enough to suggest that a serious problem exists. Soviet figures show that the nation's overall computing capacity (volume of memory, output of high-speed machines, etc.) is 1 percent that of the United States.[37] It appears that not even the Academy institutes doing research into computerisation and information sciences have PCs.[38]

The difficulties in materials science are most obvious in industry, where there is a massive imbalance in consumption of metal compared to plastics, ceramics and composites.[39] As just mentioned above, there is strong evidence that this imbalance reflects materials science difficulties in the science sector.[40]

Technological backwardness in Soviet science is primarily related to backwardness in Soviet industry as a whole. The reasons for such backwardness cannot concern us in this paper, but have a lot to do with the difficulties of innovation and *vnedrenie* which, as I mentioned at the beginning of the paper, have received so much attention from Western observers over the years. The situation seems to be compounded in the case of science by the lack of specialised facilities for building scientific apparatus and facilities. There are effectively no Soviet organisations that specialise in scientific equipment, with the main supplier, the Ministry of Instrument Making (recently merged with the Ministry of Electrotechnical Industry), also bearing responsibility for consumer and industrial instrument making and automation. The production runs for scientific instrumentation are generally far too short for enterprises to be interested. Nevertheless institutes are usually forced to go to regular series production enterprises for one-off deals, unless they can manage

to produce the required items in their workshops. Either way the results are less than satisfactory.

The Soviets are well aware of the difficulties in these areas, and are taking strenuous remedial measures. Since the beginning of the 1970s there have been substantial allocation of resources to equipment budgets in the science sector, with increasing proportions of both current and capital expenditures going to equipment and apparatus purchases (although since the early 1980s, with the decline in growth of the economy, a slowing in the rate of increase in scientific investment has become evident).[41] That funding commitment has been more than maintained under Gorbachev, with major increases in capital expenditure budgets in particular. The government has been particularly generous to the Academy of Sciences, with much of the extra funding going to building up the Academy's own instrument-making capacity. Its dedicated instrument-making organisation, the Scientific-Technical Association (NTO), has experienced massive growth under Gorbachev and its new director Maxim Aleksandrov. In mid-1987 the NTO's Special Design Bureau alone employed nearly 3,000 people. In the current Twelfth Five-Year Plan (1985-90) it was planned to double NTO's output of scientific instruments and increase the production of instruments throughout the Academy by a factor of 2.5. The latter increase entails producing instruments valued at 100 million rubles per annum by 1990, and devoting 15 percent of total capital investment in Academy science to the expansion of experimental and instrument-making capacity in the Twelfth Five-Year Plan (against 10.4 percent in the Eleventh and 4.1 percent in the Tenth).[42]

The three major areas of backwardness identified, instrumentation, materials science and computing, have all been the target of major national programmes. They are the focus of attention in the State Programme of Fundamental Research, which sets the parameters of basic research to the year 2000. 'Electronisation' and new materials are two of the five areas of top priority in the Council for Mutual Economic Assistance's (CMEA or COMECON) Comprehensive Programme of Scientific and Technical Progress to the Year 2000.[43]

There was a time when the Soviets had a demonstrated ability to devote massive resources to national priority programmes and achieve spectacular results in compressed time scales. The bomb and space programmes are the best examples. Those historical precedents might suggest that crash instrumentation, computing and materials science programmes will go a long way to rapidly solving the Soviet Union's problems. However many feel that it no longer has the political structures or culture for such prioritisation. Society has imposed too many competing demands for resources at a time of very slow if not negative economic growth, while the scientific community is unwilling to devote itself to such programmes with the same selflessness as before.[44] At the same time the West has probably improved its capacity for prioritisation.

Certainly as yet there are no signs of dramatic breakthroughs in any of the programmes mentioned above.

At this stage it is necessary to include some discussion of Western controls of high-technology imports to the Soviet bloc. Such controls have been in place ever since the beginning of the Cold War, although they attracted greatly increased publicity and controversy during the Reagan Administration, particularly after the Soviet invasion of Afghanistan. The controls, imposed primarily through the Co-ordinating Committee on Multilateral Export Controls (COCOM) procedures of the Western Alliance and the US's Militarily Critical Technologies list under the *Export Administration Act 1979,* have always been ostensibly directed against technologies, both embodied and disembodied, that could contribute to the Soviet military threat against the West, although controversy has always raged over how direct the application to military hardware needs to be. The effect on imports of scientific equipment and therefore on the general level of research technology cannot be easily quantified. The Soviets themselves have always been very coy on the subject. However it seems clear that the effect must have been considerable. By definition most scientific technologies are at the advanced end of the spectrum and therefore likely to be sensitive. Those adopting a maximalist position on technological sensitivity would claim that any contribution to Soviet scientific advance is undesirable. The most obviously affected area has been computing. Before the revision of the COCOM list in 1984 virtually all computing technology, from the simplest microchips, has also been seriously affected, with many Soviet-Western collaborations running into trouble when Western scientists have been unable to take instruments to the USSR. Controls on telecommunications equipment have indirectly affected scientific co-operation, by ensuring the continued reliance on antiquated communications networks in the USSR.

In assessing the impact of Western technology controls we have to take into account the strong anti-imports lobby in the Soviet Union itself, particularly in the scientific community. Many have claimed that large-scale imports, including of scientific equipment, would fatally weaken the Soviet Union's domestic R&D. Those holding such a view, personified in the former president of the Academy of Sciences A.P. Aleksandrov, even appeared to welcome the tougher position of the Reagan Administration, claiming that it gave a new impetus to Soviet R&D in sensitive areas.[45]

For obvious strategic reasons there has always been a strong expectation of self-sufficiency among Soviet policy makers. However the USSR's wide ranging and highly targeted technological espionage efforts suggest that in a free import environment the USSR would be interested in imports in at least a few key areas of scientific research. In some cases infrastructural shortcomings might mean that such imports could not be used to full effect; in other areas one could expect rapid improvements in Soviet performance.

The prospects for such a free import environment are unclear. The Western hardliners, primarily the US Department of Defence, are under increasing pressure from the US's COCOM partners and US commercial interests to respond to an apparently reduced strategic threat from the East. In May 1990 President Bush suggested that some relaxation of controls could be expected. However there is no sense that the complete scrapping of controls is even conceivably on the agenda.

ISOLATION

The final area of difficulty I want to deal with in this paper is that of isolation — the inability of Soviet scientists to quickly find out what other scientists are doing or to inform them of their own successes. There is a problem of internal isolation, derived from a whole host of features of Soviet science: the prevalence of 'schools' and monopolies, the reliance of institutes on one or two universities for all their recruitment, low job mobility, highly specialised institutes, an obsession with national security and secrecy, long publication delays, etc. However here I will concentrate on international isolation.

The isolation of Soviet scientists from the international community struck very deep roots in the Stalin era, with the worst period being the late 1940s. A fundamental qualitative distinction was made by Stalin's ideologists between socialist and bourgeois science, and even to cite a representative of the latter was grounds for dismissal and political persecution. Khrushchev quickly reversed that approach in the mid-1950s, both ideologically and practically. Science was recognised as an international and universal category, while co-operation between East and West was encouraged (the most dramatic symbol being Igor Kurchatov's speech on the Soviet fusion programme at Harwell in 1956). Enormous difficulties of course remained, as has been scrupulously documented by Zhores Medvedev.[46] He reveals the devastating effects on Soviet science, primarily in the Brezhnev era, of politico-bureaucractic control of passports, visas, publications, conference travel and postal communications. One assumes that those difficulties have effectively disappeared under Gorbachev. Indeed with his new thinking in the area of international relations Gorbachev has gone further than Khrushchev, by declaring universal values and co-operation to be superior to class and ideological affiliations. This suggests there might now be more than the rather grudging ideological and practical acceptance of international scientific co-operation of the past.

This does not mean that all the problems have gone. First, there is the question of Western attitudes. I think it is fair to say that Western scientists (as distinct from Western governments) have generally been prepared to meet the Soviets considerably more than half way in facilitating international co-operation. There seems no reason to believe they will be less forthcoming under current circumstances. Certainly there is every sign that Western scientists and agencies are now working

hard to fund and facilitate increased co-operation. Despite this, Soviet scientists and commentators often complain, perhaps with some justification, that the West tends to ignore or underestimate Soviet science, not necessarily for political reasons but rather out of ignorance, apathy, inertia or overwork.

The second continuing difficulty is the mundane one of funding. The Soviet ruble, despite intense discussion, remains unconvertible, and foreign currency allocations to research institutes and agencies remain severely restricted. This affects the ability of Soviet scientists to travel abroad and also seriously affects other forms of communication. In particular, the Soviet Union has been facing for a number of years an ever increasing crisis in its journals subscriptions. In early 1989 the library of the Academy of Sciences subscribed to approximately 4,000 journals (against the 160,000 of the Harvard University library). The Lededev Physics Institute, one of the leading institutes in the world, was having trouble keeping up its subscription to *Physics Review Letters!*[47]

The final area of difficulty are the technological barriers to co-operation. The benefits that Soviet science will gain from improved face-to-face communication will be considerable. But modern scientific communication cannot rely purely on face-to-face communication, or traditional publications and postal communications. Fax and e-mail have apparently revolutionised Western scientific communication, and these are areas where the Soviet Union effectively has no capacity at all. Indeed we are talking of a science sector which is virtually devoid of photocopiers and has a far from satisfactory intercity and international telephone network. As far as e-mail is concerned, this is unlikely to be highly developed when computer availability is so limited and the country does not produce modems.[48]

I am not sure how much significance we should attach to these problems. It might be possible to argue that fax and e-mail are essential only for those who are obsessed with priority. If you are prepared to wait a few months you can still make do with more traditional means of communication. However there is the great danger that in this, as in other areas of technological advance, the new will come to supersede the old entirely or make effective reliance on the old alone impractical. The other area of uncertainty in evaluating these issues is what the Soviet Union's capacity might be for catching up rapidly. Clearly to build up a large-scale domestic computing capacity is not a short-term matter. To import a lot of fax machines and PCs and plug them into the international communications network might be more straightforward.

CONCLUSION

At the moment I am not sure which is more risky — predicting structural and cultural changes in Gorbachev's Soviet Union or global technological change. As far as the former is concerned I certainly have

no scenario for the future of *perestroika* in general or in science in particular. I remain sceptical as to the capacity of the economic system, both of the managers and the managed, to assimilate the changes that are being spoken of. My scepticism is particularly strong with regard to the psychological *perestroika* on which Gorbachev has put so much stress, i.e., the change in people's attitudes towards their own work performance and their expectations of their colleagues and superiors. Without that the vital change in management style and management-staff relations will not happen. As far as the global issues are concerned, I see Soviet technological backwardness as a major factor that will not be easily overcome. Indeed it is quite possible that the Soviets will not be able to redress these problems fast enough to prevent their scientific backwardness from increasing. My prognosis is that the Soviet Union will not become a Third World scientific nation. Its leaders are sufficiently aware of the dangers and the problems to take urgent remedial action, while the nation has the resources to respond to that action. However they do not have the resources — financial, material or human — to be able to do more than prevent a rapid downward spiral.

NOTES AND REFERENCES

1. I do not wish for a moment to belittle the immense importance of these issues or the extremely high quality of the Western research devoted to them. As exceptions to the neglect of Soviet research performance, see T. Gustafson, 'Why doesn't Soviet science do better than it does?' in L.L. Lubrano and S.G. Solomon (eds), *The Social Context of Soviet Science,* Westview, Boulder and Dawson, Folkestone, 1980 and P. Kneen, *Soviet Scientists and the State,* Macmillan, London and Basingstoke, 1984, ch. 4.
2. S. Fortescue, *Science Policy Making in the USSR,* Routledge, London, 1990, pp. 165-6.
3. See S. Fortescue, 'The Soviet Academy of Sciences under Gorbachev', *Australian Slavonic and East European Studies,* 1, 2, 1987, p.24.
4. *Poisk*, 12, July 1989, pp. 1-2.
5. *Vestnik Akademii nauk SSSR*, 4, 1989, pp.31-4.
6. See Roald Sagdeev in *Physics Today*, September 1988, p. 98; the oceanologist Andrei Monin in *Izvestiia*, 13 Septmber 1989, p.4; and Zhores Alferov in *Izvestiia*, 10 August 1988, p.2.
7. J. Irvine and B.R. Martin, 'Basic research in the East and West: a comparison of the scientific performance of high-energy accelerators', *Social Studies of Science,* 15, 1985, pp. 293-341.
8. F. Narin and M.P. Carpenter, 'National publication and citation comparisons', *Journal of the American Society for Information Science,* 26, 1975, pp. 80-93; J.D.Frame and F. Narin, 'The international distribution of biomedical publications', *Federation Proceedings,* 36, May 1977, pp. 1790-5; J.D. Frame and J.J. Baum, 'Cross-national information flows: examples taken from physics', *Journal of the American Society for Information Science,* 29, September 1978, pp. 247-52; F. Narin, J.D. Frame and M.P. Carpenter, 'Highly cited Soviet papers: an exploratory investigation', *Social Studies of Science,* 13, 1983, pp. 307-19; J.D. Frame and M.P. Carpenter, 'International research collaboration', *Social Studies of Science,* 9, 4, December 1979, p. 490; *Nature,* 14 October 1982, p. 568. For some recent Soviet scientometric measurement of its performance, see *Vestnik Akademii nauk SSSR, 5, 1988, p. 79; Izvestiia,* 16 September 1989, p. 18.

9. H. Balzer, *Soviet Science on the Edge of Reform,* Westview, Boulder, 1989. The survey's data have been extensively used in R.F. Miller, 'The role of the Communist Party in Soviet research and development', *Soviet Studies,* 37, 1, January 1985, pp. 31-59.
10. Blazer, *ibid.,* p. 163.
11. M.A. Popovskii, *Science in Chains: The crisis of science and scientists in the Soviet Union today,* Collins and Harvill, London, 1980 (a revision of *Manipulated Science,* Doubleday, New York, 1979, a translation of *Upravliaemaia nauka,* Overseas Publications Interchange, London, 1978).
12. For example, Z. Medvedev, *Soviet Science,* Oxford University Press, Oxford, 1979; M.Ya. Azbel, *Refusenik. Trapped in the Soviet Union,* Hamish Hamilton, London, 1982; R.L. Berg, *Acquired Traits. Memoirs of a geneticist from the Soviet Union,* Viking, New York, 1988.
13. *New Scientist,* 10 November 1983, p. 442.
14. C. Sinclair (ed.), *The Status of Soviet Civil Science,* Nijhoff, Dordrecht, 1987.
15. C. Kaysen, chairman, *Review of US-USSR Interacademy Exchanges and Relations,* National Academy of Sciences, Washington, DC, 1977. For commentary, see *Science,* 27, October 1978, pp. 383-90; Lubrano, 'National and international politics in US-USSR co-operation', *Social Studies of Science,* 11, 4, November 1981, pp. 451-80; C.P. Ailes and A.E. Pardee, *Cooperation in Science and Technology: an evaluation of the US-Soviet agreement,* Westview, Boulder, 1986.
16. *Physics Today,* October 1988, pp. 73-6.
17. *op. cit.,* p. 32.
18. I. Wirszup, 'Soviet secondary school mathematics and science programs', in Sinclair, *The Status,* ch. 1.2.
19. Blazer, *ibid.,* ch. 4.
20. The chemist Aleksei Baraboshkin recently suggested that data showing that 20 percent of Soviet fundamental research was above world levels, 20 percent at that level, and 60 percent below was not a bad result considering that the Soviets spent 5-6 times less than the US on basic science. *Vestnik Akademii nauk,* 8, 1989, p. 102.
21. L.E. Nolting, *Financing of Research, Development, and Innovation in the USSR,* Foreign Economic Report No. 22, Department of Commerce, Washington DC, September 1985, p. 19; Fortescue, *Science Policy Making,* pp. 1-7. Some Soviet commentators even dispute the Soviet lead in percentage terms. For example, *Voprosy istorii estestvoznaniia i tekhniki,* 3, 1989, p. 124.
22. *Voprosy istorii estestvoznaniia i tekhniki,* 3, 1989, p. 62.
23. *Sobranie postanovlenii SSSR,* 48, 1987, art.158, paras. 4 and 10.
24. *Moscow News,* 16 July 1989, p. 15. It should be pointed out that many Academy institutes have for many years derived as much as 50 percent of their budget from contract research, a situation which causes concern among many scientists.
25. For detailed examples, see Fortescue, *Science Policy Making,* pp. 150-4.
26. *Moscow News,* 16 July 1989, p. 15.
27. S. Fortescue, *The Communist Party and Soviet Science,* Macmillan, London and Basingstoke, 1986, p. 47.
28. Fortescue, *The Communist Party,* p. 52.
29. Fortescue, *The Communist Party,* pp. 46-9; P.G. Belkin, E.N. Emel'ianov, M.A. Ivanov, *Sotsial'naia psikhologiia nauchnogo kollektiva,* 'Nauka;, Moscow, 1987, pp. 151-2.
30. Belkin, *Sotsial'naia psikhologiia,* pp. 147-9, 159.
31. For example, *Izvestiia,* 27 September 1989, p. 3.
32. For details on these factors, see Fortescue, *Science Policy Making,* pp. 162-76.
33. *Physics Today,* October 1988, p. 76.
34. J. Irvine and B.R.Martin, 'Basic research in the East and West: a comparison of the scientific performance of high-energy accelerators', *Social Studies of Science,* 15, 1985,pp. 293-341.
35. S. Kassel, 'The outlook for Soviet advanced technologies', in *Science and Technology in the Soviet Union. Proceedings of a conference,* Stanford University, July 1984, pp. 65-6.
36. *Vestnik Akademii nauk SSSR,* 8, 1989, p. 11.

37. *Izvestiia,* 2 October 1989, p. 3.
38. *Vestnik Akademii nauk SSSR,* 2, 1989, p. 15. For more details, see P. Snell, 'Computers', in M.J.Berry (ed.), *Science and Technology in the USSR,* Longman, Harlow, 1988, ch. 23; P. Snell, 'Soviet microprocessors and microcomputers', in R. Amann and J. Cooper (eds), *Technical Progress and Soviet Economic Development,* Blackwell, Oxford, 1986, ch. 3; S.E. Goodman, 'Technology transfer and the development of the Soviet computer industry', in B. Parrott (ed.), *Trade, Technology, and Soviet-American Relations,* Indiana UP, Bloomington, 1985.
39. *Sotsialisticheskaia industriia,* 15 October 1988, p. 4.
40. For an account of difficulties in materials research, see N.J. Grant, 'Soviet science in the materials world', in Sinclair, *The Status,* ch. 4.2.
41. I.V. Shul'gina, *Infrastruktura nauki v SSSR,* 'Nauka', Moscow, 1988, p. 81.
42. *Vestnik Akademii nauk SSSR,* 11, 1986, p. 25.
43. P. Kneen, 'Soviet science policy under Gorbachev', *Soviet Studies,* 41, 1, January 1989, pp. 67-8; *Izvestiia,* 15 August 1988, p. 2. On materials, see *Izvestiia,* 21 February 1989, p. 2. For a complaint over the recent failure to include scientific instrumentation as a national programme, see *Vestnik Akademii nauk SSSR,* 2, 1989, p. 6.
44. As a retired defence designer put it: "To expect people to pull off military exploits in peacetime is not only foolish but immoral." *Sotsialisticheskaia industriia,* 13, November 1988, p. 2.
45. P. Hanson, 'Technical chauvinism in the Soviet Union', *Radio Liberty Research,* RL138/85, 30 April 1985.
46. Z. Medvedev, *The Medvedev Papers,* Macmillan, London, 1971.
47. *Vestnik Akademii nauk SSSR,* 2, 1989, pp. 24, 64.
48. *Vestnik Akademii nauk SSSR,* 8, 1989, p. 25. For details on information flows, including computer networking, within Soviet science and abroad, see Sinclair, *The Status,* part 3.