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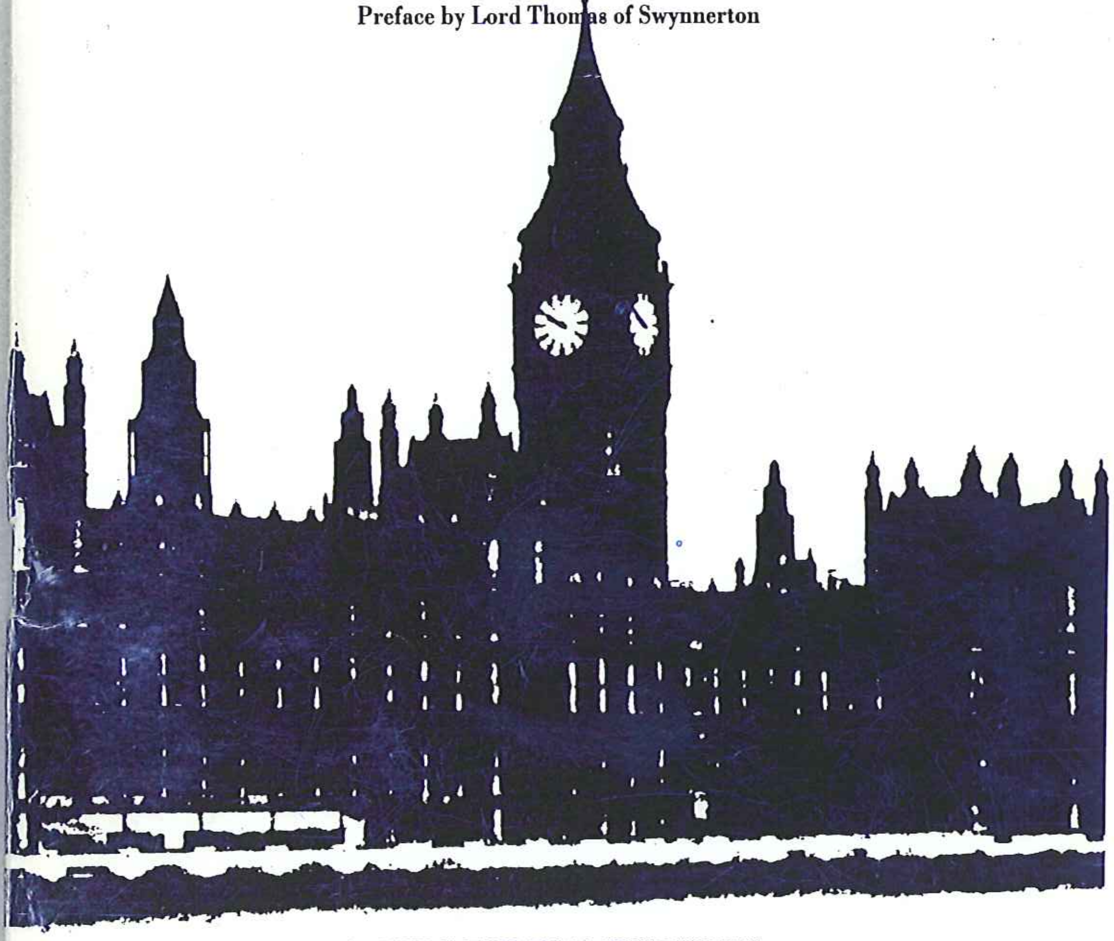
Policy Study No. 71

New Light on Star Wars

a contribution to the SDI debate
Professor R. V. Jones
with a
Preface by Lord Thomas of Swynnerton



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New Light on Star Wars

a contribution to the SDI debate

Professor R. V. Jones

CENTRE FOR POLICY STUDIES
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Professor R. V. Jones contributed his thoughts on 'Star Wars' to the Centre for Policy Studies, of which he is a Director, in June 1985.

Lt General James A. Abrahamson, Director of the Strategic Defence Initiative, made his statement before the Subcommittee on Strategic and Theatre Nuclear Forces, Committee on Armed Services, United States Senate, in March 1985.

Robert C. McFarlane, National Security Adviser at the White House, addressed his remarks to the Overseas Writers Association in Washington in March 1985.

The Centre for Policy Studies emphasises that the facts and arguments in this study are the responsibility of the authors alone. *The Centre never expresses a corporate opinion in any of its publications.*

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Biographical Note

PROFESSOR R. V. JONES was responsible for British Scientific Intelligence in World War II. He was subsequently Director of Scientific Intelligence in the Ministry of Defence, Chairman of the ministry's Working Party on Air Defence Planning for 1975-85, Chairman of the Electronics Research Council, and Special Adviser on Electronic Warfare to the United States Air Force.

Preface

Serious discussion about strategic defence in space began in the United States in the late 1960s. It figured largely during the intricate negotiations on arms control between the Soviet government in Brezhnev's day and President Nixon's administration. Those discussions can be fully followed in the fascinating memoirs of Dr Kissinger. President Nixon's administration came to accept that uncontrolled development of anti-ballistic defence would make it impossible to establish any kind of balance between the United States and the Soviet Union. The matter was, therefore, included in the discussions. Accord was eventually reached whereby both the United States and the Soviet Union would be allowed three anti-ballistic missile systems. This was then scaled down to one. Such was the basis for the ABM Treaty of 1972. In the event the United States did not go ahead with their one permitted system. The Soviet Union did, and this is now established around Moscow.

These agreements were made by the United States with the expectation that the Soviet Union could be persuaded, through a multitude of minor agreements, to accept their responsibility as a great power and help to maintain the fabric of international relations, faulty and unsatisfactory though that fabric was. A power capable of blowing up the world had surely to be treated as if it were responsible; and perhaps it would grow to be so. This was the essential basis of the 'détente' of the 1970s.

It is easy to criticise those agreements now; it was just as easy to criticise, on rather similar grounds, the efforts to appease Hitler in the 1930s. In both cases the effort to reach understanding required courage and imagination, and should surely have been tried since it was desired by the vast majority of the electorates of the countries of the West.

As we now know, the Soviet Union did not observe the spirit of 'détente'. The 1970s were the years of substantial Soviet investment in naval capacity, in new weapons with nuclear capacity (for example the SS20s and the Backfire bomber) and in surrogate states, such as Cuba, the Yemen People's Democratic Republic and North Korea, whose unfortunate people were made to give the stiffening to Soviet support for 'wars of liberation'. All the evidence is that the Russians continued with their defensive research, including research into laser defence.

'Détente' ended with Congress' refusal to ratify the Salt II Treaty, following the Soviet invasion of Afghanistan. All the same, the United States had, throughout the 1970s, themselves observed the spirit of 'détente' as conceived by President Nixon and Dr Kissinger. Without going into detailed discussion of figures, it is clear that the United States spent a much lower percentage of her admittedly larger GDP than did the Soviet Union on armaments. They ceased manufacture of chemical weapons (whereas the Russians did not) and they froze production of ICBMs at the levels of 1969.

After the invasion of Afghanistan, President Carter began his programme of modernisation of the United States' defences. This was carried on by President Reagan. The present situation looks a good deal more healthy though, in some respects, particularly in Europe, the West is still in a slightly inferior position.

It is against this background that we have to judge the new debate over strategic defence. In this argument certainties are not easy and it will be many years before all the possibilities can be demonstrated.

In addition to the maintenance of their existing ABM system around Moscow, the Russians have certainly continued with research. The extent to which this research envisages action which breaks the terms of the ABM Treaty is controversial. No doubt further information will clarify the matter at some point. However, three points seem worth making.

First, the idea of a switch from offensive to defensive arrangements in the nuclear age has a moral significance which we Europeans have perhaps not always recognised. Anyone who has talked to any representative of the present United States administration knows that this moral purpose is uppermost in the mind of President Reagan, Mr Weinberger and their colleagues. It is not only the fact that the present knife-edge balance between the Western and Soviet alliances could, considering all historical precedent, one day topple; but that the present arrangements depend so much for their effectiveness, in the last resort, on a capacity for taking a momentous decision very quickly. Everything should be done to enable the President to escape, in the long term, from the dangers of those policies. We have seen some reluctance on the part of the Europeans to put themselves in the shoes of the United States in the discussion of this matter.

Secondly, the present state of affairs is less static than one might judge from the speeches of the opponents of strategic defence. The Soviet Union, for example, has never accepted, in its rhetoric at least, the doctrine of mutually assured destruction. On the contrary, there have been many Soviet pronouncements suggesting that their build-up of nuclear weapons is intended less to maintain a balance than to secure an overwhelming strength from which it would be easy, in certain circumstances, to bully neighbours and opponents into surrender.

At the same time, of course, there are many sections of Western opinion which are dissatisfied with the present so-called balance. Many responsible people have suggested, indeed (and these have included, oddly enough, many opponents of SDI), that the world would be a safer place if a ban on first use of nuclear weapons were to be written into Western defence policies. That is surely a recipe either for conventional defeat or confusion – probably the latter since, as Clement Attlee said in 1945, in the last resort governments do not keep declarations of this sort and use all weapons they have to prevent themselves being overwhelmed. But a nuclear weapon kept for such an eventuality would have no deterrent power. Nor would it be properly serviced and its delivery would be uncertain. All the same there seems to be a lot of evidence that this policy may gain credibility in the next few years.

The third point to make about strategic defence is that, although it looks as if it can never be 100 per cent effective, it might have benefits even so. The aggressor might well count on only five per cent of his weapons getting through. But he would not know which five per cent. This would make it difficult to plan for a first strike.

The political arguments against SDI are, however, substantial. If it did turn out that one or other of the United States and the Soviet Union were near to establishing such a defensive system, it would cause a lot of anxiety in the other. Whether that would make for a less stable world is a matter of judgement. One might take into account the Thucydidean maxim about the cause of war – the now or never mood of one side or the other. But I do not think that it would lead the United States to a policy of adventure and the historical precedent for thinking that it would lead the Soviet Union to one is not strong. The Soviet Union in the past has taken initiatives when it has been in an overwhelmingly strong position, not in a weak one.

I do not take the economic arguments against SDI very seriously. The sums concerned are of little account when put against the overall United States arms budget and are likely to be compensated for a hundred times over by even minor technological consequences.

The controversy will continue. It is fair to say that no one will know the effectiveness of strategic defence in the United States for some years – perhaps not before the year 2000. In the desire to help elucidate the problems raised, the Centre for Policy Studies has much pleasure in publishing this paper by Professor R. V. Jones, scientific adviser to the government during the Second World War, and the author of *Most Secret War*, one of the most remarkable books on intelligence ever written. Alongside his thoughts we are reprinting two recent statements by Robert McFarlane, National Security Adviser at the White House, and General Abrahamson, Director of the Strategic Defence Initiative in Washington, which throw light on the present state of affairs as seen in America.

I confess that the work of Professor Jones has somewhat shaken my own hopes that ultimately the problems of the cold war 'might be reconciled among the stars'.

> And hear upon the sodden floor
> Below, the boarhound and the boar
> Pursue their pattern as before
> But reconciled among the stars.
>
> T. S. Eliot, *Burnt Norton*

But it does not, it seems to me at any rate, counter arguments based on the fact that a great deal of work on the SDI is going on in the Soviet Union, and has been since the 1960s. We should, therefore, carry on with our research and see what it throws up. The West has with perfect justification since 1945 sought to defend itself by technological superiority rather than with huge conventional armaments. We should surely continue to do so.

Lord Thomas of Swynnerton
Chairman

R. V. JONES

Some thoughts on 'Star Wars'

On 23 March 1983, President Reagan launched his Strategic Defence Initiative with, 'I call upon the scientific community who gave us nuclear weapons to turn their great talents to the cause of mankind and world peace: to give us the means of rendering these nuclear weapons impotent and obsolete', and he called for a programme with the 'ultimate goal of eliminating the threat posed by strategic nuclear missiles'.

On 25 May 1961, President Kennedy had similarly challenged America's scientists and engineers: 'I believe that this nation should commit itself to achieving the goal before this decade is out of landing a man on the moon and returning him safely to earth.' In its time that goal appeared nearly impossible to many of us but the world was quickly to witness how marvellously that challenge was answered. With such a precedent, what are the prospects for the Strategic Defence Initiative as regards technical fulfilment and its military and geopolitical impact? This paper attempts to look at some of the relevant factors, drawing mainly on published statements by some of the interested parties in the United States.

President Reagan and those on whose advice he launched his initiative did not expect it to be fulfilled within a single decade. 'It will', he said, 'take years, probably decades, of efforts in many fields' and 'may not be accomplished before the end of this century'. While the President did not actually guarantee the prospect of ultimate success, his speech engendered great optimism, made all the stronger by what Secretary of Defence Caspar Weinberger said four days later in a 'Meet the Press' interview in Washington on 27 March 1983: 'The defensive systems the President is talking about are not designed to be partial. What we want to try to get is a system which will develop a defence that is thoroughly reliable and total, yes, and I don't see any reason why that can't be done.'[1] And Lieutenant General James A. Abrahamson, who early in 1984 was appointed manager of the Pentagon's SDI programme, gave an extensive interview to the journal *Science* (Volume 225, pp. 601-2, 10 August 1984) which reported that 'he fully expected the United States to begin deployment of such a system before 2000'.

The Deputy Administrator of the National Aeronautical and

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[1] Department of Defence transcript, 28 March 1983.

Space Administration, Dr Hans Mark, more cautiously told a conference on new technology sponsored by the National Academies of Sciences and of Engineering in Washington in May 1984, 'It is difficult to make any really firm statements about the time scale on which the deployment of such a system could be achieved. My own guess is that by the middle of the next century a defensive system could be in place that would make it necessary to change the doctrine of mutually assured destruction.'

Mark's estimate of 2050 appears the closer to realism when the technical difficulties of the programme are considered. While two groups appointed by the White House, the Defensive Studies Group and the Future Strategy Group, 'failed to detect any invincible technical obstacles that would prevent the attainment of the President's goal' and recommended that 18 to 27 billion dollars be allocated to the problem up to 1990 (*Science*, 25 November 1983), Dr Richard DeLauer, the Under-Secretary of Defence for Research and Development, estimated that the R & D portion of the programme had at least eight components, 'every single one . . . equivalent to or greater than the Manhattan Project' (quoted in *Space-based Missile Defense*, published by the Union of Concerned Scientists in March 1984). Early in 1945 Lord Cherwell told me that the Manhattan Project had already cost 1600 million dollars; this would be about 8 billion dollars in 1983 terms,[2] and so on DeLauer's estimate the R & D portion of SDI might cost 60 billion dollars or more. To put this sum into perspective, the current US defence budget is approaching 300 billion dollars, and assuming that the proportion of this allocated to R & D is about 11% (as it was in previous years – and the figure for Britain is 12%), the amount available for defence R & D in total is about 30 billion dollars.[3] Thus the estimate for 'Star Wars' R & D, although huge, is not out of question if spaced over 10 years.[4]

What is an effective defence?

What is more questionable is whether the many technical and logistic problems can be solved so successfully that an Anti-Ballistic-Missile (ABM) defence could be effective. How do we define 'effective'? We may start by looking at the complementary problem of what would be an effective attack on a country as large as the United States or Russia, for the British government has already offered an answer in its 1984 defence estimates where it states that four Trident submarines each armed with 16 missiles will provide 'a credible and effective deterrent'. On this criterion an effective defence for America or Russia must be one that would ensure that less than 64 missiles would get through. According to the International Institute of Strategic Studies, the Russians currently have *1398* Intercontinental Ballistic Missiles (ICBM) launchers, and so an effective defence would have to destroy all but 60-70 of these, or around 95%. True, the Trident D5 missiles have each 14 warheads, and the nearest Russian missile, the SS18, has no more than 10, but by the time any SDI could be deployed the Russians could well have caught up. Alternatively, we might consider individual warheads: the British Trident force will have *916*, and the Russian ICBMs have currently about *6400*, of which some 85% would therefore have to be destroyed to fall below the criterion of an effective attack. But a lower number of warheads per missile means that fewer would be lost for a given number of missiles destroyed in the boost phase, against which the main thrust of SDI is likely to be made. These simple numerical considerations leave aside the question of the operational survival of a country after the impact of the several hundred warheads which even a 95% effective defence might fail to stop but we will take 95% as the credible figure for an effective defence: although independently (and questionably) derived, it coincides with the figures generally accepted in the American debate.[5]

The interception of ballistic missiles

The basic problems for an ABM defence are to detect the approach of a threatening missile as quickly as possible, and to project something at it that will get near enough to it to ensure its destruction, and at a sufficient distance to minimize harm to friendly objectives and territory. For this purpose the trajectory of the missile may be regarded in four phases. For the first four minutes or so (*150 seconds* for the MX,

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[2] Other estimates would rate the current cost of Manhattan or Apollo scale projects as 20-40 billion dollars.

[3] According to William J. Perry, Under Secretary of Defence for Research and Engineering under President Carter, the total R & D budget for 1980 was 13 billion dollars; and in 1982 was to be 20 billion (*Defence Electronics*, April 1981).

[4] On 25 March 1985 General Abrahamson stated to the US Senate that his appropriation for 1985 was 1.4 billion dollars, and requested that this be increased to 3.7 billion in 1986.

[5] When discussing anti-ballistic missile systems in 1975 the Russian physicist Andrei Sakharov in his book *My Country and the World* (Vintage Books, New York) estimated that even the 5 per cent of missiles that survived a 95 per cent defence 'would inevitably entail the destruction of a great part of the cities, and a major portion of both the countries involved in a nuclear exchange'.

300 for the SS18) it is accelerating upwards from the ground, emitting huge amounts of light and heat from its exhaust plume and carrying its multiple warheads in one integral packet. By the time the boost up to final speed is finished, the missile will have travelled 200 to 400 kilometres, and it will be in free flight above the atmosphere and can now, over the next 5 to 10 minutes (the 'busing' phase), disperse its multiple warheads programmed for their independent targets; these then proceed as an expanding swarm throughout the long mid-course phase until they re-enter the earth's atmosphere heading for their targets, and heating up in their terminal phase by aerodynamic compression.

Mid-course attack

Of the three phases, that of midcourse is the most difficult to attack economically, especially if the independent warheads are accompanied by decoys which may simulate them to confuse both radar and infra-red detection.[6] That it is already possible *in principle* to intercept and destroy an ICBM in mid-trajectory was demonstrated by the Americans (after one or two failures) on 10 June 1984, when an intercepting missile with an infra-red sensor and on-board computer was successfully launched from Kwajalein Atoll in the Marshall Islands to destroy by direct impact a dummy Minuteman warhead launched from Vandenberg Air Force Base, some 4500 miles away. A few seconds before impact the intercepting vehicle expanded an umbrella-like 15 foot disc of aluminium spokes loaded with small steel weights and this was sufficient to catch the incoming warhead. But, great feat though this was, it would be more difficult by orders of magnitude to intercept and destroy a large proportion of a salvo of missiles launched without warning, especially if accompanied by decoys. Moreover the Kwajalein demonstration is reported to have resulted in interception 'at an altitude of more than 100 miles' (*Defense Electronics*, December 1984) which suggests that the missile was nearing its terminal phase rather than strictly in mid-course.

Terminal phase attack

Interception in the terminal phase would be less difficult for several reasons. There would be more time for detection and less distance for a defending missile to cover, and decoys easier to distinguish because they would behave differently both aerodynamically and thermally. Defence of point targets, such as one's own missile launchers, might thus be feasible – but it is difficult to contemplate with enthusiasm the prospect of many missiles being destroyed over civilian-occupied territory, especially if these involved nuclear explosions. There is a small-scale precedent in the V2 bombardment of London in 1944-5, when Anti-Aircraft Command started to fire in the hope of creating swarms of shrapnel in the path (predicted from radar) of V2s launched from Holland, but this was swiftly stopped when calculations showed that the falling shrapnel was likely to cause many more casualites than would be prevented by its destruction of V2s.

Boost phase attack

It is generally agreed, by both proponents and critics of SDI, that the boost phase is easily the most attractive to attack because the vulnerability of the ICBM then outweighs the remoteness of the phase from the defences. A single hit on the rising missile would be likely to upset every one of its multiple warheads; and its plume radiates large amounts of light and heat which are easy to detect, even from geostationary satellites 22,000 miles above the Equator, and the radiation is relatively easy to home on to – but there is the important proviso that it is the missile and its boosters, rather than the exhaust plume, which have to be hit.

For a missile launch to be detected, the detector has to be within sight of the launch. The geographical distribution of territory over the globe being as it is, this means that for the Americans to detect missile launchings in Russia, their detectors have to be on satellites, and they then have two main choices. The first, and much the more economical, is to have these satellites in geostationary orbits above the Equator – but supposing that the satellite has detected a launch, what action can be taken? Even if a material device could be fired, either from the detecting satellite or from a part of the world's surface accessible to the Americans, this device could not travel fast enough to reach the rising missile during its boost phase – even at 5 miles a second it would have to be fired from within a range of 1200 miles for a boost phase lasting 4 minutes even if detection, recognition and firing were instantaneous. So any destructive energy fired at the rising missile would have to travel at a far greater speed, and the obviously attractive possibility would be some form of laser or particle beam device, mounted on a satellite.

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[6] The decoys could simply be metallised balloons of the same shape as the warheads; and although it has been suggested that the decoys could be distinguished by the Doppler effect produced by reaction to radiation from a probing laser, the genuine warheads could probably be made to look like decoys in this respect, maintaining the confusion.

Geostationary lasers

Looking first at lasers in geostationary orbit, and these would need much energy to be effective at 20,000 miles range, the Union of Concerned Scientists in America has estimated that to deal with a salvo of 1400 Russian ICBMs would require power plants in orbit costing 40 to 110 billion dollars:[7] for this they have assumed that such plants would cost 300 dollars per kilowatt, compared to 1000 to 3000 per kilowatt for nuclear power plants. Here they might be pessimistic, just as Lord Cherwell was in 1943 when he argued that the gearing associated with the pumps in the V2 rocket would have to be very heavy to handle the power that they were required to transmit, for he had depended on the advice of experts who could only think of continuously running gears, and not of a simple turbine driven by hydrogen peroxide which had only to function for a very short life. But even if the Concerned Scientists have heavily over-estimated – and this is questionable – the power bill for the lasers would still be substantial and it is only one part of the total cost. And even if the laser power can be generated, and concentrated into beams that are sharp enough to be no more than one metre in diameter at 20,000 miles range, the detecting and aiming system may have to be good enough to hit and follow a moving target for a few seconds with even greater accuracy at this range. Moreover, the laser has to be aimed at – or, more strictly, somewhat ahead of – the rising missile itself and not at its plume; these demands are for several reasons beyond anything feasible today. To ease the problem of hoisting heavy lasers into orbit, it has been suggested that the lasers might be ground-based and aimed at geostationary mirrors that would be pointed in the right direction, either to aim directly at the rising missile itself or towards mirrors on other satellites on lower orbits much closer to the Russian launching sites. But none of these schemes appears practicable for many years, apart from the scale on which they would be needed. The same is true of all forms of lasers, including X-ray lasers and particle beams.

That at least is the conclusion of the Union of Concerned Scientists, who have discussed all these problems in a report *Space Based Missile Defence* which appeared in March 1984.[8] Its panel was composed of physicists up to Nobel Laureate level, defence analysts

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[7] Strictly, the UCS cost estimate was for lasers based on the ground and aimed via mirrors in geostationary orbit.

[8] Subsequently published in an amended form as a paperback, *The Fallacy of Star Wars* (Vintage Books, New York, October 1984).

and other members with command experience in operations and in intelligence: geostationary platforms are amazingly good for surveillance but most unpromising as sites for killer-lasers. This is not, incidentally, to decry the potential of lasers as high-speed weapons at short range: the US Air Force in May 1983 demonstrated a 10.6 micron carbon dioxide laser mounted in a large jet transport which destroyed five air-launched Sidewinder AIM9-L missiles fired in rapid succession.

Laser and particle beams: accuracy of aiming

It is worth looking at the aiming accuracy required of any device, laser or mirror or particle beam generator, in geostationary orbit. First the rising booster, some 40,000 kilometres away, has to be detected with sufficient precision for aiming the energy which is intended to destroy it. The accuracy required is of the order of 10 centimetres at 35,000 kilometres, or an angle of one in 350 million. The Union of Concerned Scientists has stated that since the detection system would have to use mainly the infra-red radiation of 1 micron wavelength from the booster, the necessary angular discrimination would need a detecting system 100 to 150 metres in diameter 'about the size of a football pitch' up in geostationary orbit.

The need for such a huge mirror arises from the requirement to form an image which would distinguish the booster itself from the plume. A much smaller mirror, say a few metres in diameter, would suffice to detect and direct energy on to the still-hot bus in the post-boost phase; but one would still need a large mirror, which even its proponents admit would have to be at least 15 metres in diameter to focus the destructive energy from an optical laser on an area less than one metre across at 35,000 kilometres range. This presents severe problems: the mirror has to be of very high quality and keep its shape as its temperature changes as it constantly changes its attitude relative to the sun. Assuming that these problems are overcome the energy has then to be aimed in the direction pointed by the detection system to a precision of one in 350 million.

Now the most precise aiming system so far contemplated in any practical development in space is that of the space telescope currently nearing completion, where the specified precision is an angle of one in 30 million. So each geostationary laser, mirror or beam device will have to work to a precision at least 10 times better than the space telescope. And it will be very difficult to calibrate any errors in alignment between the detecting and firing systems. It will be comparable with having to check in advance that the sights on a rifle are aligned so accurately with the barrel that the aiming error would be no more than one bullet diameter at a range of 1000 miles, without having a chance to fire a trial shot and with the rifle more than 20,000 miles away in space.

Moreover, the problem is complicated by the fact that the target is not standing still: at 35,000 kilometres range, light would take more than one-tenth of a second to reach the target, which will have moved by a hundred or more metres in the meantime, and so the destructive beam will have to be 'aimed off' to the requisite extent. And this difficulty will be even greater if the laser is on the ground and aimed via a geostationary mirror.[9]

Even this is not the end of the problem. Supposing that everything has so far gone perfectly and the system has destroyed its first rising booster: this destruction must either be assumed or be revealed by the detector, which has then to steer the system on to another booster, for presumably the Russians are launching a salvo. If this included some hundreds of missiles, either there would have to be a comparable number of geostationary laser or other beam stations, or each station would have to destroy several boosters in succession, involving rapid slewing to the same high degree of precision.

Orbiting missile killers

The great merits of a geostationary platform are that it remains in one position relative to the earth for a long time and that it can view a large portion of the earth's surface from that position. The only feasible way of overcoming its disadvantage of range is to mount whatever is intended to destroy the rising missile on a satellite in a much lower orbit, and typically travelling along a north-south line at a few hundred kilometres height and with a period of around 94 minutes. Such a satellite, once it has detected a rising missile might aim a missile-killer at it, rather along the lines of the American ASAT which currently is intended to be fired from an F-15 fighter, boosted upwards by a two-stage rocket. The ASAT is a small cylinder about 30 centimetres in length and in diameter weighing about 15 kilograms, and it is steered by small auxiliary jets controlled by infra-red sensors which pick up heat radiated by the target, with the intention of destroying it by direct impact.

One satellite in low orbit could carry many ASATs which could be fired rapidly against several rising missiles provided that it has first seen them, alerted either by its own detection system or by signals from a geostationary surveyor. But such ASATs will not be able to operate much below 80 kilometres altitude because they would themselves heat up aerodynamically and this self-generated heat would at least partly 'blind' their infra-red sensors. And they would also need some means of distinguishing the body of the missile so that they did not home instead on to its plume, through which they might pass as through the tail of a comet and probably be incinerated in the process. The Concerned Scientists, taking an optimistic case, assumed that an ASAT might be developed to weigh 5 kilograms instead of the present 15, and that by carrying nine times this weight of fuel for the booster it could be accelerated to about 8 kilometres per second.[10]

The question then arises of how far away we could afford the orbiting satellite to be for it to have a useful chance of hitting the rising booster with one of its killer-missiles (or hittiles). The Union of Concerned Scientists assumed that the *boost phase would last 100 seconds*, which gives a maximum stand-off for the orbiting satellites of 800 kilometres. If, to give the missile-killer technique its most optimistic chance of success we take the case of the Russian SS18 missile, this is said to have a *boost phase lasting 300 seconds*, which would permit a stand-off range of 2400 kilometres, assuming that the orbiting satellite detects the launch immediately and no less immediately launches one of its hittiles.

Orbital geometry: killing range 800 kilometres[11]

The two ranges, 800 and 2400 kilometres, lead to different estimates for the number of orbiting satellite required. For a killing range of 800 kilometres any one satellite will be within range of the Russian

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[9] The aiming problem could be eased by using a self-aligning system in which a detector on the geostationary satellite sent signals to the ground-based laser to correct any errors in the latter's aim, so that the beam was servo-controlled to hit the satellite mirror. If the beam is then to be reflected to fall on a second mirror on an orbiting satellite, this too could send signals to correct the aiming of the geostationary mirror. But the final aiming of the mirror on the orbiting satellite to hit the rising ICBM cannot be corrected by such a system.

[10] General Abrahamson was recently reported (*Defense Electronics*, March 1985) as looking forward to an electromagnetic railgun technology which would launch 'a six or seven pound projectile, containing some minor terminal guidance ability, to speeds of from 25 to 30 kilometres per second. But the real challenge in this technology is in the electric switching, to get the rapid firing rates. It is a problem of power management'.

[11] There has been much argument in America about how many satellites would be needed on patrol, and the following rough calculations are included mainly to show some of the key factors and the numbers involved.

launching area for about 5 minutes, or one-twentieth of the 94 minutes round its orbit, so that to be sure of having one satellite within range, 20 or more satellites would be needed to be following it spaced at regular intervals around the orbit. Each satellite would menace a swathe 1600 kilometres wide cut through the Russian launching area from south to north or vice versa, and so satellites would be needed in other orbits spaced laterally at not more than 1600 kilometre intervals as they cross the area, which lies at about 55° latitude, where a line of latitude right round the earth has a circumference of about 23,000 kilometres; and satellite orbits would have to be spaced around this at no greater than 1600 kilometre intervals to ensure that at least one orbit would be within sight of any one of the possible launching points. So 23,000 ÷ 1600 or about 15 orbits would be needed to be spaced rather like the divisions between the segments of an orange, as the earth rotates below them. Actually, the number can be halved because 15 orbits would ensure that any one point on earth that has been covered once by a satellite, say from south to north, will be covered a second time, this time from north to south, about 12 hours later.[12]

Number of patrolling satellites for a killing range of 800 kilometres

So we need 8 orbits, each holding about 20 satellites, to be reasonably sure that any one point in the Russian launching area has at least one American satellite within sight at any one time. So with 8 x 20, or 160, satellites we might hope at best to destroy as many ICBMs as the hittiles that can be fired from the American satellites at any one time within sight of the Russian launching area. If, as the UCS assumed, this area extends roughly from west to east (Sverdlovsk to Irkutsk) for about 2700 kilometres, there would not be more than three such satellites on the foregoing calculation – and since several hundred ICBMs might be fired in one salvo, then either each American satellite must be able to carry (and aim) at least 100 killers or, more realistically, many more satellites would be required – at least five times to reduce each satellite to carrying and aiming no more than 20 killers. So on this argument 5 x 160, or 800 satellites would be required to ensure that 300 ICBMs could be attacked out of one salvo.

Number of patrolling satellites for 2400 kilometres killing range

The foregoing calculation has made some highly optimistic assumptions, such as the unerring detection of ICBM launches and immediate dispatch of hittiles. We will now stretch optimism further by supposing that the entire duration of a 300-second boost phase would be available for attack by killers. We could then afford the orbiting satellite to be 2400 kilometres away from the ICBM launch. Instead of about 20 satellites spaced around any one orbit, we would need only 7, and the orbits could be spaced laterally at 4800 kilometres instead of 1600. So we now need only about one-third of the orbits we need for 1600 kilometre spacing, or 8 ÷ 3 =3, to the nearest integer. Thus 21 orbiting satellites could ensure that at least one is within sight of the Russian launching area at any one time. Moreover, since this satellite can oversee and menace a swathe 4800 kilometres wide, it does not matter whether the launching area stretches from Sverdlovsk to Irkutsk or from Moscow to Sakhalin (5000 kilometres). But either that one satellite within menacing range must carry enough killers to deal with an entire salvo of 300 ICBMs, or we must have many more satellites to make the task of any one satellite feasible. At 20 hittiles per satellite, we therefore need 15 x 21 or about 300 satellites – not as many as for an 800 kilometre killing range, but still a large number.

Other factors affecting the required number of patrolling satellites

The foregoing calculations indicate that when a very small number of ICBMs would have to be dealt with, the requirement of having one satellite within killing range results in the number of satellites needed being inversely proportional to the square of the killing range. But for hundreds of ICBMs to be countered simultaneously the number of satellites required is determined much more by the numbers of ICBMs to be countered than by the killing range.

The number of ICBMs out of a salvo that could be detected and engaged by each patrolling satellite depends in turn on two other factors: (1) the total number of killing devices that can be carried by any one patrolling satellite; and (2) the rate at which the satellite can detect and engage rising ICBMs, which determines how many ICBMs the one satellite could engage out of a single salvo while they are in the boost or immediate post-boost ('busing') phase. With missile-killers, each one of which would be autonomous after launching from its parent satellite, the latter could immediately turn its attention to a second ICBM and launch a second killer. Even so, it seems extremely optimistic to assume that this could be accomplished in less than 3

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[12] Some further reduction might be possible by placing the satellites not in strict north-south orbits, but in ones inclined at, say, 60° to the Equator.

seconds,[13] and so no more than 30 killers could be launched if 100 seconds were available in the boost phase.

Rather similar considerations would apply if it becomes possible to replace missile-killers with a laser or particle-beam device which is aimed directly from the patrol-satellite against the rising boosters, with the additional requirement that the aiming system of the satellite must 'dwell' on each ICBM long enough for the aimed laser or particle beam to destroy it. If the satellite's system is 'intelligent' enough to recognise that the target has been destroyed, and immediately switches itself to another target, a favourable factor in killing performance can be gained. For if, say, the laser particle beam is powerful enough to destroy an ICBM at 2400 kilometres range in 5 seconds, it could probably destroy the same ICBM at 1200 kilometres range in little over 1 second, assuming the inverse square law. This would mean that the system could deal with four times as many missiles if these were to come up randomly in its survey area as it would if they had all to be engaged at extreme range. The number of satellites required could therefore be no more than a quarter of the number calculated on an extreme-range basis, provided that enough destructive energy can be carried in each satellite to destroy the required number of ICBMs.

The necessary number of satellites therefore appears to be highly dependent on the assumptions that are made concerning the killing range, the slewing time, the energy store that can be carried in each satellite, and on the number of missiles that the Russians are likely to launch in one salvo. We have seen that at least 900 satellites would have to be on patrol to give even a hope of attacking every one of a salvo of 300 ICBMs with a 100-second boost phase assuming that each satellite carried 20 hittiles, and this number would rise to 4000 satellites if the salvo included all 1400 of the Russian ICBMs. By contrast, if either a laser or a particle beam system could be made intelligent enough not to dwell on any one ICBM any longer than is necessary to destroy it, and if the laser or particle beam could be fired 20 times over a period of 300 seconds (or 100 seconds, depending on the duration of the boost phase), then about 300 satellites would be needed on patrol for a salvo of 300 ICBMs.

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[13] In a paper of 30 August 1984 from the Livermore Laboratory, C. T. Cunningham assumed, along with the Congressional Office of Technology Assessment (which nevertheless concluded in *Directed Energy Missile Defense in Space* in April 1984 the chance of protecting the American people from a Soviet missile attack is 'so remote that it should not serve as the basis for public expectations or national policy') that the 'slewing time' could be much less than a twentieth of a second.

Whether such slewing alacrity, especially in handling an extremely intense beam, is achievable must be open to question. Obviously an electro-optic technique would be necessary – R. Jastrow in *Commentary* for March 1985 mentions 'phase conjugate coatings'.

The cost of continuous patrols

Since the Russians would be aware of how many American satellites were on patrol, they would try to fire a big enough salvo to ensure that the defences were saturated. The Americans would in turn try to increase the number of patrolling satellites, and the Russians would in turn try to saturate this new number by launching, if necessary, all their 1400 ICBMs (or even by building still more of them). And if the SDI showed any sign of success the Russians might revise the policy, initiated by the US, of multiple-warheaded missiles, since if the boost phase proves the most vulnerable it could pay to have fewer warheads per booster and more boosters. So it does not seem entirely unreasonable to assume that the Russians would try to launch as many of their ICBMs in one salvo – let us say about a thousand.

For hittile-firing satellites some 2500-3000 might therefore be required on patrol against a boost phase lasting 100 seconds, while for laser or particle beam satellites, and a boost phase of 300 seconds, around 900 would appear necessary. Taking the hittile-carriers, the mass of hittiles to be lifted into orbit, at 50 kilograms[14] per hittile, would be about 2500 tons; and the mass of the satellites to carry the hittiles might be of the same order, making the mass to be lifted about 5000 tons all told. The Union of Concerned Scientists estimates that the cost of lifting into orbit is about 3 million dollars per ton, so the cost of putting the satellites into orbit would be about 15 billion dollars.

In comparison with some of the other costs involved, 15 billion dollars is very minor. As for the costs of the basic satellites, one of the few positive statements is that by one of the 'Star Wars' protagonists, Robert Jastrow, in *Commentary* (December 1984) who said, 'Now, everyone acknowledges that these satellites are going to be extremely expensive. Each one will cost a billion dollars or more – as much as an aircraft carrier.'[15] And another of the protagonists, General Daniel Graham, whose persuasion was largely responsible for President Reagan's launching of the SDI programme, was reported in *Science* (1 July 1983) as saying that 'more than 400' satellites would be needed. If Jastrow and Graham were referring to the same kind of satellite this

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[14] 5 kilograms hittile + 45 kilograms booster.

[15] According to Bethe and Garwin the typical cost of present satellites is between 100 and 200 million dollars; a laser satellite would be substantially more sophisticated.

A paper from the Russian Academy of Sciences in 1984 (republished in *Survival* for March-April 1985) comments, 'Western estimates putting the cost of a multi-layer space anti-missile system at 1.5 or 2 trillion [dollars] appear to be justified.'

would imply a cost of more than 400 million dollars but Jastrow points to a computation by the Livermore Laboratory that no more than 90 satellites would suffice. But it is hard to reconcile the Livermore figure[16] with the admittedly rough estimates of the present paper, or with the revised estimates of the Union of Concerned Scientists. At minimum it would imply that each satellite could kill at least 15 ICBMs if all the satellites were within sight of the ICBM lauchings at the same time, but this would only be so if (1), as is most unlikely, all satellites could be over the Russian area at the same time; or (2) the lasers are not on patrolling but are on geostationary satellites, in which case a solution of the aiming problem appears beyond reasonable expectation.

More or less backing up Graham's estimate of at least 400 satellites are the revised calculations of the UCS (300) and of Drell, Farley and Holloway in 'The Reagan Strategic Defense Initiative: a Technical, Politicial, and Arms Control Appraisal' (Stanford University, July 1984). And a valuable paper of 30 December 1984 by a leading member of the UCS 'Star Wars' Panel, Richard L. Garwin, gives the estimate for a range of assumptions, of which the following are typical, assuming a launch of 1400 ICBMs:

Boost duration (seconds)	100	100	40	40
Slewing time between engagements (seconds)	3	0.5	3	0.5
Number of satellites required	422	278	1056	695

For 3000 ICBMs launched simultaneously the numbers in the last row would be increased so that, for example, for a 40-second boost duration and a slewing time of 0.5 seconds the required satellite number would rise from 695 to 1488.

So apart from the very low Livermore figure there is a general consensus that at least some hundreds of satellites would be required, and Garwin's detailed calculations also suggest, as do the rough ones of this paper, that the numbers required are approximately proportional to the number of ICBMs to be countered in any one salvo, and not to the square root of that number as Jastrow reports *los* Alamos and Livermore to conclude. The point is important because it bears on the question of whether SDI defences can be saturated by the Russians building more ICBMs. From Garwin's figures this appears at least a probability. His figures also show how many more satellites would be required if the boost-phase duration were shortened from 100 to 40 seconds, as American designers would consider feasible. The shortening might involve a payload penalty (20 per cent has been suggested), and Russian technology in fast-burn is thought to lag behind American; but it would not be beyond Russian competence in the time-scale that SDI is likely to involve.

Laser or particle beams on patrol

In attempting to estimate the numbers of satellites required on patrol we have made some very optimistic assumptions indeed regarding the performance of the systems. With all systems we have assumed a perfect and near-immediate detection by any one satellite of an ICBM, which could take place in any compass-direction around it. If it is to launch a hittile this has to be fired in the appropriate direction within a margin of error that can be corrected by the homing system of the missile-killer; this done, the satellite can immediately look for another ICBM. If instead of a hittile the satellite has to fire a particle beam, then this has to be aimed much more precisely than a killer-missile and has to be held on the target long enough to disrupt it. The precision demanded at an average distance of, say, 2000 kilometres is of course around 20 times less stringent than that which we estimated for the 35,000 kilometres range from geostationary orbit but it is still comparable with that required for the space telescope, which will be the greatest yet achieved by man.

Moreover, for a laser to produce the necessary concentration of energy, say an area 50 to 100 centimetre diameter at 2000 kilometres range, the optical system associated with the laser needs a much smaller aperture than that required for the 35,000 kilometre range from geostationary orbit; a mirror about 2 metres in diameter might suffice if the laser operated with green light. If, though, it operated in the infra-red region (2.7 microns wavelength was assumed by UCS since the most powerful laser yet devised, based on the hydrogen-fluorine reaction, works at this wavelength) the mirror would need to be 10 metres in diameter. Assuming that such a laser could work at a power of 25 megawatts (more than ten times that scheduled by the Fletcher Commission for demonstration by 1987), it would need to 'dwell' on a spot of just under one metre diameter on a booster at a range of 3000 kilometres for 7 seconds in order to produce sufficient disruption

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[16] The Livermore paper (that by C. T. Cunningham already mentioned) contains some fantastic assumptions: the laser satellites would be in six orbits at 300 kilometres altitude: against the simultaneous launch of 1400 Russian ICBMs, no more than 8 satellites could be engaged, and 4 of them would be expected to destroy some 1200 missiles, or 300 per satellite, each satellite killing 10 ICBMs per second!

(assuming the Fletcher Commission's reported figure of 200 megajoules per square metre as the necessary dose).[17]

As in the case of geostationary lasers we still have the problem of knowing when the laser is aiming precisely at the booster whose rise has been detected by the visible or infra-red radiation from its plume. One way of doing this might be to use the laser as its own 'radar' system; if it can be set on an initial scan around the direction indicated by the plume-detector some of the laser energy will be reflected back from the booster as soon as the laser beam strikes it in the course of scanning. A photoelectric detector system on the satellite might then 'lock' the laser on to the booster until the latter breaks up under the cumulative effect of the beam. Unfortunately, though, some further technique would be necessary to ensure that the laser aims precisely, not merely at the booster but at a fixed area on the booster. But an advantage of using the beam from the laser as its own scanner to find the target is that it might be possible to broaden the beam while it was in the searching mode and then sharpen it again once it had located target.

Such a technique might give a laser system an important advantage over a particle beam, where there would be no obvious way of ensuring that the beam was actually striking the target until the latter was disrupted. But, taking an overall view it is hard to differ from the opinion of Edward Teller who, although he supports SDI, is quoted in *Commentary* for March 1985 as saying 'lasers in space won't fill the bill – they must be deployed in great numbers at terrible cost, and could be destroyed in advance of an attack'.

Are 'Star Wars' technologies feasible?

Part of the purpose of the rather laboured approach of the preceding sections has been to work out, roughly but independently, some of the figures that are feasibly calculable to see which of the two main American schools of thought – 'Star Wars' or 'Anti-Star Wars' – is the more likely to prove right. The Union of Concerned Scientists, which belongs to the second school, has made its calculations and comments publicly available for criticism and has revised them in the light of that criticism. Although one or two of the technical criticisms have been important they have not given the union cause to change its conclusions substantially.

In general, the union has considered many other factors and techniques besides those mentioned in the foregoing survey and has in most instances stretched hope to its limits in supposing possibilities, such as a hittile with a mass of no more than 5 kilograms, or accurately bouncing a beam from a ground-based laser on to a geostationary mirror so oriented as to bounce the beam back down to another mirror on a patrolling satellite over the Russian area, again so oriented as to direct the beam precisely on to a spot on a rising booster, and keeping the entire system aligned for several seconds. Even with all these highly favourable assumptions, the Concerned Scientists conclude that if the task for a ballistic missile defence is to deal effectively with a salvo of ICBMs of the order of hundreds or a thousand:

> (1) A highly efficient boost phase intercept is a prerequisite of total BMD (Ballistic Missile Defence) but is doomed by the inherent limitations of the weapons, insoluble basing dilemmas, and an array of offensive counter-measures.
>
> (2) As a result, the failure of midcourse systems is preordained. Midcourse BMD is plagued not so much by the laws of physics and geometry (as is boost phase BMD) as by the unmanageability of its task in the absence of a ruthless thinning out of the attack in the boost phase.
>
> (3) Terminal phase BMD is fundamentally unsuitable for area defence of population centres, as opposed to hardpoint-targets.

An overstated counter-case?

We may ask whether the Concerned Scientists have overstated their case: but as regards the technologies involved in BMD they have given the pro-BMD lobby the benefits of any doubts regarding the limits of performance to which foreseeable technology may be stretched; and the same applies to the human abilities involved in taking the necessary command decisions before a defence would be activated. But have they overstated the scale of any possible attack? I recall the wild but official overestimate amounting to hundreds of thousands of casualties expected in London from German bombing in the first week of war in 1939. Again, in 1943 the Ministry of Home Security insisted on the estimate of its 'experts' that the V2 rockets would kill 108,000 people per month, and yet the average monthly rate over the seven months of the actual bombardment was less than 400.

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[17] 200 megajoules is about equivalent in energy to that produced by 100lbs of TNT. In an article in *Scientific American* for October 1984, Bethe, Garwin, Gottfried and Kendall give the possible output of a hydrogen-fluorine laser as 500 joules per gram of fuel. So to destroy 300 ICBMs could require 120 tons of fuel, assuming that all the energy was successfully focused on the targets.

In both these cases there had been gross overestimates of the scale of attack: could the Concerned Scientists have fallen into the same error? The Russians would have every incentive to fire as many missiles as possible in one salvo, to saturate any possible defences; but could they, or would they, launch all 1400 at once? They might, for example, hold back half to deal with any possible threat from China, or they might be concerned about the effects of a nuclear winter or of radioactive fall-out if they fired more missiles than necessary to neutralise America. So they might not fire more than, say, 200 in one salvo. This would, in effect, produce something of the 'ruthless thinning out' that the Concerned Scientists find necessary for any hope of mid-course BMD; but the Russians would be equally aware of this danger and would probably decide to fire a salvo numerous enough, on their calculations, to ensure that enough ICBMs survived to deliver a knock-out blow to America.

A factor that might ease the Americans' problem to some extent is the difficulty that the Russians would have in concealing their preparations from the American Intelligence Services. But this does not seem likely to help much with the problem of attacking the boost phase, where so many satellites have to be already in orbit if any salvo of, say, 50 or more ICBMs is to be dealt with.[18]

A factor which would substantially add to the difficulty of the Americans' problem is the Russian ability to take counter-measures. We have already noted that concentration is one of these, as it has so often been in the past, for example in Bomber Command's battle with the Geman night defences. Another simple counter might be to make the rising boosters spin slowly, say once every second or two, which would spread the disruptive effect of a laser over the entire circumference and thus dilute its effect on any one spot; while this might be offset by making the laser emit its beam in pulses it is likely to add a further complication. Decoys of various forms, so as to blind or deflect killer-missiles from genuine ICBMs, are an obvious counter-measure; and by the time the Americans have developed killer-missiles to the sophisticated degree for anti-ICBM work, the Russians will have developed killers of a performance which, while not equalling that of ASAT might well be able to cope with American satellites. And since the BMD concept depends on defeating any *Russian* initiative in starting an intercontinental nuclear war the Russians can always delay this initiative until their technology has sufficiently caught up.

Another American problem may occur in recognition: supposing that they have a swarm of satellites each carrying a clutch of missile-killers, each satellite capable of detecting a rising ICBM and launching a killer to home on to it, and that each killer can achieve this satisfactorily, for every member of the swarm over the Russian launching area there will be another over the American launching area, if the two areas are comparable in extent. Somehow the American satellites must be prevented from initiating killer action when they detect the rise of an American ICBM launched in response to the Russian attack. If the inhibition of action depends on the receipt of some signal from the American ICBM or from its launching territory, this offers the possibility of Russian counter-measures: but it may be possible to devise some form of internal timing arrangement which would disarm the American satellites while near their own ICBM launching area.

Beside the counter-measures that the Russians might develop to defeat BMD directly, they will also have available the alternative of nuclear missiles launched from submarines either ballistically or on airborne cruise vehicles. Of course, if there were such a swarm of American defending satellites as to cover the entire globe, as a successful boost phase attack demands, then these could also detect the firing of ballistic missiles from submarines and attack them subject to one proviso – this is that the boost phase of such a missile lasts as long as the 100 or so seconds for an ICBM. If it were, for example, only half as long, then this would roughly halve the time for a missile-killer to reach the rising missile, which would need a closer spacing of satellites requiring roughly four times as many as for the 100 second boosters. And as the Concerned Scientists point out (quoting evidence presented to the President's own Fletcher Commission, the Defensive Technologies Study Team), it may be possible to reduce the boost-time of even an ICBM to the order of 50 seconds (certainly this appears in prospect to be much easier than many of the development problems facing BMD technology), which would make their general conclusions even more plausible than they are already.

The surprises of the past

Notwithstanding all the arguments so far presented in this paper any critic must ask himself, in view of the optimism shown by the President

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[18] In *Military Space* for 4 February 1985, the SDI staff is stated to expect retargeting times of 0.1 seconds, to discount any substantial increase in threat from fast-burn boosters, and to maintain that less than 100 patrolling satellites will be needed against 1400 ICBMs.

and those who have influenced him, how often the critic has been suprised by technological developments in the past. For myself, satellites were no surprise: a few of us had forecast in 1944, against general opinion, that sooner or later the moon would be hit. But even we would have doubted whether by 1970 men would have been landed on the moon and safely brought back. And although surveillance, both photographic and electronic, by satellite was conceivable, I for one was surprised by the exquisite quality that has been achieved; and although I was a witness of the early development of radar I have since been astonished by the feats of precision radar in measuring the distances of Venus and the divination of its surface features from the information contained in its radar actions, and even more by the fantastic feats of radio navigational command and control of the probes to Jupiter and Saturn. Moreover, the whole Polaris concept of ballistic missiles launched and accurately aimed from submarines seemed highly optimistic when it was suggested at Peenemünde before 1945; it would have been even more so to suggest that by 1985 each missile could carry 14 independently targeted nuclear warheads. And if any testimony is required to the American ability to react and improvise in an emergency situation, the history of the Apollo 13 ('we have a problem') mission is more than sufficient.

Why is the President enthusiastic?

The problem for a critic is therefore whether despite his doubts American ability, industry and ingenuity might successfully implement the SDI programme. The examples of Lord Cherwell in doubting the feasibility of the V2 or Henry Tizard of the atomic bomb are disquieting precedents from the past. But my personal guess is that SDI is of an entirely different order of difficulty from anything so far within human achievement. All the fantastic achievements mentioned in the preceding paragraph were made in contention with Nature which, although a hard mistress always plays fair, and not against an opponent who will be trying to trick you at every stage.[19] And my doubt is reinforced by the fact that American technological enthusiasm has not always been well founded. An example that I have in mind concerns the detection of submarines by infra-red reconnaissance of the ocean surface, based on the idea that a submarine moving at depth would force water from its path upwards to the surface, and this water would be at a temperature different from that at the surface and would therefore show up as a thermal wake on infra-red scans. While this could sometimes happen, it seemed to those of us concerned with military infra-red in Britain that it would be most unlikely to be reliable enough to be adopted as a reliable, or even partial, method of detecting submarines. But American opinion was so confident and enthusiastic that there were doubts in British defence circles about the competence of the British infra-red committee which I chaired: but subsequent developments entirely vindicated our doubts.

This could be part of the answer to the inevitable question of why the President and his advisers are so enthusiastic about SDI – the enthusiasm of some of its proponents may have carried them too far beyond what the facts of nature and of conflict will permit. SDI and its prospect of freeing humanity from nuclear bombardments has a great emotional appeal; but all the more because of this we need to remember the words Louis Pasteur said that he would like to see inscribed on the threshhold of all the temples of science: 'The greatest derangement of the human mind is to believe in something because one wishes it to be so.' Or, in the words of Crow's Law: 'Do not think what you want to think until you know what you ought to know.'

The second part of my answer is that not all American authorities, and not even all of the President's advisers, are so enthusiastic. A former Secretary of Defence, Dr James Schlesinger (formerly a defence analyst with the Rand Corporation and the director of CIA, as well as a counsellor to the President's Commission on Strategic Forces which reported in 1983) said at a conference on space and national security in 1984: 'The heart of Reagan's speech was the promise that some day Amercian cities might indeed be safe from nuclear attack'; and he went on, 'There is no serious likelihood of removing the nuclear threat from our cities in our lifetime or in the lifetime of our children.' He also ventured the cost of the 'defensive missile shield' as at least 1000 billion dollars. And it was noteworthy that at the same conference both General Abrahamson and Gerald Yonas, his chief scientific adviser on SDI, consciously downplayed any hopes of using it to defend cities (*Science*, 9 November 1984).

Why do the Russians appear to be worried?

Well if, as it seems, the President was led to over-enthusiasm in his

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[19] Nature itself can be difficult enough: all the superb American precision in the flights to the moon, whose position could be predicted precisely, was often reduced to clumsiness at the end of the flights when helicopters had to recover the capsules from the surface of an unpredictably heaving ocean. If the ocean could give so much trouble to moon shots, what could Russian counter-measures do to SDI?

original statement by a pressure group, and SDI does not offer prospect of a believable defence until long into the future, at best, then why are the Russians so apprehensive about it? One answer is that the sooner the Americans start on the programme the sooner it will achieve its aims however far they may be into the future, and at that time – unless the Russians have caught up – the Americans would have a strategic advantage.

Another conceivable answer is that the Russians are not really apprehensive at all but by appearing to be so they may raise American enthusiasm for and confidence in SDI, so that much of the trillion dollars spent in its pursuit will be diverted away from projects which would contribute more substantially to American military potential. Again, there is a precedent from World War II: the effort spent by the Germans in developing the V2, though technically brilliant, was largely wasted as far as the war was concerned – if it had gone instead into jet fighters, or even into building many more of the much cheaper V1, it would have caused the Allies far more trouble militarily.

And another answer may be that the Russian leaders are after all just as human as those in America, or indeed as those in Germany and Britain were in the Second World War. For rocket missiles seem to have an extraordinary appeal and influence. After some initial scepticism Hitler waxed enthusiastic over the V2: 'This is the decisive weapon of the war', he told Albert Speer on 7 July 1943 (Speer, *Inside the Third Reich*, p.496, Cardinal paperback). And, reciprocally, the threat was very much over-estimated in Britian – so much so that, Lord Cherwell told me in 1944, the construction of two battleships was cancelled to provide the steel estimated to be required to make enormous numbers of Morrison shelters. And the alarm caused by the prospect of 10 tons of explosive delivered by rocket was much more than that of 50 tons delivered by bombing aircraft. Could the same semi-irrational factors be at work on either side today? And could that be why the Russians appear so apprehensive?

Another, and less subtle, answer is to imagine ourselves in the Kremlin. We have opposing us a country with a leadership that believes, rightly or wrongly, that it can shield its homeland from our nuclear missiles while being able to launch its own at us. Although it may declare that it would never *start* a nuclear war, the fact that it believes that BMD would ensure that it would not lose such a war could make it less reluctant to resort to nuclear attack. The Russians might therefore conclude that the American leadership might be the more prepared to risk a nuclear war because they believed that they could win without incurring serious casualties among their population: if they were right the Russians must lose: and if they were wrong they – the Americans – could lose but the ensuing nuclear exchange would still have dire consequences for Russia as well as for America. True, the President has spoken of sharing BMD technology with the Russians but such altruism is not a quality that they have given much evidence of recognising.

The possible effect of the SDI programme on the Kremlin outlook is not in itself an argument for not pursuing it if it has a good chance of successful fulfilment. Sooner or later some nation or other is likely to go for any development in military technology if it thinks that this will give it an advantage, despite the moral issues this may raise. Whatever scruples the Oppenheimers and Wieners may have, sooner or later the Tellers[20] and von Neumanns will prevail. High principles, unhappily, tend to be overwhelmed in the face of military extremity. The German employment of gas and unrestricted U-boat warfare, and of biological warfare with anthrax, in World War I, and the Allied development of napalm and of anthrax and of the atomic bomb, and their bombing of civilian populations, are all examples. These were all offensive in intention: and yet, despite considerations of morality, they were nearly all employed. There is no such moral brake on a purely defensive programme such as SDI, and so it will be pursued by at least one side, and probably both, if it offers them any hope of success.

The problems of asymmetry

It is not easy to view the world through Russian eyes, especially because the Russian and NATO positions are so asymmetrical. Their geographical circumstances are disparate – Russia's huge territory forms one continuous land mass with its Warsaw Pact dependencies, America is separated by the ocean from its NATO partners which are in the main contiguous with countries in the Warsaw Pact, and physically nearer to Russia than to America. NATO is vitally dependent on sea lanes: Russia is not. All countries in NATO have open societies, with the opportunities these offer the Russians for intelligence-gathering, both overt and covert: Russia is a closed

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[20] And in *Commentary* for March 1985, Teller pointed with some justification, to the argument preceding the development of the hydrogen bomb in America. Oppenheimer and two members of the current UCS panel (Bethe and Weisskopf) argued against development, partly on the grounds of morality, and the hope that if the United States refrained the Russians would do likewise – when in fact the Russians had already started development.

society, far more difficult for the gathering of intelligence, which has to be obtained predominantly by photographic and electronic means. Not only are the oceanic transport links of NATO far more vulnerable than the land transport links inside Russia but the dispersed dispositions of the NATO allies, and particularly of the American forces supporting them, make the West far more dependent on radio communications, both by conventional links and by satellite, than the Russians who can largely communicate by landlines.

Two problems arise from these asymmetries. The first is general: whenever the Americans and the Russians attempt to negotiate they inevitably have differing, and sometimes even opposite, views regarding the importance of particular techniques and types of weapons, for what may appear the greatest threat to one side may be of lesser importance to the other. Anything that threatens the command of the sea would, for example, be vital to NATO but not to the Warsaw Pact: conversely the convention on human rights which is taken for granted in the open society of America might appear to the Politburo to threaten the closed structure of the Russian state.

In any one of several specific fields, any agreement based on equality between the two sides will benefit one side more than the other: NATO, for example, requires more naval forces to protect its sea links, whereas the Russians have few such links that they need to guard. So any agreement giving the same number of naval escorts to both sides would give an advantage to the Russians. And they in turn feel that any agreement on inspection of nuclear test sites based on equal numbers of inspections on each side might give the American inspectors useful opportunities for espionage. While Russian inspectors on American soil would have similar opportunities, these might seem of relatively little value because of the large amount of information the Russians can already gather in America by virtue of its far more open society. Further, any agreement on intermediate range ballistic missiles will be viewed differently by the two sides, for while these will bring Russian centres within range of American missiles sited in Europe (and conversely NATO centres within range of Russian IRBMs), Russian IRBMs could not reach the American homeland.

So there is often little incentive for the prospectively disadvantaged side to come to agreement in any one field and bargaining has to be extended to at least two fields simultaneously, with one side giving more in one field and taking more in another; but there then arises the question of how much chalk is equivalent to so much cheese, with the difference that the commodities to be bargained are so sophisticated that there is little prospect of reasonable agreement. Negotiation is then fraught with frustration, all the more so because a further asymmetry arises from the growing power of China on Russia's land frontier.

ASAT

We have already noted that American intelligence is much more dependent on spy-satellites than is Russian intelligence, and that American forces are far more dependent on satellite communications than are the Russian. And so any agreement that satellites should be immune from attack would appear to benefit America much more than Russia and it is therefore not surprising that while both the Americans and the Russians started to develop anti-satellite capabilities in the 1960s, the Americans dismantled theirs and took up the position that their national security would be better served by abstaining from competition in ASAT weaponry. The Russians, though, continued with their own ASAT work and late in the 1970s the Americans restarted. According to the Concerned Scientists, the Russian Satellite-killer weighs about three tons and is launched from an SS9 booster weighing about 200 tons. It could not reach geosynchronous orbits and can only be launched into low-altitude orbits; it is operated in such a manner as to chase its target from astern, perhaps taking one or two entire orbits to get into a killing position, and destroy the target by a shrapnel explosion using a conventional explosive.

The American ASAT which is due to be tested shortly is, by contrast, very small: its characteristics have already been mentioned in considering how its principles might be adapted to a missile-killer against Russian ICBMs in the boost phase. Apart from its small size its other main differences are that it is designed to kill by direct impact, and to be fired to intercept its satellite target head-on after a trajectory of relatively short duration and not to lose time in a stern chase. Its design is much more sophisticated, as it needs to be, than that of its Russian rival but the Americans believe that their greater accuracy in detection and control systems will enable them to make it effective. In any case, in comparison with the SDI project, and difficult as it is, it is a mere stepping stone on the way to SDI.

Despite the promise of the American ASAT, it seems that a ban on all anti-satellite weapons would benefit the Americans more than the Russians because of the greater dependence of the former on satellites for reconnaissance and communication. It was therefore noteworthy that President Andropov in August 1981 proposed a treaty banning anti-satellite weapons. Whether or not this was because he thought that the Russians had already developed a proven system, while a ban might hamstring the Americans, his concern about the future in space was repeated in his reply of 1 April 1983 to the petition that the Concerned Scientists cabled to him on 24 February 1983. Incidentally, they sent parallel petitions to the leaders of France, India, Japan, China, Britain and America, but Andropov alone answered within three months. Their subsequent challenge to Andropov to make a public statement that, as part of a general treaty banning space weaponry, the Russians would be willing to forego further tests of any anti-satellite system provided that the Americans would make an identical commitment, was not answered before Andropov died (as far as I am aware) and has been overtaken by more recent arms talks.

The economics of SDI

Reverting to the Strategic Defence Initiative, what are the prospects for its deployment in the foreseeable future? Earlier we have cited opinions from authorities qualified in one way or another to comment, and these range from the expectation of some degree of deployment by 2000, through 2050 to virtually never. And as for the development of the necessary technology, some believe that it will be forthcoming – or at least can see no absolute obstacle to its ultimate success – and that it will be possible to intercept ICBMs in any one of the three phases: boost, midcourse, and terminal.

Assuming that, against the odds, the SDI proponents are right about the technical possibilities, the vital question then becomes the one posed by the Concerned Scientists: what scale of effort is required? One simple observation appears to me crucial: while ICBMs are already in existence there is widespread agreement, even among the proponents of SDI, that a successful technology for intercepting ICBMs, particularly in the vital boost phase, will be very difficult and will take great effort and much time to achieve. Therefore it is going to be much more expensive to intercept and destroy an ICBM than it is to build it, a conclusion which is supported by the kind of numerical assessment made by the Concerned Scientists. This is not by itself an argument for not pursuing SDI, because the economic balance that has to be struck is not simply between the cost of destoying an ICBM and the cost to build it but between the cost of destroying an ICBM and the cost of the damage it would cause if it reached its target. We in Britain learned this in the V1 campaign of 1944, where the cost to Britain (and the US Forces) of defending against the V1s substantially exceeded the cost of the V1 campaign to the Germans, but where the cost of damage to Britain would have been very much greater if no defence had been made.

But, if as seems most likely, the cost of destroying an ICBM greatly exceeds the cost of constructing it, then all the Russians have to do is to build more ICBMs to the point where the Americans cannot stand the economic strain.[21] This argument would require qualifications if, say, the cost of defence against 1000 ICBMs is not as much as 10 times the cost of defending against 100 ICBMs; some factors could work in this direction – general surveillance, for example, would have to be provided irrespective of the number of ICBMs to be contained – but others would work the other way, especially since the greater number of ICBMs must require greater defensive effort, if this is not to be saturated. So anything like the complete defence optimistically envisaged by President Reagan and Secretary Weinberger seems quite out of question on scale alone, if not on technological difficulty.[22]

Effects on NATO

This paper has been concerned primarily with the questions of whether SDI is technologically and logistically sensible, and only secondarily with its geopolitical implications.[23] Obviously, if SDI offered the prospect of substantially shielding America against nuclear ICBMs the Americans would adopt it regardless – in the end – of any

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[21] Costings are hard to estimate: President Reagan has recently (9 March 1985) asked for 1.5 billion dollars to buy a further 21 MX missiles. If this is all to be spent on missiles and their associated equipment, it implies a cost of 70 million dollars a missile, while a Trident D5 missile has been estimated to cost 25 million dollars; we therefore take a median figure of 50 million dollars per ICBM. If, say, seven satellites have to be in orbit to ensure that one is over the Russian launching area, and each costs 'a billion dollars or more' then 7 billion dollars have to be expended to eliminate the number of ICBMs that can be destroyed by a single satellite. Unless this number is at least 140, the economics are adverse: and it would be even less favourable if the Russians can build ICBMs (perhaps with fewer warheads) for less.

[22] Harold Brown, Chairman of the Foreign Policy Institute of the John Hopkins University (and Secretary of Defence 1977-81 and a physicist) came to the same conclusion in his report *The Strategic Defense Initiative: Defensive Systems and the Strategic Debate* of December 1984): 'American political and military leaders should publicly acknowledge that there is no realistic prospect for a successful population defense, certainly for many decades, and probably never.' (Full text in *Survival*, March-April 1985.)

[23] For a discussion of the effect of SDI on Europe see T. Taylor in JRUSI, Vol. 30, No. 1, March 1985.

repercussions on other members of NATO, and who could blame them? The fear would be the withdrawal of the US Forces into Fortress America, leaving the other members open to Russian attack. But this fear will exist regardless of whether or not SDI is successfully developed.

Another ground for fear might be found in contemplating the deployment phase of SDI, for the Russians might see this as a last chance for a successful first strike before the American deployment, which could not be hidden, proceeded too far. But such a risk might be worth taking.

Two further fears may be less easy to discount: (1) American over-confidence in SDI might make some future administration less cautious in risking a nuclear war, which would be bound to result in enormous damage to the European members, if not to America itself; and (2) if SDI does not in fact offer the prospect of an effective shield, then enormous amounts of American effort will have been wasted, much to the detriment of the whole of NATO, both as regards its military potential and its economic viability. Of these fears the first may well disappear if the reasoning in this paper is correct because, barring some unforeseen invention, long before SDI could be deployed its defects would have become evident. The second, though, given the present outlook of the administration, could persist for some time. And although it is entirely for the Americans to determine how they spend their efforts, it would be reassuring if they could convincingly demolish the arguments in this paper and those of others more expert than I am in the field of geowarfare.

What will come out of SDI?

In the 1986 budget, President Reagan has asked for the expenditure on SDI research to be increased from 1.3 to 3.7 billion dollars; and in December 1984 *Defense Electronics* stated that the programme is scheduled to receive more than 25 billion dollars over the next five years. This is a huge sum, sufficient to cover three projects each of magnitude comparable with that required to develop the atomic bomb in World War II, and presumably this will be expended whether or not SDI ultimately becomes practicable. Such an effort is bound to have many results, both in the development of existing technologies such as lasers and mirrors for X-rays and in the birth of new technologies at present unconceived.

If the arguments in this paper are correct, then it is on such unforeseen developments in technology that a successful SDI must depend. The rational case against SDI is as strong as that against attempting to bomb Germany by day in World War II, where the logic was almost faultless. Experience had shown that bomber formations unescorted by protective fighters could not survive against fighters defending their homeland. Moreover, protective fighters, too, could be picked off by defensive fighters, because these – since they were operating at much shorter range and therefore having to carry less fuel – were always likely to have a superior combat performance, all the more so because they had the benefit of radar control from their ground stations. So both bombers and escorting fighters could not be expected to survive against the German defences and early experiences fully justified this expectation. Then came an invention and an accident. The invention was the drop-tank, which gave an escorting fighter sufficient range to operate over Gemany but which could be jettisoned to give the fighter a better performance in combat. The accident was the Mustang fighter whose original performance was insufficient; but when fitted with the Merlin engine it became outstanding. So escorting fighters could now enjoy a period of superiority until German fighters of comparable performance could be produced and this period proved decisive in the daylight bombing of Germany.

The main hope for SDI may well have to lie in the appearance of inventions as vital for space defence as was the drop-tank for daylight bombing.

The drop-tank precedent, though, should not be taken too seriously, for its advantage was very temporary: had the war gone on better German fighters would have appeared. SDI aims at producing a permanent defence for all times in the foreseeable future, and since the United States is committed never to start a war then it follows that SDI would only come into action after the Russians had started the war – and the Russians could presumably not do this until they were reasonably sure of being able to render SDI ineffective. If they could not do this, then a successful SDI might fulfil its aim of preventing nuclear war; but much faith is required to believe that SDI is feasible and that the necessary inventions will be forthcoming.

Some recent statements in America

In a White House statement of January 1985 on SDI, President Reagan affirmed his position: 'I have called upon the great scientific talents of our country to turn to the cause of strengthening world peace by rendering ballistic missiles obsolete. In short, I propose to channel technological progress toward building a more secure and stable world.' And in a statement of 15 March 1985 to the Committee on Armed Services of the Senate,* General Abrahamson emphasized that SDI is not a weapons research programme, nor is it a programme 'with preconceived notions of what a potential defensive system against ballistic missiles should entail'. But, strictly can this be true? Without some preconceptions regarding feasible methods, how could anyone decide that the odds of success and the likely cost were such as to justify starting the programme?

There are some signs that the initiators of the programme have back-tracked from their originally optimistic statements in the light of criticisms coming from many scientists and military authorities with experience (and achievement) in advanced defence projects. And there has been some shifting of ground, with an argument that even though SDI might not be able to protect civil populations it could protect American missile launching sites – or even that although it might not work it could be a useful 'bargaining chip' in negotiating arms limitation. But besides the back-tracking there have been some optimistic statements such as that made by General Abrahamson to the Armed Services Committee of 15 March 1985, which records 'remarkable progress'. And if George Keyworth was correctly reported in the *Daily Telegraph* for 24 April 1985, the progress is indeed remarkable, even fantastic: he anticipates the testing within three years of the feasibility of a laser that could fire 3000 missile-destroying pulses within the first five minutes of the launching of a Russian salvo. Somehow, too, 'SDI was a system that could be tested at any time without threatening anybody.' It would be interesting to know how all this is to be achieved.

Those who doubt the prospects of SDI succeeding are faced with a fait accompli: the programme is already actively in being and has acquired a self-interested impetus, not unlike that of the Robbins expansion in higher education in Britain which (inviting recall of Dean Inge's comment on the Gadarene swine, 'no doubt they thought the going was good for the first half of the way') ultimately resulted in the present unhappy state of many of Britain's universities. As James Schlesinger told a recent meeting at the Mitre Corporation, 'whether or not the President should have said what he did in March 1983 is now overtaken by events. One cannot eliminate those words he spoke. It is an illusion of critics of SDI that somehow all of this can be rolled back. It cannot be.' (*Defense Electronics*, March 1985.)

America's invitation to its friends

Early in February 1985 Secretary Weinberger offered the opportunity to NATO and other powers to participate in SDI research. It was a big programme, he said, and the US needed 'all the help that we can get' (*The Times*, 9 February 1985). So Britain has the chance of being henceforth more than simply a friendly observer, and the questions arise of how much British effort is justified, how that effort might best be made, and what the return is likely to be. Some interesting advances are bound to come out of the SDI programme, for example in laser power generation, optical beam switching, the working of large optical surfaces, image analysis, hittiles, and strategic and tactical control networks. But all these will be incidental products on the way to a fufilment of SDI, and it would be reasonable for British authorities to ask for evidence that there are reasonable hopes of overcoming some of the key technical problems.

Among these problems are:

(1) How are aiming accuracies of the order of 10 centimetres at 40,000 kilometres (or 4 inches at 20,000 miles) to be achieved, especially with a laser on the ground aimed via two mirrors on satellites?

(2) Is an X-ray laser, which is a one-shot device powered by a nuclear explosion, a sensible weapon?

(3) How is a target to be located, identified, aimed at, and seen to be destroyed, in a total time of less than 1 second, as required by some of the proposals advanced? (It would, for example, take a quarter of a second for the energy from a ground based laser to travel via two mirrors to the target.)

(4) How are any of the proposed systems going to deal with prospective counter-measures, eg rotation of ICBMs and decoys – and with the likelihood that long before a successful SDI system can be attained the Russians will have developed ASAT techniques (which are much simpler) which would neutralise the surveillance satellites on which SDI depends?

(5) Is there a reasonable economic prospect that SDI could cope with a Russian effort to outbuild it by further ICBM construction?

Beyond these, and many other, technical problems there are some of a

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* See p. 38.

more general nature. If the Americans can develop a successful SDI so in the course of time can the Russians: and while that could conceivably render nuclear delivery on either side by ballistic missile 'impotent and obsolete', in the President's words, other forms of nuclear delivery such as cruise missiles or by clandestine means must be dealt with as well. But, accepting that the countering of ballistic missiles could be an important step (at least in defence of one's own missile launchers) and that the Americans are committed to SDI, what should Britain do? Active participation would involve effort that must be diverted from other projects, and before any substantial commitment it is reasonable to ask for convincingly optimistic answers to the questions raised in this paper and elsewhere concerning the prospects for SDI success.

Acknowledgements

Dr R. L. Garwin has kindly provided copies of many of the papers quoted in this report from both sides of the American debate; and I am also indebted to the Leverhulme Trustees for assistance.

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Assessments by George A. Keyworth and William J. Parry were published in the issue of *SIPIscope*, the magazine of the Scientists' Institute for Public Information, for January-February 1985.

Survival (Vol. 27, No. 2, for March-April 1985) contains the following papers:

- Colin S. Gray, 'A Case for Strategic Defence'
- Harold Brown, 'The Strategic Defense Initiative'
- Lt General Abrahamson, 'Statement to Congress', 9 May 1984 (excerpted)
- President Reagan, 'Statement 3 January 1985' (excerpted)
- R. Sagdayev and A. Kokoshin, 'Space Based Defences: a Soviet Study', 1984.

A coming publication *The American Academy Space Weapons Book* will contain a chapter by H. Bethe on new BMD technologies.

LT GENERAL JAMES A. ABRAHAMSON

Statement before the Subcommittee on Strategic & Nuclear Forces

15 March 1985

I would like to highlight a few points with respect to the Strategic Defence Initiative, or SDI, to build on our session of 21 February.

Since the President's speech in 1983, we have seen many interpretations of what his vision entailed and what the SDI was expected to accomplish. In spite of what would appear to be many conflicting reports, I would like to emphasise that our goal has not changed and has, in fact, remained consistent with the direction outlined by the President. The driving force behind his concept is freeing the world from the fear of nuclear conflict. An ultimate goal is the elimination of all nuclear weapons. To move toward this objective, then, the SDI has been structured as a programme of vigorous research focused on advanced defensive technologies with the aim of finding ways to provide a better basis for deterring agression, strengthening stability and increasing the security of the United States and our Allies. I would again stress that the SDI is a *research programme* geared to provide a future President and Congress with the technical knowledge required to support a decision on whether to develop and later deploy advanced defensive systems. Such a deployment could enhance and strengthen deterrence while also providing critical leverage for very significant reductions in nuclear weapons.

Further, as a research programme, the SDI is *not* a weapons development programme, *nor* is it a programme with preconceived notions of what a potential defensive system against ballistic missiles should entail. Emphasis in the programme is being given to *non-nuclear* weapons for defence. The posture that might evolve from the SDI will not be intended to defend only our strategic weapons systems, nor is it a programme that should lead to an arms competition in space. We are considering ways to defend both ourselves and our Allies against the ballistic missile threat. As the work moves ahead, we are in full consultation with our Allies. It *is* a research programme designed to answer numbers of scientific and engineering questions that must be addressed before the promise of new technologies can be fully assessed. Finally, all the research in SDI will be carried out in strict compliance with our obligations within the ABM Treaty. An appreciation of these tenets is essential to an understanding of the SDI.

Since assuming the position as Director of the Programme less than a year ago, we have made every effort to convey such an understanding of the programme. The importance of the SDI and the implications for future peace and stability cannot be overstated. Nonetheless, our budget sustained a 21% reduction in its first year. There is clearly damage done by these FY 1985 cuts. We tried to minimise that damage by managing the reductions in accordance with the following:

- For new starts, we delayed the initial implementation.
- For existing programmes we either delayed programme enhancements designed to tailor the programme more closely to SDI needs, or we stretched out or temporarily interrupted the progress of such programmes where it was possible to do so without disrupting the integrity and continuity of the programme. In one particular case – the demonstration of advanced acquisition, pointing and tracking, known as Talon Gold – we severely limited the scope of the existing programme so that we could provide a major restucturing of our efforts.
- For some programmes we continued to fund at the rate indicated in our FY 1985 budget request, because they are fundamentally important to decisions which must be made in the early stages of the SDI programme.

While we were generally successful in meeting our overall strategy, achieving the planned funding levels in FY 1986 has become much more important if we are to continue the goals, schedules and tasks of the SDI.

In spite of the reductions we have continued to move ahead as rapidly as possible with the programme. In the short time since its inception the SDI has made remarkable progress. The commitment and dedication of those involved with every element of the programme is evident. In continuing to build on this solid foundation and very encouraging beginning, we estimate that the SDI will cost about $26 billion between fiscal years 1985 and 1989. Elements are again summarised as follows:

SD10 Programme	*FY'85 Appropriation*	*FY'86 Request*
Sensors	$ 546 million	$ 1386 million
Directed energy	$ 376	$ 966
Kinetic energy	$ 256	$ 860
System analysis & battle management	$ 99	$ 243
Survivability, lethality, space power & logistics	$ 112	$ 258
Management	$ 11	$ 9
Total	$ 1400 million	$ 3722 million

To some, this may appear to be an overly ambitious expansion. This assuredly is not the case. The SDI is a multi-faceted research programme, not a business-as-usual weapons development effort. As a research programme, resources are allocated and utilised more quickly than in a procurement endeavour. In fact, in FY 1985 the SDI had obligated nearly 40% of its budgeted resources by the end of the first quarter. This is unprecedented in a programme of this magnitude and certainly shows that the programme is on track, vigorously pursuing the objectives that have been set forth and clearly able to execute at the pace that has been programmed.

Further, as a multi-faceted programme as opposed to a 'single product development', it is critical that all elements of the SDI be orchestrated in a coordinated, phased approach. To provide the information necessary for our nation to make an informed decision with respect to moving ahead with development of a strategic defence against ballistic missiles, all aspects of relevant technology must be comprehensively developed to yield results in logical order. Elements of the programme are truly interrelated. Delays caused by reduction in given areas will ultimately delay attainment of overall programme objectives.

At the same time, within major projects in the programme, a complete effort must be maintained as well. For example, development of a space-based sensor is dependent, in part, on an intergrated sensor, which is in turn dependent on focal plane technology built on technology supporting new developments of arrays, sub-modules and modules. Multiply this by nearly a hundredfold and one begins to get an idea of the complex inter-relationships that intertwine throughout the programme.

As we continue to develop these technologies at a rapid pace, we build on the foundation established by Dr Fletcher in the Defensive Technologies Study. We are doing this, in no small measure, through the SDI Systems Architecture Studies.

10 contractors were awarded a Phase I contract in December 1984 to perform the SDI Systems Architecture and Key Trade-Off Studies – known at the 'Horserace Acquisition'. The purpose of this procurement is threefold:

- Provide an initial definition and assessment of several alternative constructs of systems architectures that can detect, identify, discriminate, intercept and negate ballistic missiles in their boost, post-boost, midcourse and/or terminal phases.
- Provide a complete and balanced set of technological and functional requirements by developing the key trade-offs for sensors, weapons, command, control, communications (C^3), and supporting sub-systems that can make the individual architecture a viable and cost effective strategic defence system.
- Define and give priority to critical technical issues which must be resolved before decisions can be made on whether or not to implement a given defensive strategy.

The 'Horserace' procurement is a phased acquisition approach. It is divided into two phases with the second being a unilateral government option. Phase I is a concept definition phase not to exceed $1 million. Period of performance ranges from a minimum of 6 months to a maximum of 12 months. Phase II, the detailed definition study, is planned to last 12 months. It is a priced option not to exceed $5 million. Approximately four contractors will be selected on the basis of quality and timelines to proceed into Phase II. The emphasis on timely completion gives rise to the comparison with a horserace.

In conclusion, we continue to be excited by the challenge and the responsibility for bringing this much needed initiative to fruition. In accomplishing this goal we will have pushed the level of technical achievement across a spectrum of technologies that are broadly applicable to defence needs. We will have resolved many outstanding issues about the future role and impact of such emerging technologies as directed energy. And, of course, we will give a future President, Congress, and our Allies the necessary ingredients for taking the first step on the road to eliminating the destabilising threat of ballistic missiles.

ROBERT C. McFARLANE

Remarks delivered to the Overseas Writers Association

7 March 1985

No issue is of greater importance to mankind today than strategic stability. A world awaits, with asperity, the reconvening of nuclear arms control negotiations on 12 March. The Soviet Union has returned to the bargaining table and we welcome them back. Ahead of us stretches a difficult path. The United States seeks equitable and verifiable agreements which significantly reduce the size of both US and Soviet nuclear arsenals. We hope the Soviet Union will join us in a constructive search for necessary solutions to our differences.

These differences are profound. To see this best, it is useful to take an historical perspective. We live in a world of change. As in social and scientific areas, the strategic picture too has changed greatly since the early '70s when the ABM Treaty was signed. Certain hopes and assumptions underlying that treaty, and the accompanying Salt I Interim Agreement, have been altered substantially.

One of these underlying assumptions was that the two agreements would lead to real reductions in offensive nuclear systems. That didn't happen. In negotiations, the Soviet Union has consistently refused to accept meaningful and verifiable reductions in offensive nuclear arsenals. Salt II did no more than set caps on already high levels of strategic arms. It is clear now that the Soviet Union never intended to settle for the rough equivalent of offensive strategic forces foreshadowed in the Salt I Agreements.

Since Salt I was signed, the Soviet Union has deployed eight new strategic ballistic missiles, five new ballistic missile submarine classes, and a new strategic bomber. In comparison, the United States has fielded only one new missile system, one submarine class, and has delayed deployment of the B-1 bomber. This build-up by the Soviet Union has altered the balance between opposing forces so necessary to maintaining stable deterrence. We are very concerned about the qualities of new Soviet ballistic missile systems. In time of crisis, these weapons are the most destabilizing; they are swift, carry a big payload, are mobile, and are accurate. It is becoming increasingly apparent that the Soviet Union is acquiring a survivable, first strike capability which will be far less easy to deter.

The second assumption was that there would be mutual restraints on strategic defence. This was based on the hope that the Soviets would come to accept, in doctrine and in practice, that this mutual vulnerability to each other's offensive nuclear forces was in our common interest. This innocent expectation did not materialise either. While the US stopped deployment of strategic defences, the Soviet Union continued to develop and deploy successive generations of anti-ballistic missiles, tracking radars, interceptor aircraft, and surface to air missiles. In fact, spending on strategic defence has been equal to or greater than on strategic offence. They have deployed around Moscow the world's only ballistic missile defensive system. Soviet research and development of more advanced technologies, including sophisticated directed energy weapons, proceeded throughout the 1970s into the mid '80s at a pace far in excess of our own efforts. Furthermore, along with already deployed phased array radars, construction continues on one in Central Siberia apparently capable of battle management, in clear violation of the ABM Treaty. They have constructed numerous hardened leadership bunkers, and continue expansion of their extensive network of civil defence. Altogether, these efforts increase the possibility of sudden Soviet abandonment of the ABM Treaty and rapid nationwide expansion of their anti-ballistic defences.

We could say that a third assumption, not surprisingly, was an expectation in the West that these and other arms control agreements would be fully observed. Here, too, we have been disappointed. The Soviet record on compliance overall is, at best, disappointing. And it is particularly disturbing in the strategic area, where they have committed serious violations of both offensive and defensive agreements. Although we have pursued resolution of these violations with the Soviet Union in diplomatic channels, we have received little satisfaction to date.

There is one more change I would like to mention. The assumptions made by the American negotiators in 1972 also had a technological premise. It was not feasible then to develop an effective defence against ballistic missiles. But technology does not stand still. Just as we have observed the qualitative advance in strategic offensive arms, new breakthroughs in the past few years offer the promise that a militarily sound and cost effective defence may be possible.

The pattern since 1972 is clear and disturbing. Soviet actions have disproved our assumptions and thwarted real arms reductions. The balances between offensive forces which have for years maintained deterrence between the nuclear powers are being upset by the Soviet

Union. Restraint on our part since Salt 1 in the deployment of offensive strategic weapons has gone unmatched by the Soviets. Instead, they have continued to increase the size, mobility and accuracy of their offensive nuclear arsenals.

No less alarming in both size and scope, is their investment in strategic defence over the last 20 years. As they develop anti-ballistic missiles capable of being moved and widely deployed in relatively little time, we must ask, for what purpose? When they harden an expanding system of command and control, we must ask the question, why? As they shield their leadership, harden their missile silos, and spend vast sums on civil defence, we must ask, to what end? The West simply has not posed a growing threat that would warrant such Soviet actions. But faced with Soviet unwillingness to date to agree to mutual, verifiable reductions in offensive arsenals, the West has no choice. We have to examine restoring the balance and alternative means for preserving a stable deterrence. We face three interrelated options in our efforts to restore and maintain the balance.

First, we can attempt through negotiations to get the Soviet to reduce offensive systems to equal levels. This will be our priority task in Geneva. But, if the past is any guide, our job will be difficult. We are prepared to be open, flexible, and constructive and will work diligently with the Soviet Union to negotiate effective, verifiable arms reductions. Remember, though, it will take two to make these negotiations work.

Second, we can try to reverse the trends by simply attempting to match the Soviet activity and maintain an offensive nuclear balance. In the short run, we certainly have to restore and maintain that balance until other options are available. Our strategic modernisation programme and NATO's LRINF missile modernisation programme do this.

Finally, we can devote our energies to see if there is a better way to provide for the security of both the US and our Allies by strengthening deterrence through greater reliance on defensive systems – systems that threaten no one.

We will pursue all three options in the necessary and appropriate ways.

- We will press on in pursuit of equitable and verifiable arms reductions. But this must be a two-way street and it will take time.
- We will maintain the nuclear balance until other alternatives are available. Peacekeeper and the NATO LRINF modernisation programme are essential in this regard.

- Finally, we must explore the growing potential of the new defensive technologies

Let me concentrate on the need to explore strategic defences, and give you three concrete arguments why we have made SDI a central point of our defence programmes.

The first argument revolves around deterrence. We have ignored one basic fact about a world in which there are no defences. Without defences, it is extremly easy for an attacker to plan his first strike. Once an attacker launches his ICBM, he knows, within a certain range, just what damage he will do because there is nothing to interfere with his attack. He can plan and calculate just what forces he needs to destroy the forces on the other side. If he has the money and the inclination, he can then buy those forces. It is basically an engineering problem. Well, the Soviets have done their calculations, and they had had the time and money to buy their forces.

But when you introduce defences, even defences that are less than perfect, the problem is entirely different. An attacker will not be able to launch a missile and destroy a target. He has no real idea of whether his attack plan will work or, if he succeeds partially, which targets he will miss because he cannot know how good our defences will be. The defender will also be uncertain. But he is not deciding whether to attack. With defences, suddenly what was an engineering problem becomes a much tougher, more expensive military problem. Even defences that are imperfect stengthen deterrence because they create enormous headaches and uncertainties for anyone contemplating an attack. That is a good thing to do.

The second point involves saving lives. Very bluntly, we can deter an attack by defeating that attack or by threatening to kill enemy civilians in retaliation. There is no question in my mind that it is far better to be able to defeat the attack and thus deter it from occurring in the first place. SDI, for the reasons I have just discussed, can help us make that judgement. Without defences, we must continue to rely on retaliation in order to deter a nuclear attack.

Many of those who oppose SDI advocate reliance on assured destruction in order to keep the peace. Let me point out something about assured destruction. There has been much discussion about nuclear winter recently. While there are many uncertainties, one thing is clear. Nuclear winter is most likely to be caused by the smoke and dust from burning cities that have been attacked by nuclear weapons.

Everything in our administration's strategic weapons policy, including SDI, is designed to move us away from that kind of attack. Those who disagree with us and who continue to support the discredited policy of assured destruction must face the following fact: the kind of war that could occur if their policies were adopted is precisely the kind of war most likely to cause nuclear winter.

Finally, I would like to address a problem less massive but perhaps more urgent than deterring a Soviet attack. Our efforts to prevent nuclear proliferation have had a good deal of success. Certainly there are fewer countries today with nuclear weapons than anyone could have predicted 20 years ago. But many countries continue to seek nuclear weapons. We know that many of them also seek ballistic missile technology. We will not reduce our non-proliferation work. But I believe it is an act of simple prudence to investigate defences that could defeat limited nuclear attacks or accidental nuclear attacks.

For these reasons, President Reagan has asked this nation to undertake a programme of vigorous research, the Strategic Defence Initiative. It will focus on advanced defensive technologies with the aim of finding ways to provide a better basis for deterring aggression, strengthening stability and increasing the security of the United States and our Allies. Our efforts will be in full compliance with the ABM Treaty.

In practical terms, a strategic defensive option must be cost-effective. That is, it must be cheaper and easier to add defensive capability than offensive capability. Otherwise, there would be incentive to expand the offensive arms we seek to reduce. In addition, any defensive system must be survivable in the face of attack or else it could invite an effort to overwhelm it regardless of cost. The goal of strategic stability demands such high performance standards.

In our relations with other nations, strategic defensive options must satisfy not only our own security concerns but also those of our Allies and the Soviet Union. The US is actively consulting our Allies to respond to their concerns and questions regarding SDI. Since this is a research programme, their thoughts are essential as we examine the capabilities and set performance criteria for the defensive technology. Further, no step away from an offensive deterrent structure which has so effectively kept the peace in Europe can or will ignore the voice of our Allies. Our own national survival depends on our Allies' security from attack and safety from all wars.

In the new negotiations in Geneva and in other talks, we hope to develop with the Soviet Union mutual understanding of each other's security concerns. The United States does not seek superiority. This is difficult for the Soviet Union to comprehend since they judge us by their own ambitions. But the facts of history are clear in this regard. No nation in history has acted so responsibly while possessing so superior a position in weaponry as the United States after World War Two, when we were the only nation with nuclear arms. We are ready, if the technology proves feasible and cost effective, to consider integration of defensive systems into the mix of forces of both sides. This would be in the context of a cooperative, balanced, and verifiable environment that reflects a balance of offensive and defensive forces in ways that reduce existing nuclear arsenals while enhancing security and stability. If our research proves the feasibility of the concepts, a negotiated transition period of many years with assurance of stability and security throughout will be essential.

Finally, there are at least four myths about SDI which I wish to dispel.

The first myth is that the United States is attempting to 'militarise space'.

This is a Soviet progaganda line and it is grievously misleading. Activities in space generally fall into three categories: commercial, scientific, and military. Orbiting overhead are over 800 Soviet satellites, compared to some 400 satellites of the West. That is a ratio of two to one and, unlike in the West, the vast majority of Soviet satellites are military. These military satellites travel overhead in a space the Soviets threaten with the only existing anti-satellite weapons now in existence. Further, it was the Soviet Union which first developed, in 1957, the ICBMs which travel through space and which now carry far more warheads in total than US systems. What space is there left which the Soviet Union has not already militarised? Space has long been used for military purposes. When the Soviet Union speaks of 'preventing the militarisation of space' and of an ASAT Moratorium, they are being extremely disingenuous by ignoring 15 years of their detemined effort in this domain.

The next myth is that the US is upsetting an agreed philosophy of 'mutual assured destruction', upon which stability allegedly rests.

I hope I have exploded that myth already today by describing the destabilising march of the Soviet strategic build-up and the ever expanding shielding of their forces and leadership from 'assured destruction'. A US-Soviet comparison of the investment in so-called