SOVIET DIRECTED ENERGY WEAPONS --
Perspectives on Strategic Defense

March, 1985

Preface

Since the President's announcement on March 23, 1983, which marked the birth of the US Strategic Defense Initiative (SDI), a controversy has arisen over it which is concerned not only with the technical feasibility and costs of strategic defense against ballistic missiles but also its impact on the strategic balance between the US and the Soviet Union, on US allies, and on arms control negotiations.

In the past few months, however, lines of argument have begun to be made which involve counterpart Soviet defensive systems. And though we believe that in the planning and development of defensive weapons attention should be directed primarily at the threat posed by the enemy's offensive systems, i.e., the numbers, characteristics, performance and vulnerabilities of Soviet ICBMs and SLBMs, it is becoming necessary to provide basic information on Soviet defensive, or counterpart-SDI, research and developments. Opponents and proponents alike of the SDI should have a basic understanding and an appreciation of the nature and magnitude of Soviet efforts in strategic ballistic missile defense.

This paper is intended to meet a part of that requirement. It addresses Soviet research and development in directed-energy weapons: high-power/high-energy lasers, particle beams, and the microwave or radio-frequency beams.

"Directed energy" is a term that has become popular in the past decade and is used to refer to three types of beam weapon concepts based on lasers, radiofrequency (microwave) devices, or particle beams:

- In a laser weapon, an intense beam or pulse of visible or invisible (infrared, ultraviolet, X-ray, gamma-ray) electromagnetic radiation is aimed at a target by a telescope or other aiming device. The target's surface may be damaged by explosive shock, melting, or vaporizing; optical components can be damaged and personnel injured or blinded.

- In a radiofrequency (RF) weapon, electromagnetic radiation at wavelengths close to those of conventional radars is aimed at a target by an antenna; electronic components, or possibly the target structure itself, may be damaged or destroyed by circuit overloading or thermal effects.

- In a particle beam weapon (PBW), intense beams of electrons, protons, or atoms are produced by a high-energy accelerator and aimed at a target by magnets. In addition to thermal or mechanical damage, such beams can produce damaging secondary nuclear or X-ray radiation deep within a target.

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Key Judgements

- *The Soviet Union is believed to be interested in the development of directed energy weapons (lasers, particle beams, and microwaves) for ballistic missile defense and anti-satellite (ASAT) applications.*

- *The Soviet Union has been engaged in research on the directed energy weapons technologies for as long as the United States. Soviet efforts are under the leadership of some of the finest scientific minds in the USSR. The resources the Soviets have applied to these efforts are believed to be greater than those which the United States has applied.*

- *In directed energy technologies, the Soviets are in a comparable, or highly competitive position with respect to the United States. In laser technologies, there is an essential equivalence, though the Soviets are pursuing some types of lasers which the US has either abandoned or has ignored for weapons applications. In particle beam and microwave technologies, the Soviets may have the edge over the US in some important areas.*

- *The Soviets are believed to have progressed beyond the stage of pure or basic laboratory research in directed energy technologies; the Soviets have begun to develop and test laser weapons. The Soviets already have a ground-based laser capable of damaging some US satellites and which may be used to investigate the feasibility of lasers for ballistic missile defense applications.*

- *Hostile Soviet reactions to the US Strategic Defense Initiative (SDI) and lobbying against the SDI by high-level Soviet scientists must be tempered by the fact that the Soviet Union has not admitted to its own long-standing counterpart research and the most vocal Soviet scientists have themselves been heavily involved in that weapons research.*

CONTENTS

Introduction

Strategic defenses are important to the Soviets' overall strategy for nuclear war. The Soviets believe that nuclear war could occur and, if it does, they intend to do everything possible to survive and prevail. The operations of their defensive and offensive forces are closely coupled; offensive strikes would reduce the burden of the defensive forces. In the Soviet concept of a layered defense, effectiveness is achieved through multiple types of defensive capabilities compensating for shortcomings in individual systems.

The Soviets have devoted considerable resources to strategic defense. Over the last two decades, the Soviet Union has spent roughly as much on defense as it has on its massive offensive forces. The Soviets have been working on traditional and advanced technologies with the potential for defending against ballistic missiles.

-- The Soviet Union has the world's only operational ballistic missile defense system (at Moscow) and it has had, for over a decade, an operational anti-satellite (ASAT) system (the orbital interceptor).

Within the constraints of the ABM Treaty, the Soviets are currently upgrading their present systems. But they are also engaged in research and development on rapidly deployable systems which raise concerns about their potential ability to "break out" of the ABM Treaty and deploy a nationwide ABM system in the next decade.

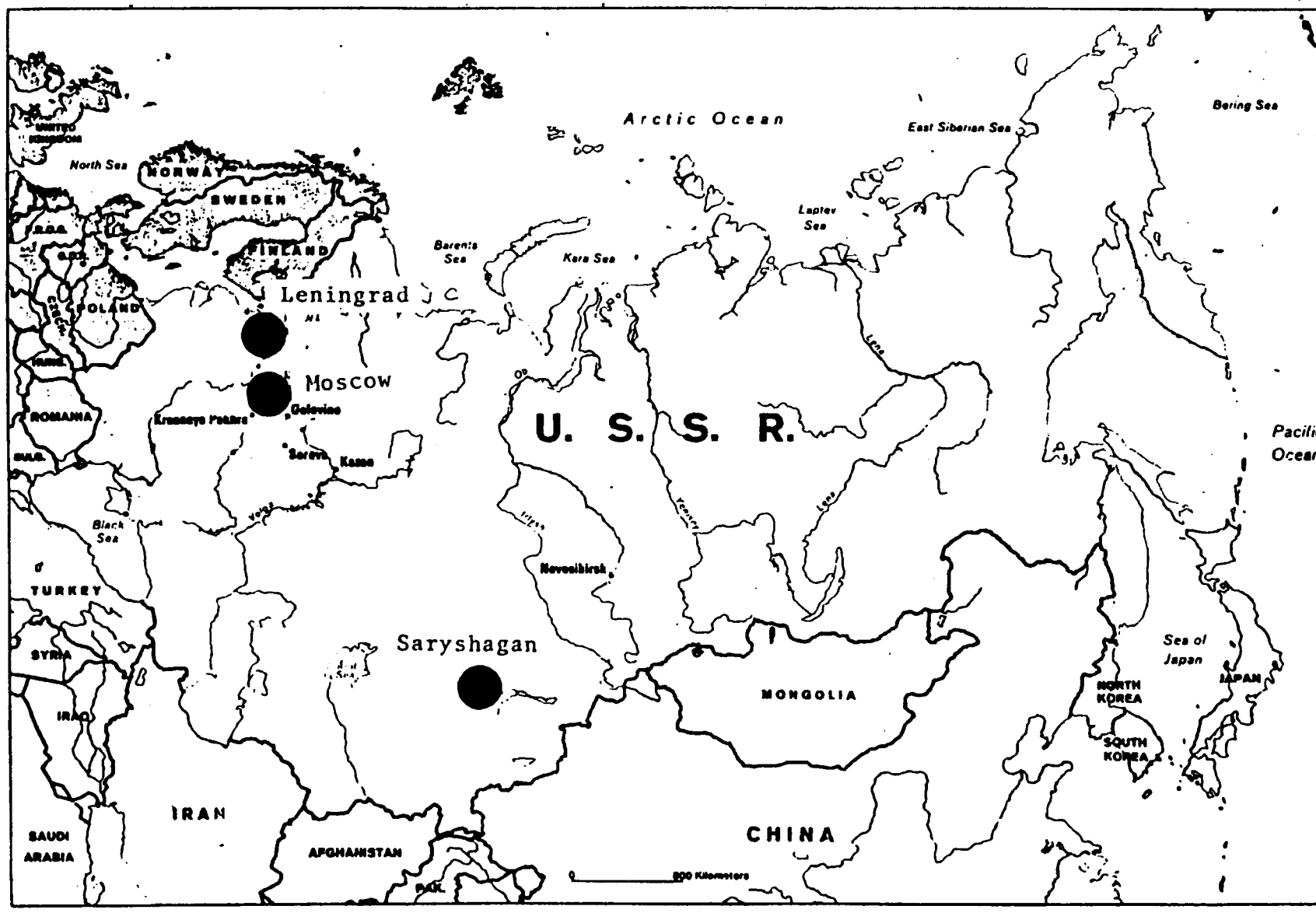
The USSR has an improving potential for large-scale deployment of modernized ballistic missile defenses beyond the 100-launcher Treaty limits. Since the signing of the Treaty, the Soviets have built large phased-array radars with improved capabilities to provide target tracking data in support of ABM deployment, they have upgraded the Moscow system, and continued development of a rapidly-deployable system. Also, they are deploying a surface-to-air missile system, the SA-X-12, which has the potential to intercept some types of US ballistic missiles.

Since the late 1960s, the Soviet Union has also been pursuing advanced technologies for strategic defense--technologies which the US is intending to explore in its Strategic Defense Initiative Program. The Soviets have expectations that military applications of directed energy technologies hold promise of overcoming weaknesses in their conventional air and missile defenses. The Soviets have been working as long as the United States in laser, particle beam, and microwave technologies applicable to strategic weapons. Of these, the Soviet emphasis has been on laser weapons.

Laser Weapons

The Soviet laser weapons program began in the 1960s. Many Soviet organizations and personnel, both civilian and military, are involved. Key institutes and design bureaus are located in and around Moscow and Leningrad, and the Saryshagan proving ground is the traditional site for most of the Soviet Union's ballistic missile defense testing since the 1950s.

LOCATIONS OF KEY SOVIET DIRECTED-ENERGY AND BALLISTIC MISSILE DEFENSE FACILITIES



Management and Resources

The Soviet laser weapon effort is guided and supported by some of the best scientists and engineers in the Soviet Union. Yevgeniy Velikhov, the rising Vice President of the Soviet Academy of Sciences, made his early mark in directed-energy related research; Nobel Laureates Basov and Prokhorov are believed to be driving forces behind the Soviet effort for over twenty years.

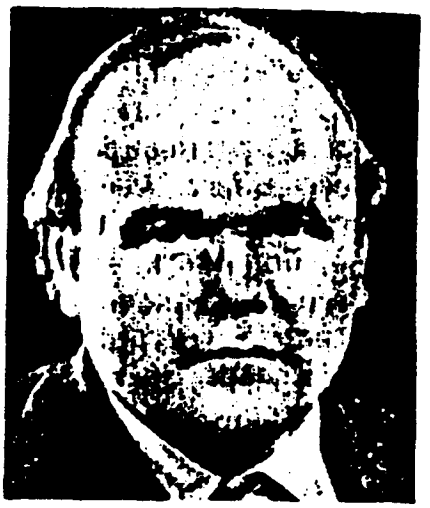
The level-of-effort that the Soviets have applied to their laser weapons program is considerable. Cost data are unavailable and the estimates have had to be more subjective. Some have estimated that the Soviet effort is some 3-5 times greater than that of the United States. We believe that it is not possible to make an estimate of this ratio but that it seems clear, based on the observed scale and scope of the Soviet effort, that the Soviet program is larger than that of the US. Exaggeration of the relative effort is not warranted, as the Soviet effort is clearly appreciable.

-- The Soviets have built over half a dozen major R&D facilities and test ranges.

-- The Soviets have an estimated 10,000 scientists and engineers associated with the development of lasers for weapons.

Yevgeniy Pavlovich VELIKHOV
(Phonetic: VELikuf)

Vice President, Academy of Sciences



One of the leading policy-makers in Soviet science. A physicist, he is Deputy Director of the Kurchatov Atomic Energy Institute. Considered to be a central figure in Soviet laser and particle beam weapon efforts.

Nikolay Gennadiyevich BASOV
(Phonetic: BAHsuf)

Director, Lebedev Physics Institute, Academy of Sciences

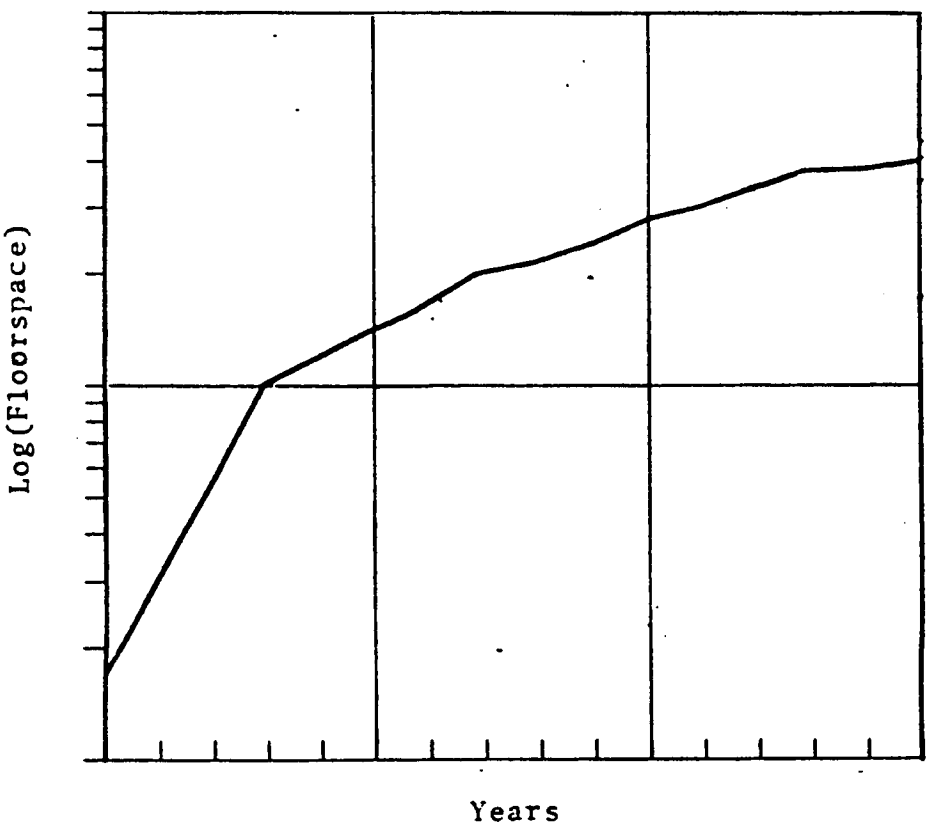
An internationally recognized expert in quantum electronics, Basov shared the 1964 Nobel Prize in Physics with Prokhorov (below) and Charles Townes (US) for work leading to the development of lasers. Believed to be a scientific adviser to laser weapon programs.

Aleksandr Mikhaylovich PROKHOROV
(Phonetic: PROkuhruf)

Academician Secretary, General Physics and Astronomy Department, Academy of Sciences

Prominent Soviet scientist and administrator, he is the Director of the Institute of General Physics in Moscow. Also believed to act as a scientific adviser in Soviet laser weapon programs.

-- Estimates have been made of the amount of floorspace that the Soviets have allocated to laser weapons R&D. The growth was very rapid in the first decade; now it is leveling off with a growth rate of a few per cent per year. Currently, the Soviets appear to have space for lasers that is comparable to that of a typical large Soviet missile or space design bureau.



SOVIET LASER FACILITIES--GROWTH IN FLOORSPACE.

Technologies

The United States is judged to be currently ahead of, or equal to, the Soviet Union in many of the technologies that are relevant to a strategic ballistic missile defense system. These include: computers, signal processing, command and control, and radar or electro-optical sensors and sensing systems.

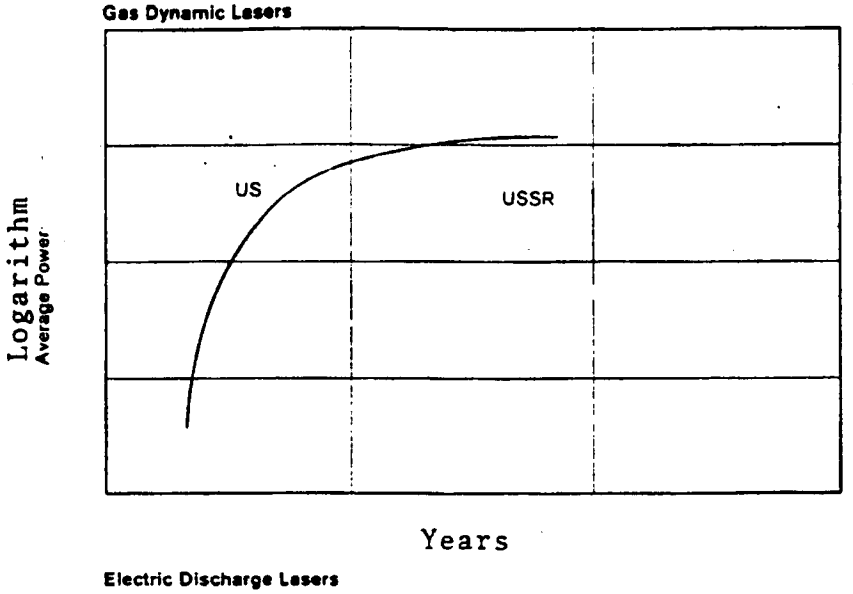
In lasers, the Soviets have conducted research in the three types of gas lasers that the US considered promising for weapons applications: the gas-dynamic laser (GDL), the electric discharge laser (EDL), and the chemical laser. These lasers operate at various wavelengths in the infra-red region, from about 10.6 to 2.7 microns, depending upon the lasing medium that is being used.

Laser Type	Medium	Wavelength
GDL, EDL	CO_2	10.6
GDL, EDL	CO	5.0
chemical	DF	3.8
chemical	HF	2.7

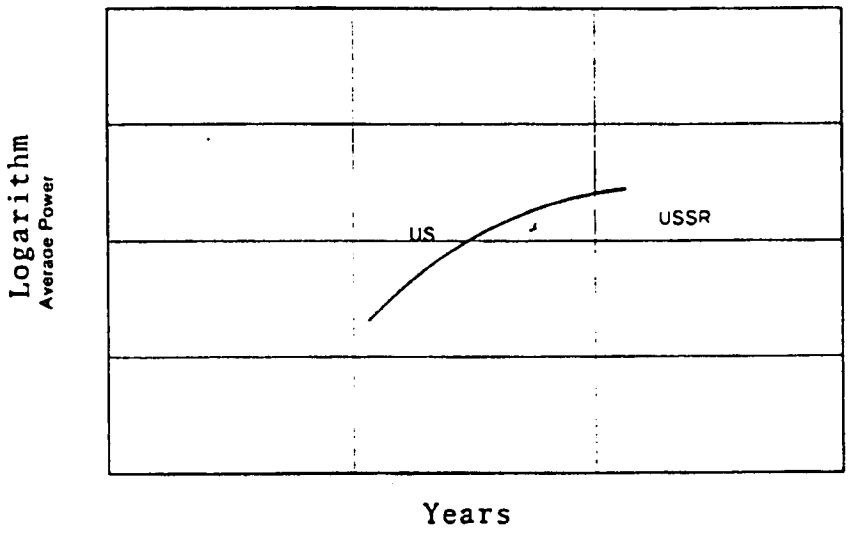
Soviet achievements, as measured by output power, are impressive. Their work on GDLs, EDLs, and chemical lasers seem to mirror US efforts. The Soviets have not only "followed suit" with the US--they have continued to work on certain types of lasers which the US abandoned in favor of other, more attractive, short-wavelength lasers. Soviet work is cumulative; the US is progressive. Yet there are asymmetries: the Soviets have been working on other

Soviet and US CW High Energy Laser Developments

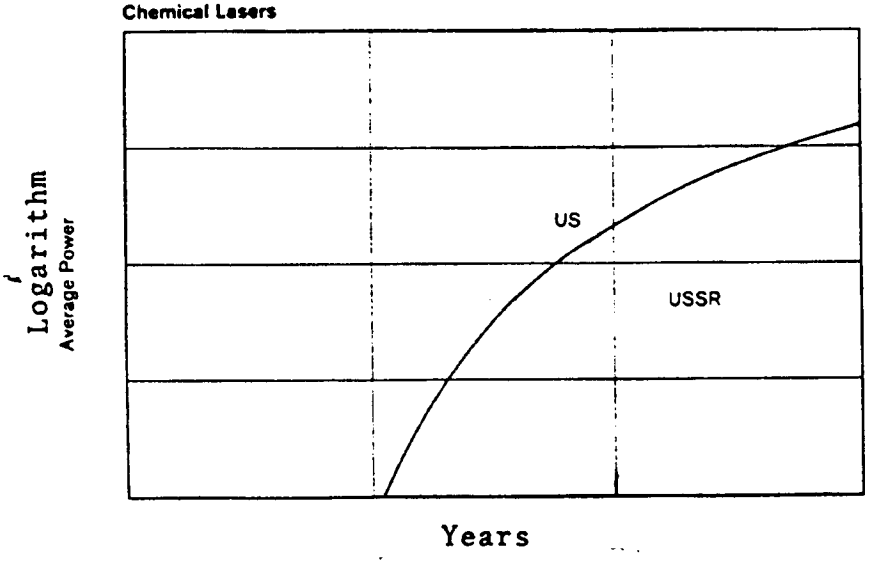
Gas Dynamic Lasers



Electric Discharge Lasers



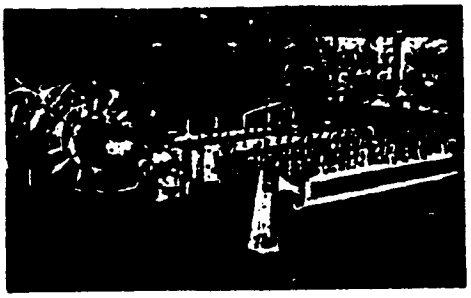
Chemical Lasers



types of lasers that the US has not seriously considered for weapons applications until very recently. These are the lasers which operate at about a micron wavelength.

The Soviets are aware of the visible and very short wavelength lasers and their potential for military applications. The Soviets are investigating the excimer and free-electron lasers. For over a decade, researchers at Novosibirsk have been developing argon-ion lasers; the Soviets continue to dominate in literature published on metal-vapor lasers. And the Soviets have published work on X-ray lasers; the use of nuclear explosions has been proposed as a method for creating conditions for X-ray lasers.

(a)



(b)

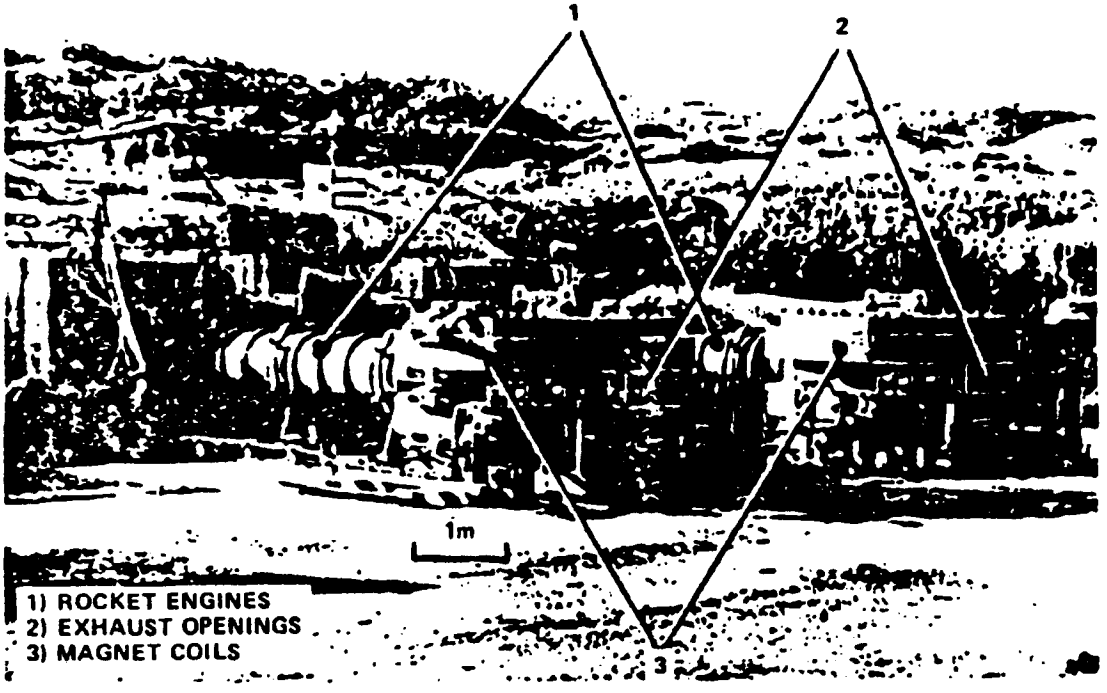
DESCRIPTIONS OF A SOVIET GDL IN THE POPULAR LITERATURE (CA 1975)

(a) Gas-dynamic continuous-wave laser with output power of 15 kW. It operates on ignition of carbon monoxide. (b) Gas-dynamic laser in operation. Its emission is directed by means of a mirror to a target in the upper part of the photograph. The burning torch is formed by the incandescent particles of the target material.

Aside from the asymmetries already noted, we believe the Soviets are on a par with the US in high-power/high-energy lasers and laser technologies for weapons applications.

We believe the Soviets are generally capable of supplying the requisite prime power, energy storage, and auxiliary components for most laser (and other directed-energy) weapons.

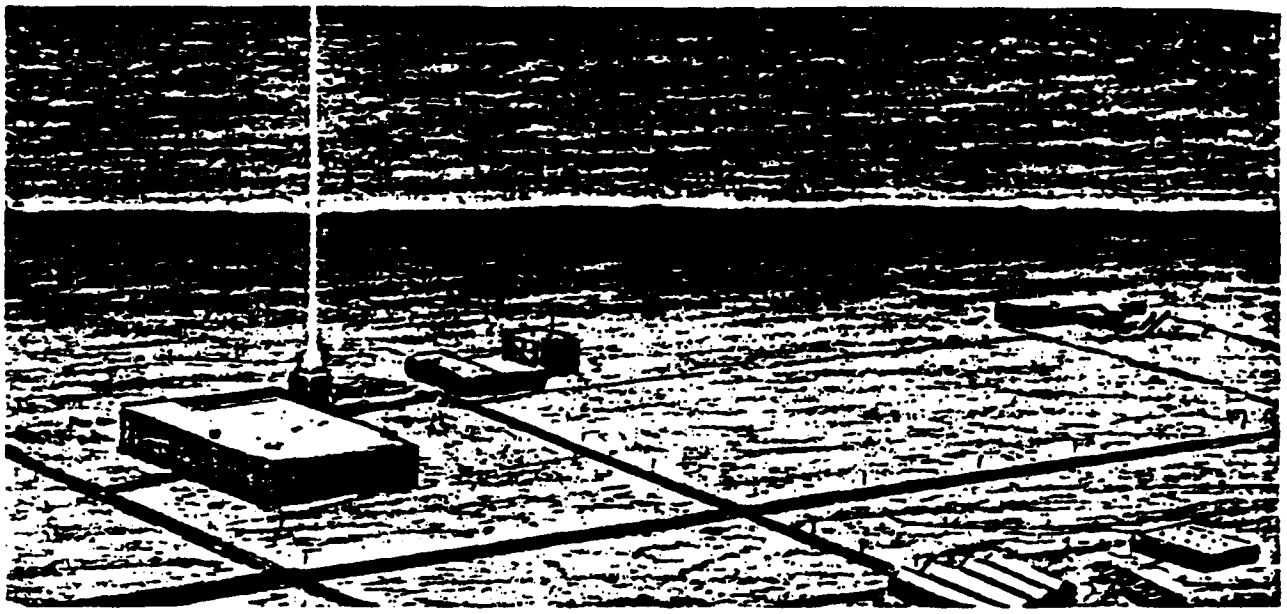
-- The Soviet magneto-hydrodynamic (MHD) power source development is the largest in the world; they have developed a rocket-driven MHD generator which produces over 15 MW of electrical power. This device has no western counterpart.



The Soviets may have the capability to develop the necessary optical systems for laser weapons. They produced a 1.2-meter segmented mirror, the AST-1200, for an astrophysical telescope in 1978 and claimed that this was a prototype for a 25-meter mirror that would be constructed in the future.

Advanced Developments

The Soviets have progressed beyond basic technology research in some cases to the development of prototype laser weapons. They already have a ground-based laser that could be used to interfere with US satellites.



This directed-energy R&D site at the Sary Shagan proving ground in the central USSR could provide some anti-satellite capabilities today and possibly ABM prototype testing in the future.

In the late 1980s, the Soviets could have prototypes of ground- and space-based laser weapons for use against satellites and ballistic missiles. They may deploy operational space-based laser systems for antisatellite purposes in the 1990s if their technology developments prove successful. And they can be expected to pursue development of space-based laser weapons for ballistic missile defense for possible deployment after the year 2000.

Particle Beam Weapons

Soviet research and development of those technologies that could support a particle beam weapon have been impressive. Work on ion sources has been spectacular. And a recent Rand study has noted that "Soviet development of ion induction linear accelerators has been remarkable in its steady pursuit of such goals as high current levels, reliability, efficiency, reduced size, and simplicity of operation." It was noted also that the Soviets acknowledge only peaceful, high-energy physics research as the intended applications of these developments, but it was observed that "Soviet ion linac development (appears) singularly applicable to the task of propagating particle beams in space."

> -- Soviet ion source designs, developed in their fusion research but applicable to beam weapons, have been superior to those of the West.

The Soviets are believed to have had research projects since the early 1970s to explore the feasibility of a space-based particle beam weapon. A prototype weapon intended to disrupt the electronics of satellites could be tested in the 1990s; a weapon designed to destroy satellites could follow later.

Macro-Particle Streams

In the particle beam weapon, the particle (electrons or protons) are accelerated to velocities approaching that of light. A macro-particle stream, on the other hand, consists of heavier particles with velocities of less than one per cent of the speed of light.

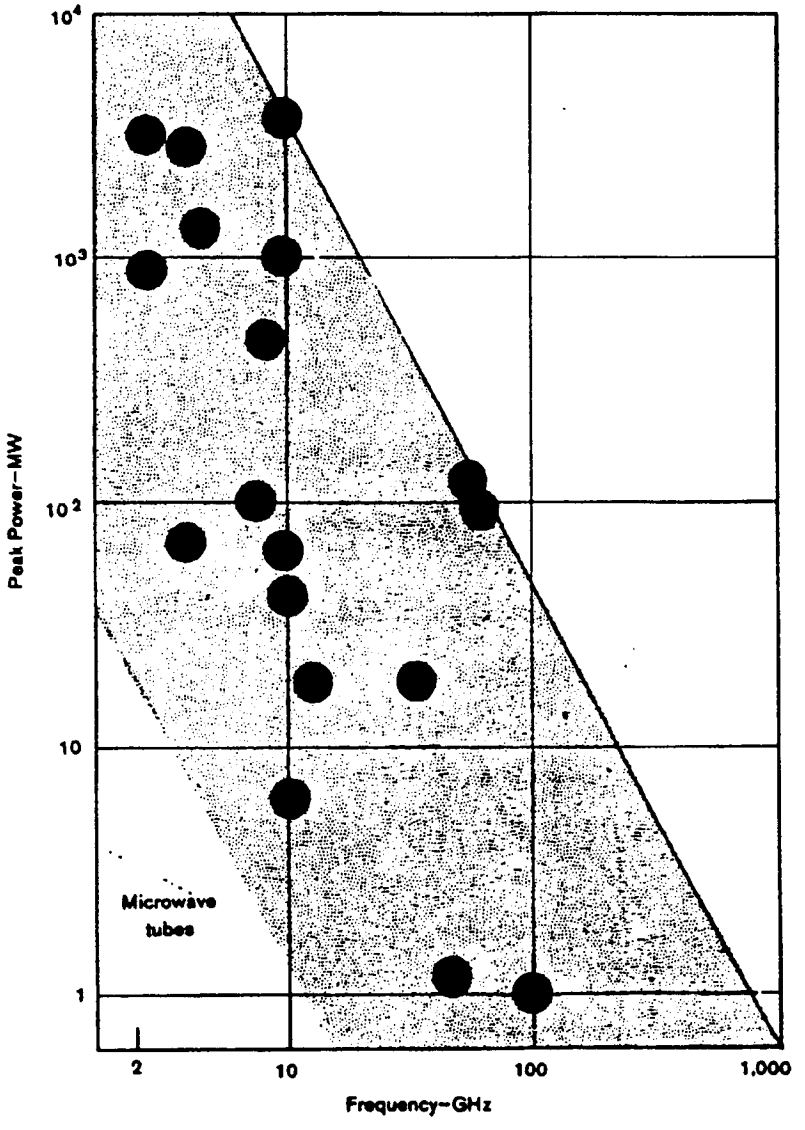
Open literature indicates that as early as 1966 the Soviets had an experimental "gun" that could shoot streams of particles of a heavy metal such as tungsten or molybdenum at velocities of over 60 kilometers per second in a vacuum and nearly 25 kilometers per second in air.

-- The impressive target penetration effects of the macro-particle streams in air have been published openly. The effects of the higher velocity streams in vacuum have not.

Microwave Weapons

We believe there are no technological obstacles to Soviet development of a radio-frequency or microwave weapon for strategic applications. The Soviets have conducted research for decades on sources of high-power microwaves (magnetrons, gyrocons, gyrotrons) and the antennas which would be required to direct and focus the beams on distant targets. Soviet capabilities to develop microwave weapons are on a par, if not superior to those of the US.

-- Many systems would be vulnerable to an rf weapon; critical electronic components could be damaged or disrupted.



SOVIET DEVELOPMENTS IN RADIOFREQUENCY SOURCES

Soviet Responses to the SDI

Soviet reactions and responses to the SDI have, not unexpectedly, been negative. Their statements on the SDI must be tempered by the knowledge that well before the President's speech on March 23rd, 1983, the Soviets were themselves pursuing most of the technologies that are to be investigated in the US SDI and were heavily involved in applied research toward testing the feasibility of advanced weapons for ballistic missile defense.

Within a month of the President's announcement, a letter signed by a large group of senior Soviet scientists was published in the New York Times, denouncing the US initiative. But it is significant to note that of the more than 200 signatories of the letter, a number of them have been instrumental in the development of both conventional and exotic ballistic missile defense systems: Grushin, Semenikhin, Bunkin, Velikhov, Prokhorov, and Basov.

-- Velikhov was the director for several years of the Institute of Atomic Energy laboratories at Troitsk where lasers for strategic and tactical applications are being developed.

-- Avduyevskiy has long been involved with strategic systems, and he now has responsibility for a number of projects for the military use of space, including a space-based laser weapon.

Other signatories have spent their careers developing strategic offensive weapons and other military systems: Chelomey, Glushko, Nadiradze, and Makeyev in ICBMs and SLBMs; Antonov, Belyakov, and Yakovlev have designed military aircraft; Isanin is a chief designer of nuclear submarines; and Dollezhal and Khariton are long-standing leaders in the Soviet military nuclear energy programs.

Last year, a group of scientists published a technical report critical of space-based weapons. The report was prepared by a working group of the Committee of Soviet Scientists for Peace, Against Nuclear Threat and headed by Academician R. Z. Sagdeyev, Director of the Institute of Space Research of the Soviet Academy of Sciences. We believe this report was written and disseminated to serve as a propaganda tool against the SDI. The report was made widely available in the West, but it has apparently been given little attention within the Soviet Union. The report asserts that space-based systems are too technically complex, expensive, and easily counter-measured to be worthwhile. The report examines only the hydrogen fluoride chemical laser in detail; neutral particle beams, x-ray lasers, and excimer lasers are barely discussed. Ground-based terminal defense systems and space-based kinetic-energy weapons are omitted.

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* "A Space-Based Anti-Missile System with Directed Energy Weapons: Strategic, Legal, and Political Implications," Committee of Soviet Scientists for Peace, Against Nuclear Threat, Moscow, 1984.

The Soviets probably wish that the March 23rd announcement had never been made and that they could pursue their own research on strategic defense without real competition from the US. With the advent of the SDI, the Soviets are faced with a mobilization of efforts on strategic missile defense in the US and their actions of late are intended to persuade the US to drop it. The Soviet lobbying and criticism of the SDI is the cheapest and least risky approach to undermining congressional and public support for the SDI.

The Soviets have not admitted to their own efforts in SDI-counterpart activities. And they may never do so. But perhaps we are now on the threshold of an alternative Soviet line of attack--to compete with the US.

> -- Nikolay Basov declared in January that Moscow would have 'no technological difficulty' in matching the US SDI program.

And from what we have observed thus far of Soviet capabilities in directed energy research, development, and testing, his claim is not without foundation.