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Trends and Priorities in Soviet Military Research and Development

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Scientific Intelligence Study

TRENDS AND PRIORITIES IN SOVIET MILITARY RESEARCH AND DEVELOPMENT

[redacted]

March 1973

SCIENTIFIC INTELLIGENCE COMMITTEE

PREFACE

This study updates a previous review of the scope and direction of Soviet military research and development published in January 1967. (SIC-S-1-67)

In this review we examine the Soviet military R&D system in some detail and attempt to describe its essential features. We have paid particular attention to areas in which significant R&D effort is being expended and is apt to be continued because of the promise of payoff or because of a need to correct existing deficiencies. We have looked for trends that have important implications for Soviet military capabilities over the next 5 to 10 years. But, recognizing that decisions to embark on weapons programs are not made on the basis of R&D programs alone, we have not set as a primary goal the forecasting of specific future weapons which might result in the next decade from present R&D programs. Such estimates are more properly made in the larger context of the National Intelligence Estimates dealing with the component elements of the Soviet military structure. Lastly, we recognize that significant military programs other than those discussed could be in an early R&D phase without our being able to identify them as such.

Much of the subject matter discussed in this report has been covered in some detail in one or more of the recent National Intelligence Estimates, particularly NIE 11-12-72, NIE 11-3-72, and NIE 11-8-72. With respect to some weapons systems it was found that little new could be added to the coverage of the subject in the NIEs. In such cases we have presented only a brief discussion, highlighting R&D aspects, in order to provide readers with a comprehensive review of Soviet military R&D in a single publication. Thus, in such subjects as ballistic missiles, nuclear weapons and naval warfare, the reader will find the detailed treatment in the NIEs while in this study we have confined our attention largely to R&D trends. For this study we have drawn heavily on contributions made by the participating subcommittees to the referenced NIEs.

The following USIB Committees contributed to this interdepartmental study:

Scientific Intelligence Committee

Joint Atomic Energy Intelligence Committee

Guided Missile and Astronautic Intelligence Committee

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TRENDS AND PRIORITIES IN SOVIET MILITARY RESEARCH AND DEVELOPMENT

SUMMARY AND CONCLUSIONS

GENERAL

The strong support that the Soviets have given to military research and development since World War II continues. The major portion of the total Soviet research and development effort continues to be devoted to military—or closely related—requirements, including space, with highest priority on strategic offensive and defensive systems. A stream of new and improved military hardware has emerged from this effort.

Many facilities built during the 1950s and 1960s are still expanding, presaging additional investments in coming years. It seems clear that the USSR intends to maintain a vigorous program to update its military capabilities. For the most part progress will come through gradual improvements in range, accuracy, reliability, and other critical parameters of present strategic offensive and defensive systems. There is always the chance, however, that radically new systems may evolve from work now in progress [redacted]

Centralization of responsibility, specialization of effort, and continuity in management and leadership are typical strengths of the Soviet military R&D environment. National-level management is marked by close partnership of the Party and Government in defining short- and long-term directions and managing resource allocations. As a consequence, the decision-making process is in many cases less time-consuming than it is in the US.

On the other hand, a number of shortcomings impose limitations on the effectiveness of the Soviet military R&D effort and at least some of these are not apt to be overcome for many years. The industrial base that supports Soviet military R&D lacks the sophistication of the US industrial sector. The full exploitation of very elaborate research, development, and testing resources is constrained by rigid planning and control of programs and by compartmentation of research. Emphasis on program plan fulfillment and goal achievement, combined with the inherent inflexibility of the Soviet environment, often results in a certain amount of conservatism in systems design. And occasionally program goals are adhered to even after a lack of realism in the schedules related to the goals must have become apparent. Typical examples are the tardiness of the fast breeder reactor at Shevchenko and the nuclear power programs as called for by the 6th Five Year Plan.

[redacted] Despite the small size and closely knit character of the Soviet policy summit and its good internal communications, there is little evidence to suggest that it is organized and staffed to do routine systems evaluations of new programs. In practice the policy-makers probably defer to professional military judgment in weapon program decisions. As long as the Soviet leaders perceive no overriding economic pressures toward restraint in military programs, the built-in biases of the decision-making system appear to lead to the pursuance of military programs along lines which satisfy all or most of their military advocates. The Ministry of Defense and its subordinate agencies appear to exercise a major influence on which advanced military technologies are to be pursued.

The apparent absence of elaborate mechanisms for systems analysis of new weapons and their cost-effectiveness is perhaps the more striking in a country which has for 15 years devoted so much effort to detailed defense planning. But it is rather consistent with the system we find in practice that is, the basic features of a new weapon system are decided upon, the system is developed, deployed, and then modified as required on the basis of field experience. If we are correct in concluding that, compared to US practice, decision-making times are shorter and fewer people are involved, relatively less time would be spent on the decision to initiate a project and relatively more time on the production and deployment phases. Such an explanation would fit the widespread use of off-the-shelf components which tends to shorten the time in the pre-production phases. Whether the changed conditions brought about by arms limitations will cause the Soviets to do more systems analysis as a prerequisite for program initiation remains to be seen.

The Soviets clearly have a large and growing capability to investigate new concepts and exploit promising avenues in the design and development of weapons systems. An ability to concentrate the resources needed to accomplish high-priority R&D expeditiously has been demonstrated, as has the willingness to build and deploy the highest priority systems where field experience has indicated a likely need. Many of the Soviet test facilities are designed to accommodate needs well beyond those readily apparent at the time of their construction as, for example, in space vehicle and missile development. We therefore believe that the Soviet R&D program will continue to provide a wide range of military equipment generally capable of achieving the purpose for which it is designed. Much of the future effort will be concerned with the introduction of new technology and techniques to achieve incremental improvements.

How the Soviets will choose to direct their military R&D efforts in the next few years is a matter of prime interest. We have searched for indications such as a pattern of Soviet reactions to particular US actions. In general, we have been unable to detect reliable overall military R&D patterns. And now that the USSR has achieved near-parity with the US in military strength, the "defense of the homeland" theme may no longer dominate Soviet weapons choices as it has for so long. The uncertainties about where Soviet priorities in military R&D lie [redacted] increase the possibility that we could be confronted with a technological surprise.

In a perhaps less awesome sense the prospective era of strategic arms limitations poses many difficult questions for those who must analyze Soviet military R&D. In many cases the qualitative improvements that seem likely to be allowed may be as difficult to detect as were the original systems. Moreover the Soviets can be expected to stress R&D that may lead to radically new—and uncontrolled—weapons systems. [redacted]

In assessing the future of Soviet military R&D, it is useful to consider where Soviet science and technology stand today after more than two decades of concerted effort. First, the strong military technology that has been developed, coupled with adequate production and operational resources, has enabled the USSR to attain the long-sought goal of military strength comparable with that of the US. Thus, the "catch-up" era that required the expenditure of vast resources during the 1950s and early 1960s has come to a close and the USSR is in a position to negotiate agreements to preserve its secure position. Second, a technological base the near equal of that of the US in most respects has been established enabling the Soviets virtually unrestricted freedom to move into areas of their own choosing. And third, as a result of the first two the

Soviets are in a position to focus their efforts on overcoming deficiencies that tend to inhibit their progress, notably persistent difficulties in areas of production that are highly dependent on advanced technology.

These considerations suggest that Soviet military R&D may lose some of the conservatism, and hence some of the predictability, that we have considered to be characteristic of it. This is not to say that Soviet scientists will suddenly swing to the other extreme. But the rather consistent pattern of reliance on existing technology and components may increasingly give way to innovative approaches less easy to foresee and analyze. In this respect the threat of technological surprise, not so much in the form of a scientific breakthrough as in a development that stretches the limits of available technology, may increase over time.

In a more conventional way the Soviets will undoubtedly continue, even increase, the R&D effort aimed at improving existing weapons systems. Given the growing strength of their technology, they will probably be increasingly inclined to look for exploitable phenomena as a means of upgrading military capabilities in such difficult areas as submarine detection and tracking, increased survivability of reentry vehicles, and advanced antiballistic missile, antisatellite, and aircraft defense systems. To this end we expect to see vigorous programs in electro-optics (infrared, long-wave infrared, lasers), acoustics, electromagnetics, space electronics, signal processing and data transmission, and computer technology.

MISSILE SYSTEMS

Offensive ballistic missiles

The Soviets have equipped themselves with a large and varied ICBM force based almost exclusively on liquid propellant technology. They have taken a conservative approach to ICBM development—in general using proven technology to upgrade each successive generation of ballistic missiles. This approach has resulted in a reliable ICBM force which is versatile enough to cope with a broad spectrum of potential threats.

With the signing of the Interim Agreement limiting strategic offensive missiles, the Soviets have agreed to put numerical limits on their ICBM and SLBM forces. This suggests that they are confident that the size of their strategic missile force is sufficient which, in turn, suggests that their missile development efforts in the future will be focused on quality. This is not to say that the Soviets will not develop new missiles. On the contrary, they appear to be flight testing three new missile systems. And, as long as the provisions embodied in the Interim Agreement remain in effect, they probably will continue to bring forth new ICBMs from time to time as replacements for older, obsolescent systems. Barring a breakdown in the follow-on SALT negotiations and a withdrawal from the Interim Agreement, the most dramatic technological changes in the character of Soviet ICBM and SLBM forces are likely to be qualitative improvements, especially the development of more accurate guidance and multiple independently targetable reentry vehicles (MIRVs).

The Soviets appear to be seeking greater accuracy for their ICBM systems. One of the steps they might be expected to take would be the development of RVs with higher ballistic coefficients (betas). There has been a trend in that direction with some of their more recent ICBM modification programs—especially the SS-11 Mods 2 and 3. [redacted]

The Soviets appear to be trying to upgrade the accuracy and reliability of the components used in ballistic missile guidance systems. To achieve very accurate systems, they almost certainly would have to develop a guidance system with additional features, such as midcourse guidance or terminal RV guidance. There is evidence that they are experimenting with more sophisticated guidance techniques for naval systems. [redacted]

Over the past few years the Soviets clearly have been concerned with evolving US ABM defenses. Exoatmospheric decoys and multiple reentry vehicles have been tested and several modifications to ICBM systems apparently intended to enhance penetration in an ABM environment have been developed. These developments have been overtaken by the ABM Treaty, however, which limits both the US and USSR to low levels of ABM defense. While the Soviets may undertake programs to develop new and more sophisticated systems to penetrate ABM defenses as a hedge against abrogation of the Treaty, these programs probably will move forward at a more deliberate pace than would be the case without the Treaty.

The Soviets have developed multiple reentry vehicles for the SS-9 and SS-11 which are not independently targetable, however, and apparently were developed to attack ABM-defended soft targets. The Soviets probably will develop MIRV systems for their ICBMs and possibly for future SLBMs. A MIRV payload could be part of the two new missiles under development at Tyuratam. If the Soviets decide to develop a "bus" type MIRV payload, the guidance system tested on their new large ICBM might provide the flexibility and accuracy required to attack hard targets.

The USSR has a large and varied solid-propellant production capability. R&D programs concerned with solid-propellant ballistic missiles are continuing. In 1972 a new solid-propellant ICBM [redacted] was tested [redacted] The USSR is judged to lag the US in thrust vector control techniques and shutdown mechanisms as applied to solid-propellant vehicles. The Soviets have the technological capacity to solve these problems and undoubtedly will do so if the development effort is accorded a high enough priority.

Defensive missiles

Truly integrated aerospace defense is believed to be an overriding Soviet military goal. High-priority R&D programs to accomplish the overall objective include early warning and tracking systems against aircraft, missiles, and space objects; several complex air defense missile systems; new interceptor aircraft with higher performance; and ABM defenses. As these new systems are deployed, the Soviets must inevitably appreciate the need for integrating these total defenses through advanced means of command and control and the necessity for R&D in the areas of computers, displays, and communications.

ANTIBALLISTIC MISSILES—The Soviet ABM R&D effort has been concentrated at the Sary Shagan Missile Test Center (SSMTC). Since the late 1950s, Soviet emphasis on radar and missile technology for ABM applications has resulted in the deployed Moscow ABM system and the network of Hen House early warning radars which support the system. The several very serious limitations of the system, among them vulnerability to exhaustion, saturation, and nuclear blackout, and an inability to discriminate real targets from false ones, appear to point the way for future Moscow system R&D. Soviet ABM R&D efforts elsewhere, however, probably will be directed toward the development of an entirely new ABM system for the defense of ICBM silos. In addition, the Soviets probably will eventually explore entirely different concepts which could improve their defense against ballistic missiles, such as synchronous satellite early warning systems or air or spaceborne laser ABM systems.

The most severe limitation of the Moscow system—vulnerability to exhaustion—cannot be overcome within the terms of the recently signed ABM agreement. The Soviets are permitted an additional 35 ABM launchers for a total of 100 launchers. The lack of a large ABM interceptor force assures successful penetration of the system by a determined attacker. Soviet research directed toward alleviation of other limitations of the system is permitted, however, and with some restrictions the components developed may be deployed. For example, unconventional weaponry like lasers may be developed but its inclusion in the Moscow ABM system would require renegotiation or abrogation of the ABM Treaty.

Soviet efforts to reduce the vulnerability of the Moscow system to saturation apparently are concentrated in the development of planar array radars. Such radars have better multiple target/interceptor handling capabilities than the presently deployed dish-type radars. Research on the problems of nuclear blackout and discrimination has not yet been identified. To reduce the system's vulnerability to nuclear blackout, the Soviets probably will develop "cleaner" nuclear warheads (or effective non-nuclear warheads) or increase radar operating frequencies.

[redacted]

Future Soviet developments in optical devices, lasers, long wave infrared (LWIR) sensors and high resolution radar technology could contribute to the development of a capability to discriminate reentry vehicles from accompanying penetration aids. A more immediate Soviet approach, however, would probably include the use of simple atmospheric filtering and the development of a high acceleration interceptor. Such an interceptor, desirable for an ABM system designed to defend ICBM silos, as permitted by the ABM Treaty, apparently is not yet being developed.

SURFACE-TO-AIR MISSILES—The Soviets have been engaged in a well-conceived program of surface-to-air missile (SAM) system development. The systems generally have been designed to counter a specific threat or a facet of an expected new threat. Over the years an attempt has been made to develop SAM defenses capable of coping with aircraft at low altitudes, primarily through incremental improvements in all aspects of low-altitude defense. The use of older systems and the introduction of new systems have resulted in a diversity of equipment, redundancy of coverage, and improved capability against all threats. All of the ground-based short-range Soviet SAMs (except the SA-1) are van-mounted and characterized by transportability. SAM design approach has typically used a command guidance scheme with track-while-scan fire-control radars to minimize system complexity.

During the period of our forecast, we expect the Soviets to employ R&D resources in the design of new equipment that would provide for shorter reaction times, lower vulnerability to electronic countermeasures, and better low-altitude defense capabilities. The reaction time problem is expected to be alleviated by the additional use of computer control equipment in SAM batteries and improved command-coordination-control data transmission systems which have been in limited use for some time. The vulnerability of Soviet SAM systems to electronic countermeasures is being reduced to some degree by the employment of straightforward techniques which include the use of frequency diverse radars and the addition of optical and electro-optical trackers to the fire-control radars. Improvements in the acquisition and fire-control radars and SAM proximity fuses, which would provide more efficient operation in a clutter environment, could result in a better low-altitude capability. Other expected improvements in Soviet SAM systems could include the development of multipurpose radars [redacted] and the use of electro-optical trackers with most short-range SAM radars to complement the primary tracker.

Antiship cruise missiles

The USSR has been developing antiship cruise missile (ASCM) systems since the late 1940s. The Soviet ASCM developmental programs tend to reflect two major concerns. These are the increasing number of US attack carriers (CVAs) which could be brought to bear against the USSR and the area and terminal defenses which their cruise missiles must penetrate to reach the primary target, the attack carrier. The result of Soviet developmental programs is an impressive family of cruise missile systems. As the CVA threat has evolved in terms of increasing numbers as well as sophistication, improvements in the Soviet cruise missile capability have been phased in appropriately. Changes during recent years have included increased standoff range, supersonic cruise velocity, electronic counter-countermeasure (ECCM) features in the guidance systems, and greater numbers of cruise missiles per launch platform. Of particular significance was the recent introduction of the element of a possible surprise attack through the use of an underwater launch platform.

[redacted] a continuing Soviet antiship cruise missile development program. Such a program will continue to be evolutionary in nature and focus on those limitations which significantly influence the effectiveness of the targeting system, cruise missile, and launch platform. Improvements expected to appear during the next decade include smaller cruise missiles, utilizing technological advances to increase the firepower of a single launch platform and to reduce the radar cross section, and greater standoff range to reduce launch platform vulnerability. A significant improvement in Soviet ASCM targeting capability could result from the development of an improved ocean surveillance system. Major advances in technology would not be required for such a development. Also, the Soviets are expected to make greater use of advanced ECCM techniques, increase missile maneuverability in the terminal encounter, and develop better discrimination techniques for identification of high-value targets.

Air-to-air missiles

The Soviets have five basic operational air-to-air missile (AAM) systems, all except the earliest (AA-1) produced in both an infrared and semiactive radar guidance version. Their AAM developmental program has been well-planned; each new model introduced into service has reflected advances in technology. A family of weapons has been developed which is capable of destroying targets in the medium- to high-altitude regimes by means of head-on or tail attack in all weather conditions. But all of the missiles lack the capabilities required for low-speed, low-altitude engagement in a ground-clutter environment.

We expect the Soviets to develop a new, short-range missile with decreased minimum launch range, high maneuverability and good low- to medium-altitude capability against low-altitude penetrators and maneuvering targets. Such a missile could probably be developed using current state-of-the-art technology for all major components and appear by the mid-1970s. Also a new, long-range AAM could be required if the postulated advanced long-range, all-weather interceptor is developed.

MILITARY SPACE

We expect the USSR to continue to emphasize military uses of space and to conduct active R&D programs in support of such uses. While the Soviet space program generally has been successful, it has been plagued with a succession of problems over the years both with spacecraft and launch vehicles. During the next several years better environmental ground testing, improved checkout procedures, and the use of improved technology should result in increased reliability in Soviet military-related spacecraft. The Soviets probably will develop new or modified stages to the proven boosters to provide cost effective delivery of heavier payloads into varied orbits. Current Soviet technology is believed adequate to support the power, guidance, and attitude control requirements for military space systems over the next 10 years. In the long term, the Soviets could develop reusable launch systems should the launch rate demand them. To do so, however, advances in the technologies associated with high temperature structures, lightweight heat protection, and hypersonic aerodynamics would be required.

The development phase of a Soviet orbital satellite interceptor may be nearing completion. Antisatellite capabilities could be extended to geostationary altitudes during the next five years, based on existing technology. Advances in reconnaissance, surveillance, and meteorological satellites are predicated on advanced sensor development. We are not aware of any limitations of Soviet military research facilities that would hamper such development. Experiments with manned spacecraft indicate an interest in missile-launch detection/surveillance sensors and photoreconnaissance. We expect the Soviets to pursue the development of new reconnaissance sensors and systems to monitor US compliance with the strategic arms limitation (SAL) agreement. [redacted] Soviet experimentation with ocean area observation could lead to ocean surveillance systems using multi-spectral sensors.

AERONAUTICS

For at least the past 10 years the Soviets have pursued vigorously a broad and uninterrupted program in practically all areas of aerodynamic R&D. They have increasingly emphasized use of experimental capabilities to support existing high-quality analytical and numerical capabilities. They are capable of addressing the complex development problems of more advanced system concepts. Research programs include studies intended to improve aerodynamic efficiency in all speed regimes and the examination of unique problems associated with specific vehicle types.

The Soviets continue to devote extensive aeronautical R&D resources to the development of turbine and jet engine concepts. Relatively short engine life continues to be a major shortcoming of the Soviet aircraft gas turbine industry. The Soviet turbine materials that have become available for exploitation continue to be "dirty" with inclusions and high porosity. This apparent inability to manufacture high-quality turbine materials is the probable reason for low turbine inlet temperatures and the short life of current Soviet engines. This shortcoming is expected to be overcome through the use of more effective cooling schemes, better fabrication techniques, and improved alloys. [redacted]

Despite the above shortcoming, Soviet engine technology has shown a number of strengths in inlet technology, positive expulsion tanks, and compressor design. The Soviets have been developing a turboramjet engine (which they define as an afterburning turbofan) since about 1964. They are also aggressively pursuing the technology necessary for the development of rocket-ramjet combined cycle engines. Various missiles and an airbreathing booster for a space shuttle vehicle are their indicated goals.

The Soviets continue to build and fly an impressive number of prototype aircraft of all types. Additionally, progressive improvements have appeared in numerous new models. Three new and different types of fighter designs are currently in flight testing; two of these are in the weapon systems test stage. Continuing emphasis on VTOL and STOL developments is being supported by investigation into flow field effects around such vehicles operating near the ground in hover or in transition to forward flight modes. Development of new bombers in addition to those now being tested does not present an insurmountable technological challenge to the Soviets.

A unique Soviet vehicle which appears to have no Western counterpart is the 10-engine vehicle 300 feet in length which has been in existence at Kaspiysk on the west coast of the Caspian Sea since 1966. The vehicle appears capable of exploiting propulsion and lift interaction to provide several modes of operation and may be able to lift payloads comparable with those of the C-5A in STOL operations from water or ice. [redacted] there may be a family of vehicles of this type with lengths of 50, 75, 100, and 300 feet.

GROUND WARFARE

Efforts to modernize Soviet ground forces have been moderately successful. Since World War II roughly three generations of weapons and support equipment have been furnished to the Soviet ground forces. Much of the old materiel is obsolete but usable and often effective. We see no trends in Soviet ground weapons R&D which would materially affect ground forces doctrine during the next decade.

Future Soviet ground warfare R&D probably will be directed toward development of equipment which will improve river crossing, airborne, oversnow, and amphibious capabilities. Better self-propelled armored support weapons and close-range missile and artillery support weapons should be forthcoming. Soviet smoothbore technology is the most advanced in the world, and further development of smoothbore weapons for firing rocket-assisted and guided projectiles may be expected. The Soviets will continue their efforts to upgrade command and control systems and develop an effective military operations research program which encompasses all areas—from electromagnetic propagation studies, communications devices and ADP usage to selection and training of technical personnel.

NAVAL WARFARE

During the past several years the Soviets have developed a wide variety of new naval weapon systems, including submarine-launched strategic ballistic missile systems, improved antiship and antiaircraft missile systems, and antisubmarine warfare ships and systems. While the new major surface combatant types have designations which indicate a main mission of antisubmarine warfare, surface-to-surface missile armament makes them formidable threats in ship-to-ship combat. Soviet naval R&D during the next 10 years will continue to be directed largely toward improvements in existing weapon systems. New naval systems, however, are possible.

Soviet efforts to improve their submarine forces continue. Four modifications of existing ballistic missile submarine designs are in the experimental stage. Of these, a large nuclear-powered submarine, the newly designated D-class, has appeared and is assessed to be the platform for the SS-NX-8 missile. The speed of this submarine is unknown but presumably will be comparable with that of the Y-class. The D-class submarine possibly will incorporate improved sound quieting features over those of the

Y-class. As anticipated, the Soviets have developed a new and quieter second generation nuclear torpedo attack-class submarine, designated the V-class SSN, but they apparently have chosen not to sacrifice speed in order to incorporate quieting features. In addition to noise reduction, Soviet submarine R&D during the next decade probably will continue to emphasize precision navigation, command/control systems, and improved steels and welding for deeper diving hulls.

The new Krivak-class combatant probably will be used primarily in an ASW role and may be followed in the latter part of the decade by new surface combatants having a primary role of ASW. The new aircraft carrier under construction at Nikolayev, designated the 444B, probably will be operational in several years. This ship is expected to carry V/STOL aircraft and probably will be used in an air support and/or air defense role. The ship may also carry ASW helicopters for surface ship ASW screening operations or be equipped with assault helicopters for projecting forces ashore.

Soviet ASW has been largely dependent upon acoustic detection of submarines and has increased substantially over the past few years. Only one Soviet nonacoustic system—magnetic anomaly detection (MAD) equipment used in ASW aircraft—is known to be in operation, but the Soviets are well aware of a wide range of other nonacoustic techniques. The USSR can be expected to improve ASW capabilities through development of improved acoustic and nonacoustic detection/classification equipment and more effective weapons for surface ships, submarines, aircraft, and helicopters. The Soviets probably will install improved acoustic detection devices on ships and submarines and deploy some improved fixed acoustic arrays and moored buoys. While we are unable to predict the precise direction of Soviet R&D in naval-associated acoustic detection systems, their research appears to be following conventional avenues of US investigation. The Soviets may be attempting to develop advanced types of detection/sonar systems, based upon infrasonic waves, bioacoustics, and nonlinear acoustics and possibly nonacoustic methods (MAD, radar and laser, infrared radiometers, radioactive detectors and others). For at least the next decade, however, nonacoustic methods probably will continue to complement acoustic detection systems.

MILITARY ELECTRONICS

The USSR is expected to increase the use of those devices and techniques which will lead to more compact and reliable electronics equipment for military applications. Soviet capabilities in the theory of solid-state devices are good and will remain so; improvements are expected in their capability to produce quantities of such devices for use in military systems. Throughout the period, increased miniaturization, microminiaturization, and integrated circuit applications to weapons systems electronics are expected. Based on a strong development program and past trends, spectrum utilization throughout the next 10 years probably will be toward lightly used frequency bands for numerous reasons and there will be considerable emphasis on the use of shorter wavelengths. The trend in Soviet devices which could be applicable to both high-power and low-power use in military systems probably will be toward increased band width and stability and, where applicable, toward increased power and tunability.

In radar applications the Soviets are expected to make increased use of advanced modulation techniques. Antenna designs, while conventional for the most part, will probably emphasize electronically steered phased arrays for applications in which beam agility is important. Techniques applicable to a synthetic aperture radar using optical processing are being developed, but there is no evidence to suggest that such a radar is now operational. Also, the Soviets are expected to continue their over-the-horizon (OTH) developmental effort. Future development in OTH systems may include an OTH radar designed to look through the northern auroral zone toward the US. The key problems facing the Soviets in future OTH development are avoidance of the high losses common in transpolar propagation and improvement of system reliability.

Soviet communications efforts are currently directed toward the establishment of a unified automated communications network. Development of electronic and semielectronic switching equipment will continue, but actual integrated service of such equipment is not expected before 1980. Improvements in electronic warfare capabilities, including electronic jamming and chaff to counter US radars and communications networks, should continue during the next 10 years. Emphasis will be placed on the development of advanced electronic countermeasures equipment which will provide for higher jamming power per pound, increased capability for multiple target jamming, and quicker reaction times.

The Soviets are expected to continue to use specially designed computers, generally selecting the lowest order of software and hardware sophistication consistent with systems needs for on-line military systems applications. Small-scale integrated circuits (IC) are available for design experiments, and prototypes of large-scale IC arrays have been employed in experimental work in military-related areas such as signal processing. It is unlikely, however, that quantities of large-scale IC arrays will be used in military computers before 1976 because of insufficient amounts of quality components and the conservatism of Soviet military systems designers. Developers of computers for use in military systems probably will continue to employ proven circuit and component technology rather than depend on the concurrent development of new components and circuits to meet system needs.

MILITARY ELECTRO-OPTICS

A large effort is directed at developing and producing electro-optical systems for the Soviet armed forces. Their infrared (IR) optics technology is good and has found wide military application. Their laser program has expanded at a rapid rate over the past several years. All of the more useful types of lasers suitable for military applications are available or under development in the USSR. Future research is expected to focus on high energy pulsed and continuous wave lasers for application to new electro-optical systems for laser-induced fusion, communications, laser discrimination systems and laser beam weapons.

[redacted] the probable existence of a major Soviet military R&D program involving high energy lasers. Although a number of aspects of this program remain obscure, [redacted] the goal may be to develop a laser weapon system. While the specific application for this weapon system is not yet known, air defense appears to constitute the earliest feasible strategic use. The development of a laser radar or discriminator which might be used in conjunction with a missile defense system is an additional possibility.

Based on their laser and optical pointing and tracking capabilities, in the near future the Soviets apparently could deny us photosatellite coverage of high-interest targets should they desire to place sufficient priority on such a laser application. Such interference with national means of verification, however, would be in violation of the SAL agreements. The Soviets probably could develop the essential elements of a laser antisatellite weapon system capable of damaging low-orbit satellites through thermal means by the early to mid-1980s. It is unlikely that the Soviets could develop a directed energy kill or other laser ABM weapon system during the next 10 years.

Soviet IR optics technology is supported by a strong background in theoretical and applied optics. Their R&D of semiconductor radiation detectors has advanced considerably in the past few years. The USSR apparently has an across-the-board capability somewhat comparable with that of the US in basic detector research and development. [redacted]

MILITARY MEDICINE

Soviet military medicine is steadily improving in terms of productivity and effectiveness. The Soviet R&D effort compares favorably with that of the US, but the capability to apply the results at the troop level continues to lag that of the US. Military medical research having priority in terms of money and manpower and which has had some successes includes that related to nuclear submarines, submersibles, and hyperbaric (deep diving) medicine; study of the adverse effects of nonionizing radiation in manned military enclosures; and development of radiation drugs for pre- and post-radiation exposure. Military pharmacological research continues to be directed toward the development of antihypoxic agents, antidotes for chemical warfare agents, and antiviral chemotherapeutic agents for influenza.

CHEMICAL AND BIOLOGICAL WARFARE

Soviet CW research and development encompasses all phases from basic research to field testing in the discovery and development of new agents and munitions. We expect the Soviets to continue during the 1970s their considerable research on the toxicological and physiological effects of old and candidate agents. New compounds for testing will continue to emerge from screening natural and synthetic toxic compounds. New types of lethal and incapacitating agents might be developed at any time from this work. Research to develop improved antidotes. prophylactics, and protective equipment will continue. [redacted]

We continue to believe that a Soviet research and development program in BW has been under way since perhaps as early as the 1930s. There is evidence that BW agents have been developed, but we are unable to determine which pathogens, if any, have been standardized for military use. We have no reliable information to confirm an offensive doctrine or the deployment of hardware for offensive BW purposes and are unable to determine the extent of Soviet BW testing. The recent convention signed by the US, USSR, and other nations would seem to negate the development and stockpiling of bacteriological and toxic weapons by the Soviets, but the convention lacks provisions for verifying compliance by the signatory countries. The uncertainties in our knowledge of Soviet BW accomplishments and of the scope of their R&D effort preclude the making of valid predictions about future capabilities.

NUCLEAR R&D

Since the signing of the Test Ban Treaty in 1963, the USSR has continued to test underground and undoubtedly is carrying on R&D programs in weapons. The likely objectives and extent of the Soviet program are the development of thermonuclear warheads for new strategic systems, development of cleaner, lighter, and more flexible warheads for tactical applications, development of advanced warheads for ABM applications, and the investigation of pure fusion techniques.

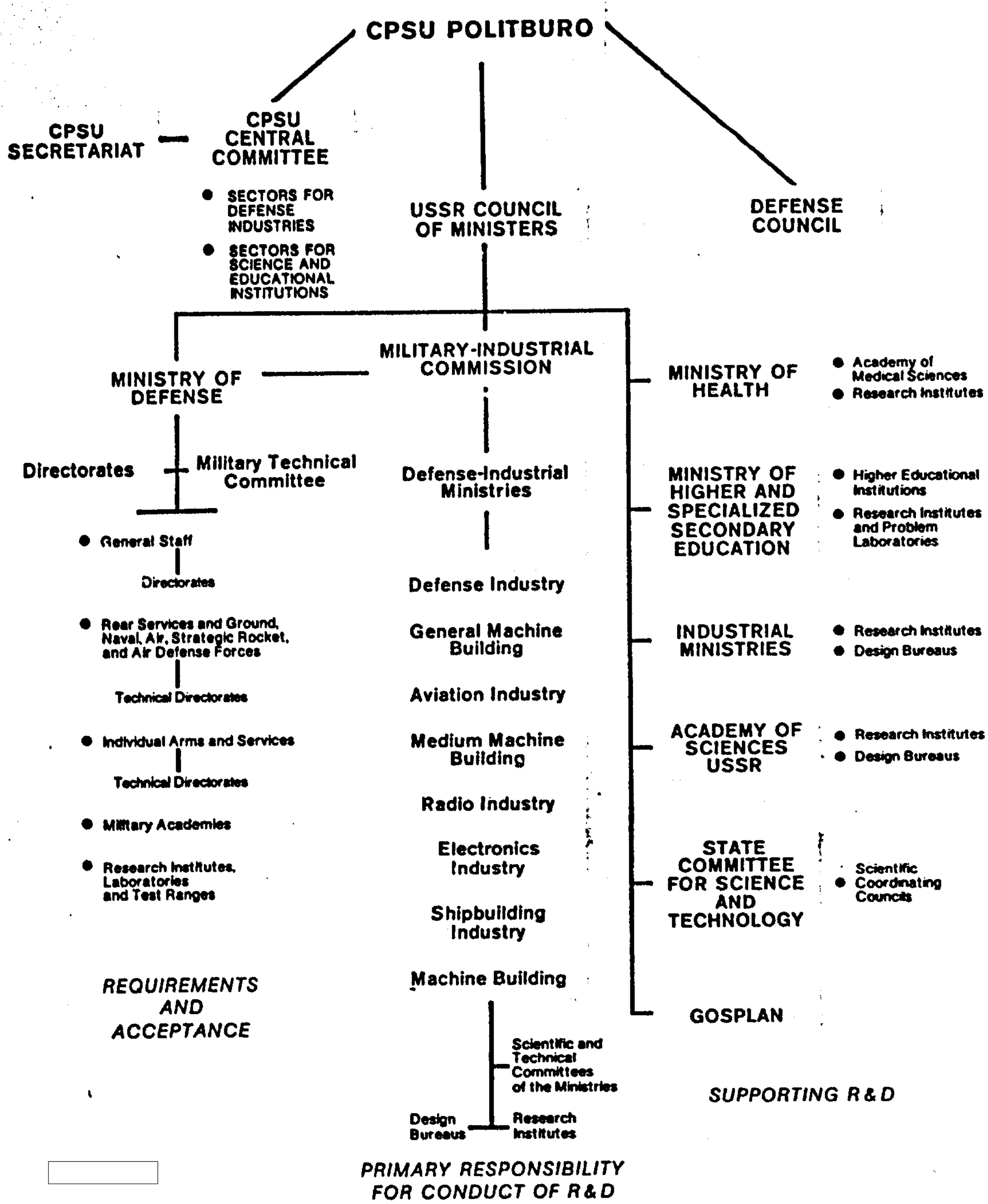
In the area of controlled thermonuclear reaction (CTR) research, the experimental program of the USSR is the world's largest in terms of the investment of equipment and manpower. At the outset the Soviet program concentrated on research with toroidal machines, with some work involving linear machines. More recently, however, the program has become more diversified and includes studies of fusion induced by laser and relativistic electron beams. In addition to the possible development of a fusion reactor, Soviet CTR R&D could result in such applications as the simulation of high-altitude nuclear weapons effects.

Soviet nuclear technological development appears to be progressing at about the same pace as in the West. Unexpected advances leading to improved nuclear-powered military systems could result from the development of new materials permitting advances in such areas as the miniaturization of control systems, the design of magnets, and high-capacity energy storage systems.

DISCUSSION

ORGANIZATION, PLANNING AND CONTROL

In their pursuit of long-range, worldwide objectives, the Soviets have placed heavy reliance on military R&D programs aimed at developing weapons systems to offset Western capabilities. For this reason, vigorous and increasingly competent Soviet military R&D programs are of extreme interest and concern at the highest levels of the Soviet government. Our knowledge of the organization and control of Soviet military research and development programs is sketchy. Nevertheless, bits of organizational information on the party and government, procedures used in the past, statements of need, and general policy directives on science and technology provide some basis for deducing the probable mechanisms involved. (Figure)



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Organizations concerned with military R&D in the USSR

SECRET

The summit of Soviet weapons R&D policy-making appears to consist of the top-level people in the most important organizations involved in the weapons R&D policy process, with good representation and communication by the defense industrial establishment and the military professionals. These organizations include the Politburo and D. F. Ustinov, candidate member of the Politburo and overseer of military R&D and production activities; the Defense Council—an advisory group to the Politburo chaired by Brezhnev which brings together top political and military leaders; the defense industry section of the Central Committee headed by I. D. Serbin; and the Military-Industrial Commission (*Voyenno Promyshlennaya Kommissiya*—VPK), a group consisting of representatives of high ranking defense industrial ministries and Ministry of Defense officials chaired by L. V. Smirnov, a deputy minister of the Council of Ministers who reports to Ustinov.

This small and closely knit group of policy-makers probably defers to professional military judgment in weapon program decisions. Although the pressures on limited national resources are considered at the summit as national priorities are defined, there is no evidence that weapon program decisions are routinely and systematically influenced by cost-effectiveness considerations as they are in the US. Despite an emergent systems analysis capability in the Soviet military establishment, it does not seem to be focused on cost-effectiveness appraisals. Soviet leaders are probably strongly inclined to accept weapons programs that the military professionals say they need and that the engineers and economists agree are feasible. The built-in bias of the decision-making system appears to lend itself to the expansion of military technology efforts along lines which satisfy all or most military advocates of new programs, subject to budgetary restraints.

Within the structure of the Council of Ministries, the VPK provides the framework for control and coordination at the national level of military-associated research and development plans, programs, and activities accomplished by the defense-industrial ministries for or in support of the Ministry of Defense. The members of the VPK appear to represent the ministries most concerned with military R&D including Defense, Defense Industry, General Machine Building, Medium Machine Building, Machine Building, Aviation Industry, Radio Industry, Electronics Industry, and Shipbuilding Industry. These defense-industrial ministries bear the primary administrative responsibility for carrying out military R&D programs as well as production of weapons systems and components for discrete customer elements of the Ministry of Defense; for example, Ground Forces, Navy, Air Force, Air Defense Forces, and Strategic Rocket Forces (SRF). These customer elements are represented by Technical Directorates which train and assign "military representatives" to monitor all military work being done within the civilian industries.

Long-range plans and requirements for military systems are believed to be formulated, consolidated, and approved by a planning directorate of the General Staff of the Ministry of Defense in conjunction with the respective operational forces. Military planning probably operates both downward and upward. Key requirements of national importance are probably initiated and approved from a general standpoint at the Politburo and Council of Ministers level, while less important requirements may be drawn up by individual forces and submitted upward for approval. Ideas from field commands are analyzed by academies, research institutes, laboratories, and test centers controlled by technical directorates of the individual forces, and recommendations are forwarded to higher authorities.

The Ministry of Defense is essentially a customer for weapons and military materiel and does not itself perform much research. Each service has a technical directorate whose responsibilities include the definition of systems requirements and the establishment of priorities for weapons and equipment. Each technical directorate administers a limited number of research and test facilities, but the mission of these facilities is mainly to explore the feasibility of new weapons, examine new projects, test new weapons and develop techniques for their tactical or strategic use. A directorate's main contribution to military R&D is the monitoring of research and development programs performed outside the Ministry of Defense in the defense-industrial ministries; this is achieved by assigning military personnel to represent the customer elements on Defense Industrial Ministry commissions which evaluate competitive design proposals and approve each phase of the development program. Military representatives are also assigned to the R&D and production facilities of the ministries that will provide the weapon system, as well as to facilities of other ministries providing subcontracted items.

Product responsibilities of the eight industrial ministries most concerned with Soviet military R&D are as follows:

Defense Industry	Armored vehicles, artillery, rockets, small arms, and aircraft armament
General Machine Building	Ballistic missiles; space launch systems, upper stages, and nonrecoverable spacecraft
Aviation Industry	Aircraft, aerodynamic missiles, defensve missiles, recoverable spacecraft
Medium Machine Building	Nuclear weapons and nuclear propulsion plants
Radio Industry	Communication/navigational/guidance equipment, computers
Electronics Industry ..	Electronic components
Shipbuilding Industry	Naval vessels, underwater weapons, fire control systems
Machine Building	Ammunition, explosives, fuses and projectiles, and solid propellants

The defense-industrial ministries plan, initiate, and conduct the applied research programs needed to support military system developments. The ministries generally strive for self-sufficiency, but part of their applied research programs is contracted to supporting agencies. Research planning is based largely on a ministry's understanding of future systems requirements and established technology. Research programs of the defense-industrial ministries usually are initiated in anticipation of future systems requirements. Only rarely is applied research initiated in response to explicit system requirements. The applied research performed by the ministries determines their capability to respond to specific customer requirements. The individual services within the Ministry of Defense define the specific requirements for weapons system developments and initiate the design development phase through the administrative channels of the Council of Ministers.

Within each defense-industrial ministry, actual responsibility for research and development is generally divided between scientific research institutes which conduct applied research programs and design bureaus which accomplish weapons system design and development. Scientific research institutes play an important role in support of design bureaus and specific weapons development programs by conducting necessary applied research activities, preparing design handbooks and specifications, conducting ground environmental testing and prototype testing activities, and evaluating design suitability during the various phases of the weapons development cycle. The actual development of specific weapons systems, however, is the sole responsibility of the chief designer who has been awarded the development program after competition with one or more design bureaus. Research and development programs are financed from the operating budget of an institute or design bureau of a ministry or from the State budget and occasionally by the Ministry of Defense. Series production costs are contracted with and paid directly by the military forces.

Our most complete documentation of the R&D process concerns Soviet procedures used in the development of aircraft, cited here as an example. Although each weapons system goes through a similar R&D cycle, the detailed administrative procedures used in handling its evolution vary with the type of system. During the development of a new aircraft, it is common practice within the Ministry of Aviation Industry to form a commission responsible for making recommendations on each significant phase of the program from preliminary design through mock-up, detail design, prototype construction, and test. The commission normally is chaired by a deputy minister and includes representatives of the Ministry, the military customer, chief designers, key scientific research institutes, and representatives of other ministries that will provide other subsystems and components. Mock-ups of the system are inspected by a military commission for the purpose of ascertaining suitability and making recommendations to the industrial commission. Final tests are made by the Ministry to ensure that performance is in accordance with military customer requirements. Service operational tests are then conducted by military customer test organizations for decisions about series production and operational use. Design bureaus continue to remain responsible for design activities and modifications during series production of a system until it is obsolete and retired from operational service.

Effective use is being made of military-related R&D resources as indicated by the steady succession of new and improved weapon systems and the large, continuing resource allocations that have been made to military product R&D facilities. Resource investments for strengthening national-level scientific and technical capability are not being used as efficiently as the Party and Government would like, however. Obstacles to full use of the national R&D potential include faulty management and planning, imbalance between theoretical and applied research, administrative barriers to the more timely introduction of R&D achievements into production, security barriers, and the lack of interchange with East European S&T personnel. As the Soviets have become increasingly aware of the high costs of modern R&D, much concern is being expressed about devising ways to measure and improve the efficiency of R&D institutions and individual scientists and engineers. From the frequency with which the military R&D industries (for example, the aerospace industries) are identified as the "lead industry" whose management techniques and efficiency are to be emulated by other Soviet industries, it is concluded that high-level dissatisfaction with the R&D effort is directed toward the general scientific and technical community.

Some of the strengths and weaknesses of the national-level S&T community are shared by the military-product R&D establishment; others are not. The features of the military-product R&D establishment which set it apart from the rest of Soviet science and technology are organizational, management-related and motivational; other features which foster improved efficiency are the urgency of national security demand for weaponry and the persistent demands of its customer, the Ministry of Defense, for quantitative and qualitative improvements in new generations of products.

Organizational separation of R&D performers and customers and between basic and applied science has several beneficial aspects within each ministry. The clear identification of responsibilities, functions, and roles reduces duplication of effort; both national- and ministry-level control and administration are enhanced by the resulting dispersion of effort, and a more favorable span of control is achieved. The relative autonomy and cohesiveness of each industry or science area permit them to exercise initiative in determining the direction of R&D programs and, at the same time, result in a high degree of self-dependency in meeting customer demands.

The higher level of R&D effectiveness of the military product ministries is also heavily influenced by the favored treatment received from Party/Government decision-makers and planners in resource allocations, higher wage levels, and preferential motivational inducements. These ministries have historically been nurtured with priority considerations to insure success in achieving Party and State military-related goals. Their effectiveness is frequently highlighted as an example to other ministries of the progress and capability that can be attained. In addition, their superior capabilities are occasionally used to satisfy critical gaps that arise in the non-military or consumer sector.

The planning of military R&D is accomplished separately from other national-level R&D planning. This allows for identity and priority in planning the scope and direction of the nation's military R&D effort and adjustments to accommodate the highest priority projects of the defense industries. Furthermore, the coordinative efforts of VPK and the supervision of high-ranking Politburo members lend the prestige and power of the Party and State to these plans to assure effective and timely implementation.

The majority of high-level decision-makers and managers associated with military product R&D have technical backgrounds or training which provide some degree of technical expertise in R&D decision making. Their selection to positions of ministerial authority, although based in part on political suitability, is mainly the result of technical and administrative competency and demonstrated professional accomplishment in their respective fields. Most have come up through the ranks from diversified assignments and are well versed in the operations of their industry. There is little rotation of high-level managers between industries. The tenure of the ministers who head the military-product ministries averages 13 years.

Tenure is enjoyed by most ministers who have been judged successful in operating their ministry, have met prescribed Party/Government goals, and have met standards of effective use of allocated resources. Similar criteria of technical administrative competency prevail for managerial personnel down to the research institute and design bureau level. Promotion from within is normal practice when replacements become necessary, thus reinforcing the continuity of leadership and minimizing perturbations in R&D programs. The frequency and diversity of awards and recognition given for professional and administrative accomplishments in fields allied to areas of importance to military R&D not only illustrate the priority emphasis devoted to the military versus non-military sector but also the powerful motivational inducement given to spur future advancement and plan achievement.

Several deficiencies exist which are believed to counterbalance the above strengths and, to a degree, tend to constrain progress in military R&D fields. The mechanisms for administration and program control have tended to become highly centralized and rigid and require meticulous and exhaustive bureaucratic procedures in planning at all levels. Soviet policy minimizes the use of direct R&D competition as an instrument for advancement of science and technology. Officially, duplication of effort in S&T is generally considered a wasteful use of resources, and emphasis continues on refining organizational responsibilities to minimize competition and resultant duplication between organizations. In practice, duplication does occur between industries, science agencies, and educational institutions where similar areas are being researched even though the end product or goal is different. Since this effort is not directly competitive, it does not effectively stimulate R&D advancement. Administrative and bureaucratic barriers also generally complicate communication channels and retard the cross-fertilization and multi-application of research effort between industries. The separation between research, design/development, and production functions within ministries also tends to retard rapid assimilation of new technology advancements, thus stifling innovations in R&D problem solutions. This prevails to a greater degree in the non-military product industries where less extensive working relationships appear to exist between research, development, and production elements. A concerted effort is being made to solve these problems in both military and non-military sectors.

Design competition is officially sanctioned as an important element for achieving progress in the military product industries where a dynamic technology environment prevails, new generations of products require performance improvements over previous ones, and competition with Western accomplishments are important milestones in achieving national and international prestige. Even here, however, degrees of specialization exist which limit the numbers and interests of competing bureaus. Emphasis on program plan fulfillment and goal achievement combined with the previously discussed aspects of the Soviet environment has generally resulted in minimizing risks and tends to foster conservatism in systems design and performance.

FACILITIES

The extensive Soviet investment in military R&D facilities during the past decade which has contributed substantially to their technological achievements noted to date has also provided them with a potential for conducting future R&D programs on advanced weapon systems during the period of our forecast. The growth trends in Soviet R&D investments during the 1960s indicate that the USSR will continue to program future system developments of high national priority and ensure momentum in the continuous process of providing new weapon systems. Because of the time lag between R&D resource investments and returns on those investments in the form of new and improved systems, the full impact of the Soviet investments in military R&D complexes during the 1960s has not yet been realized. As a Soviet R&D program is completed, the resources involved in the program are immediately recycled for use on new design tasks. Hence, Soviet capital resource investments to date should result in continuing hardware improvements and new developmental trends well into the mid- to late-1970s, even if the capital investment trend were stopped abruptly in the near future.

Ground Forces

The Soviet Ground Forces are supported by extensive RTD&E and production facilities administered by the defense-industrial ministries, particularly the Ministry of Defense Industry and the Ministry of Machine Building, and the Ministry of Tractor and Agricultural Machine Building. The Ministry of Defense Industry (*Ministerstvo Oboronnoy Promyshlennosti*—MOP) has the major responsibility for ground force weapon systems, including infantry weapons, artillery, and armored vehicles. The ministry also performs supporting R&D in the areas of fire control, optics, infrared devices, telecommunications, radar, and metallurgy. Selected components for related systems and materiel development programs are provided by the facilities of the machine building industries. Design and development of ground force systems are responsibilities of both independent design groups and production plant teams such as the one believed to be at Tank Plant No 183, Nizhniy Tagil. It is believed that in certain categories of weapons R&D, for example, small arms, ad hoc groups of scientists and engineers are formed to do the work. The development of a major weapon system is always a multiministerial effort, with the Ministry of Defense Industry having overall responsibility. Of the approximately 30 new designs introduced in the last 15 years, most are out of MOP, with cooperation from the Ministries of Radio Industry and Electronics Industry and the machine building ministries. Testing of MOP items is accomplished at numerous test ranges probably subordinate to the Ministry of Defense.

Air Forces

The R&D facilities for the Soviet Ministry of Aviation Industry (*Ministerstvo Aviatsionnoy Promyshlennosti*—MAP) have undergone rapid growth, particularly during the last decade, to meet the requirements of both military and civil air fleets. The continuing expansion of many R&D facilities combined with probable new construction activities in progress reflect an enhanced Soviet ability to to conduct aerodynamic developmental programs in support of systems that will become operational during the 1970s and 1980s. Most of these facilities are controlled by the Ministry of Aviation Industry and supported in the areas of specialized equipment and components by the R&D facilities under other ministries, for example, the Ministry of Defense Industry. Subordinate to MAP are key aviation research institutes, including the Central Aerohydrodynamics Institute; the Siberian Research Institute for Aviation; and Institutes for Aircraft Engine Construction, Aviation Materials, Aviation Technology and Organization of Production, and Flight Testing. The estimated number of S&T personnel in these institutes is about 8,000 and increasing at an annual average rate of approximately six percent. Thirteen aerodynamic-systems design bureaus supported by nine or ten propulsion bureaus and eight accessory equipment bureaus are responsible, under MAP, for new and improved system and subsystems developmental programs and experimental prototype construction activities. The design bureaus are similar in size and scope to those of the major aircraft producers in the US. Professional design staffs vary in size from about 300 to 1,300 individuals, representing approximately 25 to 30 percent of the total work force at each bureau. Design staff stability together with the continuity of development programs and specialization of design effort by type or class of system has created a highly skilled, experienced pool of designers at each bureau who are well qualified to undertake increasingly complex weapon systems developmental programs. Supporting aeronautical R&D work is also acquired through contract arrangements with educational institutes of the Ministry of Higher and Secondary Specialized Education, particularly the aviation educational institutes.

Naval Forces

The post-World War II expansion of Soviet shipbuilding research, development, and design facilities levelled off in the late 1960s. By 1971 these facilities had attained capabilities for high-quality research. The major facilities are located in the Leningrad area and are subordinate to the Ministry of Shipbuilding Industry. The foremost of these facilities is the Krylov Shipbuilding Research Institute (also known as the Central Scientific Research Institute No. 45), where research on hydrodynamics, ship structures, marine engineering, and shipbuilding materials is conducted. The professional staff at Krylov consists of about 1,800 individuals; the total staff numbers about 3,600 individuals. A group of non-Soviet hydrodynamicists was granted a rare opportunity to visit the hydrodynamic facilities at Krylov in 1971. It was their judgment that, while the Soviets were lagging in hydrodynamic research, the extensiveness and quality of their research facilities and the high caliber of their professional personnel have put them in a position to make considerable gains in the near future in the performance and quieting of high-speed ships. The course of research in the departments of marine engineering and ship structures is less clearly discernible, but it is evident that there is a definite and continuing effort directed toward increasing use of automation in ship control and propulsion systems. Other research facilities in the Leningrad area subordinate to the Ministry of Shipbuilding Industry are the Central Scientific Research Institute of Shipbuilding Technology, which is primarily concerned with the introduction to shipyard use of new techniques developed through research; and the Central Scientific Research Institute No 48, which works on naval metallurgical developments. A distinctive organization is the Central Design Bureau for Naval Standards which approves new designs and materials for the entire Shipbuilding Ministry after testing them for general use.

The Ministry of Shipbuilding Industry has central design bureaus for the design of cruisers, submarines, coastal patrol craft, minesweepers, and other types of ships. It also has specialized design bureaus like the submarine propulsion Special Design Bureau No 143 and the Special Design Bureau for Boilers. Naval designers include such Soviet prize winners as D. Ye. Brill (naval ordnance), Z. A. Deribin (submarine design), and G. A. Oglobin (naval turbines). In addition to work carried out under the Ministry of Shipbuilding Industry, research of interest to the Soviet Navy is done at facilities subordinate to the Ministries of the Defense Industry, Electronics Industry, and Aviation Industry, Radio Industry, Medium Machine Building, and General Machine Building. Supporting R&D is also conducted by such educational institutions of the Ministry of Higher and Secondary Specialized Education as the Leningrad Shipbuilding Institute and the Nikolayev Shipbuilding Institute. Although Soviet naval research is concentrated in the Leningrad area, there are several naval research facilities in Moscow, such as the Scientific Research Institute No. 10 (fire control and missile guidance) and the Marine Scientific Research Institute No. 1 (electronics of fire control). Also of particular note is the Institute of Hydromechanics. Several prolific research workers of the Krylov Institute have been transferred to this institute, and the new Director, G. V. Logvinovich, came from the Central Aerohydrodynamics Institute in Moscow. The Institute's work tends to be theoretical and appears to complement the engineering-oriented efforts at Krylov. Its principal areas of effort are boundary layer control studies, the hydrodynamics of foils and lifting surfaces near a plane surface, reactive propulsion systems, underwater rockets, and surface effect vehicles. The Institute of Hydromechanics also participates in an inter-institute program of hydrobionics.

Missiles and space

The Ministry of General Machine Building (*Ministerstvo Obskhestvennogo Mashinostroyenia*—MOM) was created in 1965 and reportedly assigned the responsibility for the research, design, development, test, and production of ballistic missiles and space hardware, formerly the responsibility of the Ministry of Defense Industry and to a limited extent the Ministry of Aviation Industry. The creation of MOM probably resulted in the transfer of certain facilities from the Ministry of Defense Industry, the Ministry of Aviation Industry, and various defense-related ministries with the provision of continued R&D support from these ministries. Surface-to-air missiles and cruise missiles are developed and produced by the Ministry of Aviation Industry with support from the Ministry of General Machine Building. The Ministry of Defense Industry develops and produces tactical and unguided rockets. Some of the research institutes and design bureaus under the Ministry of General Machine Building which support the Soviet ballistic missile and space hardware programs have been identified. Known facilities have experienced a significant growth pattern in terms of physical resource investment. Major gaps still exist in our knowledge of several elements of the industry, particularly the design bureaus responsible for naval ballistic missiles and solid-propellant missiles. About 40 major facilities for research, development, test, and production of liquid- and solid-propellant missile/space launch systems and their components have been identified, however. In addition, the Ministry of General Machine Building receives considerable design support from the Ministry of Aviation and other industries.

Some of the same facilities have also furnished the basic hardware for the Soviet space exploration program. The Ministry of General Machine Building has designed and developed space launch vehicles and space payloads, while the Tomilino Research and Development Complex of the Ministry of Aviation Industry has apparently been the focal point for the design and development of manned space flight systems. Training facilities include a center in the Shchelkovo-Monion area near Moscow and the Zhukovskiy Air Military Engineering Academy, where the cosmonauts receive their academic training. Adjacent to this academy is the Air Force Scientific Research Testing Institute for Aviation and Space Medicine, where much of the basic physiological R&D of manned space flight systems has been performed. Facilities of the Ministry of Health have provided R&D support to the Tomilino Design Bureau and the Institute for Aviation and Space Medicine.

The flight test activities under the Ministry of General Machine Building occur at three test range complexes: Kapustin Yar (vertical space probes and up through MR/IRBM-class ballistic missiles), Tyuratam (ICBMs and space) and Plesetsk (ICBMs and space). The large number of test launches that have occurred from these three complexes suggests that there has been a continuing increase in the number of launch sites available for flight test developmental programs for new Soviet missile/space systems.

Supporting research

As indicated above, most of the Soviet military R&D effort is undertaken by facilities subordinate to defense-industrial ministries. Supporting R&D effort of a limited, specialized nature, however, is conducted by a number of other ministries and agencies, including industrial ministries, the Ministry of Higher and Specialized Secondary Education, and Academy of Sciences institutes having specialized capabilities or facilities either not available within the defense-industrial ministries or considered necessary to augment or expedite existing research projects. Although this supporting research effort is well diversified and significant, it is not extensive. Several factors limit the R&D potential of these sources. Since the supporting activity is acquired directly through contract arrangements, it is generally of a problem-solving or short-term nature. Communications problems and administrative barriers to interaction limit the direction and applicability of research programs conducted independently by these agencies. The tendency for the defense-industrial ministries as well as all agencies in general to guard closely the R&D prerogatives of their assigned charter and maintain a posture of self-reliance is another major impediment.

Some research conducted by the Academy of Sciences, USSR, has been of direct value to the armed services, and specific military-related research projects have been assigned to its leading research institutes. The academy has over 200 subordinate institutes, observatories, and laboratories, employing over 30,000 scientists and a total staff of nearly 70,000. The Academy of Sciences has expanded in recent years with facilities being located in remote regions. Two new science centers were established in 1971, the Far East Science Center and the Urals Science Center. The purpose of these centers is to provide a focal point for the development of the natural resources of the area in which they are located. In addition, the republic academies have recently begun to establish science centers. Also the Soviets are continuing to expand their science city program that was begun in 1958. With 18 research institutes and a university, Novosibirsk is the most prominent of the science cities. A satellite city consisting of scientific research institutes and design bureaus has been established a short distance from Novosibirsk. By establishing the satellite city near the science city, the Soviets hope to reduce the time between research and production. The satellite city is only one of many programs undertaken by the Soviets to bridge the gap between science and production. Another science city which is being developed is at Krasnaya Pakhra, near Moscow, where several institutes of the Academy of Sciences, USSR, and a facility of the Institute of Atomic Energy imeni Kurchatov, are located; these organizations are known to be engaged in military and space R&D. The center is expected to grow to accommodate a population of 40,000 to 50,000.

The national and republic academies of the Academy of Sciences are undertaking more applied research projects. This will result in a greater impact of their contribution on the national economy. Some of the areas of scientific research which fall under the purview of the academy system and which have military significance include geomagnetism, ionospheric studies, solar physics, acoustics, communications, ocean science, and outer space. In many of these areas, institutes of the academies are working on specific projects for the Ministry of Defense.

Another source of great potential for conducting scientific research relevant to military R&D are the schools of higher education (*Vyssheye Uchebnoye Zavedeniye*—VUZ. A large share of the S&T trained manpower employed in higher education has in the past devoted its efforts primarily to teaching rather than to conducting research. During the last 15 years, the Soviet Government has stressed the need for increasing the quantity and improving the quality of research in these schools. They have been called upon to intensify research on theoretical and experimental projects essential to the development of science and industry. More than 80 Problem Laboratories at leading VUZs have been established. Laboratory staffs are being increased and teaching duties lightened or removed, permitting more research to be done on selected problems in such areas as radiochemistry, nuclear physics, electronics, transistors, and computers. The facilities of most VUZ laboratories now appear to be adequate for research needs, and a few are equal or superior to those of most US universities. In a few cases, the best and most advanced research equipment is located at a VUZ rather than at an Academy of Sciences institute. In spite of the increase and improvement in VUZ research, this source will continue to play less of a role in the USSR than higher educational institutions do in the US.

MANPOWER

No statistics are available on the numbers of scientists and engineers engaged in Soviet military R&D. It is possible, however, to indicate the size and the range of skills of the national scientific-engineering manpower pool available for employment in such R&D programs. In asmuch as military R&D receives the highest national priority, the required numbers of scientists and engineers could be diverted from lower priority programs to man these programs. There is no evidence that the availability of qualified professional scientific and technical manpower has constrained Soviet military-product R&D.

The best guage of the Soviet commitment to the rapid establishment of a research and development base for its industrial and military power is the increasing amounts of human resources involved in R&D. In 1950, the nation employed 714,000 blue and white collar workers in the "Science and Science Service" work force. This was about 1.8 percent of the total Soviet work force. By 1972 this same force had grown to 3,500,000 people, almost a five-fold increase in 22 years, and accounted for 3.5 percent of the total work force. Of this number, 635,000 full-time equivalent natural scientists and engineers were engaged in R&D.

The USSR has given top priority to the training of engineers. Although the nation already employs twice as many engineers as the US, Soviet higher schools are still graduating five engineers for every engineer graduated in the US. In 1970, 227,000 graduating students were in fields considered to be engineering fields in the US. The number of engineering graduates was over two times greater than in 1955 and comprised 36.0 percent of the 1969 graduating class in contrast to about 28 percent of the class of 1955. In the natural sciences, however, the US is graduating two scientists for every natural scientist graduated in the USSR. The total number of natural scientists and engineers graduated annually in the Soviet Union is about twice the number of US graduates in these fields. Soviet planners anticipate a large unsatisfied demand for engineers throughout the economy and particularly in consumer goods industries. The Soviet emphasis on the training of engineers is expected to strengthen further the relative industrial and scientific potential of the Soviet Union. In the last decade the general quality of higher education in the USSR has been lowered somewhat, due mainly to the increase in part-time education. Other causes include an increase in the student-teacher ratio (faculty growth has not kept pace with enrollment growth) and a trend toward lower state expenditures per student, although increasing amounts have been spent annually on higher education. In addition, inadequate classroom and laboratory space has affected the quality of education.

The number of persons in the USSR holding advanced degrees at the end of 1972 was over 290,000. Of this number, about 218,000 held scientific or technical advanced degrees:

Physics and mathematics	30,230
Chemical sciences	17,164
Biological sciences	22,340
Geological-mineralogical sciences	10,204
Technical sciences	81,786
Agricultural and veterinary sciences	18,051
Medical and pharmaceutical sciences	38,254
Total	218,029

The Soviet advantage of having such a vast body of trained manpower has been neutralized somewhat by ineffective use of that manpower. For example, as many as one-third of all engineers may be engaged in positions for which engineering training is not a necessary prerequisite. We do not know the extent to which poor manpower utilization affects military R&D, but we believe that utilization of trained personnel within the military sector is probably more effective than the utilization of such personnel generally in the USSR. The Soviets seek out and attract the top scientific and engineering graduates to positions within the military R&D organizations which generally carry more prestige than their civilian counterparts. The highly specialized training received by these graduates, who are acquired largely from a relatively concentrated nucleus of educational institutes having close ties with the defense industrial ministries, results in minimum retraining and expedites their utilization upon assignment. Workers in the military R&D organizations are provided superior laboratories and other facilities, better opportunities for advancement, and housing preferences.

MISSILE SYSTEMS

Offensive ballistic missiles

The Soviets have been conducting R&D programs on strategic missile systems for over 20 years. [redacted] During the past 10 years the USSR has developed several new ICBM systems and deployed three of these. In the late 1960s their ICBM development generally was confined to modifications of and improvements to the SS-9, SS-11, and SS-13 systems. These have included the altering of the size and shape of reentry vehicles and development of multiple RV systems and penetration aids. [redacted]

The large and varied ICBM force developed by the Soviets has been based almost exclusively on liquid propellant technology. As did the US, they began with liquid oxygen as an oxidizer and progressed to storable liquids to improve missile reaction time and ease of handling. Recent ballistic missiles using liquid propellants (the SS-9, SS-11, SS-N-6, and SS-NX-8) are believed to employ a nitrogen-based oxidizer with an amine fuel. This propellant combination provides the highest energy of all common or "conventional" storable propellants. We do not know of any Soviet program to develop more advanced propellants for ballistic missiles, but the level of technology and state-of-the-art in this field are sufficient to permit such development if so desired. The most likely improvement in propellant performance would result from employing additives in conventional propellants. The use of "exotic" propellants such as fluorine is not expected because they greatly increase the toxicity and handling problems associated with a deployed missile force. Such propellants, however, will be used in the space program.

Soviet liquid-propellant rocket-engine designers pioneered in two areas of technology—throttleable engines and high-chamber pressures. The guidance philosophy of these designers required the use of thrust control even on early ballistic missiles, and chamber pressures of about 1,000 psi were being used in the USSR before such pressures were used in the US. Evidence obtained from exhibits at the Paris Air Show indicates that the Soviets have stressed ease of fabrication, use of standard materials, and relatively simple and rugged design concepts for reliability. For the most part, Soviet ballistic missile propulsion systems have proven to be extremely reliable by the time the missile is ready for deployment.

The Soviets will very likely continue their broad spectrum of ballistic missile R&D for the foreseeable future. They are likely to concentrate on those areas of technology in which they lag the US, such as the MIRVs. [redacted]

[redacted]

MIRV SYSTEM—The Soviets have developed multiple reentry vehicles (MRVs) for the SS-9 and SS-11. They are not independently targetable, however, and apparently were developed to attack ABM-defended soft targets. The USSR probably will develop multiple independently targetable reentry vehicle (MIRV) systems for their ICBMs and possibly for future SLBMs, as well. To date no testing of MIRVs has been identified. Some of these systems probably will be accurate enough to provide a capability to attack hard targets. Increasing the number of available RVs by means of MIRVs would also be useful for penetrating ABM defenses and for enhancing the retaliatory capabilities of ICBMs surviving a pre-emptive attack. There have been various indications, some quite explicit, that the Soviets regard this as an important area of strategic weaponry in which they have need—for political, as well as military reasons—to catch up with the US.

SOLID-PROPELLANT SYSTEMS—Their large capacity for manufacturing solid propellants suggests that the Soviets have intended to stress the development of solid-propellant ballistic missiles. Moreover, several vehicles have been displayed in Moscow parades that have been described by the Soviets as using solid propellants. Two of these, the three-stage SS-13 ICBM and the SS-14 MRBM (which is made up of the upper two stages of the SS-13), flight tested, and only a limited number of SS-13s are deployed. Solid-propellant missiles have some unique advantages—such as ease of handling and simplicity of construction—but they require stringent environmental controls and do not lend themselves to the original guidance concept used in Soviet liquid-propellant missiles.

Why the Soviets have not pursued development of solid-propellant ballistic missiles more intensively is not known. [redacted]

[redacted]

REENTRY VEHICLES—The Soviet employment in the last few years of higher ballistic coefficients and multiple RVs shows an increased awareness of ABM penetration problems. Exoatmospheric decoys and multiple reentry vehicles have been tested and experiments may have been conducted with other penaids. [redacted] The development of decoys or chaff is judged to be within the Soviet capabilities, however, and could become evident in future R&D programs.

There is no firm evidence that Soviet RVs are hardened to withstand nuclear effects. In past test programs the Soviets have gained considerable experience with blast and thermal effects, and hardening is implied by the relatively close spacing of the three RVs on the SS-11 Mod 3 and on the SS-9 Mod 4. Without hardening the RVs would not represent separate targets to the present Spartan ABM. There also is a considerable number of technical publications devoted to technology that could be applied to RV hardening. On balance, therefore, we judge that Soviet RVs are hardened to a few hundred calories per cm^2. Efforts to increase this hardness are likely to continue. Also, the Soviets can be expected to develop high ballistic coefficients (1,000-1,500 psf) on future RVs for increased penetrability against US defenses.

Defensive missiles

Soviet defensive missile development and testing have been accomplished at the Kapustin Yar, Emba, and Sary Shagan test ranges. The testing of the prototypes for the SA-1, SA-2, and SA-3 systems was accomplished at the Kapustin Yar range. The Emba test range was constructed between 1960 and 1962 to support the development of tactical defensive missile systems. The systems identified to date at that range are the SA-4 (Ganef), the SA-6 (Gainful), the SA-7 (Grail), and the SA-X-8. The Sary Shagan Missile Test Range is the most extensive of the Soviet defensive missile test ranges and is the site of the SA-5 and ABM developments as well as modifications to the SA-2. Construction started at that facility between 1953 and 1956, and it is now the most heavily instrumented test range in the world.

ABM—Since the late 1950s, the Soviets have had a major ABM R&D program under way at the Sary Shagan Missile Test Center (SSMTC). The program has consisted of the development and testing of ABM radars and missile subsystems. R&D models or prototypes for each of the Moscow ABM System components—Dog House, Chekhov and Try Add radars and the Galosh ABM interceptor—first appeared at Sary Shagan, as has a prototype of the Hen House radars which provide early warning support to the system. Current activities relate to the development of new ABM systems as well as to the improvement of the existing system. Under the terms of the ABM agreement, the Soviets are allowed to continue their ABM research and development effort at Sary Shagan.

During the past nine years the Soviets have installed the Moscow ABM system and a ballistic missile early warning system on the periphery of the USSR. [redacted]

[redacted] Under the terms of the ABM agreement, only 100 interceptors on launchers are allowed, and the development of a rapid reload capability is not permitted.

[redacted]

[redacted]

Developmental research addressing all facets of the Moscow system's limitations [redacted] Vulnerability to nuclear blackout and inability to discriminate RVs from penetration aids are limitations which undoubtedly will be addressed. Present radar technology prohibits "seeing" through the fireball associated with a nuclear burst. Even propagation through nearby regions, such as those below the fireball as it rises, is distorted. Signal paths are refracted so that tracking accuracies are degraded and the signals themselves are attenuated. Signal attenuation and path refraction are reduced somewhat as operating frequencies are increased, however. Thus, the development of radars with capabilities similar to those associated with the Moscow ABM system but which operate at higher frequencies might be expected. Other approaches which might prove equally effective include the development of effective non-nuclear interceptor warheads (or at least "cleaner" nuclear warheads) or development of a firing doctrine or radar deployment pattern which would minimize the possibility of a nuclear burst occurring in front of all radars simultaneously (that is, some radars would always be capable of "seeing" behind all sections of the battle space).

Improved radar technology which would permit Soviet development of a high resolution radar in the near future could result in a capability to discriminate actual reentry vehicles from accompanying penetration aids. But the cost effectiveness of such an effort is questionable. An enormous computer capacity is required and only a slight modification of existing penetration aids would nullify any capability which might be developed. Other approaches are considered more likely. For example, development of optical devices, lasers, and LWIR sensors (although hampered by a necessity to operate in relatively clear air mass conditions) might prove more fruitful. Hardware employing such technology has yet to be deployed [redacted]

The use of nuclear weaponry or atmospheric filtering to disperse penetration aids and, thus, enable present radars to acquire and track a reentry vehicle can also be considered as a means of providing discrimination. Employment of nuclear weapons, although effective, presents a nuclear blackout problem and, hence, probably would not be pursued unless the vulnerability of the system to blackout were reduced.

Atmospheric filtering probably is the simplest, most reliable means of providing discrimination. Because the "filtering" occurs shortly before reentry vehicle detonation, however, a very high acceleration interceptor is required for this means to be effective. Although development of such an interceptor apparently is not under way in the USSR, it is expected. The ABM Treaty allows for the deployment of ABMs for defense of ICBM silos. An ABM system for this purpose would almost certainly employ a high acceleration interceptor. In fact, during the SALT discussions, the Soviets stated that their ICBM defense system would be short range and employ an interceptor like the US Sprint.

[redacted]

[redacted]

Soviet research related to the development of entirely different concepts which would improve their defense against ballistic missiles can also be expected. For example, an air or spaceborne laser ABM system could be developed if the Soviets could obtain laser output powers ranging from 100 to 1,000 Mw directed with pointing and tracking accuracies of approximately 5 microradians at ranges of 20 to 40 km. Deployment of such systems under the present ABM Treaty, however, would be prohibited without prior consultation. On the other hand, deployment of early warning sensors, for example, synchronous satellites with sophisticated sensor systems, is not prohibited and probably will be pursued.

SURFACE-TO-AIR MISSILES—The Soviet SAM R&D program has resulted in the widely deployed PVO Strany systems (SA-1, SA-2, SA-3, and SA-5), an entire family of tactical SAMs (SA-4, SA-6, SA-7, and the SA-X-8 presently under development), and systems for naval defense (including the SA-N-1, SA-N-3 and SA-N-4). The systems have for the most part been designed to counter a specific threat or a facet of an expected new threat. To do this, the Soviets have been content to develop and deploy as soon as possible a system of limited capability to counter an existing threat, and more satisfactory solutions to supplement the initial capability are developed as soon as possible. The importance of the concept of mobility in Soviet air defenses has also been evident. The SAMs began with the permanent fixed sites of the SA-1, then progressed to the road-transportable SA-2 and SA-3 systems, and finally to the cross-country mobile SA-4 and SA-6 systems.

In the past, Soviet SAM system engineers have shown a tendency to employ similar fundamental concepts in the various systems. For example, the SA-1, SA-2, SA-3 and SA-N-1 are similar in that they are command guided and employ pulse-type fire-control radars which use a track-while-scan technique. More recently, however, different concepts have been employed. For example, the SA-5 system uses homing-type guidance and a CW fire-control radar, the Square Pair.

The present Soviet SAM system inventory is quite diverse. It includes long-range, radar-guided weapons (for example, the SA-5 missile), as well as a man-launched, short-range weapon that uses infrared homing (the SA-7). Also, SAMs capable of attacking high performance aircraft flying at both very high and very low altitudes are available. For example, the SA-2 and SA-5 systems probably can engage targets flying at altitudes of 80,000 to 90,000 feet. The SA-3, SA-6 and probably the principal naval SAMs can engage targets at 300 feet, possibly down to 150 feet, under favorable conditions.

To improve a system's capabilities and to enhance its usable life, the Soviets have undertaken extensive modification programs. The SA-2 system has been continually improved through field modification and follow-on systems. Development of the Fan Song E engagement radar and its associated Guideline missiles has provided the SA-2 system with an improved high- and low-altitude, high-speed intercept capability, and an increased ECCM capability. The SA-2 system is limited, however, against high-speed (Mach 3), very high altitude targets. These limitations may have been overcome with the deployment of the SA-5 system. The low-altitude limitations of the SA-2 system are believed to have decreased with the development of the SA-2F (Fan Song F, and Guideline Mod 5 combination). This modification also provides an increased ECCM capability. The SA-3 system, designed for low-altitude intercepts, has also undergone modifications to improve its capability.

Soviet requirements for a mobile field force SAM system resulted in the development of the SA-4 and SA-6 systems. While the SA-4 provides the increased mobility desired, its low-altitude capability is considered poor. The SA-6 is believed to be the low-altitude complement to the SA-4. These systems are not well known, and uncertainty exists as to their guidance, maximum range, and altitude. The SA-4 system has been noted in exercises where simulated target destructions have been reported at altitudes between approximately 1,300 and 41,000 feet. Target distances reported at times of destruction have varied between about 6 nm and 43 nm. These figures represent extremes; the more prevalent altitude and range figures are 3,500 to 35,000 feet and 13 to 25 nm, respectively.

Deployment of the long-range SA-5 system began in 1963. [redacted]

Soviet designers of future naval SAM missile systems could consider two new systems having increased range. The first would be a medium-range replacement for the SA-N-1 system, and the second could be a longer range system. It is believed that the Soviets could build either or both of these types. An improved version of the SA-N-3 system possibly would meet an SA-N-1 replacement requirement. The longer range SAM system would likely be designed to operate at ranges of 50 to 100 nm and probably would use homing guidance for the terminal portion of the missile flight. It would appear, however, that for the present and immediate future, providing adequate point defense is a more achievable goal than providing area defense for Soviet ship formations.

While the total Soviet SAM force represents a formidable deterrent to the penetration of Soviet air space in the vicinity of targets of strategic importance, it has several major deficiencies. These include long reaction times, vulnerability to electronic countermeasures (ECM) and an inability to cope effectively with aircraft flying at very low altitudes. The reaction time problem is expected to be alleviated by the introduction of additional automatic equipment to SAM batteries and more expensive use of improved command-coordination-control data transmission systems [redacted]

The vulnerability of Soviet SAM systems to electronic countermeasures is being reduced to some degree by the employment of straight forward techniques which include the use of frequency diverse radars, such as the SA-N-3/Head Lights, and the addition of optical and electro-optical trackers to the SAM system fire-control radars. More emphasis on sophisticated electronic counter-countermeasure techniques is expected to be reflected in the newer SAM systems and in those to be developed. [redacted] A better low-altitude capability probably could be provided with improved acquisition and fire-control radars and improved proximity fuses. These improvements will provide far more efficient operation in a clutter-environment. Some future Soviet low-altitude SAM systems may employ pulse doppler radar equipment which exhibits improved inherent low-altitude tracking performance.

Other future improvements might include the development of multipurpose radars that can perform all of the required SAM system radar functions, that is, target acquisition, target tracking, missile tracking and missile command, and require computer-controlled subsystems including some type of scan-agile antenna. In addition, we estimate that most short-range Soviet SAM radars will eventually include electro-optical trackers to complement the primary tracker. These improvements are predicated to a great extent upon the capability and willingness of the Soviets to devote a significant R&D effort to the development of fundamental radar components and subsystems, especially in relation to the automation of systems.

Antiship cruise missiles

The Soviets recognized the potential of antiship cruise missiles as early as 1947 as a means of countering Western naval strike forces. Soviet developmental programs have resulted in an impressive family of cruise missile systems. Operational systems include five air-to-surface cruise missiles and eleven surface-to-surface cruise missiles (or modifications) launched from major surface combatants, patrol craft, and submarines. The design and development of new cruise missile systems generally have proceeded concurrently with the development and deployment of a new type or class of launch platform or the modification of an earlier design.

The driving force behind Soviet antiship cruise missile development program may be attributed to the relative inferiority of their surface naval forces to those of the US. In particular, the growing strength of the US attack carrier (CVA) force after World War II was a serious threat to the USSR. As the CVA threat evolved in terms of increasing numbers as well as sophistication, the Soviet ASCM development program also proceeded in an evolutionary way. Changes in recent years have included increased standoff range, supersonic cruise velocity, electronic counter-countermeasure (ECCM) features in the guidance systems, and greater numbers of cruise missiles per launch platform. The significant advance in capability represented by the SS-N-7—the use of an underwater launch platform (C-class SSGN)—introduced the element of possible surprise. Soviet systems reflect sound design concepts and the use of proven technology. Their high explosives warheads have been demonstrated under actual operating conditions. [redacted]

Soviet ASCM research and development will continue to be directed toward correcting limitations and improving the effectiveness of systems against the CVA threat. Limitations inherent in present systems include: (i) targeting that requires a forward observer or trailer, or exposes the launch platform; (ii) cruise missile designs that limit the number of missiles carried by a launch platform; (iii) current standoff range that may leave the launch platform vulnerable to attack; (iv) nonautonomous cruise missile guidance systems; (v) large radar cross-sections; and (vi) ship and submarine launch platforms that are not compatible with the need for quick reaction.

TARGETING SYSTEM—Presently recognized limitations of the ASCM system may result in a reduction of its effectiveness in an engagement with a CVA task force. Targeting requirements for the SS-N-3, which constitutes a significant fraction of the total deployed cruise missile force, can be satisfied by surveillance aircraft, by a tattle-tale trailing ship or by use of a target-marking cruise missile. Surveillance aircraft play a vital role in providing to the launcher either a plan position indicator (PPI) presentation or the coordinate location of the CVA task force, but surveillance aircraft may serve to alert the targeted task force, allowing protective measures to be taken. Similarly, a tattle-tale trailing ship could be prevented from maintaining close proximity to the task force. Thus the necessary targeting information could be denied to a missile launch platform.

Targeting also could be done directly from the launch platform, but aircraft and surface ship launch platforms would expose themselves to the intended target and thus become vulnerable to CVA task force counteraction prior to cruise missile launching. A submerged submarine using sonar could detect a CVA task force but would have difficulty in identifying the elements within it to aid the cruise missile in target discrimination.

The greatest advance in targeting capability could come from the development of a global surveillance network. This network might rely on a set of orbiting satellites with real-time read out for providing targeting information to antiship cruise missile launch platforms. Among the problems to be solved are those of target resolution and timeliness of data interpretation. Such a system, if developed and deployed, would eliminate some of the deficiencies of the present targeting methods. Multiple sensors covering the optical, microwave, and IR spectrum could be employed for an all-weather, day or night capability. Major advances in technology would not be required for this development. Most of the required development has already been demonstrated in Soviet satellite programs.

MISSILE—Further research and development advances are possible in antiship cruise missile design which would minimize current limitations. The most serious of the latter may be the limited firepower of individual launch platforms, especially that of the airborne platforms. Because of the large size of current operational cruise missiles, the launch platform is constrained by weight or volume considerations to carry only a few cruise missiles. By emphasizing high subsonic aerodynamics and modern structural concepts the size and weight of the ASCM could be significantly reduced without impairing its effectiveness against CVAs. Consequently, the number of missiles carried by a launch platform could be significantly increased.

Designing for high supersonic cruise speeds does not appear necessary (or even desirable) [redacted] High speed supersonic flight exacts a weight penalty which is proportional to the square of Mach number for a given flight time. Such a penalty would discourage the development of small cruise missiles for high speed supersonic flight.

Small turbojet engine development would be required for compatibility with a reduced air-frame size and lower drag. Such a turbojet would produce a thrust of approximately 500 lbs, weigh about 50 lbs, and project a small frontal area. Current Soviet capability in aircraft turbojet design and development is good by US standards. There is no fundamental technical reason why the Soviets could not develop a small turbojet engine for a cruise missile.

An increase in the maximum standoff range would be beneficial, either to reduce the pre-launch vulnerability of the launch platform or to provide additional flexibility to the ASCM force. In keeping with a requirement for smaller antiship cruise missiles and, hence, increased firepower of the launch platform, normal standoff range could be increased as much as 25 percent by using high density hydrocarbon fuels [redacted] Still greater increases in range could be obtained by use of exotic fuels [redacted]

Although development of high density hydrocarbon fuel and its use by turbojet engines would be neither difficult nor risky to undertake, the development of exotic, higher energy fuels, such [redacted] and associated turbojet engines would be much riskier. Hence, the Soviets most likely would choose the less difficult and least risky fuel and engine development for their next generation of antiship cruise missiles.

As the ASCM is reduced in size and weight without a reduction in effectiveness, further benefits will accrue. One such benefit is a reduction in the radar cross-section of the cruise missile. A smaller radar cross-section reduces the range at which a defensive system search radar can separate signals from clutter to classify an attacking cruise missile. Reducing the detection range strains the defense by requiring extremely short reaction times to cope with the threat.

Further reduction in the frontal aspect of radar cross-section could be obtained through the use of radar absorbing material (RAM) on the engine inlet surfaces and other areas where sharp contours exist. Available evidence indicates the Soviets are already employing RAM in their interceptor aircraft to reduce spurious radiations in their radomes. Through their writings they display an understanding of the principles of engine inlet cross-section reduction using RAM. Also, by utilizing nonresonant structural design techniques, the cross-section of an ASCM at L and S bands could be significantly reduced.

To maintain the terminal accuracy required when an HE warhead is used, homing guidance will continue to be preferred. Homing sensor operation at higher radio frequencies, such as J band, will continue to be favored. [redacted] The use of radar seekers could negate the beneficial effects of cross-section reduction mentioned earlier. Consequently, other homing sensors operating in the optical and infrared spectrum also may be developed for future cruise missile designs. Although these homing sensors will not permit all-weather operation, the problem of increased radar detectability will not occur as when radar homing sensors are employed.

To complicate further the problems of the defense, a Soviet cruise missile attacking force implemented with a variety of homing sensors could be deployed. In addition to the types of sensors already mentioned, the inclusion of an anti-radiation missile (ARM) capability in an attacking force would further complicate the defense of a CVA task force. Such developments are considered to be extremely likely for the next generation of cruise missiles.

To cope with employment of potential electronic countermeasures (ECM) by the defense, cruise missile homing sensors could be designed to have frequency agility, to home on jamming, and to track the leading edge of a pulse. These capabilities offer some protection against ECM, but development in this area will be dictated strongly by the concept of action and reaction and, hence, will be a continuing process.

As a hedge against successful ECM application by the defense, the Soviets may develop non-homing guidance techniques. The combination of inertial guidance and a small nuclear warhead payload could insure a high probability of kill against a CVA task force. Many potential problem areas peculiar to homing cruise missile development such as susceptibility to ECM, increased radar detectability when radar terminal homing sensors are used, weather restrictions, high value target discrimination, and launch platform survivability simply disappear from serious consideration. Technology for the development of inertial guidance is already on hand. Nuclear warheads compatible with the requirements of the cruise missile are within the capability of Soviet development.

Evasive terminal maneuvers by the cruise missile could reduce the effectiveness of CVA defenses. The cruise missile could be designed to be responsive to random programmed commands and have the structural strength compatible with the imposed aerodynamic loads. This capability poses no special problems for Soviet development.

LAUNCH PLATFORMS—Certain developments which would be compatible with the next generation of cruise missile designs could be undertaken with the objective of increasing the firepower and responsiveness of individual launch platforms. For air-launched cruise missile platforms, possible modifications to current airplane platforms would permit an increase in the number of cruise missiles carried externally. New airplane designs could permit internal stowage as well as external stowage of cruise missiles. Airplanes have the very desirable capability for responding faster than any other platform to any part of the ocean where a targeted CVA may be located. Therefore, future development of airplane platforms may be emphasized.

For surface ship launch platforms, attainment of a rapid reload capability may be more effective than increasing the number of cruise missile launch tubes. With smaller and lighter weight cruise missiles possible, some difficult problems associated with the design of a rapid reloading missile launcher could be avoided. For submarine launch platforms providing an underwater launch capability, Soviet development programs could increase either the number of cruise missile launch tubes per submarine or the number of cruise missiles per launch tube. Another alternative would be to provide a capability to launch a cruise missile from the torpedo tubes of a submarine. The technology required for these developments is believed to be currently available to the Soviets, but direct evidence of such developments is lacking.

Air-to-air missiles

The Soviets have five basic operational AAM systems: the AA-1 beam rider; the AA-2, the AA-3, the AA-5, and the AA-6, which were all produced in infrared and semi-active radar guidance versions. The AA-1 and AA-2 are limited to rear hemisphere attacks, while the AA-3 can be used in either a rear hemisphere or direct head-on attack. The AA-5 and the AA-6 are believed to have a 360-degree attack capability. The AA-6 became operational on the Foxbat in 1970. Its maximum launch range for head-on attack is believed to be limited by the 25-nm semi-active guidance lock-on capability.

[redacted]

[redacted]

Analysis of the operational Soviet air-to-air missiles shows weapon performance tailored to the bomber threat and matched to the airborne radar capability of the carrier aircraft and Soviet GCI tactics. In general there exists a family of weapons capable of destroying targets in the medium- to high-altitude regimes from head-on or tail attack positions in all weather conditions. None of these missiles have the capabilities required for low-speed, low-altitude engagement in a ground clutter environment.

Soviet requirements for the near future indicate the development of a new short-range missile with decreased minimum launch range, high maneuverability and good low- to medium-altitude capability for use against low-altitude penetrators and maneuvering targets. Such a missile could probably be developed using current state-of-the-art technology for all major components and could appear by the mid-1970s.

If the Soviets develop the postulated advanced long-range all weather interceptor (ALRAWI) for the 1980 time period, there would be a need for another missile development. A new, long-range missile is projected for this aircraft. The missile would be expected to incorporate improved packaging techniques and be of such size that it can be carried internally. A boost-sustain solid-propellant propulsion system and command midcourse guidance with terminal homing are expected to be used. The postulated track capability of the ALRAWI's radar limits the head-on attack launch range to a maximum of 45 nm.

Soviet AAM development has been consistent and each new model introduced into service has reflected advances in technology. Continued development in guidance, propulsion, and fusing is expected along with new materials having improved thermal characteristics and new packaging techniques which minimize component weight and volume and provide increased reliability under high-g loads and high temperatures. We would expect future developments to be the result of consistent and methodical R&D efforts.

Tactical air-to-surface missiles

The first Soviet tactical ASM, the AS-7, is operational. Prior to identification of the AS-7, the only fighter-launched guided missiles used in an air-to-ground role were the AA-1 and AA-2 air-to-air missiles. [redacted]

The AS-7 is delivered in a very shallow dive although attacks in dives up to 45 degrees are considered possible. The maximum launch range is about 6 nm with the normal operational launch ranges being 2 to 4 nm. With the beam-rider guidance system, the pilot is required to track the target in the dive until missile impact.

[redacted]

Tactical ASMs had been recognized as a Soviet requirement for many years. Detection of the AS-7 [redacted] however, provided the first evidence of the development of such a missile. In addition to the AS-7, there is evidence of a new tactical ASM under development. Additional weapons will be developed and will probably use laser, passive electro-optical, and infrared guidance systems.

MILITARY SPACE

The USSR continues to emphasize military uses of space. During 1970-71 sixty percent of all Soviet space launches had military objectives, mainly reconnaissance, and another 25 percent were for combined military and civil purposes (communications, navigation, and meteorology). The Soviet space effort contains active R&D programs intended to meet military requirements. The Soviets appear to be developing an orbiting interceptor for the purpose of engaging satellites and have the potential to develop a multiple orbit bombardment system (MOBS). The Soviets may research and develop the MOBS concept over the next few years. Improvements over current space systems, for example, a reliable, secure command link and guidance package, would be required, but the technology is believed to be available in the USSR. [redacted] The limited military utility of MOBS makes it unlikely, however, that it would be deployed in space in defiance of existing international agreements.

The SAL agreement probably has generated a Soviet requirement to upgrade R&D for military space programs. For such reasons as well as for crisis management and surveillance of China, the Soviets probably have a requirement to upgrade their satellite reconnaissance systems. Because of the lead times required to develop and perfect these complex spacecraft, the USSR may already have begun related R&D.

Boosters and propulsion

There is an active propulsion system R&D program aimed at augmenting Soviet proven space boosters. With the SL-12, a maximum of 50,000 pounds can be placed in low-earth orbit and about 7,000 pounds, in geostationary orbit. The J-vehicle (TT-05), the only other launch vehicle developed solely for the space program, will be capable of placing about 275,000 pounds in low-earth orbit if development is successful. A vehicle of this size and capability would enable the Soviets to carry out a wide variety of manned or unmanned missions which require very large payloads. The direction of follow-on work for the next several years would appear to be additions of new or modified stages to the proven boosters to provide cost effective delivery of heavier payloads into varied orbits. To develop reusable launch systems, the Soviets would be required to make advances in the technologies associated with high temperature structures, lightweight heat protection, and hypersonic aerodynamics.

Both the SL-12 and the TT-05 have suffered from reliability problems during their early flight test programs. The SL-12 has improved to the point where it is now fairly reliable. In the early phase of the flight test program, the vehicle evidenced failures in all stages. The high failure rate is believed to have been caused by inadequate checkout procedures and poor quality control. The problems encountered probably were compounded by the Soviet use of relatively low data rate telemetry systems. The TT-05 has failed in its three tests. The first two failures occurred during first stage operation. It is believed that the troubles are analogous to those that affected the SL-12. The third test failed when the second stage failed to ignite.

Although not yet flight tested, hydrogen-fueled engines may have reached th acceptance testing stage. In the future, hydrogen could be used as a fuel for the upper stages of the SL-12 and the TT-05. It is also possible that fluorine or fluoride oxidizers will appear in upper-stage applications in the 1980s, although the Soviets admit to severe problems with fluorine. The Soviets may use solid propellant technology for space booster applications. They are currently testing large segmented solid motors that may ultimately be used as strapons similar to those on the US Titan III-C. In the long term the Soviets could develop reusable launch systems, should the launch rate demand them. The problems posed in this technology are very difficult and may prove a barrier to early realization of such a system.

Nuclear power and propulsion

Nuclear energy sources suitable for aerospace applications include both radioisotopic generators and compact nuclear reactors. Various energy conversion processes may be employed to convert the heat from the above sources to auxiliary electric power: thermoelectrics, thermionics, magnetohydrodynamics (MHD), and various heat engine cycles employing turbogenerators.

To date the Soviets have relied almost exclusively on solar cells and batteries for electric power for their space missions. Nuclear radioisotopic power sources have been used rather sparingly in space. Most spectacular to date has been the use of a one-kilowatt polonium-210 isotopic heat source for the Lunokhod-1 vehicle. Soviet work on plutonium-238 sources is increasing, and it is expected that this source will receive more extensive use in the next few years. The level of Soviet technology is about on a par with that of the US, and more extensive use could be made of radioisotopic power sources with either thermoelectric or thermionic conversion if they choose to do so.

The Soviets have not launched a nuclear reactor into space and probably will not do so until at least the late 1970s. They have operated two reactor prototypes which could lead to space power sources. The first reactor, the Romashka, was a thermoelectric type of reactor that was operated in 1964. No further development of this type of reactor seems to be taking place. The second was the Topaz thermionic reactor.

An aggressive thermionic reactor program with about 300 people involved appears to be centered at the Obninsk Physics-Energetics Institute, and a second program is being carried out at the Kurchatov Institute of Atomic Energy. For the past two years, the Obninsk Institute has been operating the Topaz thermionic reactor which generates 5-10 kilowatts of electrical power. [redacted] We believe that the Soviets could have a thermionic power source with a power rating between 10 kilowatts and 100 kilowatts available for space use in the last half of this decade.

The Soviets have an intensive closed-cycle MHD program which, if successful, would provide an extremely large (that is, megawatt) source of power for use in space. Studies which were initiated in 1969 are directed at coupling a nuclear reactor to a MHD generator. A major technical problem which must be overcome is the achievement of a sufficiently high temperature in the working fluid to attain the necessary ionization and, at the same time, to match the operating pressure level of the reactor with that of the generator. The use of a nuclear reactor MHD power source in space by the Soviets is not expected until the early 1980s.

There is no convincing evidence that the Soviets plan to use heat cycles employing turbogenerators in space. In fact, several Sovicts have said definitely that they will not. The requisite technologies, however, have been under continuous development since the early 1960s.

Soviet work on electric propulsion engines has been in evidence since the late 1950s. Electric thrusters have been tested on selected space vehicles since 1964, were most recently used to maintain a Meteor satellite in the prescribed orbit (1971), and will find increased application on both orbital and deep space probes as new electric power sources become available during the late 1970s.

The USSR may have an active research and development program leading toward a nuclear space rocket propulsion capability, but we have no firm evidence of the existence of such a program. [redacted]

There is a concerted Soviet theoretical effort in progress which seems to be directed at the development of gas core reactors. There is no evidence that this effort has reached the hardware stage. We do not expect a nuclear gas core rocket engine to be developed before the mid-1980s.

Subsystem support and technology

Advances in reconnaissance, surveillance, and meteorological satellites and certain aspects of space defense are predicated on advanced sensor development. It is believed that Soviet technology will support straightforward development in these areas. We are not aware of any limitations of Soivet military research laboratories that would hamper such development. Multi-spectral observations of the earth are continuing in support of civilian research. The relationship of this work to military applications is unknown. The missile-launch observation experiments conducted with Soyuz 6 and the Salyut station were probably using a sensor in the infrared region.

Soviet space power technology is adequate to support military missions over the next 10 years. The requirements for military space system guidance and attitude control over the next 10 years, including accuracy of weapon delivery to a point in space, accuracy of sensor pointing, and stability of sensor platforms, could also be met with current Soviet technology. For low-cost, reliable earth orientation, the Soviets have begun to use the gravity gradient principle. This approach will find increasing use in long-life systems.

Antisatellite

The Soviet antisatellite capability includes a network of detection and tracking radars and an orbiting interceptor. The radars are operational and give the Soviets a capability for detecting and tracking all satellites up to about 900 nm. With assistance from early warning Hen House radars, this network could detect satellites up to a 2,000 nm altitude. Using their optical detection and tracking network the Soviets probably can detect high-altitude satellites over the Eastern Hemisphere (such as the geostationary corridor) within a few days following injection. To avoid optical detection, satellites would have to be dimmer than the 14th-15th magnitude.

The Soviets could use any of several ICBM, IRBM, or ABM boosters to achieve a nuclear kill of satellites. They could also develop terminal homing for an ABM interceptor and achieve a non-nuclear kill against low-orbit satellites. The technogloy is available within the USSR, but there is no evidence that such a system is being developed.

The Soviets have developed a satellite interceptor that is launched by the SL-11 booster from the Tyuratam Missile Test Center. [redacted] It is believed that a non-nuclear weapon will be employed on the operational system. At this time the Soviet system can probably engage all US satellites that pass over the USSR at an altitude less than 2,000 nm. Only a single kill attempt can be made by one interceptor in the present mode of attack. By 1975, the Soviets could develop an effective non-nuclear intercept system against geostationary targets with existing technology. During the late 1970s the Soviets could enhance a high-orbit interceptor with inspection sensors and a multiple target kill capability. This possibility could be met with existing technology.

Applied satellites

RECONNAISSANCE—The Soviets currently have two photographic reconnaissance systems—a low-resolution (10-20 ft) system for general search and a high-resolution (3-5 ft) system for technical intelligence. Significant performance improvements for the present systems are unlikely due to the spacecraft size and configuration. Soviet technology, however, can provide improvements in ground resolution through the use of better films, incorporation of an improved attitude control system, incorporation of yaw programming, or the use of lower altitude orbits.

We believe the Soviets have long devoted substantial resources to the research and development of technologies pertinent to photographic reconnaissance. Using current technology, the Soviets could within the next two to five years introduce a system which is capable of resolutions on the order of 1 foot; contains multiple film recovery capsules; has a longer duration mission life; and has significantly improved targeting flexibility. By the late 1970s, the Soviets could have the technology to develop a system to relay collected data to ground stations on a near-real-time basis.

[redacted]

[redacted]

Sensors other than photographic and Elint have the potential for providing useful reconnaissance information from space. The Soviets are believed to be conducting research on such sensors as infrared (IR), ultraviolet (UV), and radar. The longer wavelengths of IR and radar sensors make them amenable to the low-resolution requirements of search reconnaissance, night reconnaissance, and camouflage detection and discrimination. The Soviets are actively investigating the development and application of these types of sensors, particularly in their earth resources programs, and probably have flown individual experimental sensors. We believe that the Soviets are probably investigating the usefulness of and techniques for integrating the results of individual sensors. The Soviet technology is probably adequate to support the launch of such an experimental satellite at any time.

SURVEILLANCE—The Soviets probably have a requirement to develop space surveillance capabilities. They have conducted activities which are indicative of an intent to develop and test the technologies applicable to this mission area; for example, early warning (missile launch detection experiments on the Soyuz and Salyut manned space missions). The Cosmos "scientific" satellites have been used to obtain the space environmental background data needed for system development. It is likely that sensor tests have been carried out in this program. We believe the Soviets could at any time launch systems capable of detecting nuclear detonations in space or in the upper atmosphere. Within two to five years the Soviets could orbit [redacted] sensor systems capable of detecting missile launches from high altitudes. [redacted] The Soviets probably cannot develop operational sensor systems using this technology during the 1970s. The reconnaissance sensors technology that the Soviets could develop may also be used for military surveillance by the late 1970s.

HEAVY MANEUVERABLES—The Soviets have a heavy maneuverable satellite development program which began in 1965. The program has included Cosmos 198, 209, 367, 402, 469, 516 and two which failed to attain orbit. The mission for the heavy maneuverable satellites appears to be at least in part for coastline and ocean reconnaissance/surveillance purposes.

Since Cosmos 198, when the SL-11 was first used as the booster for this program, all heavy maneuverables have followed the same general profile. Each has been launched from Tyuratam into a ballistic trajectory with an apogee of about 150 nm. At apogee each satellite has used an on-board propulsion system to inject itself into a nominal 150 nm circular orbit. The satellites have remained in this orbit from one to 32 days at which time each satellite separated into at least three pieces with one of the pieces transferring to a 500 nm circular orbit. Once this major orbit maneuver was completed, each satellite is assessed to have begun tumbling. [redacted]

[redacted]

[redacted]

NAVIGATION—The USSR has developed a navigation satellite system using the doppler ranging technique. Analysis indicates a potential capability for a position fix accuracy of 0.05 nm for slow moving targets with a single satellite pass. For aircraft, the horizontal position uncertainty would be an order of magnitude larger. The Soviets will probably continue to use doppler navigation satellites for the next several years. During this same time period, they may also investigate the use of other concepts, such as direct ranging, for improved navigational capability. Eventual deployment of spacecraft at high altitude may occur and provide position accuracy to a few hundred feet in three dimensions and velocity to a few feet/second. Slower moving users could obtain position accuracies on the order of a hundred feet.

METEOROLOGY—The Soviets currently use meteorological satellites at nominal altitudes of 350-500 nm. One sensor is a TV camera which scans across a 600 nm swath with a resolution of about 0.5 nm. Various UV-optical IR sensors view the earth in the 0.3-30 micrometer band with resolution from 8 to 54 nm. These sensors (or slight modifications thereof) will have utility for the next few years. We believe that the Soviets will attempt to improve sensor resolution and sensitivity. They have stated, for example, that they intend to use an IR spectrometer to improve wavelength resolution. Automatic picture transmission, with reception possible on inexpensive equipment, became available in 1972. Satellites probably will be placed in higher orbits to allow weather update every several hours. By the late 1970s, systems might be introduced into the geostationary and/or Molniya orbits for weather information with a resolution of a mile or less in near real time. Lower altitude satellites with improved sensors may be used for detailed studies both of conditions of the atmosphere at various altitude layers and of surface conditions.

Tracking

During the past few years the USSR has developed two extensive tracking networks. The first consists of installations deployed within the USSR which track and control cooperative spacecraft. These tracking sites are under the control of the Soviet Rocket Forces (SRF). The other network, consisting primarily of the Hen House and Dog House radars, is used in a defensive role. One function of these radars is the detecting and tracking of foreign space objects. The network is believed to be under the control of the Air Defense Force.

COOPERATIVE SATELLITES—The SRF space tracking network has been greatly expanded in recent years. It consists of range and angle tracking systems, a doppler tracking system, and an interferometer tracking system. The higher orbit satellites, the lunar and the planetary probes, use a range and range rate system. These tracking systems are adequate for both current and near-term programs. We do not believe that technical capability will limit Soviet development of future tracking systems.

A major constraint of the Soviet space tracking network has been its geographic limitations. The Soviets have chosen not to expand their land-based active tracking network beyond the limits of the USSR. In order to overcome this deficiency to some extent, the Soviets now have three large tracking and monitoring ships (*Gagarin*, *Korolev* and *Komarov*). These ships are capable of tracking spacecraft to lunar distances. Their support of military spacecraft could be expanded to the Western Hemisphere.

NON-COOPERATIVE SATELLITES—The Soviet network for detecting, tracking, and predicting the orbits of non-cooperative satellites consists of radars built for space operations and ballistic missile and space defense. The major components of this network are the Hen House, Dog House and Chekov radars; there are a total of 31 faces. Seventeen of these radars are in operation, and three more have begun transmitting but are not operational. In addition, eight radars are externally complete but not transmitting, and three more are in various stages of construction. Those that are externally complete could begin transmitting at any time. The portion of the network now in operation provides almost complete tracking coverage for low-altitude satellites which pass over the USSR.

The radars appear more than capable of providing accurate orbit prediction after a number of orbits. For example, a typical single pass of a low-altitude satellite through a Hen House sector provides data which allow a determination of the satellite's position with an error no greater than about 1 nm. These same data can be used to predict the satellite's position—at the end of the next revolution—with an error no greater than about 30 nm. A single-pass tracking by the Dog House radar allows the prediction of the position of the satellite to be made—for one revolution ahead—with an error of no greater than about 2 to 5 nm. Comparable accuracy also can be achieved by Hen House radars, but tracking data from two orbital passes are required, with prediction made about position at the end of the third revolution. In a similar way, if a satellite in a typical inclination were tracked by the network on six consecutive revolutions, the prediction accuracy for the seventh revolution would be about 0.2 nm.

Reliability

During the past few years a continuing high reliability in some areas of Soviet military-related space hardware has been demonstrated. For example, the Soviet reconnaissance program has maintained a high degree of reliability both in the spacecraft and the SL-4 launch vehicle. Two areas of technology appear to account for most of the Soviet space missions that have failed: attitude control systems and zero gravity propulsion starts. Soviet failures indicate that inadequate check-out procedures may be the primary Soviet reliability problem. It is anticipated that over the next several years there will be a continuing increase in reliability in Soviet military-related spacecraft. Large Soviet launch vehicles have suffered from reliability problems during the first few years of their use. The SL-12 which was plagued by problems in all stages has now become somewhat more reliable. The new J-vehicle, as noted above, has failed on all launch attempts. Soviet efforts to improve spacecraft reliability are believed to be directed toward increased environmental ground testing, improved checkout procedures, and the use of improved technology.

Bioastronautics

Soviet space medicine R&D is mainly applications oriented toward the care and maintenance problems of long-term space station crews. Primary emphasis is on adaptation to and recovery from the weightless state, potential chronic irradiation effects, development and testing of advanced biomedical monitoring and life support technology, crew reliability and performance evaluation methodology, and habitability factors.

The superoxide chemical gas exchange environmental control system (ECS) has been used successfully with continuous refinement on all Soviet manned spaceflights. The system proved to be adequate for the Salyut station but not without some recurrent cabin atmosphere problems with CO_2 and relative humidity. The Soviets have developed a method which utilizes modular packaging for replacement of superoxide chemical supplies by means of suitably sized canisters which can be ferried by the Soyuz, transferred to a Salyut station, and stored aboard in quantity. Soviet ground-test data have demonstrated that three men could be maintained in a closed cabin for a six-month period, using this superoxide system for the most part and utilizing urine and atmospheric condensation water recovery systems to provide nominal water requirements. The superoxide ECS/atmospheric condensation system approach is the optimum Soviet life support system for an SL-12 payload station such as the 40,000- to 45,000-pound Salyut class and will probably be used as the primary life support system for space stations launched within the next three to five years.

Soviet development of physical chemical partially regenerative life support hardware is largely derived from similar US technology. This equipment has been used for a three-man, six-month, continuous ground trial of a partially regenerative combination of catalytic hydrogenation of CO_2 and water electrolysis. The fixed weight and power penalties of the Soviet test system make it of marginal use for the Salyut station. It probably is most applicable to long-duration multi-manned stations weighing 100,000 pounds or more and having very high power supply capabilities on board. This system may not be operational for at least 7 to 10 years.

The USSR has life support technology and crew support and monitoring capabilities which have allowed the Soviets to plan manned earth orbital missions of up to six months or longer. But a number of man-related problems argue for a conservative Soviet approach beyond increments of one month at a time. Post-flight readaptation problems experienced by Soviet cosmonauts following the 18-day, Soyuz-9 flight require resolution. The fire hazard, crew safety, and cabin integrity problems experienced during the tragic Soyuz 11/Salyut station mission are additional major concerns. An unprecedented Soviet year-long confinement and life support ground trial identified significant medical, psychological, and nutritional problems which must be resolved before the USSR can keep the same crew in orbit beyond one month. Nevertheless, the USSR apparently intends to orbit two or more manned stations by 1975 based on the Salyut technology and even larger stations by 1980.

After the first Apollo moon landing, the Soviets put all manned space priorities on the space station program. Manned lunar landing missions have been delayed for at least several years. From the biomedical and life support standpoint, there are no constraints on a Soviet attempt to perform a manned lunar landing. Soviet ground-based bioastronautic studies and biotechnological development are compatible with support of both earth orbital stations and manned lunar landing missions. Furthermore, the Soviets appear to have developed an operational liquid-cooling system for space suits and a self-contained back-pack life support system which would be useful for brief lunar excursions.

AERONAUTICS

Aerodynamics

The USSR is vigorously pursuing a broad, continuous program in practically all areas of aerodynamic R&D. Research is highly centralized, with the Central Aerohydrodynamics Institute imeni Zhukovskiy as the directing agency for virtually all important work. The programs of that institute are supported by the Moscow Physico-Technical Institute in its work on the chemical and physical aspects of problems, the Computer Center of the Academy of Sciences in the development of analytical and numerical solutions, and the Moscow State University in work on almost all significant aerodynamic problems.

The Soviets have increasingly emphasized use of their experimental capabilities to support an already existing high-quality analytical and numerical capability. New subsonic wind tunnels with a low turbulence level, either recently completed or being planned, should greatly enhance the Soviet R&D capability in subsonic aerodynamics. Soviet researchers have demonstrated the technical capability to produce a subsonic laminar flow control aircraft using suction; its development is dependent upon mission requirements and operational considerations. Further development of mathematical models for direct lift and vectored thrust V/STOL aerodynamics and correlation with flight-test data should provide them with an outstanding capability for V/STOL design. Soviet capability for handling transonic flow problems, including design of transonic airfoils, is equal to that of the US. Current Soviet R&D in rotary-wing aerodynamics probably is directed toward the development of a rigid rotor system and synchronous advancing blade rotors, further flight tests and refinement of Homer (MI-12) prototypes in preparation for series production, and continuation of Mil's heavy-lift developmental trend.

Soviet work on hypersonic nonaxisymmetric lifting bodies involves those with high lift/drag such as the waveriders and the more blunt bodies with a medium lift/drag such as the blunted half-cones. Soviet development of a slender, high-lift/drag body would be applicable to cruise, launch, or reentry configurations. A hypersonic aircraft probably will not reach the final design stage before 1980. Use of a slender, high-lift/drag body as a launch or reentry vehicle probably will not occur before the 1975-80 period—the timing depending largely upon the mission of such vehicles. With a concentrated effort, the Soviets could possibly have a final design of a blunt, medium-lift/drag body as a reentry vehicle by the 1973-75 period.

For the past 10 years the Soviets have investigated the star bodies. Their analytical and experimental studies have shown that the total drag of the star bodies at hypersonic velocities is as low as one-third to one-half of that for an equivalent cone. This program implies the availability of such bodies in the near future for use on low-drag vehicles. The Soviets have sufficient aerodynamic technology for design of a supersonic cruise vehicle of about Mach 3 to 5 if the need such a vehicle arises. Actual development of aircraft with speeds in excess of Mach 3 is not expected before 1980.

Propulsion

The Soviets have continually emphasized the development of airbreathing propulsion systems. Throughout the 1960s, their facility for the study of mass air flow capacity at the Central Scientific Research Institute for Aviation Motor Construction was recognized as the world's leading test facility of its type. Soviet flight simulation capabilities for full-scale engine testing were further improved in 1971 through expansion of this facility. A most significant technical innovation in the design and construction of the expanded test facility provided for high bypass turbofan engine testing at sea-level and to structural limits. The opportunity to obtain structural integrity data during development is a major stride in reducing the risk and time for airbreathing engine development. The flight simulation facilities at the Kuznetsov, Tumanskiy, and Lotarev propulsion design bureaus provide for the testing of components in a simulated flight environment and the logging of empirical improvements tailored to individual designs. Such capabilities presage advances in system reliability and maintenance. As in the West, the individual Soviet gas turbine engine design bureaus show considerable variance in design techniques and in general level of competence. [redacted] the Soviet designers to be a highly individualistic breed. They are obviously permitted much latitude in their design selections. It is equally evident, however, that the Soviet designer is guided by a strict set of general design objectives and design constraints relating to such factors as ease of manufacture, mechanical simplicity, selection of materials, and operational requirements.

Based on intensive research of basic aerothermodynamics, the Soviets developed an inlet concept that provides excellent stability. In general, the propulsion cross sections and volumes were held to minimum levels, particularly for fighter-interceptor propulsion systems. Integration of the nozzle with the airframe relied mainly on matching the airframe base area and the nozzle maximum area. Ejectors have been used to improve the nozzle-to-airframe match and the nozzle thrust coefficients. Soviet designers indicate that for specific applications at speeds above Mach 8, the entire vehicle forebody will function as an inlet and the vehicle afterbody will function as a nozzle. Research studies are probably in progress to integrate propulsion with the star-shaped vehicle configurations for Mach 12-25 flights.

Fuel system technology has improved rapidly in recent years. Improved insulation methods and regenerative cooling techniques have been developed. Cruise propulsion at speeds above Mach 4 probably will use fuel-cooled engine components and at higher speeds probably will use fuel cooling of the airframe.

To accommodate the high fuel temperatures and more difficult fuel pumping conditions, the Soviets probably used after about 1962 special positive expulsion tanks with screen fuel-orientation valves. In the US, these special devices are usually restricted to spacecraft. Centrifugal pumps have also been used in Soviet air-breathing propulsion systems with remote electrical drives, local hydraulic (fuel) drives, and engine-mounted pneumatic (compressor tapoff) pump drives. Higher feed system pressures and improved fuel will provide the Soviets a capability to use hydrocarbon fuels for cruise at about Mach 4.5 and dash to about Mach 6. Hydrogen and methane will be used for the higher speed ranges beginning around Mach 4 and are the most probable fuels for cruise flight speeds above Mach 5.

Soviet efforts to develop turboprop engines were reduced when low-bypass-ratio turbofans came into use in 1959. The development of small turboprop and turboshaft engines is expected to continue for future small transport and helicopter applications. Turbofans with "bypass-ratios" on the order of 5, however, are expected to reach flight qualification status by 1974 for use on large subsonic cruiser transport aircraft.

Compressor design prowess has been the vanguard of the Soviet aircraft turbine engine industry. Although the various Soviet engine design bureaus display varying levels of competence, the general level of demonstrated compressor and fan technology has been excellent. During the early 1950s the Soviets elected to pursue vigorously transonic compressor aerodynamics and aggressively applied this technology to developmental engines. Soviet compressors and fans usually are characterized by their low frontal area, compactness, and light weight which results from high stage work and flow capacity. This is particularly true in the case of the S. K. Tumanskiy turbojets. [redacted] Although the technology is representative of the maximum Soviet capability of over a decade ago (R-37F was production-qualified in 1957/58), it is highly significant because the high pressure ratio per stage combined with a very high air flow capacity (for its diameter and good efficiency) makes the R-37F compressor technologically advanced by even 1969 Western standards.

Appropriate improvements of injectors, aerodynamic combustion stabilizers and fuels have been accomplished by the Soviets. Combustion temperatures to 3,200°F probably will be available by 1975 and possibly 3,500°F may be reached by 1980.

The Soviets historically have operated their turbines at relatively modest temperature levels. Since higher engine cycle temperatures permit greater thrust per pound of airflow (specific thrust), lower engine weight, and lower specific fuel consumption during supersonic flight, the Soviets obviously have not purposely elected to restrict their turbine inlet temperature (TIT). Their modest temperature levels are a direct measure of their capability to manufacture turbine components. Soviet and Western nickel-base turbine materials have, in general, been of similar alloy composition. However, the quality of metallurgical processing in the turbine components of the USSR and the West differs substantially. [redacted] Despite use of vacuum melting techniques, the turbine materials continue to be "dirty" with inclusions and high porosity. These parts do not meet Western standards of quality and certainly must have poor thermal fatigue properties. This is considered a principal reason for the short life exhibited by Soviet turbine engines.

This shortcoming is recognized and development is continuing to improve this deficiency. Various cooling schemes for turbine components have been evaluated which would permit application of airfoils at higher temperatures and with smaller thermal gradients than is possible from actual hardware available for analysis to date. Processing is also improving, as indicated by the directionally solidified turbine buckets exhibited at the 1971 Paris Air Show. Research work has been published which indicates a capability to produce single crystal blades, at least on a laboratory scale. The most recent effort has been directed at a metallic composite based on the nickel-tungsten (Ni-W) system for use as a turbine vane material. The tungsten filament is embedded in a ZhS6-K matrix which produces a composite having marked improvement in high temperature strength (up to 1,900°F) over conventionally cast alloys. This effort is still experimental, however.

The current maximum Soviet TIT for production engines is 2,060-2,080°F, as demonstrated by the D-30KU and D-30KP turbofans. This is 300°F lower than current US production engines, such as the JT9D turbofan. The NK-144 SST powerplant is believed to have a cruise TIT of 2,060°F. It is estimated that the R-266 Foxbat turbojet has a maximum TIT of 2,000°F.

Soviet engine designers have in the past been successful in developing engines of low weight and volume despite moderate TIT levels. Excellence in aerodynamic and mechanical design has largely offset the turbine temperature deficiencies. However, overcoming deficiencies will become increasingly more difficult in the future. Although the Soviet turbine temperature picture does not appear bright, it must be cautioned that in the past Soviet reaction to a recognized deficiency has led to very vigorous and successful corrective action.

Afterburners and ram burners are thoroughly integrated with the turbine diffuser cone and airframe. Oxygen augmentation of altitude ignition is customary. The Soviets preferred integral injector-flameholders through 1969, but unique low-drag flameholders have been researched for specialized applications. Initially, Soviet nozzles were covergent-interleaved units that were actuated by pressure differentials. By 1962, positive hydraulically actuated nozzles were in use in combination with ejectors. Since 1962, convergent-divergent regulated nozzles have been available. Blow-in-door ejectors may be used after 1972 although mechanical convergent-divergent nozzles might be used if improvements in existing units are required.

Short engine life has historically been a major shortcoming of the Soviet aircraft gas turbine industry. Although the Soviets have made excellent progress since 1962 in increasing the time between overhaul (TBO) of their commercial engines, a similar occurrence has not been observed with the military powerplants. In the past the Soviets have been satisfied with TBOs of less than 300 hours for their fighter engines. Although indeed a short time span, the TBOs are perhaps not as bad as they appear since there are indications that the Soviet standards of reliability upon which TBO is established are considerably more stringent than those used in the West. As a result, the number of premature overhauls for Soviet engines is believed to be exceptionally small. The Soviet concept of very limited field maintenance is reflected in their engine designs. Maintenance in the field is generally limited to the replacement of externally mounted items only, such as controls, accessories and oil lines. Repair or replacement of internal engine components are accomplished at the engine production facilities.

Soviet work on ramjet engines has covered a span of over 40 years. The first theoretical work was reported by B. S. Stechkin in 1929 and the first military-oriented experimental work was conducted in late 1933. Continued effort resulted in the flight test of an extreme-range cruise missile in the early 1960s. Design conditions were an altitude of 80,000 feet and a speed of about Mach 3. This effort was terminated due to the superior reliability of ballistic rockets. The technology from these ramjet programs resulted in the development of the Ganef (SA-4), which was displayed in a 1964 parade, and the Gainful (SA-6), which was displayed in a 1967 parade. Both missiles have a flight speed of about Mach 2.5 to 3.

Since 1960 the Soviets have developed the technology needed for aft-mounted inlets, including external and mixed compression types ranging from axisymmetric to two-dimensional. The aft-mounted inlets improve the propulsion airframe integration by reducing the front cross-section and by smoothing the axial profile. Advances in materials, temperature capability, cooling techniques, and coatings have made it possible to reduce further the engine diameters. Research and development are also continuing on injectors, combustors, and afterburners, and associated disciplines such as cooling techniques. The technology is available for upstream injectors for engines to the Mach 4 range and downward-facing injectors for ramjet engines operating in the supersonic combustions mode (scramjet). Analytical combustion models have been developed for homogeneous mixtures in the Mach 5-6 regimes, and detonated-controlled combustion research is under way for hypersonic flight in the Mach 9-20 range. [redacted] much of the Soviet ramjet research for future developments will be used in combined cycle (rocket-ramjet) engines. In this concept the rocket acts as an ejector when the vehicle is at low-flight velocities. As the flight velocity increases, the rocket engine acts as a compressor. The exhaust products of the rocket are fuel rich and burned with air in the main combustor. The Soviets have identified several modes for the rocket-ramjet cycle including the first stage of a reusable launch vehicle, hypersonic cruising/booster aircraft, and supersonic cruise missiles. The two primary modes of the rocket-ramjet engine for supersonic missiles are terminal maneuvering for AAMs and low-level run-in for ASMs.

Structural mechanics

The Soviet Union, one of the world leaders in structural mechanics, has since the mid-1950s continued a broad and ever-increasing effort in R&D applicable to aerospace structures. Recent advances have been in the development of new fundamental methods of analysis for stress concentration and shell stability, and in theories for predicting the load-carrying capability of composite materials and structural components. Although few new related results have emerged, it is likely that in the next few years new developments of engineering value will result from these theories.

There is strong Soviet emphasis on the development of strength criteria for polymerics, fiber glass-reinforced plastic, and filament-wound composite structures. Recent Soviet contributions to the fundamentals of mathematical theory of thin shells have been heavily pointed in the direction of expanding earlier theories to encompass situations which include both plain and reinforced polymeric materials. Effects of anisotropy, inhomogeneity, creep, and bimodularity have been studied in detail. Advances in thermoelasticity have been of value in the analysis of filament-reinforced plastics and layered plates where the layers are of different materials. Elasto-plastic analysis of structures has been directed toward the development of design criteria for filament-wound composite structures, and strength criteria for predicting the behavior of plates made of composite materials have been presented in simplified form attractive to designers. The Soviets have placed considerable emphasis on digital computer solutions of thin shells, turbine components, and dynamic problems in general. The recently introduced analysis methods for shells of arbitrary curvature with many stress concentration holes are well suited to digital computer solutions. The computer solution techniques are not new, however, to Western designers.

Since 1967, the Soviets have exhibited increased interest in the design of multilayered sandwich shells indicative of the probable use of such shells in aircraft and missiles. The Soviets are placing more emphasis on optimal design than previously, but their achievements are still considerably less than those in the West. Efforts in this area have considered plates and shells under aircraft and missile loading. Specific boundary value problems have been treated for minimum-weight cylindrical tanks subject to internal pressure, minimum weight of rib-stiffened plates, and minimum weight of a variable thickness plate bent to a cylindrical configuration. The Kazan Aviation Institute recently exhibited concern for minimum weight design of structures subject to random loadings comparable with some 1962 US design work.

Materials

The mechanical behavior of materials is receiving considerable attention in the USSR. There is currently a concerted effort on metal fatigue of alloys known to be used in the airframes and engines of their operational aircraft. Thermal fatigue research has been concerned primarily with material properties and processing effects aimed at improving the life of engine components. Refractory research has included strength and endurance testing to 3,000° and 2,500°C, respectively.

The Soviets have a strong capability in both weldable and nonweldable light metal alloys generally applicable to aircraft structures. A wide range of titanium compositions is available in the USSR which should satisfy the requirements for most applications requiring corrosion resistance, low-temperature ductility and toughness, and high-temperature strength. Of particular interest is the Soviet effort to develop alloys for increasingly higher temperature capability, undoubtedly for use in the compressor section of jet engines. In this area, the ST series of alloys appear to be favored. The Soviet effort reflects a chief concern with heat resistance, while the US effort is directed at a combined heat resistance-stability goal. Present capability is probably in the 540° to 600°C range. Soviet magnesium alloys have essentially the same capability as those used in the West and in many cases are direct copies. Research is continuing on the Mg-Li system and has recently included the effects of thermal mechanical treatment. Investigations are also under way on Mg-Y-Zn and Mg-Y-Mn systems, apparently to replace the high-temperature Mg-Th alloys. The beryllium effort in the USSR has been very small compared to that of the US. Although little has been published on this effort, the work has apparently continued, as evidenced by the beryllium items exhibited at the 1971 Paris Air Show. Work is also continuing on Be-Al alloys, but the results are similar to those seen in the original US counterpart, Lockalloy.

The most significant effort in high-strength low-alloy steels is the selection of materials for thin-wall (0.060-0.080 inch) missile casing. The available data indicate the Soviets are attempting to satisfy an immediate requirement for thin-walled casings at a strength level of 260,000-270,000 psi. The Soviets also have a significant effort in the research and development of another class of steels, the maraging steels; these are the materials of the future and may be in limited use now. Maraging steels are being evaluated with yield strengths ranging from 250,000-350,000 psi. There has been little significant Soviet research in stainless steels in recent years. The Soviets have a large number of austenitic, martensitic, and precipitation hardenable (PH) stainless steels for high-temperature (480°-760°C) and/or corrosion-resistant applications. Little effort other than processing improvements is expected since titanium- and nickel-base alloys have largely replaced stainless steels outside of the temperature range noted.

Concerning superalloys, the Soviets continue to concentrate on nickel-base alloys to the virtual exclusion of cobalt which is in short supply. The cast and wrought alloys available for propulsion systems generally have the same temperature capability as those used in the West. [redacted] This situation, however, is changing, as indicated by the Soviet display of directionally solidified buckets and vanes at the 1971 Paris Air Show. The blades apparently were of excellent quality and should go far in reducing or eliminating premature failure induced by thermal fatigue.

The Soviets are conducting research on thermal stress in an arbitrary shell with consideration to coupled thermo-elasticity involving extremely rapid applications of thermal fluxes to structures. Possible application of this research would be the response of a thin shell to a laser pulse. The extensive research being conducted in the area of thermal fatigue, stress concentration, and vibration damping of turbine engine blades and disks could be indicative of engine failure problems. Fatigue research of aluminum alloys used on current Soviet aircraft is being emphasized.

Soviet materials research through 1975 will continue to focus on the optimal design of lightweight composite structure for aerodynamically heated aircraft in the Mach 4 regime. Proven Soviet capability in theoretical and applied mechanics and current research on the mechanical behavior of materials at temperatures to 3,000°C portend the development of hypersonic cruise vehicle structures by 1985.

Studies devoted to niobium and molybdenum alloys outnumber by far those devoted to the other refractory metal alloys. Much of the effort on molybdenum and niobium appears to be in support of aerospace interests, while the tungsten and tantalum effort is in support of the electronics industry. A comparison of Soviet alloys with Western counterparts indicates that a similar capability exists at least with respect to high-temperature strength. However, strength improvements are of little value unless satisfactory coating systems are developed. The Soviets have developed coatings for niobium alloys that will provide oxidation protection for short periods (30 hours) up to 1,100°C. For molybdenum alloys, the trend is toward developing complex silicide coatings for temperatures above 1,200°C and a chromium and/or boron-base coating for applications below 1,200°C. Of interest is a recent Soviet investigation which evaluated an $MoSi_2+HfO_2$ coating on TsM-5 molybdenum alloy. The coating appeared to offer good protection up to 2,130°C for 300 seconds, which may be sufficient time for some weapon requirements. Recent tantalum, tungsten, vanadium, and chromium research has been of little aerospace significance. The Soviet tantalum and vanadium work is still in its infancy, and the tungsten alloys available are similar to those in the West, with little originality shown. In chromium alloy development, the Soviets have not done any original work in recent years but have followed promising US leads in dispersion strengthening.

The Soviets have glass-reinforced materials which have been used to fabricate such rocket and missile components as heat shields, leading edges, skirts, motor cases, nozzles, and pressure bottles. Although limited material development continues, most of the current effort is concerned with improving the adhesion between binders and reinforcing materials. The Soviets are also interested in glass filament-wound structures and filament winding techniques. [redacted] In addition, they have announced a new adhesive, designated V-23, which produces vacuum tight (10^{-5} mm) seams in the −196° to 300°C range. Within 10 years, the Soviets may have stable polymeric adhesives capable of 650°C application for long periods. Polymethylmethacrylate (PMMA) is used widely in aircraft in the USSR. Where high Mach conditions are maintained, the Soviets use high-strength, stress-relieved plate glass or glass laminated by polymeric interlayers bonded by adhesives. In addition, special heat-resistant zinc-borosilicate glasses have been developed.

The Soviets appear to be approaching the West in the growth and handling of whiskers, but in the production of continuous filaments, they are probably two years behind the West, particularly with respect to mass production of high-quality filament. The availability of both carbon and boron filaments has been noted. Based on available information, the Soviet effort on metal matrices might be categorized as exploratory; selected Western experiments are being repeated and some original work is being done, but there is no concentrated effort along a particular material line. Tungsten fibers in both copper and nickel matrices have been evaluated, but the effort is of a basic nature, though both materials have long-range potential for aerospace hardware. Powder metallurgy, diffusion bonding, infiltration with molten matrix, and explosive bonding have been evaluated as methods of preparing composites. The Soviets are keeping a close watch on Western developments in this area so as not to fall behind. The Soviet efforts on nonmetallic composites include polymeric composites reinforced by nylon, carbon cloth, metallic wire, hollow glass fibers, asbestos, and organic textiles. The Soviet prepregging capability is currently adequate to produce tape and broad goods of the graphite/resin and boron/resin variety. The Soviets apparently can produce continuous carbon filaments, but whether this is an industrial production capability is not known. Work has been reported on graphitization of cellulose and of polyacrylonitrile fibers.

Production technology

Production technology development has paralleled that of materials and design, and the processes necessary to build future operational systems of advanced performance levels are now available. The appearance of integral structures in both high- and low-performance aircraft indicates common usage. This usage, together with the continuing expansion of Soviet heavy press resources, indicate that future Soviet aircraft systems will make more use of integral structures (for example, panels, spars, frames, and carrythrough structures).

Evidence of bonded honeycomb and foamed fillers in low-performance aircraft for secondary structural applications indicates that the Soviets are easing into the use of sandwich construction. Their continuous research program in high-temperature adhesives, diffusion bonding, brazing, welding, and application of high-temperature materials indicates that limited applications of sandwich construction for primary structural application will be found in future high-performance vehicle systems. Precipitation-hardened stainless steel sandwich or high-strength titanium sandwich are now believed to be available for aerodynamic systems. This applies primarily to large aerodynamic vehicles where significant weight advantages accrue. Initial applications will probably be limited to simple curvature or flat panels and be broadened later to include more complex, three-dimensional, contoured shapes. The use of refractory materials for either airframe or propulsion design is not expected until the late

1970s and will depend to a large degree on the success of Soviet developmental work in fabrication techniques.

The Soviets are using all types of welding. A combination of spot welding and adhesive bonding, called glue welding, has been accepted by a number of design bureaus, and the process is now employed in the production of several aircraft. Development of both diffusion bonding and adhesive bonding processes continues, and more composite structure is expected on future designs.

Soviet efforts in metal forming, forging, casting, and extruding, with particular emphasis on titanium, have kept abreast of requirements. Metal removal has received considerable attention, but numerical control machine technology and its use lag the West. Chemical milling is being used, and laser machining is under development.

Trends in Soviet production technology developments for the past two years reflect continuing research in materials and manufacturing. Perhaps most pronounced has been the improvement and commitment to production of some of the processes that have been developed previously. Titanium in numerous extruded shapes, including stepped extrusion, is available and being used in production aircraft. Casting of complex shapes in titanium and nickel-base alloys has been vastly improved. Welding process reliability in production has improved to the point where designers are beginning to use more welding in high-strength structural parts. Forging techniques have permitted sophisticated aluminum forgings and titanium forgings that were not possible several years ago. In short, the Soviets are now making parts that result in reduction of manufacturing costs and, in addition, are making parts for aircraft that operate in the high-temperature regimes.

Interceptor aircraft

In the last six years the Soviets have introduced new interceptors into the Air Defense Force. These have been the large, long-range Fiddler (1966), the Mach 2.5 dash Flagon A (1967), and the supersonic cruise Foxbat (1970). In addition, the Soviets have introduced improved variants of existing designs, such as the Fishpot C and Firebar B. Present Soviet operational interceptors, with the exception of the Foxbat, have speeds of about Mach 2 to 2.3. Speeds of about Mach 3.0 have occasionally been noted for Foxbat; however, most of its flights have been in the Mach 2.3 to 2.6 regime. Foxbat carries externally four new, large AAMs which are designated AA-6.

The Flagon A carries the IR and semi-active homing Anab (AA-3) missile and uses a version of the Firebar/Skip Spin radar. This interceptor is powered by two Type 37 engines that are also used for the Fishbed (MiG-21). The Flagon is assessed as basically a Mach 2.3 interceptor, although it is credited with a maximum capability to Mach 2.5. The normal operating radius of Flagon is estimated to be 370 nm. The data link system is estimated to be interconnected to the autopilot for automatic ground-controlled intercepts. There is some evidence that the Soviets are interested in improving the low-altitude intercept capability of Flagon A. The development of Flagon was undertaken to improve on the relatively limited radar and missile capability of the Fishpot B, which was limited to rear-hemisphere attacks with beam-rider missiles.

The Fiddler aircraft is the largest fighter ever produced by the Soviets. The aircraft progressed from that observed in the 1961 Tushino Airshow, configured with two missiles, to the present configuration with four externally mounted AA-5 missiles, usually carried in mixed loads of IR and semi-active radar-guided versions. The Fiddler has frequently operated in conjunction with the Moss (airborne warning and control) aircraft. The Fiddler's airborne intercept radar [redacted] gives it the best capability of the Soviet fighters (with the possible exception of the Foxbat) to find targets without good height-finding information. With a radius of action of 865 nm, Fiddler was developed as the first Soviet long-range interceptor; interceptors developed earlier have a radius of about one-third to one-half that of the Fiddler.

A large, twin-engine subsonic cruise, supersonic (Mach 2.0-2.5) interceptor of Sukhoy design, designated the Ram E, is under development and could be operational by 1975. Its engines are believed to be of the same type as those used on the Flogger. Development of air intercept capabilities at low and medium altitudes, regions where the Soviet probably desire improvements, probably is being emphasized; such capabilities for current Soviet aircraft are best represented in the Firebar. The Ram E's size will allow it to use the new fire-control technology of the Foxbat and the new AA-6 missile carried on that aircraft. Another more likely possibility, however, is a new AAM believed to be in flight test for use against penetrators flying at low and medium altitudes.

Although there is no firm evidence that the Soviets are developing a supersonic cruise interceptor with a radius of about 1,000 nm, a definite trend toward developing aircraft with greater speed, altitude, and weapon system capabilities is indicated. The Soviets may possibly have a requirement for such a system during the next 10 years. Also indicated are subsystem developments and R&D efforts in materials, propulsion, and electronics which indicate technical interest in more advanced high-speed aircraft. Vigorous efforts in design techniques and materials would be required to achieve the low specific fuel consumption necessary, but this objective could be realized, technically, by the Soviets before 1980.

Tactical fighters

Most Soviet advances in tactical air weaponry have been a byproduct of developmental work aimed at improving strategic air defense capability. In tactical weaponry, the Soviets have stressed reliability, mobility, and strength through numbers rather than sophistication. Emphasis has been on modification of existing systems to meet tactical requirements rather than on designing new systems to perform tactical missions. The introduction of Fishbeds J and K into Soviet tactical air units and the initial production of both the Mikoyan-designed variable-geometry wing Flogger and Sukhoy's variable-geometry wing Fitter B indicate increased Soviet interest in improving their tactical warfare capability. The trend evident in the evolution of the various MiG-21 models is toward increased complexity in electronics and armament with a resultant increase in capability.

The Flogger entered Soviet tactical air units in 1970. With its improved combat radius and all-weather intercept capability, this system is expected to increase the effectiveness of the Soviet Tactical Air Forces. With its variable-geometry wings, the Flogger should be capable of operating from secondary and unimproved forward airfields. The installation of variable-geometry wings on the older Fitter may have been primarily to improve its known poor low-speed flying characteristics.

There is evidence that the Soviets are departing from their past practice of basing tactical fighter designs on defensive requirements. Flight tests were started in early 1970 of an advanced variable-geometry wing fighter. This aircraft is more like a fighter-bomber because its estimated gross takeoff weight is approximately twice that of the Flogger. Weapons testing has emphasized activities associated with ASM launches at low and medium altitudes, which suggest interdiction and close support roles. Development has progressed to the point where an IOC of about 1974-75 can be predicted with reasonable confidence. Future Soviet efforts in tactical aircraft probably will include the development of designs specifically for an air superiority mission. Additional resources probably will be expanded toward improved avionics, air-to-air missiles, and guided air-to-surface missiles.

V/STOL aircraft

Soviet interest in decreasing takeoff and landing distances was evident from the number and types of aircraft at the 1967 Moscow Air Show. The appearance of three STOL fighters equipped with lift engines—the Flagon B, Faithless, and Fishbed G—and two variable-geometry wing aircraft and the VTOL aircraft, the Freehand, represents significant Soviet V/STOL developmental trends. Work on the first Soviet vertical takeoff and landing aircraft is estimated to have started in the mid-1950s. These efforts resulted in the development of the Yakovlev-designed Freehand which is believed to have been built for the purpose of investigating the engineering problems of vertical takeoff and landing, using deflected thrust principles. The first flight of this vehicle is estimated to have occurred in 1964, but its testing activity ceased in 1967. There is some evidence that the program may have been reactivated in late 1970. None of the V/STOL designs observed in 1967 resulted in an operationally suitable design, apparently because Soviet propulsion technology was not sufficiently advanced to permit the design of an aircraft with suitable radius/payload capability.

Another VTOL fighter-type aircraft of Yakovlev design, the Ram G, appeared at Ramenskoye during 1971. We do not know whether the expected improvements in the Ram G over the older Freehand have been incorporated. We believe that Yakovlev is developing a dual-propulsion system which includes one or two direct lift engines in addition to one or two deflected-thrust cruise engines. This system cannot be related to a propulsion system on any known aircraft at this time. Despite the high level of past and present Soviet activity in the development and testing of STOL and VTOL fighters, little definitive information on the details of their powerplants has been obtained.

Soviet interest in the STOL and VTOL fighter concept will continue to grow as propulsion technology advances. The efforts in the next few years are expected to be concentrated primarily on combinations of pure lift engines and lift/cruise-type engines for VTOL aircraft. A satisfactory lift or lift/cruise powerplant for a VTOL aircraft must have a very high thrust-to-weight ratio, probably on the order of 22 for the direct lift engine and 10 for the lift/cruise type. The Soviets are not expected to reach this capability with production-qualified engines before 1975. A Soviet VTOL fighter is not expected to become operational prior to 1977.

Bombers

Soviet bomber design philosophy over the past 20 years has been based on an evolutionary approach to weapon system development. The practical effect has been that secondary mission objectives did not dictate design—rather, existing designs were modified, or "tailored," to suit subsequent mission objectives. This practice, together with the appearance of a new prototype on the average every 2 years during the past 20 years, reflects an established long-range policy of continually upgrading overall bomber capability by incorporating subsystem technological advances as they occur. The Soviets have been very successful in denying intelligence on new designs at least until prototype rollout. Therefore, the fact that no prototypes beyond Ram-H have been detected is not to say that none are in design and development. If past practice continues, it is most likely that undetected designs are presently in development and should appear within 2 years.

The Backfire has been in flight test at the Ramenskoye Flight Test Center in excess of 3 years and in weapons compatibility testing at Vladimirovka for about 1½ years. There are four instrumented prototypes at Ramenskoye, and the program appears to be progressing well. Backfire is a variable-geometry wing, Tupolev-designed aircraft weighing about 270,000 pounds. It will probably be introduced both as a bomber and ASM carrier and be operational by 1974. The maximum unrefueled range of Backfire is estimated to be 5,600 nm, and it can reach speeds of Mach 2.0 with its wings swept.

The Soviets also continue to express interest in sustained supersonic cruise aircraft. A large (300,000 lb takeoff gross weight) double-delta winged prototype designated Ram-H has been observed at Ramenskoye. This aircraft is probably either a bomber/reconnaissance prototype or a research vehicle and may be of high temperature alloy construction. If it is of aluminum construction it could have an unrefueled combat range of 3,000 nm cruising at Mach 2.2. If Ram-H is constructed of high temperature materials, it could have a unrefueled combat range of about 2,600 nm cruising at Mach 3.0.

The Backfire and Ram-H developments are not, in themselves, reliably indicative of future developments. Innovations in aeronautical design, at least within the next 10 years, will most likely consist of developments in lightweight structures, lighter, more efficient turbine engines; and improved avionics. The only aerodynamic innovation we foresee is the incorporation of supercritical wing technology. This range-enhancing development could be expected to appear in a transport design.

Aerodynamic development such as that discussed above could be expected to appear in a replacement for the TU-95/Bear bomber. Such a design could feature a high aspect ratio wing and power provided by four high bypass-ratio turbofan engines. The appearance of such a replacement aircraft within the next 10 years is questionable in view of the Soviet's continued reliance on the eminently successful Bear airframe. Approximately 20 Bear F aircraft have now been produced. This aircraft incorporates so many departures from the original design that the Soviets may plan to employ the newer design for many years to come.

The Backfire development removes any doubt about Soviet capability to design and build a larger variable-geometry wing aircraft or extend this type of wing design to a four-engine bomber with greater payload and range than the Backfire.

A Soviet strategic bomber with supersonic penetration capability at low altitude is not expected within 10 years. Innovations in low-altitude operation will most likely consist of developments in terrain-following radar, gust-response technology, low-level launch, low-level cruise ASMs, and supercritical wing technology.

The Brewer tactical bomber, due to its limited range and payload capability, is a likely candidate for replacement. A good possibility is a variable-geometry wing aircraft in the 60,000-pound category. The Ram-F could easily be the basis of such a design, just as the Firebar was the basis of the Brewer design. Ram-F has superior range and payload capability and is capable of Mach 1.2 operation at sea level.

The Ram-H, if it is a Mach 2.2 design, merely reflects Charger technology and has no clear implication for future bomber development. If the aircraft is a Mach 3.0 design, it incorporates the high-speed technology characterized by Foxbat but in a much larger aircraft and is, in this sense, an extension of existing technology. Again however, implications for future long-range bomber development are negative—the low lift-to-drag ratio and high specific fuel consumption of a supersonic cruise vehicle continue to severely limit range capability. The vulnerability of a high-altitude penetration mission at speeds less than hypersonic can be expected to be substantially greater than that of a low-level, subsonic penetration mission. Nevertheless, there may be an application of a Mach 3.0 design as a limited-range bomber.

Transports

The Charger (TU-144) is the only supersonic cruise transport known to be under development in the Soviet Union. Design objectives claimed for the Charger are Mach 2.35 cruise with 121 passengers over a 3,500-nm range. It is powered by four NK-144 turbofan engines rated at 38,600 lbs thrust with afterburning. On 31 December 1968, Charger became the first supersonic transport to fly when it completed a 38-minute maiden flight. By the end of 1971, it had accumulated more than 100 hours of flight tests. Sporadic interruptions throughout the flight program including three lengthy periods of inactivity indicate modifications, repairs, and equipment changes probably took place. Based on a comparison with the Concorde SST, the prototype Charger is estimated to weigh considerably more than is claimed by the Soviets, and it is doubtful that it could meet the original range objective at a cruise speed of Mach 2.2. [redacted] This aircraft had a longer fuselage, larger wing, and apparently some modification to the engine nacelles. The TU-144 could begin limited operational service on internal routes in late 1973. The Soviets are not expected to develop another SST design in the near future; however, a Mach 3.0 cruise SST is a long-term possibility.

The Soviets are currently flight testing the Candid (IL-76), which was exhibited at the 1971 Paris Air Show. This new transport resembles the C-141 and is the first Soviet turbojet heavy transport. The aircraft has been noted para-dropping personnel and equipment and is expected to have a military application. Future efforts in transports are expected to be directed toward the development of a high-capacity subsonic "jumbo jet" and vertical and short takeoff and landing designs.

Helicopters

The Mil Design Bureau and the Kamov Design Bureau have the primary responsibility for helicopter design and development in the Soviet Union. In addition to its successful development of conventional piston-powered and turbine-powered helicopters in the light- and medium-weight categories, the Mil Design Bureau has designed and developed the world's largest heavy-lift helicopter. In the medium-weight category, Mil's most recent helicopter development is the Hind A, which compares favorably in size and weight with the French Puma (SA-330). This new helicopter, probably to be used as a tactical assault and transport helicopter, reflects the first significant Soviet development of rotary wing aircraft for specific use in a combat environment. In the heavy-lift category, the Hook (MI-6) and the Harke (MI-10) are operational, and the Homer (MI-12) is currently in the flight-test stage. The Homer is basically a conventional-winged helicopter. As with previous Soviet rotary-wing aircraft, the development of Homer indicates no major state-of-the-art developments or breakthroughs. The impressive capabilities of Soviet helicopters are the result of administrative programming and design optimization rather than significant aerodynamic research. The first factor is the administrative trend of specialization, that is, designing a vehicle for specific operations without considering secondary or alternate mission roles. The second factor is close attention to minor aerodynamic detail and fundamentals and optimization of existing state-of-the-art, using off-the-shelf components with minor modifications. Sophisticated analytical procedures are being developed to optimize existing hardware. Of significance in the development of the Homer was the extensive, high-priority computerized simulation of the vehicle in various flight modes. It is speculated that the Soviets have developed the capability for modeling unsteady flow fields to a high degree of accuracy. As a result of this capability, simulators have been developed primarily for analytical design work. This enables Soviet engineers to simulate all flight modes, including autorotation which has typically been a difficult area to model [redacted] According to leading Soviet helicopter designers, the Homer reflects solutions to problems the US will not encounter for another 10 to 15 years.

The Kamov Design Bureau has historically been associated with helicopter coaxial designs. Current design activity centers around the continued development of the Hormone (KA-25), which is in service with Soviet Naval Forces, and the Hoodlum (KA-26), which is oriented to civil uses. Both helicopters are unique because of their coaxial rotor system, although design techniques and materials are conventional when compared with the present state-of-the-art in helicopter design.

Future Soviet research and development in rotary wing aerodynamics will probably be directed toward the development of a rigid rotor system and synchronous advancing blade rotors, further weight tests, refinement of Homer prototypes in preparation for series production, and continuation of Mil's heavy-lift development trend. If the established heavy-lift helicopter trend continues, significant departures from existing designs can be expected. Analysis of TIP jet propulsive systems could receive extensive support in the interest of developing a craft larger than the Homer. Such a project would probably involve the development of a 400,000-lb craft which could appear during the 1980-86 time period. Further refinement and development of the Hind A assault helicopter will also continue during the 1972-80 period. Because of Kamov's expertise in the coaxial rotor field, his design bureau is most probably conducting studies and analysis of the advancing blade concept (ABC), as developed by Sikorsky, for incorporation into their designs. Kamov is particularly well suited to this development and could possibly have a prototype developed before Sikorsky. A possible Kamov development of an entirely new helicopter design for an integrated weapons platform employing rigid or semirigid ABC rotors and forward thrust engines could be realized by 1975-80.

Ground effect machines

The major air cushion vehicle (ACV) developmental work in the USSR is probably conducted at the Central Aerohydrodynamics Institute, Moscow, and at about five other research institutes and shipyards. While no single agency is known to direct this work, I. Khanzhonkov probably is the leading Soviet researcher in the ACV field; he is associated with the Central Aerohydrodynmics Institute.

The Soviets still lag the West in applied ACV developments but are improving as the result of an intensified and expanding program. Their past R&D in this field has encountered major problems in skirt and air distribution design, power train, and fan design. During the 1970s their design efforts will be directed toward the development of improved skirt design and related materials and overall simplification of construction materials for a stronger and more desirable structure. Any resulting machines that may appear in the 1980s will probably be designed as high-speed (50 to 70 knots) patrol craft with light missile armament and larger over-the-beach logistic craft. The importance of arctic use of ACVs has not been ignored in the USSR, and related developmental work probably will be emphasized in the 1975-80 period. If the Soviets can maintain their current R&D momentum in this field, which seems likely, they will match the West in conventional ACV technology within five years. The USSR may already be far ahead of the US in the development of unconventional hybrid ground effect technology, such as that reflected in the ram wing vehicles.

Unique vehicles

An extremely large aerohydrodynamic vehicle, first known as the Caspian Sea Monster but now called the Monster 300, [redacted]

The precise purpose of these craft is not known. A recent hypothesis, to which engineering studies and wind tunnel tests lend credence, suggests that the Monster 300 may be a considerably more capable and flexible logistics carrier or platform than first estimated. If it is postulated that eight of its ten turbofan engines are used to direct engine exhaust under the wing/flap system, the vehicle appears capable of hovering and accelerating to reasonably efficient ground effect vehicle conditions as an augmented ram wing; if the exhaust is directed over the wings, it can cruise highly efficiently at altitude. Speeds in excess of 300 knots and ranges exceeding 2,000 nm are estimated. Under these conditions, the Monster 300 appears to be capable of C-5A-like payload capacity but with the advantage of short take off and landing on calm water or ice.

Armament

Soviet fighter aircraft began to appear in about 1960 with two definite types of armament configurations. One type is strictly an interceptor with only missile armament and fire-control equipment consisting of a data link, airborne intercept radar, and missile-launch computers. The other is more of the air superiority type of fighter; some aircraft of this type have missiles as prime armament while others have both missile and gun armament. The second type of fighter uses as its fire-control equipment, radars (either range-only or airborne intercept), missile-release computers, and optical sights. Both types can carry and deliver other ordnance such as rockets and bombs.

No basic changes are expected in the armament configuration of future Soviet fighters employed strictly as interceptors. Missiles will remain as the only armament. Improvements in existing missiles as well as the possible introduction of new missiles can be expected. Increased use of infrared search/track sets and improvements in detection range can be expected as the Soviets make advancements in interceptor fire-control systems.

The trend of armament configurations for the air superiority fighters is toward a reduction in the use of guns with total reliance on missiles to perform air intercepts; however, the recent introduction of the Fishbed J with a permanent new gun installation and the possible use of gun pods on the gunless Fishbed Ds and Fs reflect a reversal in this trend. New tactical or air superiority fighters introduced by the Soviets in the next 10 years are expected to have both missiles and guns. In addition, these new fighters will have optical sights and be capable of carrying ordnance for air-to-ground delivery to support a secondary ground support role.

Any new Soviet guns would most likely retain the Soviet preference for large caliber and exhibit increased muzzle velocity over their existing aircraft cannons. The Soviets have four types of unguided rockets in their operational inventory, and future rocket developments are expected to be modest. As in the past the Soviets will continue to improve the design of their bombs. Improvements are expected in bomb ballistics and fuzing. In addition, a retardation system will probably be developed to permit low-level delivery of bombs. To improve a limited store carriage capability, the Soviets may well develop multiple ejection racks (MERs). The MERs would probably be designed to carry two or three bombs each. This could increase the number of stores carried and may also increase the total-per-station load capacity of Soviet fighters by as much as 300 percent.

When delivering munitions against ground targets, Soviet tactical fighters use a simple fixed-collimating sight, a gyroscopic-lead computing gunsight, or a gyroscopic-lead computing gunsight mated with an automatic bomb release computer. Some tactical fighters have the capability to release munitions either manually or automatically. Soviet tactical fighters still rely mainly on the dive technique for attacking ground targets with cannon, rockets, or bombs. Cannon and rocket attacks are performed from a dive. Bombing is performed from dive or low-level flight. Low-level bombing is employed during low cloud base conditions or when target antiaircraft defenses are heavy. The loft and toss bomb methods are also used to deliver bombs. These two methods of delivery are used to deliver large conventional or tactical nuclear bombs. Loft bombing is performed from a 106° pull-up angle and toss is performed from a 45° pull-up angle. In all three methods (level, toss, and loft), bombs can be released manually or automatically. The Soviets have not yet employed an automatic release computer which receives range to target inputs. But, a system of this type is necessary and will probably be developed in the next 5 years.

[redacted] Another tactical ASM possibly using radiation homing guidance is being developed for probable use on the Ram F by 1974-75. Launches would be just above the radar line-of-sight with maximum launch ranges out to 20-30 nm.

In the past several years, the Soviets have deployed aircraft fitted with an abundance of radomes. The electronics associated with these aircraft are mostly passive and hence are probably used for Sigint collection and DF purposes. One particular configuration is the 8-GHz-band radar believed to be fitted under the 25-foot belly radome of the naval Bear D aircraft. While its exact function is not yet known, the radar appears to have at least a good long-range surface search capability. It transmits at times on two RFs (within the same band) simultaneously, a technique which the Soviets have used for lobe pattern control but which in highly advanced systems could be used for clutter suppression. This radar has also been tentatively associated with the Hook helicopter.

There is no evidence to indicate that the Soviets possess a side-looking radar for military reconnaissance use; however, a side-looking radar on an AN-24 has been used for ice-field reconnaissance in the Arctic.

It is believed that future development of Soviet electronic reconnaissance equipment will be directed toward battlefield support as well as naval surveillance and target spotting. The equipment will in all probability use the 14-GHz-band portion of the spectrum as well as the 9-GHz-band areas.

GROUND WARFARE

The Soviet ground forces are supported by extensive development, design, and test facilities. Excluding CBR, the number of known major ground weapons R&D facilities exceeds 60. These facilities have successfully designed and developed approximately three generations of ground force equipment since World War II, and the recent models emerging appear quite improved in design and performance. Changes in equipment to be developed over the next five years, at least, probably will not be drastic, but will be mostly evolutionary. Products now in blueprint probably include a new medium tank, a new amphibious armored personnel carrier, antitank guided missiles with improved guidance, close support artillery and associated ammunition, and mobile SAMs.

Soviet ground force materiel is based on sound design principles, and needs are derived from requirements as determined by Soviet army planners. In many respects, the materiel lacks the refinement of comparable Western developments; and of the three major general purpose forces, Soviet ground force equipment best exemplifies an adherence to the philosophy of "The better is the enemy of the good." This has resulted in the identification of fairly well defined patterns of constraint in weapons and equipment development, albeit, not without meeting the basic Soviet requirements of tactical firepower, over-the-ground mobility, and command and control. The most notable shortcomings appear to be in some types of logistical support equipment and in the lagging development of suitable fixed and rotary wing aircraft for effective ground force air mobility.

Armored vehicles

Soviet medium tank design work is directed toward the development of more mobile and flexible combat vehicles with improved main armament and fire-control equipment. Design concepts essentially reflect a future main battle tank approach of product modification of existing tanks. The medium tank will continue to be the Soviet main battle tank. It is believed that a new Soviet tank (tentatively designated Medium Tank M-1970) is currently in production and will be added to the inventory. This tank is similar in appearance to the T-62, having the same low silhouette and weighing perhaps slightly more than 40 tons. The main armament probably consists of the same or somewhat improved 115-mm smoothbore gun. A noticeable difference is the suspension system which features smaller road wheels and flat track system than used on previous Soviet medium tanks.

The most probable advance in Soviet main battle tank development anticipated within the next 10 years is the fielding of a follow-on to the Medium Tank M-1970, possibly equipped with a combination gun and missile system which would retain the advantages of the high-velocity smoothbore gun for short ranges and provide a high-velocity guided missile capability at extended ranges.

Current Soviet preference for smoothbore guns, especially for direct fire roles (that is, tank and antitank), is expected to continue during most of the 1970s because of their advantages. Such weapons are devoid of rifling and projectile velocities for hypervelocity armor-piercing (HVAP) rounds are higher than for comparable rifled versions since there are no engraving and torque forces to overcome. Likewise, the gun design permits the use of non-spin high-explosive antitank (HEAT) ammunition, resulting in more efficient terminal ballistics. Further development of smoothbore weapons for firing rocket-assisted and guided projectiles may be expected by the end of the forecast period.

[redacted] attenuation liners for the interior of tank turrets have appeared. Preliminary estimates indicate that these liners are of limited effectiveness against radiation, but exact details are lacking. The Soviets have the technological capability to develop devices and features which would provide a higher degree of protection for tank crews in contaminated areas. The most likely achievements expected in the next few years are the use of collective protector filtration and over-pressurization for defense against chemical and biological attack, as well as protection from alpha and beta particulates.

Since tank mobility adds to protection, improved speed and cruising range of the medium tank are anticipated. By the end of the 1970s, the cruising range with on-board fuel may be extended to 500 miles through higher horsepower-to-weight ratios, the use of improved suspension systems, and improved power conversion devices. The Soviets are expected to continue efforts to increase off-road speeds with an objective of as much as 30 mph for favorable terrain.

Armored personnel carriers (APCs), armored reconnaissance vehicles, and armored amphibious infantry combat vehicles (AAICVs) are found in Soviet inventories. These include a full-tracked, wheeled APC in three versions; 4 x 4-wheeled armored amphibious reconnaissance vehicle in two versions, plus a modified version to act as the carrier for three different antitank guided missiles (ATGM) systems; and a full-tracked armored amphibious infantry combat vehicle. In addition, two older nonamphibious wheeled APCs are still in service.

In late 1967, the appearance of a new vehicle, the BMP, marked a major departure in armament and interior layout design from earlier Soviet armored carriers. This full-tracked vehicle features a turret-mounted 76-mm smoothbore gun with a 7.62-mm coaxial machinegun and a superposed Sagger ATGM launcher over the gun. The BMP has a crew of three—driver, commander, and gunner. The squad seen mounted in this vehicle consists of eight men armed with a RPG-7, RPK-type machinegun and 6 AKMs. The 76-mm smoothbore gun combined with the Sagger ATGM represents a new Soviet concept in armored vehicle armament and is indicative of the direction of related future Soviet developments. The BMP is the first Soviet APC to have the troop entrance-exit doors in the rear, thus providing more protection than previous APCs which had hatches on the sides or tops of the vehicles.

Current Soviet wheeled APCs and reconnaissance vehicles mounting 14.5-mm machineguns will be retained for many years. Two types of armored personnel carriers will continue to be required—an APC vehicle with a large caliber machinegun and an infantry combat vehicle which can fight in close proximity to main battle tanks and is armed with a weapons system for engaging tanks. Product-improved or new versions of current vehicles probably will be fielded prior to the end of the decade. Improvements probably will include better protective features, more effective gun ammunition, and a newer model antitank guided missile system. During the latter part of the forecast period a replacement vehicle, either wheeled or tracked, is expected to appear. This vehicle probably will have a combination gun and missile system in one version and an automatic weapon in a second version, a minimum of one-inch equivalent armor protection over the frontal arc, and CBR collective protection for the crew.

Artillery

Towed light, medium, and heavy antiaircraft guns produced since the end of World War II have demonstrated a continued effort by the Soviets in the development of air defense weapons. Although only antiaircraft heavy machineguns and light AA artillery are currently considered to be standard, quantities of larger caliber weapons through 130 mm are available in reserve stocks. The S-60 57-mm AA gun system has been modified over the years, with the latest known improvement being the gradual replacement of the radar/director by an updated/modernized integrated fire-control system. Exploitation reports indicate that the current Soviet D-130 howitzer is perhaps the best weapon of its class in existence. The introduction of the ZSU-23-4 quad 23-mm self-propelled antiaircraft gun system into the Soviet inventory in the mid-1960s clearly indicates an effort devoted toward increased capability in air defense. With an on-board integrated fire-control system (radar-optical-director), this weapon system is considered a major threat to attacking aircraft. The Soviets are expected to retain antiaircraft artillery weapons in active use by field forces and to continue to improve their weapons, ammunition, and fire-control equipment.

The Soviets have also made significant strides within the past decade in tube field artillery weapons. [redacted] the latest Soviet tube artillery about 1963 showed excellent design and engineering, and performance that is on a par with that of comparable artillery of any nation. The Soviets have also developed and produced in the last decade a series of smoothbore weapons (antitank artillery, tank armament, and infantry weapons) that, from the standpoint of production state-of-the-art and technology and possibly engineering and design, may have surpassed related weapons of Free World nations. Recent information indicates that the Soviets are experimenting with high-speed rotary forging and electro-slag remelt steel processing for the production of artillery and tank gun barrels.

Artillery rockets

The Soviets have developed and used multiple- and single-launch, free-flight rocket systems to provide fire support for their ground forces. They have been innovative and for some systems have made a minimum application of technology with good results; for example, in the design of aerodynamic baffle-type devices to shape the rocket trajectory. They have mounted a crane on a rocket launcher vehicle which has eliminated the requirement for a separate crane truck. Most evident is their philosophy of adopting a basic rocket system, then upgrading the performance and reliability through a series of product improvements.

Infantry weapons

There exists a Soviet family of small-arms that are simple in design, extremely reliable, sufficiently accurate at combat ranges, and easily manufactured. All contemporary Soviet small arms (except pistols) are designed around the Kalashnikov rotary-bolt system mechanism and use one of two cartridges—either the 7.62 x 39 M43 or the 7.62 x 54 rimmed cartridge. Squad-level weapons use the low-recoil M43 round; sniper rifles and machineguns use the more powerful 7.62 x 54 cartridge. The Soviets appear content with their current weapons and for the next few years, until 1980 at least, only minor product improvements are expected to evolve. Soviet troops now have second-generation infantry antitank weapons employing rocket-assisted projectiles. These consist of the squad 40/85-mm recoiless grenade launcher, the RPG-7; the battalion 73-mm recoiless gun; and possibly a new squad antitank weapon, the RPG-15. The Soviets are well advanced in this field and have introduced a number of significant features such as in-bore spinning of projectiles that will function in both closed- and open-breech smoothbore weapons, thus meeting a requirement for uniform thrust alignment of rocket-assisted projectile; wave-shaping techniques that have reportedly achieved six-cone diameter penetration; and simple but high-quality optical sights that enhance hit probability.

Ammunition

The Soviets are expected to continue their considerable research effort in improving ammunition effectiveness. Although new items to be developed will be greater casualty producers, they will be the result of evolution, and no major breakthrough in design technology is anticipated within the next five years. The USSR is at present slightly ahead of the US in the penetration capability of armor-piercing ammunition, but Soviet state-of-the-art for fuses and antipersonnel ammunition is well behind that of the US. It can be expected that the Soviet R&D effort will be accelerated to close these gaps.

Mine detection equipment

Soviet mine detection equipment has received continued attention. The Soviet Ground Forces are equipped with electronic detectors capable of detecting metallic mines. Ongoing R&D is directed toward providing a reliable means of detecting nonmetallic mines. Infrared and trace gas analysis techniques under investigation may result in the introduction of a nonmetallic mine detector into the Ground Forces within the next five years. Soviet mine field-breaching equipment consists principally of mine rollers, plows, and rigid explosive line charges. These devices are expected to remain in the Ground Forces inventory and may be augmented by fuel-air explosives if current R&D efforts in this field produce promising results.

Transport vehicles

Soviet transport vehicle RDT&E is under the direction of the Scientific Research Automotive and Engine Institute. Current efforts are aimed at continued improvements of vehicle configurations, performance, and mobility. These goals are being attained by concentrating design efforts on the development of such improved components as propulsion, suspension, braking, steering, and electrical systems for both wheeled and tracked vehicles. The Soviets have also evaluated the prototypes of such special purpose vehicles as the Archimedian screw, marginal terrain (air-roll), wheeled 5- and 15-ton amphibians for ship-to-shore operation, and electric-powered vehicles. Additionally, a highly mobile, tracked, self-propelled field kitchen designed to support armored and mechanized units has been developed and field tested.

A new family of cab-over-engine, diesel-powered vehicles in the payload category of 8 tons and over are currently undergoing prototype evaluation. The vehicles are intended for future production (1975-80) at the new Kama River Plant which is now under construction. Additionally, the Scientific Research Automotive and Engine Institute is currently evaluating two high-performance diesel engine prototypes of 75 and 125 hp. The successful development of these prototypes coupled with the production of larger diesel engines for the future Kama vehicles will provide the Soviet Union with the capability of converting all military vehicles to diesel power, if so desired.

Development of 8 x 8 vehicles in the payload category of 10 tons and over will continue. A redesigned version of the ZIL-135 (8 x 8) and a replacement vehicle for the one-half ton GAZ-69 (4 x 4) possibly incorporating diesel engines are anticipated in the 1975-80 period. A prototype vehicle incorporating the Archimedian screw principle with a 4 x 4-wheeled vehicle may appear in the early 1980s. Concepts of this design have been recently published.

By the mid-1970s, improved PMP-type ponton bridge equipment probably will make its appearance along with helicopter-emplacement short-gap bridging. Development of a multiple-span, scissors-type, tank-launched assault bridge is likely in the 1975-80 period. By 1985, Soviet multipurpose amphibious bridges will be available to supplement or replace the PMP-type equipment.

Reconnaissance drones

There has been a conspicuous lack of information on Soviet activities and thinking on this subject; however, four Soviet drone developments have become known. Two, the LA-17 radio-controlled ramjet target drone launched from aircraft inflight and the LA-17M ground-launched reconnaissance drone, are subsonic. The third, which appeared as a sketch in an East German publication, is a reconnaissance drone mounted on a launching rack on top of an eight-wheeled amphibious vehicle. The caption stated that the drone has a piston engine and carries cameras. The fourth drone, known as the Luggage, is about 84 feet in length, pilotless, and believed to be a surfaced-launched tactical reconnaissance aircraft.

The concept of employing small pilotless aircraft for battlefield surveillance and reconnaissance, particularly in nuclear warfare, has distinct advantages. Fabrication and deployment of large numbers of such drone aircraft are entirely within the Soviet capability with respect to airframe, powerplant, and sensor components. Consequently, a steady advance of the Soviet drone program may be expected during the 1972-80 period. Such aircraft would be relatively unsophisticated, reflecting current military requirements and state-of-the-art for this period. By 1980 the Soviet drone program might be in full stride, and by this time a number of special-purpose, high-performance (probably supersonic) aircraft could be in operation.

Nuclear power supply

The Soviets are making a concerted effort to develop nuclear power supplies for military use on land as well as in space. Small nuclear reactor power plants were begun to be developed before 1956; however, by 1963 only two types of nuclear plants had entered the testing stage. These were the TES-3, a water-cooled reactor, and the Arbus, an organic liquid-cooled reactor. Because of problems associated with fouling of the fuel element heat transfer surfaces, development of the Arbus was discontinued in 1969. The follow-on to the TES-3 is the Sever, which is an air-transportable plant that generates 1500 kWe and can operate for four years between refuelings.

NAVAL WARFARE

Organizations within the staff of the Naval Headquarters in Moscow appear to have overall supervision of Soviet naval research and development. The Deputy Commander-in-Chief for Shipbuilding and Armaments and subordinate directorates probably have the largest share of this responsibility. The most significant of these directorates are the Directorate of Shipbuilding, the Mine and Torpedo Directorate, and the Rocket and Artillery Directorate. One other naval directorate known only as the Fifth Directorate is important in Soviet naval research and development but may not be subordinate to the Deputy Commander-in-Chief for Shipbuilding and Armament. The Fifth Directorate is clearly concerned with naval electronics, particularly fire-control electronics and electronics for submarine detection including sonar. Coordination of the research activities of the various directorates is probably accomplished through the Naval Scientific and Technical Committee, of which the Deputy Commander-in-Chief for Shipbuilding and Armament is chairman.

In addition to the naval R&D and design facilities noted earlier in the Facilities section, including research organizations subordinate to the Ministry of Shipbuilding Industry and other military-industrial ministries, direct support work for naval R&D in the fields of hydroacoustics and radio wave propagation has also been identified in the Academy of Sciences. Hydroacoustics R&D support work for the Navy has been conducted at the Acoustics Institute, and the radio wave propagation work has been conducted at the Institute of Terrestrial Magnetism, the Ionosphere and Radio Wave Propagation (IZMIRAN), Krasnaya Pakhra. In addition, some unidentified research in the field of terrestrial magnetism is currently being carried out for an unidentified naval organization by personnel of the Magnetic Measurements Laboratory of IZMIRAN. Other unidentified research possibly related to submarine detection is being carried out for the Fifth Directorate of the Navy by a group within the Department of Plasma Energetics at Krasnaya Pakhra which is subordinate to the Kurchatov Institute of Atomic Energy in Moscow.

Surface ships

A substantial number of the major Soviet surface combatants which have appeared in the past 5 years have Russian designations which indicate a main mission of antisubmarine warfare. The Kresta-I, Kresta-II, Kanin, and probably the Krivak classes of ships are designated Bolshoy Protivolodochnyy Korabl'—BPK (large antisubmarine ships), the Moskva is designated Protivolodochnyy Kreyser—PKR (for antisubmarine cruiser), and the Grisha is designated Maliy Protivolodochnyy Korabl'—MPK (small antisubmarine ship). The one exception to this pattern is the Nanuchka class which is designated Raketnyy Korabl' Maliy—RKM (small rocket ship). This designation is similar to that for the older Kildin and Krupnyy classes which were designated RKB (large rocket ship) but are now being converted to BPKs. While the new combatant types are apparently oriented toward antisubmarine warfare, their surface-to-surface missile armament renders them formidable threats in ship-to-ship combat. In this respect there is some evidence to suggest that the SAM systems on some of these ships—Kresta-I and -II, Moskva, and Kanin—may have a surface-to-surface capability.

The continuing Soviet capability to design and construct good-quality surface ships armed with a variety of missile systems is demonstrated by the new Kara-class CLGM. This ship is larger than the Kresta-I and -II. It has surface-to-surface and surface-to-air missiles and appears to be the first Soviet combatant equipped with both short- and long-range SAMs. The precise missile systems on this ship are not yet clearly defined, but they appear to be the SS-N-10, SA-N-3, and SA-N-4. The multilayer air defense capabilities associated with this ship suggest it may be intended as a task force command cruiser, but it could also be a new and larger ASW ship (BPK).

The large ship under construction at Nikolayev, designated the 444B, was launched in December 1972. This ship may represent a new direction in Soviet surface combatants. It is about 890 feet long and has a waterline beam of about 110 feet. An angled flight deck some 600 feet long, 84 feet wide, and angled about 4° to port has been installed. The widest part of the ship is about 155 feet. An island type of superstructure is under construction amidships on the starboard side. Weapons or electronic positions occupy an area just beyond the forward edge of the flight deck, probably restricting flight operations to the angled deck.

Most likely connected with this ship is the development program of the Ram-G V/STOL aircraft. The guided-missile helicopter ship Moskva is believed to have conducted flight operations with the Ram-G on 18 November 1972. These tests probably were to determine relative wind conditions over the flight deck for launch and recovery operations while under way. [redacted] It is expected that the Ram-G will continue its test program aboard the Moskva and eventually be deployed aboard the 444B when it is completed.

The 444B with its embarked V/STOL aircraft probably will be used to provide air support to amphibious forces or air defense for surface task forces. It may also have an ASW or amphibious assault mission if helicopters are embarked.

It is estimated that the 444B will begin operating in early 1975. There are indications that construction of a second unit commenced in January 1973.

No large new amphibious support ships have appeared in the past five years. The most significant new craft for amphibious forces are the ACVs of the Gus and Aist classes. The 30-ton Gus class appears to be in limited series production. The 120- to 180-ton Aist class is temporarily, at least, the largest military air cushion vehicle (ACV) in the world, though it is roughly comparable in size to the British SRN-4 passenger and vehicle ferry. Further Soviet accomplishments in amphibious ACVs are suggested by the fact that in the past five years new shipyard facilities have been built in Leningrad apparently dedicated largely to ACV construction.

A significant new naval auxiliary, the Boris Chilikin—a large under way replenishment ship—appeared in 1971. It appears to be the first Soviet auxiliary to be equipped with modern gear for the efficient and rapid transfer of liquids and dry stores to warships under way at sea. Only one unit exists at present; however, others may be built later. Such ships will increase the effectiveness of fleet operations in the Mediterranean Sea and other areas far from Soviet bases.

Submarines

Shortly after the Cuban missile crisis, the production of a Soviet strategic counterpart to the US Polaris force was authorized. The very limited capability of the first generation of Soviet ballistic missile submarines (H-class SSBN, G-class SSB, and Z-conversion SSB), taken together with Soviet statements avowing their rejection of an inferior posture in the strength of SLBM forces, made it virtually certain that a submarine like the new Y-class with its 1,300-nm SS-N-6 missile would appear. Construction on the first of these 16-tube submarines began at Severodvinsk in 1964. This lead unit was launched in 1966. In 1969 the first Y-class submarine was launched at a second yard—Komsomolsk—in the Soviet Far East. While this class of submarine was predictable, we were surprised at the intensity and speed of construction of these enormously complex and expensive ships.

At the beginning of 1972, evidence was available on the development of four new Soviet ballistic missile submarines. Three of these—the H-III, the 402M, and 402K—are modifications of existing ballistic missile types. The oldest, the H-III, has been observed since 1967 and is the test platform for the SS-NX-8, the new 4,150-nm naval missile. The 402M is a lengthened G-class diesel-powered ballistic missile submarine whose modification resembles that of the H-III. The reason for the 402M modification is unknown. It could be the beginning of a program to modify the remaining Golf-I submarines to carry the SS-NX-8 missile, or it could represent a test platform for a new, as yet unidentified, missile. The program to convert 15 G-I class units (which carry the 350-nm SS-N-4 missile) to G-IIs (which carry the 750-nm SS-N-5 missile), however, appears to be continuing, and only eight G-I class units remain to be converted.

The third modification involves another modified G-I, designated the 402K. This also is a lengthened G class but is of quite different configuration from the 402M and H-III. The original length of the sail on the 402K has been retained but made narrower, and its original missile tubes appear to have been removed. Aft of the old sail a low "turtle back" containing four missile-launch tubes has been added, and the overall length of the ship is 58 feet greater than the original G class. There is no logical explanation for the retention of the same length of sail without missile tubes, but this fact suggests that the 402K is an experimental effort. In December 1969 a new missile, designated the KY-9, was [redacted] at the Kapustin Yar Missile Test Range. There is tenuous evidence that it may be a naval missile and that the missile transporters and support equipment are similar to those used for the SS-N-6 missile carried by the Y class. This suggests that KY-9 may have dimensions close to those of the SS-N-6. It is estimated that the tubes in the low "turtle back" on the 402K submarine could probably accommodate a missile of about the same length as the SS-N-6, and this leads to speculation that the 402K may be a test platform for the KY-9.

In addition to the foregoing three modifications of existing ballistic missile submarines, a new, large nuclear-powered ballistic missile submarine, designated the D class, has appeared. This ship is similar to but longer than the Y class and is fitted with 12 instead of 16 missile tubes. It seems virtually certain that this submarine is the long sought platform on which the SS-NX-8 missile will be deployed. The D class is 24 to 26 feet longer than the Y class. Its speed is unknown but presumably will be comparable with that of the Y class and possibly will incorporate improved sound quieting features over those of the Y class.

In the torpedo attack class submarines we had anticipated during the past 5 years a follow-on, quieter submarine than the N-class SSN. The new V-class SSN, as predicted, is quieter in many respects than the older N class but not nearly as quiet at comparable speeds as the quietest US nuclear submarines. One of the reasons why the V-class (and the other second-generation Soviet nuclear submarines) is not as quiet as US submarines apparently is because the Soviets deliberately chose to give it a very high speed (32 knots) capability. This evidently led to the omission, to any significant degree, of sound isolation mounting of machinery in order to pack a large amount of power into the limited hull volume. The quieting that was accomplished appears to be related primarily to improved hydrodynamic design of the hull and the use of larger, slower turning propellers. This insistence on high speed at the expense of quietness is a significant peculiarity of Soviet submarine design philosophy. There is little indication at present that speed will be sacrificed for quietness.

Also appearing during the past few years was the B-class, diesel-powered submarine. While not unexpected, it is not considered a significant threat as a combatant. Only four of these were built, and they are widely dispersed in the Pacific, Northern and Black Sea fleets. It is speculated that they are intended as very quiet target submarines for use in ASW exercises and development. If this is correct, the B-class represents another Soviet R&D effort to improve ASW capabilities.

The A-class SSN, the third new Soviet torpedo attack submarine appearing in the past few years, is unique in that it is the smallest Soviet nuclear-powered submarine and has had nearly a 3-year period of fitting out and shipyard availability following its launching in 1969. The long delay in its becoming operational suggests there is something special about it. Possible explanations of this based on very tenuous evidence are:

a. Difficulties with a new type of nuclear propulsion plant, possibly incorporating more advanced noise control features;

b. Difficulties with a new type of "rocket torpedo" weapon system or a counter to such a system;

c. Difficulties entailed in the possible first use on this submarine of a substantial quantity of hull or machinery components made of advanced new materials such as titanium alloys.

d. Some combination of the above.

Concerning Soviet cruise missile submarine developments, the C-class SSGN with its revolutionary, short-range, submerged-launched, antishipping cruise missiles [redacted] There was some evidence of Soviet interest in and tenuous evidence of the possible testing of a submerged-launched cruise missile of unidentified characteristics in 1966. The evidence, however, was judged insufficient as a basis for predicting the early appearance of such a weapon system. The C-class submarine and its weapon system is a startling example of the Soviet capability to conceive and execute unique new weapons in virtually complete secrecy.

Like the A-class torpedo attack submarine, the P-class SSGN (which also appeared in 1969) was thought to be in series production. The conspicuous absence after nearly 3 years of any additional units, however, suggests that the P class is also a developmental prototype. The P class appears to have become operational, but little is known about its weapon systems. It appears to have 10 or 12 missile tubes in its bow in an arrangement similar to that in the C class. This suggests that it also is intended to launch cruise missiles from a submerged position. On the other hand, the P class is much larger than the C class and has twin rather than single screw propulsion. Also, there is some evidence that the A-class submarine launches a missile having a greater range than that of C class by a factor of 3 to 5. There is no evidence to explain how target acquisition and fire-control data could be obtained for the submerged launching of a missile having this great range.

Of particular note in Soviet submarine-related R&D during the past 5 years have been developments in navigation and communications systems and the appearance of a "submersible" project. Developments bearing on the navigation of ballistic missile submarines include the appearance of radiometric sextants (Cod Eye) on the H- and Y-class submarines. The navigation satellite system may have become operational only in early 1972. Underwater communications equipment has been firmly identified in Soviet submarines and surface ships, and it is highly probable that the Soviets have been developing improved underwater communications systems. Such systems can greatly facilitate joint submarine and surface ship ASW operations.

[redacted]

During the past 15 years Soviet open literature has revealed a significant interest on the part of the shipbuilding industry in titanium alloys. Two known applications of titanium alloys by the shipbuilding industry have been in the manufacture of some components of torpedoes and in the manufacture of sonar domes. Some aspects of the open literature after 1965, however, have suggested that the Soviets may be about to introduce titanium as a hull structural material. There were indications in 1970 of Soviet use of titanium at a submarine shipyard, but this evidence does not permit a determination of how and for what purpose the material was used. Although titanium alloys are generally expensive and difficult to weld, these disadvantages are rapidly being overcome and the high strength-to-weight ratio of these materials can have very significant effects on the capabilities of surface ships or submarines where they are used extensively in the hull structure. It should not be a surprise if some Soviet shipbuilding use of titanium alloys in the hull structure of surface ships or submarines is identified in the next few years.

Soviet literature also has revealed continuing research activity related to industrial noise control leading to improved understanding of vibrations, with particular applications to marine structures. The quantitative evaluation of actual Soviet progress in noise reduction, however, must await observation of ships and submarines at sea. In this respect, as previously mentioned, the new A-class submarine is of particular interest.

[redacted] Thin anti-sonar coatings have previously been identified on Soviet submarines, and this new thicker coating indicates continued Soviet development in this field. It is considered most likely that a coating of this thickness is intended to reduce the reflected energy of sonar signals from torpedoes with active acoustic homing systems. The thicker coating also would probably be more effective than the earlier thin coating against the lower frequency active sonars on the more modern surface ASW ships. There is some possibility that the coating could be designed to reduce the radiated noise of the submarine at some of the higher radiated noise frequencies, but this is considered a less likely intended purpose.

Aircraft

The Soviets have continued to emphasize development of naval airborne systems. During the past 5 years the Bear D (TU-95R) reconnaissance version of the Bear aircraft, equipped with the Drambuie target acquisition data link and serving antiship cruise missile launching ships and submarines of the various fleets, has appeared in the Soviet Naval Air Force. In addition, the Hormone B helicopter equipped with Drambuie has appeared on the Kresta-I class ship. Three new ASW aircraft also made their appearance: the May (IL-38), which is a land-based turboprop equipped with sonobuoys, a J-band surface-search radar (Wet Eye), magnetic anomaly detection (MAD) gear, and ASW weapons; an ASW version of the Bear (TU-142), apparently equipped similarly to the May but without a MAD boom; and the Hormone A helicopter, equipped with dipping sonar and deployed on the Moskva and Leningrad ASW helicopter carriers.

Another development has been the appearance of the LRAF Blinder B aircraft equipped with the AS-4 in naval exercises. The missile on the Blinder B has probably been modified and provided with a homing capability and conventional warhead. Participation of this aircraft in naval exercises probably will continue.

The appearance of the new swing-wing supersonic bomber, the Backfire, in a naval context is estimated. There is no evidence of its intended deployment in the navy, but past experience (as with the Blinder B, Bear, and the Badger) shows that aircraft apparently developed for the LRAF eventually are used in a naval role, either within the naval air force or in joint operations in support of the navy. Another development, referred to above, is that the Soviet V/STOL aircraft, the Ram G, has been observed on the Moskva helicopter carrier.

Naval missiles

Soviet naval missiles which became operational in the past 5 years include one ballistic, four antiship cruise, two surface-to-air, and two air-to-surface weapons. A third air-to-surface missile, the AS-4, is the one carried by Blinder B, but its naval role is not firmly identified. Of particular note is the preponderance of new Soviet antishipping missile developments during the past 5 years; four of the weapons are ship or submarine launched and two are aircraft launched. The chief significance of the new antishipping weapons lies more in diversity added to the antiship cruise missile threat than in an across-the-board improvement in any particular aspect of performance. Nevertheless, there is much that is new in these systems. Probably the most important single development has been the submerged-launched capability of the SS-N-7 with its introduction of the element of surprise. Also of importance is the fact that the AS-6 has twice the speed of previous air-to-surface missiles (except for the AS-4), and other new systems have higher speeds and probably improved homing systems.

Among the new missiles known or suspected to be under development during 1972, only one is firmly identified as an antiship cruise missile, namely the SS-NX-12 (FAD-011) [redacted]

Available information on the KY-9 missile associates it with the Soviet Navy. If intended for naval use, it could be an unusual new type of weapon. [redacted]

ASW weapons

Perhaps the most significant new Soviet ASW weapon identified in the past 5 years is the rocket-assisted probable antisubmarine nuclear depth charge designated FRAS-1 (free flight antisubmarine rocket), which is launched from the SUW-N-1 launcher. To date this weapon has been identified only on the Moskva-class antisubmarine helicopter carriers. The SUW-N-1 launcher has been sighted on one unit of the Petya class destroyer escort in the Black Sea, but no further installations have been noted. No data on the actual range and payload of FRAS-1 have been obtained. Its estimated maximum range is 32,000 yards.

Several new air-dropped weapons were identified during the past few years. The E45-70A is a new 18-inch acoustic homing antisubmarine torpedo. Two aviation depth bomb weapons, called PLAB by the Soviets, have been identified. One is a small aviation depth bomb intended to be dropped in clusters of 5 to 20 and the other, the PLAB-50, is a 250-pound high-explosive bomb that is dropped singly.

[redacted]

Two new antisubmarine mines [redacted] Called rising mines, one of these apparently is laid from surface ships and submarines and the other, laid from aircraft. These weapons, which are intended to be anchored in water having depths to 2,000 feet, float at depths from 150 to 1,150 feet at the end of a cable. Upon receipt of an acoustic signal in a specific frequency range, the mine is released and rises toward the target. The air-dropped version incorporates a rocket that propels the mine up toward the target. These weapons incoporate features which prevent them from attacking surface ships. No evidence of widespread deployment of such mines has appeared, but this is as would be expected in peace-time. Mines such as these could be stockpiled without our knowledge.

Because it has been so long since the Soviet introduction (in 1960) of its latest known acoustic homing antisubmarine torpedo intended to be launched from submarines and surface ships, it is estimated that a new improved torpedo of this type may have become operational in about 1967. [redacted]

Among the types of torpedoes under development [redacted] was what was called a "rocket torpedo." This was a weapon that could be launched from surface ships and submarines and propelled through the air by a rocket to a point where it would enter the water. A "rocket torpedo" or a countermeasure to such a weapon may be in the new A-class nuclear-powered submarine. [redacted] In addition to firing the FRAS-1, the SUW-N-1 launcher on the single Petya unit and on Moskva-class helicopter carriers could also fire this kind of weapon. [redacted] It is thought that the weapon payload [redacted] may be the E45-70A air-dropped acoustic antisubmarine torpedo. This torpedo has been seen on the Moskva class and could be delivered either by the Hormone A helicopter or an Ikara-like weapon. Finally, although the Kresta-II is currently thought to carry the SS-N-10 antishipping cruise missile, the absence on this ship of clearly identifiable guidance radar for the SS-N-10 missile suggests that its missile launchers are possibly for an ASW weapon like the Ikara.

ASW detection systems

With the expansion of the Soviet Navy over the years, there has also been a marked increase in Soviet ASW activity, most of which has depended upon acoustic detection of submarines. The Soviets are known to have in operation only one nonacoustic system—MAD equipment in their ASW aircraft—but are fully aware of a wide range of other nonacoustic techniques.

New Soviet active sonars and ASW radar identified during the past 5 years and the ships on which they are deployed where known are as follows:

- 3 kHz sonar (submarines)
- 3 and 4.5 kHz sonar (Moskva)
- Possible 4 kHz sonar (Krivak)
- 8 kHz hull-mounted sonar (Kanin and Kresta-II)
- 14-16 kHz dipping sonar
- 11-18 kHz sonar (Petya)
- BM-1 sonobuoy
- Moored acoustic buoy
- Ingul device
- J-band ASW radar

These new, lower frequency sonars are deployed mainly in the newer Soviet ships and submarines, whereas the majority of the fleet is equipped with sonars operating in the 15 to 30 kHz frequency range, characteristic of technology between World War II and 1955. The identification of the lower frequency sets, however, clearly illustrates Soviet efforts to increase the range of sonar systems. Backfitting of older ships with new lower frequency sonars continues slowly.

In addition to using the lower sonar frequencies, the Soviets also first used dipping sonar and variable depth sonar (VDS) during the past five years. The dipping sonar is used mainly by the Hormone helicopters on the Moskva- and Leningrad-class ships, but it also has been noted in a few Mirka- and Petya-class ships and on at least one hydrographic ship. The Hormone sonar is an active-passive type with active frequencies in the 14-16 kHz range. There are as yet insufficient data to estimate with confidence the initial detection ranges achieved by the Hormone's dip sonar, [redacted] A reasonable initial detection range of the Moskva VDS under good conditions with the transducer and target on the same side of the layer would be between 4,500 and 7,500 yards. The use of dipping sonar by surface ships is not particularly significant since the ship must be practically at rest in the water before it can be used, but it does provide a type of "quick-and-dirty" variable depth capability useful in some special situations. Towed VDSs have appeared on the Moskva and Leningrad, the Krivak class, one unit of the Petya class, and there is some evidence that it is to be backfitted in units of the Kashin class.

In general it appears that the Soviets are "pushing" their designers of acoustic antisubmarine detection devices. There is some evidence that the Moskva and Leningrad helicopter antisubmarine ships were possibly intended to be able to make use of the theoretically high search rates provided by bistatic operations; however, there is little evidence of use of this method, possibly because of difficulties with the complex signal processing techniques required by such a system. It is anticipated that the Soviets may pursue this development, however, with an eventual measure of success.

New Soviet ASW detection systems for aircraft have included an improved sonobuoy, designated BM-1; a high-resolution radar, designated Wet Eye; and possibly an improved magnetic anomaly detector. These new systems do not significantly extend detection ranges of ASW aircraft, but they improve the probability of accurate localization of a submarine contact. The Wet Eye ASW radar and the BM-1 sonobuoy are part of the new ASW detection system of the IL-38 and Tu-142. Wet Eye is a J-band search radar with a range of up to 75 miles against a surfaced submarine. In addition, Wet Eye can transmit coded pulses to interrogate a BM-1 buoy. The BM-1 is the first Soviet sonobuoy to use an FM radio carrier. It is a passive, omnidirectional buoy, but several buoys together apparently can provide target bearing. An unusual feature of the BM-1 is its restricted audio range of 6 to 7.5 kHz, a narrower bandwidth than any other Soviet ASW sonobuoy. [redacted]

Soviet accomplishments in fixed submarine detection systems generally have been unspectacular, and there is no evidence that they are anywhere near an effective ocean surveillance system. Soviet development of fixed (shore-based) hydroacoustic systems has continued during the past 5 years with the installation of a second limited range, acoustic device, designated the Ingul device and the introduction of a moored hydroacoustic buoy, designated Cluster Sand by the US. The medium-range Ingul device has been under development since at least 1963. Two of these devices are known to exist, both in the Pacific. The Ingul device is a large cylinder, 65 feet in diameter, probably bottom moored in the deep sound channel which could probably provide detection ranges of less than 100 miles when fully operational against a modern submarine. [redacted] Probably not yet an operational system, it may be intended for surveillance of the Kamchatka basin to augment other defenses. It probably would not be effective in most Soviet coastal waters where geographic factors, coupled with limitations in Soviet cable technology, preclude the exploitation of the deep sound channel. Since the spring of 1970, several Cluster Sand buoys have been recovered in widely separate locations in the Barents/Norwegian Sea area. The buoys are strong, well-made, expensive devices that are capable of being moored at considerable depth (to about 4,000 feet) for a long period. [redacted] a preliminary estimate is that detection ranges against a modern nuclear submarine would be less than 10 miles in most areas. Thus, the Cluster Sand system would probably have little effectiveness against SSBNs, unless it was to monitor choke points or other restricted areas. Other uses of the Cluster Sand might be for defense of the sea approaches to the USSR and as delouse points for transiting Soviet submarines.

Because of the requirements to protect their own forces and coastal areas from submarine intruders as well as the existence of US Polaris/Poseidon ballistic missile submarines, it is virtually certain that the Soviets will vigorously pursue research on acoustic and nonacoustic submarine detection systems. For the long term, the Soviet may be attempting to develop a revolutionary type of detection/sonar system based upon infrasonic waves, bioacoustics, or nonlinear acoustics. The Soviets possess a vigorous program for the *in situ* study of physics of sound in the sea. This type of investigation is costly and tedious but, in the long term is fundamental to prediction of the acoustic environment. Soviet research in array design and signal processing is more or less evolutionary in nature. Progress in array design is suggested by the changes in the sonar domes appearing on naval ships. [redacted]

For over a decade the Soviets have carried out research and development in a number of areas either directly applicable to or related to the nonacoustic detection of submarines. The full potential of nonacoustic techniques for submarine detection is not yet generally understood, and there is no indication that the Soviets have made greater progress than any other country in developing these techniques. While there is no evidence of a comprehensive, coordinated R&D program in the USSR for the overall problem of nonacoustic submarine detection, some pertinent research activities are undoubtedly receiving military support and direction. The Soviets have been investigating a number of technologies which have potential application to submarine detection. These include work in such fields as electro-optics and nuclear and magnetic detection devices. [redacted]

[redacted] an infrared submarine detection device is being developed. None of these have been developed sufficiently for deployment in an ocean surveillance system. Very little evidence of R&D in this and other nonacoustic areas, however, is available.

MILITARY ELECTRONICS

Communications

Soviet communications efforts are currently directed toward the creation of a unified automated communications network with the majority of the stated goals of the 1971-75 Five Year Plan having this as their end. Electronic and semi-electronic switching equipment will continue to be developed with actual service not contemplated before 1980. When the problems in developing and producing quality multiplexing equipment are solved, the Soviets can be expected to make full use of the recently developed Voskhod and Druzhba high-capacity radio relay systems. These systems will replace the medium-capacity R-60/120 and R-600 systems in main trunk routes with such new equipment as the R-300 and fully transistorized low-capacity links being used on branches and in rural systems. Development of these systems in quantity should not materialize until 1975. Frequency division multiplexing will continue to be heavily used with the emphasis on reliability, miniaturization, and better filter techniques. By 1975, pulse amplitude and pulse width modulation will be possible in voice communications. Multichannel laser communications have been tested and could come into operational military use in the next few years. Waveguides also have been tested, but the problems inherent in installing and maintaining such a system make its use doubtful. Troposcatter systems will continue to be widely deployed, mainly across inaccessible and rugged terrain. Increased use can be expected of mountain diffraction and passive relay systems for microwave communications beyond the horizon.

The USSR has been using buried antennas operating in the lower portion of the HF spectrum since about 1961. These antennas have a high degree of survivability and probably will be used to assure the availability of strategic communications in the period after a nuclear attack. Communications blackout in a nuclear environment would probably exist for an unknown period of time, although there is evidence to indicate that the Soviets consider this blackout to be less disruptive and to last for a shorter period of time than predicted in the US. Such antennas were first deployed within the USSR, but they are now appearing in East Germany, Bulgaria, Romania and Hungary, with the total number exceeding 370 antennas at some 150 facilities.

Most of the antennas are 16-element arrays of two basic sizes which are usually deployed in pairs on the same azimuth to broaden the frequency range. The gain of the array is about 10 db below that of an aboveground vertical monopole. Even though these antennas launch surface waves that are usable at very short distances (<200 km), all evidence indicates that they were designed for sky wave propagation at distances up to 1,000 km or more.

Communications in the North Siberian areas have been greatly augmented by the scatter and microwave links constructed from the Kola Peninsula across the northern mainland to the northeastern tip of the USSR. Intermediate areas are served with high-capacity, broadband communications facilities, and the east-to-west trunk line facilities have been greatly relieved.

The Molniya communications satellite program is broadening the Soviet communications base and provides service to military as well as civilian users. Communications satellites (comsats) are expected to fulfill a necessary function in the Soviet command structure. As an adjunct to ground systems, comsats will provide redundant communication paths. Terminals already are installed at SRF headquarters and ICBM sites. Tactical and naval terminals may soon follow. An apparent trend in comsat hardware is toward larger and higher power satellites to reduce the size of ground dishes required, as exemplified by the small dishes used at ICBM sites. Soviet comsats may employ higher gain beams and power on the order of hundreds of watts to enhance significantly the system's capability by at least 1975.

Use of communications satellites will increase during the period and future systems are expected to have significantly increased channel capacity. The recently launched Molniya-II series of elliptical orbit comsats will be used with the stationary Statsionar-1 satellite to provide around-the-clock coverage for the entire Soviet Union. With the successful assumption of this role, the Molniya-I satellite series may then be dedicated to military or space use. The Orbita ground station system will be upgraded to transmit and receive, and facsimile newspaper service to these stations will be improved and expanded. Comsat-to-ground laser links may come into use by 1980.

The R100 series of ground force tactical radios through at least the R125 model has long been in existence, but not all models have been in widespread use until recent years. Most notably among those not in widespread use until recently are the R107 and R123, both high HF/low VHF and VHF/FM radios designed mainly for voice communication. Some modified models of R100 series radios operated in the high HF/low VHF range are suspected to incorporate total solid-state components. Introduction of smaller, lighter, and more efficient models could occur at any time.

A significant event related to Soviet communications in recent years is the introduction of HF single sideband equipment. At least two military versions are being used, and both are a continuation of the basic R100 series of tactical radios. These are the R130 and R140. The R130 is designed to replace the R112 and some of the VHF/FM voice radios at division level and below. The R140, though essentially the same as the R130, is designed to operate over a greater range and, in conjunction with the R405, to be remotely keyed. The R140 is intended to replace the R118 and some VHF/FM voice facilities at front through division levels. [redacted]

In recent years the R408 and R409 have been brought into fairly widespread use among the ground forces. The R408 and FM/FDM troposcatter system, operating in the 470-630 MHz frequency range with a 13-channel capacity, is being used for communications from the Ministry of Defense to front level and tactical air armies. In some areas where either terrain or widely separated operations dictate, it could be used for communications to army level. [redacted]

The total Soviet air defense communications complex uses the radio-frequency spectrum from LF to SHF and landlines for carrying voice, morse, printer, and data transmissions. The shortcomings of low-speed, low-capacity manual morse, which has been the backbone of air defense communications for many years, are being overcome by the spread of multichannel radio relay systems, often transmitting formatted data between lower military echelons.

There is a trend in Soviet air defense communications toward increased frequency flexibility, traffic capacity, and transmission speed. A variety of equipment operating in several portions of the LF, MF, HF, VHF, UHF, and SHF ranges provides propagation reliability as well as some degree of protection against jamming. Traffic capacity has increased with the spread of multichannel radio relay equipment such as the R400/M and R401/M to lower echelons and the R400/M and R405 to higher echelons. The 24-channel R404 was introduced in 1965 into air defense echelons from army through regiment level. The R408 tropospheric scatter system is used in some areas. This system has the advantage of fewer relay stations and serves medium echelon (zonal level-corps to division) air defense command and control communications.

The Soviets will continue to use VHF equipment and gradually add UHF equipment for ground-to-air, air-to-air, and air-to-ground communications.

Older fighters use the six-channel R801 (RSIU-4), and newer fighters use the 20-channel R802 (RSIU-5), both operating in the 100-150 MHz range. [redacted] The R801 and R802 are believed to have an adapter for reception of data link transmissions, and both probably will continue to be used for voice and data command communications.

Improvements in military airborne HF communications are expected at any time and will include single sideband (SSB) and selective calling capabilities. SSB sets—Prizma-2 and Mikron HF sets—are used on civil aircraft. These modern sets use frequency synthesis schemes to provide a large number of selectable channels. The channelization scheme of Mikron has been adopted as the Soviet standard and provides for 220,000 channels spaced 100 hertz apart throughout the operating portion of the HF band. The present standard airborne HF set, the R837, provides 18 pretuned channels. The VHF transceiver Lotus provides 1,040 channels with 50 kHz intervals in the 100 to 151.95 MHz range. Airborne radio usage is expected to expand in the 200-400 MHz frequency range due to the overcrowding in the 100-150 MHz portion of the spectrum.

The Soviet Navy will continue to use effectively many different methods of communication with ever-increasing technical sophistication in its equipment and procedures. Manual morse has generally continued to be the basic and most reliable mode of communication but has declined in overall use with the introduction of faster, more secure systems. The use of automatic morse has also declined, but it may be retained for back-up. Increased use of frequency shift keying (FSK) radioprinter and secure voice systems is expected. Radioprinter scrambler is in wide use and provides a long-range secure broadcast technique for communicating with out-of-area vessels. Soviet interest in the use of the UHF band for tactical communications continues, although there has been no move in that direction. The only communications data system specifically designed for use in a frequency region well above VHF is one that operates in the 1450-1750 MHz range and has a coastal/shipboard ASW application.

A very significant development in Soviet naval communications has been the development and operational deployment of several tactical communications systems. One of these, the only tactical ciphony system that operates in the VHF region, is in widespread use throughout the Soviet Fleet. The Soviet Navy's basic HF analog ciphony secure speech system on both ship-to-shore and shore-to-shore links has also been extensively used at reduced powers for tactical ship-to-ship communications. [redacted] Use of acoustic communications devices and techniques is expected to be expanded. Some form of satellite communications systems serving out-of-area naval units may be imminent.

The considerable research devoted to electronics-associated microminiaturization could find applications in military communications equipment. The development and production of such equipment will depend on an improved Soviet capability to produce microelectronics, particularly integrated circuits, which is now clearly lagging the capabilities of the Western nations.

Soviet researchers at IZMIRAN are investigating the propagation of VLF and HF waves via magnetospheric paths and the stimulation of VLF emissions in the magnetosphere. Propagation from both earth-to-satellite and earth-to-earth conjugate point has been investigated. Voyages of the SSESS Borovichi in 1968 and the Nevel and Borovichi in 1970-71 to the Indian Ocean provided an opportunity for reception of VLF and HF signals transmitted from Gorkiy. A separate, joint Soviet-French program involves the conjugate points of Sogra, USSR, and Kerguelen Island. Both programs are unclassified, relatively low-level efforts to explore propagation phenomena. Their results, however, may be used in the development of future long-range communications techniques.

The Soviets have intensified their R&D program in troposcatter communications, with emphasis on systems utilizing frequencies in the low SHF range. A system announced in 1967 as a proposed follow-on to the presently deployed Gorizont system apparently is under test in the Leningrad area. It will operate at about 4.5 GHz and is intended for video transmission as well as the voice, facsimile, and teletype modes presently being carried by the troposcatter mode. There is some evidence that this new system will use angle diversity to minimize fading; if proven successful, this technique will permit more economical and rapid deployment than systems employing space diversity.

As the required digital and analog hardware becomes available, the Soviets could develop and deploy by the late 1970s communications systems employing spread spectrum techniques. Such systems will improve signal reception in both a man-made and natural noise environment, provide signal security by the transmission of noiselike sequences, and allow for random access into multi-channel communications links. [redacted] Recent emphasis on the development of acoustic delay lines, which may be used in lieu of shift registers in the correlation process, may further suggest Soviet efforts to develop the necessary hardware to permit the deployment of spread spectrum signals.

Considerable information is available on Soviet research in the microwave radiometry region. It is known that they have flown radiometers in the 0.8, 1.5 and 3.2 cm bands in aircraft and in the 0.8, 1.35, 3.4 and 8.5 cm bands in the Cosmos satellite series for Arctic ice and ocean surface temperature surveys and atmospheric absorption studies.

Electromagnetic warfare

The Soviets have an intensive electronic countermeasures program which includes electronic jamming, deceptive repeating, and chaff. While electro-optical countermeasures have not yet been observed, except for infrared flares, their deployment is expected at least by 1974. The Soviets are believed to have a comprehensive inventory of airborne, shipborne, and land-based jammers [redacted] Ground-based spot and barrage noise jammers provide the Soviets with a capability to jam air-ground and ground-ground communications links and airborne radar. Airborne jammers provide them with a capability to be used in helicopter and ECM support aircraft for jamming ground-ground communications links and ground-based air defense radars. [redacted] Multichannel operation is a regular feature of Soviet airborne masking jamming, while the multiple modes of operation include sweeping, hopping, on-off switching, bandwidth changes, "clicks," and tone rate changes. They have successfully interfered with US navigational systems; known communications jamming efforts have been directed at single sideband teletype and AM/FM voice systems. The current Soviet anti-radar jamming capability is evaluated as having provision for automatic frequency set-on of the jammer transmitter and for look through (that is, turning off jammers momentarily to listen for radars being jammed). The sizes and variety of waveguide-fed radomes on Soviet ships are believed to be evidence of wide frequency coverage jamming capability.

A Soviet trend toward the development of new techniques for performing barrage and confusion jamming has been evidenced. One particular technique is the use of several spot-noise jammers stacked to cover a specific frequency range with possible synchronized look-through features. Additionally, there is evidence that the Soviets are now employing deceptive jammers against airborne intercept radars. This deceptive jamming is judged to have taken the form of range and velocity gate stealing, coupled with some means of angle deception. It is within their capability to extend these pulse-deception techniques to encompass ground radar threats. The Soviets are expanding an established program of deploying specially configured ECM aircraft whose sole function is to provide active and/or passive jamming support. Such aircraft as the ECM-configured Cub, Brewer, and Badger incorporate the newest advances in Soviet jamming technology. All major air arms including Military Transport Aviation now incorporate these support aircraft. The main objective of these aircraft is to create confusion and indecision in the early warning and ground controlled intercept network, thus enabling penetration of the weapons-carrying aircraft into the target areas. The weapons-carrying bombers maintain their own self-protection ECM against terminal threat tracking radars. Soviet development of active ECM devices has relied mainly on wide-band noise jammers, with repeaters as an alternate technique. Jammers using voltage tunable magnetrons (1-3 kW power output) are believed to have been developed at the Scientific Research Institute for Electro-Technics (NIIET), Fryazino. Jammers for both ground-based and airborne use are believed to be under continuous development.

Soviet development and deployment of chaff includes metalized paper, metal foil, and metal-coated glass fibers. The Soviets have shown some originality in the selection of materials and techniques in their metal-coated fiber chaff. Some of the most significant advances in Soviet chaff technology probably have been in the development of dispersion techniques. Recent events indicate the Soviets may have developed dispensing techniques for use with a modified form (partial coating) of their zinc-coated, fiber-glass chaff. Airborne chaff cutters which cut chaff according to the frequency band of the threat radar have been reported, and delayed-opening chaff has been observed. Whereas the Soviets have employed trail-dispensed obliteration chaff from aircraft for many years in numerous and regular ECM exercises, there is now evidence suggesting the use of rocket-fired chaff, for example, of a wing pylon mounted type in the Firebar for evasive purposes.

Reported observations of chaff launchings from Soviet ships are sparse and generally unconfirmed. Probable chaff launchers that have been seen include dual-type rocket launchers on the Moskva and Kresta classes and 16-shot launchers on the Krivak and Nanuchka classes. These shipboard rockets are likely to be weapons oriented and have decoy and centroid-shift functions and not obliteration functions. The deployment in Soviet warships of a large amount of new generation ESM/ECM equipment, supported by chaff launchers, has been observed during the past several years. The Soviets undoubtedly have a continuing R&D effort in the area of electronic defense of ships against both aircraft and antiship missiles. Although exoatmospheric dispersion of chaff has not been noted, the Soviets probably will develop a capability for sowing chaff or other penetration aids, including jammers, to mask reentry vehicles against Western ABM systems.

The Soviets have long maintained an extensive fleet of ships deployed worldwide for data collection, particularly for signal intelligence purposes. The tactical role of these ships, however, has been considered as extremely minimal, but the deployment of Primorye-class ships has signaled the initiation of a totally new concept for Soviet AGIs during wartime tactical environments. The Primorye-class ships, capable of speeds compatible with a naval task force, have been assessed as having extensive, sophisticated intelligence collection capabilities. The ships have on-board processing facilities for analysis of information collected by them or provided by other sources; jamming and deception equipment for electronic warfare support of a task force; and high-power secure communications for receipt and dissemination of intelligence information and for command and control.

It is expected that the Soviets will continue their current rapid rate of developing electronic warfare capabilities to counter US radars and communication networks for the next 5-10 years. Soviet equipment and techniques for radar and communications (including secure communications) deception and jamming of advanced radar fuses will become increasingly sophisticated and will have improved performance capabilities. Development of equipment with higher jamming power per pound will be emphasized. Reaction times for electronic countermeasures devices are expected to be shortened, and the capabilities for multiple-target jamming increased. Equipment for confusing and/or denying the use of navigational devices is likely to be expanded in an effort to keep pace with improve navigational systems developments.

Soviet reliance on chaff has prompted research programs aimed at developing lighter, more efficient chaff. The development of new types of chaff cannot be discounted. At present, however, there is no firm evidence of such development. Also, the Soviets are probably actively engaged in the research and development of infrared countermeasures equipment, including flares, coherent light sources, arc lamps, and infrared detectors for their aircraft. Details on the type of equipment that might be deployed, however, are still not fully understood.

The heavy Soviet investment in beam-plasma devices during the late 1960s may result in the development of high-power broad-band noise jammers in the next 5-10 years. These devices are capable of generating 10-100 kW of noise power distributed over an octave or more of frequency bandwidth. Another possible area of development is the use of high-energy pulses from ground-based jammers as an RF burnout technique against airborne radars.

Airborne radar

The Soviets continue to develop and deploy a variety of new airborne intercept (AI) radar systems. The Big Nose/Fiddler weapon system, operational in 1968, was the first Soviet all-aspect attack system. The Big Nose radar is a dual-frequency radar, operates in the 9-GHz band, and employs passive lobing in the track mode. The search/track ranges observed for this radar have been greater than those of any previous Soviet airborne intercept (AI) system. The Jay Bird/Fishbed J system, which became operational in mid-1969, operates in the 13-14 GHz band and uses a 10-bar raster search scan with 4-way lobe switching for the tracking mode. This radar has demonstrated a low-altitude performance capability that is better than that of the Spin Scan/Fishbed systems. The Spin Scan radars have continued in use on the new models of the Fishbed (including the export version of the J model). [redacted] To realize the full capability of the Foxbat, a high-average power, pulse-doppler AI radar appears to be required to provide the longer search/track range and look-down/shoot-down performance. A capability of the radar on Foxbat to detect airborne targets immersed in a clutter background would provide the Soviets with their first true airborne moving target indicator (MTI) capability, but limited available evidence does not indicate a look-down capability for that aircraft.

Solution to the problems associated with low-altitude flight operation both from the AI and the ground support aspects will require the development of terrain avoidance/clearance radars, likely in the form of multifunction radars. The development of a passive or home-on radiation radar system along with compatible missile guidance systems is believed to be currently in a test phase and may soon be operational.

The Moss/Flat Jack, an AWAC aircraft, was introduced in 1968 to extend the range of the Soviet air defense system. The most unusual external feature of the radar is its 35-foot rotodome antenna. Flat Jack is estimated to have the capability to search for, detect, and track both airborne and surface targets over sea areas and is used to control interceptor aircraft.

The Soviets have carried out research in all important areas related to the development of a low-altitude AMTI AI radar system. The level of Soviet work and the time frame in which the pertinent research was carried out indicate that development and testing of such a system could be going on at present or could begin shortly. Although the particular type of AMTI radar under consideration by the Soviets cannot be determined on the basis of available information, it probably will incorporate coherent processing techniques and probably will be capable of detecting and tracking low-flying aircraft in at least moderate clutter. Soviet conformal array antenna research is applicable to airborne monopulse tracking and homing radars, multifunction array radars in the nose of a fighter aircraft, or side-looking radars for bombers.

Development of conventional 8 to 15 GHz-band bombing systems characterized by RF switching capability and frequency diversity will continue. Bombing navigation radars appearing in the 1970s will include a capability for frequency diversity. The Soviets are expected to continue to increase the portion of the spectrum used in their offensive electronics in order to reduce the effectiveness of specialized Western ECM equipment. ECCM development for these systems will be stressed and will probably be comparable with similar development in the West. The Soviets have developed an improved follow-on to the older Shore Walk [redacted] tactical blind bombing system, which is on their tactical bombers. The Soviet tactical fighter Fitter has demonstrated a lob bombing capability. The delivery system is not presently known but because of the accuracies involved it is believed to use more than a simple optical system, possibly an inertial-type similar to US low-altitude bombing system (LABS) equipment. By 1975 the Soviets will probably have perfected an effective low-altitude terrain avoidance radar which will enable 500-foot altitude flights over rugged and unknown terrain.

ASM target acquisition radars have been designed to provide the launch aircraft with accurate range and target bearing data. A new ASM system target acquisition radar, Down Beat, is now operational on the Blinder B. Other recent developments include an improved capability for the AS-3/Kangaroo with the introduction of a second RF in the Crown Drum radar.

The first Soviet tactical ASM has been deployed on Fishbed F aircraft in East Germany. This weapon should offer greatly improved accuracy over that of unguided rockets against ground targets. As a result of Soviet efforts to build advanced strategic aircraft, for example, the Backfire, improved target acquisition systems compatible with high-speed, long-range, standoff missiles can be expected.

Navigation aids

The Soviets have achieved a level of adequacy in navigational electronics through a program using copied Western equipment designs and methods mixed with native designs in selected areas. Conventional methods and equipment have been employed for aerospace navigational purposes, with emphasis on radars and improved traffic control equipment. The most recent Soviet developments have been highlighted by doppler and possibly inertial techniques. The widespread deployment of the SVOD system appears to have satisfied present requirements for short-range navigation within the Soviet Union. SVOD [redacted] furnishes range and azimuth information, but it is believed to have the additional capability of identifying as well as relaying position information to a controller on the ground. Western-type VHF omni range (VOR) and distance-measuring equipment (DME) systems have been noted on some Soviet transport aircraft. The SOD-57 system is capable of passing altitude data from the interrogated aircraft to the traffic controller while the aircraft is in a landing pattern. This feature is found on fighters as well as on other military aircraft. The Soviets appear to have made some advances in air traffic control in the last few years, such as the development of the Big Eye air route surveillance radar and its associated beacon interrogator.

Limitations in inertial component technology and problems with the associated electronics hardware are believed to have prevented the Soviets from deploying an airborne inertial navigation system (INS). Although greater space and opportunity for maintenance have probably permitted development of some type of INS onboard Soviet ballistic missile submarines, the quality of these systems is probably inferior to that of US systems and the Soviets probably have to update these systems more frequently by the use of external navigation aids. Otherwise, errors of the INS will contribute considerably to the CEP of a missile carried on board. The operating lifetime of inertial components is considered a major problem for the Soviets. A newly placed Soviet emphasis on component quality control and improved production techniques is probably directed toward solving this problem. A major achievement for the Soviets would be the development and deployment of a reliable gyroscope with gas bearings, a type of gyro which displays an extremely long operational lifetime. Soviet attempts to purchase this COCOM-restricted item [redacted] are expected to continue.

The Soviets are expected to increase their long-range navigation capabilities by developing an integrated navigation system which will use a combination of doppler, inertial, and stellar navigation systems eventually leading to a completely fail-safe air traffic control (ATC) system and a zero-zero visibility blind landing system. Although existing evidence shows that such a system has not yet been developed, the Soviets have been known to be highly involved in either producing or purchasing an inertial navigation system as a step toward the goal of an integrated system. A completely automated takeoff and landing system is probably now undergoing flight test.

While existing types of navigational aids will be modified to reflect improvements in accuracy, the trend will be toward fully automated systems such as the Trassa doppler navigation system, combined with secure communications. Doppler navigation systems will be used to provide highly accurate ground speed and draft angle information. When combined with inertial and other existing navigation systems and utilizing an onboard navigation computer, present position, course, and distance to destination can be provided. Future effort related to aircraft will be directed toward the improvement of doppler and inertial navigation systems, which will result in the overall improvement in Soviet aerospace navigational capabilities. A VLF navaid developed and installed by the Soviets does not provide optimum coverage for naval use and for this and other reasons, is believed to be associated with continental air traffic control.

The USSR has a long-range LF hyperbolic system, Moon 4, [redacted] Moon 4 is used to a considerable extent on Soviet aircraft and is also of value to the Soviet Navy. Although possible, there is no evidence on its use by the ground forces. Of special navy interest are the Soviet versions of the Western beam-swinging pulse-count system Consol and the Decca-like phase hyperbolic system Dash Fix; chains of this latter system exist in the Northern and Far Eastern sea areas. A great deal of expansion of the Moon 4 system is not anticipated due to the development of navigation satellites and, to some extent, the existing coverage of other systems, including Western equivalents.

A Soviet operational Navsat system like Transit will be improved and probably will become a prime means of updating naval ships equipped with ships inertial navigational systems (SINS). Currently, both radiometric sextants and star tracking periscopes are utilized by Soviet submarines (Y and H-II classes) for inertial system resets. Although there have been improvements in SLBM guidance systems, the advantages of electro-optics in gyro technology may be the major upgrading factor affecting SINS through the period of this estimate. Deployment of worldwide optical tracking stations provides the Soviets with detailed geodetic data and ties required to perfect navigation systems and improve chart accuracy.

Ground and shipboard radar

Soviet air surveillance radars, which are used for EW and GCI, operate chiefly in four portions of the frequency spectrum: the 70 to 170 MHz portion of the VHF band, the 800 to 900 MHz band, the 1800 to 3300 MHz band, and the 6500 MHz portions of the UHF and SHF bands. The frequency range of 545 to 635 MHz is being used by the Part Time/Full Time radars. New Soviet radars have appeared in the VHF band, but there has been a tendency to use higher frequencies in that band, as well as narrower beam widths, increased pulse rates, and better detection capabilities. All Soviet VHF radars have characteristics which result in a high number of hits per scan, usually several tens to several hundreds. The mechanical designs of these radars together with their pulse width/beamwidth characteristics indicate that they are not precision sets, although they have in some instances excellent detection characteristics.

Unlike the trend in the VHF radars, Soviet S-band radars have shown a remarkable sameness in their beam-width/pulse-width/pulse-rate/scan-rate/hits-per-scan characteristics. The frequencies employed by these radars were between 2600 MHz and 3250 MHz until the appearance of Long Track and Back Net, which operate at frequencies in the 2000-2500 MHz region. This departure from the overcrowded region of the older sets was expected for some time and indicates one of the portions of the spectrum which is likely to have greater use. The Back Net also represents a better mechanical design in that the antennas are mounted back-to-back instead of being mounted one above the other in a cumbersome arrangement.

Although the Soviets continue to use the older 3 GHz-band AAA fire-control radars, newer systems have been introduced which will supplement and probably eventually replace this older equipment. For example, Flap Wheel has begun to replace the older Firecan radar (used primarily with 57-mm AAA) and the associated Puazo director. The Flap Wheel System is estimated to incorporate numerous improvements over the older equipment. Improvements include (i) greater mobility (radar, director and power generator are all integrated into a truck-mounted van); (ii) probably a low-light level TV tracker; and (iii) possibly an additional IR tracker. The operation of Flap Wheel in the 9-GHz band also provides the Soviets with increased frequency diversity of fire-control equipment. Improved defense against low-level aircraft attack should be provided by the Gun Dish/ZSU-23-4 weapon system. The ZSU-23-4 represents a modern, operational fire-control system and indicates a capability for advanced system development. It provides the Soviets with increased frequency diversity and greater mobility. Both Flat Wheel and Gun Dish are expected to have such ECCM features as RF turnability, instantaneous automatic gain control (IAGC), and PRF jitter. The current combat surveillance radar, Pork Trough, will probably be improved by a device such as a tunable magnetron. A new 15-GHz radar is probably replacing the Pork Trough, and a new signal in the 14-GHz band possibly is transmitted by a follow-on for the Small Yawn. Such a new combat surveillance radar would incorporate weight-saving techniques, RF agility, MTI which can discriminate moving targets from stationary ground targets, and other ECCM features. A new counter-mortar counter-battery radar capable of locating accurately gun and rocket weapon firing positions as well as mortar positions will probably be developed. It could conceivably use an electronically scanned antenna and have an MTI capability and some ECCM circuitry. The Soviets will probably continue to improve their ground radar system by use of increased power, advanced receiving and ECCM techniques, and advanced modulation schemes. This trend will probably continue during the period, and future operational radars will have higher power and low-noise reception; some form of correlation detection; MTI; and more sophisticated signal processing including, in particular, pulse compression. The Soviets have devoted extensive efforts toward developing and producing components for advanced radar systems, especially high-power transmitting tubes and low-noise receiving tubes.

Among the most significant developments of the last several years in naval radar have been the extension of microwave band usage, the introduction of some new basic concepts (for example, 3-D radar), the introduction of new and modified SAM systems of unique naval design and, of special importance, the radar aspects of a continually growing Soviet antiship missile threat. Naval microwave band usage now embraces the 2.5-3, 4, 5, 6, 6.5, 8.9-10 and 10-20 GHz regions. The 10-20 GHz region is used in the radar seekers of at least one and probably several types of naval antiship missiles. Multiple band usage in a particular application is best exemplified by the SA-N-3 system whose radar employs both the 5- and 6.5-GHz bands redundantly for target tracking, the 10-GHz region for missile tracking, and the 4-GHz region for command. The independence of target tracking and missile tracking in this unique naval radar is a departure from past naval SAM radar design. The still newer SA-N-4 short-range SAM system employs the 7-GHz band and may be related to a new ground-base system.

The Soviet Navy has not departed very significantly from the much-favored 800-900-MHz region for some surveillance purposes. Operating in this band is a 3-D surveillance radar, the Top Sail; in principle, it appears to be similar to a US 3-D but using UK scanner production techniques. Several shipboard and submarine-borne radars associated with antiship weapon systems have not been satisfactorily evaluated. The radar-video system is still favored for beyond-horizon target acquisition, and its use on ship-based helicopters and the Bear D is an important electronic development. Radar-video is also employed as part of the long-range system of missile control in flight, and deliberate redundancy of frequency band has also been observed in this context. There is ever-increasing evidence that the Soviets are designing ECCM features in their naval radars. No convincing shipboard antenna for the detection of periscopes has yet appeared, but a ship-based helicopter capability in this area is expected.

Work on land-based VHF early-warning radars is likely to continue. In the 2-3-GHz band, the trend will be toward the provision of frequency agility and the use of new regions of the frequency spectrum.

The Soviets continue to be concerned with improving the low-altitude aircraft detection and ECCM capabilities of their air defense radar network. Low-altitude detection improvements will continue to be made by adding more radars, improving the detection capability of existing radars, locating radars on towers and hills, and by improving the performance of MTI equipment. Special CW radar alarm systems may possibly be developed and deployed. There is extensive evidence of modification to existing radars to improve ECCM capability, and such efforts are expected to continue. Emphasis will be placed on such techniques as rapid RF change, rapid PRF change, PRF jitter, and sidelobe suppression to defeat various kinds of jamming. Continuation of frequency diversity, frequency change capability, and dense deployment of ECCM aids is expected. High-power radars with the capability to burn through jamming will probably be developed and may be deployed. High-power transmitters have been developed for ABM radars, and such technology could be adapted to aircraft detection radars for key area defense if aircraft attack continues to be a major threat.

Soviet antenna theory is well advanced. R&D in phased array antennas began in 1954 at the Moscow Aviation Institute. This work led to development of the large frequency-steered antennas used for ESV tracking and such ABM radars as Hen House and Dog House. Basic research is continuing in phase-steered as well as frequency-steered arrays, and such new arrays appear to be under development at the Sary Shagan Missile Test Center. A number of sophisticated antennas for airborne radars, for example, conformal active arrays using solid-state transmitters, appear to be in the research stage. Conformal slot arrays for monopulse radar, also under investigation, could be used in active homing missiles.

The Soviet 3-D shipboard radar, the Top Sail, is indicative of the latest trend in Soviet naval radar development. This radar is frequency scanned in elevation and mechanically scanned in azimuth and operates in the 840-910 megahertz frequency range. A ground-based version of this radar could be under development at the Gorkiy Electronic R&D facility. The trend is probably toward three-dimensional radars utilizing mechanical azimuthal scan and either multiple beams or electronic scanning (probably frequency scanning) in elevation, and possibly a mobile tactical phased array.

Radar research and development now under way in the USSR will not only result in further advances in operational radars but may result in the use of unconventional radar techniques in the future. The Soviets have for many years investigated the phenomenon of over-the-horizon (OTH) propagation of high frequency (3-30 MHz) radio energy and now have a developmental long-range detection capability with OTH radars. Their research on OTH propagation in the 1950s and early 1960s relied on the backscatter sounding work of N. I. Kabanov and Yu. A. Chernov. In the early 1960s the Soviets began a program in the use of OTH radar to detect ballistic missile launches. Much of this research and development was conducted at Nikolayev, with possible experiments in radar netting in cooperation with transmitters located at Taldom near Moscow. The B384Z (Marylebone) signal transmitted from Nikolayev has apparently been used for detection of some Soviet ICBM launches at Tyuratam and for detection of US Apollo launches. In 1968 the Soviets began construction of an operational OTH radar at Nikolayev. When this system is complete, probably in 1973, it will most likely use some form of the B384Z signal in its probable role of early warning against missiles launched from the People's Republic of China.

Future developments in systems may include an OTH radar designed to look toward the US. Such a radar would encounter the problem of trying to avoid the high propagation losses involved in transauroral propagation. The Soviets have been investigating transpolar HF propagation since the 1950s and it is possible that they can avoid much of the auroral absorption loss by suitable positioning of OTH radars to choose propagation paths over or under the high loss regions. A large HF broadcast antenna under construction near Angarsk may be used to test the feasibility of using such a propagation path. Another problem for the Soviets is improving OTH detection reliability, which can be degraded by ionospheric phenomena. One recent Soviet approach which may succeed in improving reliability is to use a backscatter sounder in association with the OTH radar. The sounder can provide real-time ionospheric data for OTH radar frequency control. Such sounders appear to be used in conjunction with the B384Z testing, and a backscatter sounder is believed to be under construction at the Nikolayev OTH radar facility.

The Soviets possibly will deploy OTH radars in the future to observe regions around the periphery of the USSR. Such radars could provide early warning of an IRBM, MRBM or SLBM attack on the USSR. An antenna suspected of being part of such a system is now under construction near Lvov on the Soviet/Polish border, but such radars would probably have no greater azimuthal coverage capability than the Nikolayev OTH radar, which is estimated to have less than ±20 degrees coverage. Therefore, a number of such radars would be needed for complete coverage of peripheral areas, and the total system cost would be high.

The Soviets have displayed no interest in using OTH radar for real-time detection and tracking of hostile aircraft. Such OTH use presents a more difficult problem than does ballistic missile detection because of the low cross-section of aircraft targets compared with that of missiles in the ionosphere. Therefore the development of Soviet aircraft-detection OTH radars does not appear to be an immediate prospect. If a Soviet need for such radars arises, however, they could be developed within five years.

Soviet research to support the development of synthetic aperture radars appears to be under way at the Scientific Research Institute of Radiophysics, Gor'kiy. Much of this research has focused on solving the problems associated with optical processing and film recording of the received signal. Available evidence suggests that the Soviets are developing and may have at least one synthetic aperture radar for test purposes, but there is no evidence to indicate that an operational Soviet synthetic aperture radar has been deployed. It is likely that the Soviets will develop operational synthetic aperature radars for reconnaissance aircraft in the next few years.

Radio-radar intercept and direction finding equipment is employed for tactical surveillance and target acquisition in the radio technical company, which is organic to the Soviet divisional reconnaissance battalion and signal intercept units at higher echelons. Tactical communications intercept equipment is available to cover communications frequencies from the HF band through the lower multichannel radio relay frequencies in Western use. Tactical radar direction finders in these units and possibly in artillery instrumental reconnaissance units cover at least the .75-10 GHz band radars. The principal improvement expected is the continued deployment of a new tactical direction finding system, the Spike Square, which will provide improved capabilities and coverage of the entire Western FM voice band (20-100 MHz).

A limited number of target acquisition and countermortar radars have been seen with Soviet artillery units: Track Dish, Small Yawn, and Pork Trough. These radars are mounted on full-tracked artillery tractor chassis. None are credited with any extensive ECCM capabilities. Another transportable surveillance radar may also exist. The countermortar radars do not have a true first round capability, and the Pork Trough surveillance radar has no MTI capability. Soviet technology is capable of providing more capable radars including manpack surveillance radars at any time, although there appears to be little emphasis on improving surveillance, target acquisition and height observation aspects of existing radars.

Component development

Soviet scientists are engaged in developing klystrons, magnetrons, waveguides, antennas, and other electronic components suitable for operation in the portion of the frequency spectrum above the 9-GHz band; the lower 15-GHz band and the lower 30-GHz band appear to be the areas of most R&D interest. Some of the components could have applications to radar, where reductions in size and weight are desirable. There are indications that they have developed an inverted coaxial magnetron, probably with high peak and average power at 37 GHz, which would be suitable for radar application. The Soviets have klystrons in the approximately 2 to 79 GHz band. The lower power devices (up to 100 milliwatts) can be used for microwave instrumentation; local oscillators in receiver systems, since they are of sufficient output to be used with crystal mixers with the necessary degree of isolation; and pump tubes in parametric amplifiers and masers where excellent frequency and power stability are required. Those of one watt can be used as frequency modulators in microwave links as well as for parametric amplifier pumping. The characteristics given for these devices may well be indicative of the operational frequencies for some of the newer Soviet developed radars and communications systems.

Soviet high-power linear beam tubes have been developed since the 1950s, and development of higher peak powers and better efficiencies in these tubes is continuing. Klystron peak powers of 60 MW have been achieved. Soviet research in the use of platinum cobalt magnets in traveling wave tubes (TWTs) has begun recently, and production of such TWTs is believed under way. The use of these magnets will allow significant increases in TWT output power and reductions in tube weight.

Almost all Soviet radars operating above 500 MHz are believed to use crossed-field tubes in their output stage. Until 1960, this tube usually was some type of magnetron oscillator. Though magnetron oscillators are still predominant in radar use, amplifier chains using crossed-field amplifiers (CFAs) may be expected to come into use in increasing numbers. Newer Soviet radars, such as Top Sail and Long Track, probably use CFAs in their output stages. The frequency stability of the Part Time radar suggests that an amplifier chain of some type is used for its transmitter.

Soviet high-power crossed-field tubes for radar use were developed in a continuing program begun at NIIET (formerly NII-160) prior to 1945. Almost all significant Soviet work in this area has been done at NIIET, Scientific Research Institute for Electronic Instruments (NIIEP) (formed in 1961), or at the Experimental Design Bureau 382, all located in the Moscow area. The objective of this program was the development of tubes with high-peak power and, after 1948, tunability. The developmental program produced a 30-MW magnetron for the Hen Egg radar and a 60-MW CFA for the Try Add radar. A number of lower power (2 MW and below) magnetrons or CFAs are now available for use in the frequency bands from 500 MHz through about 40 GHz. Coaxial magnetrons have apparently been under development at least since the early 1960s, and a design group at NIIEP is working on increased power and higher frequency operation of these tubes. This work appears to be intended for the development of high-power, stable-coaxial magnetrons, possibly for use in rapidly tunable pulsed-on FM-CW radars in the wavelength range from about 3 cm into the millimeter wave range. While they have been successful in attaining high-peak powers, the attainment of high-average powers in crossed field tubes does not appear to have been a priority Soviet goal and, consequently, most Soviet crossed-field tubes have rather low-average power capability.

The Soviets developed a number of grid-controlled tubes for use in their VHF and low UHF band radars during the 1950s. Two basic tube designs have resulted from this development: the gridded tube oscillator for pulsed radars and the resnatron for CW radars. Soviet pulse-power triodes or tetrodes normally are used in an oscillator circuit which has a very wide mechanical tuning capability. This application would allow Soviet VHF radars to tune over wide frequency ranges in a few seconds to overcome electronic countermeasures attempts. Versions of these tubes have been developed which can be tuned electronically over a narrow range on a pulse-to-pulse basis. In the development of high-power gridded tubes for CW radar, the Soviets have departed significantly from Western design practice. The resnatron, a tube long considered obsolete in the US, has been made into an efficient device which can be mechanically tuned in less than 100 milliseconds over a 10 percent bandwidth. A number of these tubes, each producing 100-kW of CW power, are believed to be used in the Dog House radar, probably as phased-locked oscillators. The Soviets presently are believed to have the capability to develop resnatrons for radar output tubes up to about 2 GHz. [redacted]

The Soviets make use of traveling wave tube (TWT) RF pre-amplifiers in radar receivers ranging from low UHF (Flat Face) to the 3-GHz Bar Lock (2690-3120 MHz); TWTs are probably also used in the 5-GHz Fan Song and in the Thin Skin (6500 GHz). The TWT in the 3-GHz Fan Song achieves a 6 to 7 db noise figure, but those used in search radars of the same development period have noise figures of 9 to 11 db. Noise figures of down to 3 db may be available in some narrow band TWTs for some applications. The Soviet TWTs are designed to allow easy change of the vacuum-sealed glass envelope in the field and do not require exchange of any of the magnetic or mechanical structure. Other probable characteristics of Soviet TWTs are power output of 20 watts CW and probably of 200 watts CW or 2 to 5 kW peak and saturation gains of 45 db. The status of Soviet projects on the Spiratron and of a possible one on a traveling wave tube incorporating superconductivity is not known.

The Soviets have generally been slow in applying solid state technology in their military electronics, although a defector stated that Soviet ABM receivers were transistorized. It is not known to what extent the Soviets have protected circuits that incorporate transistors, printed circuits, and other components against the effects of electromagnetic pulse.

The Soviets make wide use of electrostatic storage tubes in radar signal processing. Storage tubes are used both as memory devices and as video integrators for the purpose of suppressing nonsynchronous interference. Many Soviet ground-based radars have MTI that use storage tubes as memory devices. The LN9 storage tube in the Spoon Rest is a sophisticated design and provides adequate MTI performance. Reportedly, a more complex tube, the LN12, is used in the height-finder Side Net radar.

Research on amorphous semiconducting materials originated in the USSR about 1955. Such properties of these materials as inherent radiation resistance, insensitivity to impurities, and ability to retain memory in the event of power failure are the main reason for Soviet interest in amorphous materials. Prototype amorphous semiconductor switches are known to have been developed in the USSR prior to 1968. Soviet emphasis on amorphous semiconductor R&D, funded possibly by the Ministry of Electronics Industry, appears to have increased since the 1966 US announcement of the development of an amorphous electronic switch.

Soviet research in plasma-filled or beam-plasma devices has been in progress for over 12 years. No production devices are known to have resulted from this research, and the problems of plasma generation and confinement remain as obstacles to a production device, but the potential for a breakthrough in this research area is high.

The Soviets exercise close control over information on advanced microelectronic applied R&D, apparently because they consider the results to be critical to military uses. Although considerable strength in basic R&D has been demonstrated, the Soviets have been unable to engineer the rapid translation of basic results into large quantities of high-quality microelectronic components and devices. With strong Party pressure, they are increasing efforts to overcome such lags through rapid proliferation of large microelectronics R&D facilities that are closely tied to production facilities. A notable example of such facilities is found at the very large complex built up over the last 10 years at Zelenograd, about 44 kilometers northwest of Moscow. The several large facilities for R&D on integrated circuits and other components and devices work directly with large production facilities in the Zelenograd complex, but information on their products is fragmentary. Although they have developed domestic equipment for making micro-electronic devices, the Soviets continue to depend on exploitation of Western equipment and technical know-how to implement microelectronic production. The current emphasis in such exploitation is on techniques and devices needed to resolve specialized problems for improving the operation of production lines. The Soviets have not yet indicated any deliveries in quantity of specific models of equipment that employ large numbers of high-quality microelectronic circuit modules. They have described and displayed some samples of many types of thin- and thick-film hybrid circuit modules since the early 1960s. The use of such circuits in relatively simple devices, such as the Mikro radio which was offered for export in 1964 and 1965, indicates Soviet capabilities for making at least limited quantities of hybrid microelectronic circuits for special applications. Since 1967, the Soviets have described numerous types of small-scale integrated circuits in catalogs and displayed some samples at international exhibits. Although they clearly can make at least small-scale integrated circuits for special uses, they have not yet demonstrated the ability to achieve high yields in making large numbers of high-quality integrated circuits. Examinations of earlier samples of Soviet integrated circuits revealed poor quality control in types no more complex than those produced in the US prior to 1965. The most recent samples show some increase in circuit design complexity and evidence improvements in quality control in integrated circuits up to the level of types produced in the US in about 1965-66. Since 1969, the Soviet also claim to have made metal oxide semiconductor (MOS) circuit arrays, but none of these more advanced types have been available for examination. Some Soviet R&D institutions concerned with advanced signal and data processing developments also have facilities for making and testing prototypes of large-scale MOS arrays, apparently using equipment available from industry.

Many of these new components will permit the development of improved electronic systems, since wider frequency ranges will be available with increased bandwidths and improved stability. These newer devices may not be available in the USSR in sufficient quantity for incorporation into their newly developed radars and countermeasure equipment.

Computers

Soviet computer developments probably have been adequate to meet military system needs, although the designers of such systems have tended to incorporate less demanding computer requirements than found in similar US systems. The main thrust of past Soviet developments in this area has been on computers for scientific and engineering problem solving, and R&D on more advanced, large-scale models for this purpose probably will continue. Through major efforts now under way, the Soviets probably will develop and make available large numbers of computers and related equipment comparable to US models of 1965-67 for use in industrial and economic data processing applications. The Soviets probably have some domestic computers which exceed the computational capabilities of the BESM-6, although this has remained the largest openly revealed Soviet model since its announcement in 1965. The Soviets have major facilities that have demonstrated capabilities for developing such large-scale scientific computers, but tight security control is exercised over information on their advanced work. There is a similar dearth of information on the products of some large computer production facilities in the USSR. The need for Western technical assistance and some Western devices suggests that the Soviets will continue to be much more open with information on their development and wide-scale introduction of data processing equipment.

In cooperation with Eastern European countries, the Soviets have begun production of the smaller models in a series of computers employing hybrid or integrated circuits based on design copied from the IBM 360 computer; this program already has encountered hardware difficulties. In addition, the USSR has not yet established software and maintenance capabilities adequate to support the use of large numbers of these computers. Concurrent development of auxiliary storage and input/output equipment similar to Western equipment used with IBM 360 computers is in progress. Successful fulfillment of plans for this new peripheral equipment should remove some of the existing constraints on computer applications in the USSR. Nevertheless, the resultant equipment will be no more advanced than Western 1967 production models. The Communist Party of the USSR has demonstrated an unusually strong commitment to this program.

Even though this new computer series, called Ryad, and related equipment are aimed primarily at civilian needs, it also will be used in military logistics and command and control applications. The wide availability and use of this equipment in civilian applications also will provide a large base of experienced manpower to assist in the implementation of military logistics planning systems. Military R&D facilities have developed independently displays as well as other specialized computer interface devices specifically designed for use in command and control applications. Because of the specialized nature of models resulting from military R&D and because most devices will be designed for use in rigorous environments, they are apt to be unsuited or too expensive for wide general uses, even if security restrictions on their dissemination do not prevail.

For on-line military systems applications, the Soviets are expected to continue their past practice of using specially designed computers of the simplest possible types consistent with the system needs. These computers will include a choice of computational approaches that minimize the level of sophistication required in the hardware and software.

It is doubtful that Soviet military computers employ components more advanced than those that have been described in the literature, but they may employ component types not available for civilian use. Installations for the development of computers for specific military systems uses are kept carefully separated from civilian installations.

Soviet capabilities in computer circuit technology now extend into the region of integrated circuits (ICs). Small scale ICs are available for design experiments, and some are being used in industrial production models. Prototypes of large-scale IC arrays also have been employed in experimental work in military-related areas such as signal processing. It is unlikely that any substantial quantities of large-scale IC arrays will be used in military computers before 1976 because of the lack of sufficient numbers of quality components and the conservative philosophy of Soviet military systems designers.

The Soviet practices of incorporating a much higher degree of quality control in military-related computer equipment and of packaging this equipment appropriately for a military environment are likely to continue. The military systems will probably continue to make greater use of expensive technology which is not economically feasible for widespread nonmilitary use. Developers of computers for use in military systems probably also will continue their practice of employing proven circuit and component technology rather than of depending on a concurrent development of new components and circuits to meet system needs.

Command and control

The Soviets will continue to upgrade their command and control communications systems and will implement new systems as they have constantly done for the last decade. They have already implemented rather effectively command and control systems for the Soviet Rocket Forces, and future improvements will be directed toward increased reaction capability and survivability. [redacted] Further expansion can be expected in the coming years due to the deployment of an elaborate, hardened command post system. This system provides for the deployment of alternates for major decision-making centers at the Moscow level to points away from that city, as well as the creation of major regional centers. In addition to advanced signal processing modulation developments (employing error correcting techniques) for HF and VLF radio networks, higher capacity communications satellites and networks will also be implemented for direct communications and weapon-unit levels of command. These may also include speech security systems and fully synchronous scramblers. Soviet Navy out-of-area communications reliability will be improved by the use of relay stations located outside the USSR, thus achieving reliable worldwide communications support for ships and submarines at sea. New high-power VLF stations will be added to an already impressive inventory of such stations, thus permitting the possibility of VLF jamming as well as adequately supporting their own communications needs. In addition to these improvements in transmission systems, the command structure, using digital processing equipment, will continue to be streamlined in support of the unified command plan of the General Staff which was initiated in the mid-1960s. Survivability of strategically important command and control systems will be achieved by a multiplicity of techniques, that is, dispersal, redundancy, and hardening.

Command and control of Soviet ground forces continued to improve over the past decade. [redacted] Military commands controlling ground forces within the USSR and groups of Soviet forces in other Warsaw Pact countries have access to highly redundant national telecommunications systems while deployed in garrison. The structure is comprised of multichannel cable, microwave, troposcatter, and satellite systems. In addition, there are many point-to-single-channel radio networks with a "skip echelon" capability tuned exclusively by the ground forces. [redacted]

Computers have been used on several occasions at the higher echelons for tactical and logistic planning, as well as for assistance in command decision-making. Improvements in communications together with the capability of automation of many command and control functions undoubtedly reduce the reaction time of the ground forces. It is expected that in the future, more command and control systems will be introduced, refined, and automated, which should reduce reaction times even further. Radio is the principal means of communications, except in static situations where wire is used. Communications systems are provided on an austere basis to implement command and control concepts. High-echelon, high-priority nets are established with multichannel microwave radio relay, VHF multichannel radio relay, and high-powered HF radio equipment at front, army, and division headquarters, and are provided to SSM and SAM battalions. Middle-echelon nets primarily employ HF radio with supplemental FM nets. At these echelons, marginal communications capabilities can cause the greatest command and control problems. Within line battalions, FM tactical radio nets should provide adequate communications; low-powered HF communications and FM radio for artillery and reconnaissance units should now provide adequate ranges when employed in mobile situations.

The principal Soviet tactical communications equipment consists of four FM manpack radios, a standard armored FM radio, a low-powered HF radio for manpack and vehicular use, an HF armored command set, a series of medium and heavy HF radio stations, and radio relay equipment. [redacted]

Overall capabilities for air defense command and control will be upgraded substantially, with changes in equipment and subsystems as well as in their employment. The use of pro forma data signals (Swamp, Tricorn, Breaker, Heartburn) for ground point-to-point reporting and control purposes will continue to spread. The use of Swamp for ground point-to-point data links of the air surveillance and weapon control networks will continue, as will the ground-to-air GCI data system (Markham), now in its third variant (Markham C). The remote radar video data system, Cointreau (ground point-to-point), will continue to be used.

The Swamp-Markham system has been evolving for more than a decade and has achieved widespread deployment. Tricorn is used for assignment of air targets in the SAM arm of the air defense forces. The system provides the Air Defense Force with a near real-time basis from the SAM control authority to the firing sites. Breaker has appeared in the same role for control of tactical SAM units. Heartburn is flexible in the type of information it can pass and has been seen deployed to serve different functions. The Heartburn system appears to be a good candidate for replacing the Swamp system. These new data systems with their improved track reporting resolution and timeliness should greatly improve the Soviet ability to control "mixed" weapons (SAMs and fighter interceptors) in a battle environment. These data systems will also improve the flow of information and thus improve low-altitude defense command and control.

Other improvements include deployment of AWACS to provide more complete coverage of remote northern regions of the USSR. The Feldspar air-to-ground data transmission system links the AWACS to the ground control point by HF radio. Limited intercept control capability aboard AWACS aircraft will probably be increased. A data link for direct ground controlled flight may be incorporated in a future Soviet interceptor; however, a capability for semiautomatic guidance will be retained. The improved control systems if used with tower-mounted radars could substantially improve defensive low-altitude command and control capabilities. Mixed weapon control capability will continue to be improved.

In naval command and control, the use of both manual and automatic Morse has declined. The use of the FSK radioprinter and the Doeskin voice ciphony system has been emphasized. The latter has been used in a single-sideband application with the Necrosis voice and/or facsimile system. While Doeskin and Necrosis are often used when high ranking naval officers are involved, Bitumen is the Soviet Navy's basic HF secure speech system. It is of the analog ciphony type. Hampden, a digital ciphony system, is primarily used in the VHF region and is in very wide use throughout the Soviet Fleet. Manual Morse and probably automatic Morse are almost certain to be retained as the most basic means of radio-communication, particularly for long haul circuits.

Although the offensive command and control system is not worldwide in scope, it continues to be compatible with Soviet policies on deployment and control of the strategic forces and weapons. The technical subsystems for command and control are generally adequate for the rocket and air forces through 1975. Survivability is being improved by physical hardening of facilities and by employing backup communications in several modes and media using facilities of the military as well as those provided by the Ministry of Communications. For the future, expansion and hardening of facilities, technical improvements, and adoption of automated equipment and methods will substantially improve survivability, speed, circuit access capability, and security.

The SRF is proceeding rapidly in upgrading command and control systems. The SRF/HF Marula enciphered printer network has been expanded to provide links between the SRF Headquarters in Moscow and all division level entities and will be further expanded to encompass units at the regimental level. The Doeskin enciphered voice communications links are used between SRF Headquarters in Moscow and all SRF Army Headquarters. There is evidence that this type of communications will also be extended down to the division level. The SRF is installing comsat transceiving equipment at various headquarters and at all ICBM complexes. A new multichannel communications system, designated Ragchew, enables Moscow to communicate simultaneously with the SRF missile sites receiving the new comsat equipment. Testing of the Ragchew via the Molniya-I satellite began in July 1970, and it is now nearing operational status. The SRF continues to test Daybed, a highly redundant error-protected communications system [redacted] Daybed has also been carried in the multichannel Ragchew system.

Military cybernetics

Military cybernetics has emerged in the USSR since 1963 as a distinct research activity directed toward increasing the operational efficiency of the Soviet armed forces. Soviet research in this area is directed toward providing a theoretical basis and the applied methodology and equipment for solving tactical, strategic, military-economic, and other specific military problems. As in the past, Soviet military cybernetics R&D during the next 10 years will stress operations research, systems analysis, decision-making and management, as well as the automation of troop control. The main objective of Soviet military cybernetics R&D during the next decade is improvement of command and control in all components and branches of the Soviet armed forces through greater use of mathematical methods and modern communication and computing technology to enhance military decision-making.

Soviet progress in military cybernetics R&D probably has been affected by events which have influenced progress in Soviet civilian R&D in cybernetics. In 1959 the Soviets initiated a rather large cybernetics R&D effort with the establishment of a Cybernetics Council of the Presidium of the USSR Academy of Sciences. It was not until about 1968, however, that the Soviets apparently reexamined cybernetics R&D in terms of the gap between promises and actual application. As a result they have adopted a more conservative, pragmatic approach to R&D programs directed toward achievable applications. Soviet reevaluation of military cybernetics may have occurred three to five years prior to that in civilian cybernetics. This hypothesis is supported by accumulating evidence of Soviet implementation of military cybernetics applications derived from R&D.

Soviet military planners appear to be devising and using techniques for enhancing human decision-making in certain military situations. In this context, Soviet military planners have turned to the possibility of automating not only information systems but also the decision-making process itself. Within the next 10 years Soviet designers of military systems will construct systems in which the functions of human operators will be designed into the systems. The overall effect of this practice will be to improve the efficiency and effectiveness of all aspects of the weapon system.

The Soviet armed forces have an organized and active military operations research effort, the results of which are used to support the making of military decisions. The level and quality of this effort has risen sharply during the past decade, but its results have not compensated for the very low level at which the activity was maintained over the decade or more following World War II. As a result, the Soviet armed forces now appear to be at least five years behind the US in implementing the total results of operations research. Military operations research activity in the USSR is conducted at national, Warsaw Pact, and armed forces branch levels. Operations research methods are being used mainly to evaluate the effectiveness of existing individual weapons and other items of military equipment and combined forces operations. The use of operations research methods as an aid to the problem of selecting the optimal characteristics of future weapons and/or weapon systems is a relatively new area of application which will probably have an important impact on military decision-making in the future.

The main detectable thrust of Soviet military operations research now appears to be directed toward the development of integrated, automated command and control systems for Soviet and Warsaw Pact ground forces. Soviet General Staff plans in 1967 required such systems to be operational at front and army levels by 1975 and at lower command levels by 1977. These plans were reviewed by a Warsaw Pact automation group at a symposium in May 1968 which included the reported head of the Tenth Directorate of the Soviet General Staff. Specific developmental tasks were assigned to Pact members and agreement was reached on a common programming language. Problems in the implementation of ground forces command and control systems were being encountered at this time, due mainly to the lack of military computers and trained personnel and suitable means for inputing large masses of data into computers. To the extent that these systems are based on Soviet capabilities for implementing the results of military operations research and not on hardware deficiencies, the probability of future success in fulfilling their plans is estimated to be about 20 percent.

Game theory research having military applications is being pursued vigorously in the USSR. Game theory, which establishes quantitative rules for selection of actions in conflict situations to ensure the highest likelihood of achieving desired goals, is of high interest to Soviet military operations research specialists. The Soviets have employed conventional game theory concepts and techniques for analysis of military problems involving selection of optimal strategies. They also have indicated that game theory has been utilized to evaluate such problems as the reliability of missile complexes in the face of enemy effort to minimize their effectiveness. The most significant area of Soviet game theory research is the study of differential game theory. Differential games is a methodology for the analysis and solution of conflict situations in which both adversaries are confronted with a lengthy, continuous flow of decisions. Such control or decision problems are classed as pursuit problems. The possibility exists that a portion of Soviet differential game theory research is directed toward optimal control of weapons systems using attack or evasive strategies. The degree and extent of direct application of conventional and differential game theory to Soviet military purposes is difficult to determine, but it is highly likely that such research is finding application. Major areas of application during the next decade should include development of optimal tactics for underwater combat and antisubmarine warfare, contributions to defensive missile systems concepts, and support to strategic decision-making policy.

Soviet cybernetics-related research which bears watching includes widespread studies in dolphin acoustics and biological hydrodynamics. Evidence of classified naval-related research on dolphins, primarily in the field of underwater acoustics, exists. Researchers of the Institute of Acoustics are known to be repeating US work on size discrimination and have extended it to a variety of materials and object sizes. Such work on dolphin target recognition has application to the design of sonars with improved target classification capability. Soviet sonars are presently limited in capability, particularly because of their use of simple pulsed signals and straightforward signal processing techniques. The study of the complex acoustic processing capability of the dolphin may provide useful information for incorporation in Soviet acoustic technology. The incorporation of more complex signals and improved processing techniques could substantially improve the target discrimination capabilities of present and future Soviet sonars.

The USSR has been studying the hydrodynamics of aquatic animals with the stated intention of applying any significant findings to submarine and torpedo design. The features exhibited by these animals which are of most interest to Soviet hydrodynamicists are (i) alleged low skin friction drag, possibly attributable to various means of boundary layer control; (ii) low pressure drag resulting from the streamlined shapes; and (iii) natural secretions of fish and metabolic products of microorganisms which have drag-reducing properties. In the past, the hydrodynamics of animals have been studied primarily by Soviet biologists, but collaboration between Soviet biologists and scientists concerned with operational hydrodynamic problems now is becoming apparent. The USSR is obviously aware of US research in this area and apparently is conducting research which parallels US efforts. Within the next 5 to 10 years the Soviets will continue to explore the hydrodynamic potential of these biological phenomena. They also are likely to develop and test engineering models translated from biological mechanisms.

MILITARY ELECTRO-OPTICS

The Soviets have a large effort directed toward developing and producing electro-optical systems for their armed forces. These systems include such electro-optical active and passive devices as lasers, light sources, and light receivers utilizing the ultraviolet to the far infrared portion of the electromagnetic spectrum. Lasers could have strategic weapon applications in air, missile, and satellite defense as well as other applications such as discriminators which might be used in conjunction with a missile defense system. Recent evidence indicates that the Soviets probably have under way a major military laser weapon program involving high energy lasers. Other visible and infrared electro-optical sources and sensors, as well as lasers, can also be used for communications, reconnaissance, surveillance, ranging, and guidance.

High energy laser technology

Soviet laser research and development has continued its rapid rate of expansion over the past several years as evidenced by the construction of new laboratory facilities and increases in associated manpower. The early emphasis on laser development is evident from indications that it was one of the major scientific and technical research areas of Soviet military spending in 1965.

The Soviets have performed significant theoretical and experimental research on most of the gas lasers which have the potential to become part of a first generation laser weapon system. These candidate lasers include the gas dynamic laser (GDL), the chemical laser, and the electrically excited laser (such as the electron beam laser and the transversely excited atmospheric pressure laser). The principal gas used in these lasers is carbon dioxide which is stimulated to emit laser radiation near the infrared wavelength of 10.6 micrometers, a wavelength for which the atmosphere is relatively transparent.

Significant Soviet GDL work extends back to at least 1966 when Nobel Laureate A. M. Prokhorov published the theory of the GDL. Since then the Soviets have openly reported the development of a GDL with several watts of output power, but [redacted] they may have devices with tens of kilowatts of power.

During 1971, Soviet scientists under Nobel Laureate N. G. Basov published their first results of experiments with an electron beam laser operating at a pressure of 16 to 20 atmospheres with a relatively high efficiency of 20 percent. The Soviets are interested in the scalability of electron-beam pumped CO_2 lasers, probably with beam weaponry or laser-induced fusion in mind.

Chemical lasers show considerable promise for applications in future laser beam weapons, especially in mobile or spaceborne applications, because of shorter wavelength and potential weight/volume savings compared to other systems. There is a large Soviet R&D effort in chemical lasers, especially hydrogen fluoride chemical lasers. Chemical laser technology, however, is not as advanced as that of gas dynamic and electric lasers, hence, weapon systems utilizing chemical lasers may not appear until after these other systems have been developed.

Military laser applications

AIR DEFENSE WEAPONS—Evidence [redacted] indicates the probable existence of a major Soviet military R&D program involving high energy lasers. Although a number of aspects of this program remain obscure, enough information is available to suggest that a major effort is under way probably to develop and test the potential of a laser weapon system. The additional development of a laser radar or discriminator which might be used in conjunction with a missile defense system is also a possibility that cannot be discounted.

Available evidence indicates that the customer in this program is the PVO Strany, the organization responsible for air, missile, and satellite defense of the Soviet Union. Asssessments of the Soviet technological capabilities required to develop a laser beam weapon system suggest that air defense is the earliest feasible strategic application, but there is no firm evidence that this is the Soviet goal. The initiation of this laser weapon program probably occurred at least as early as 1968. The likely time frame for prototype demonstration tests is estimated to be the late 1970s or early 1980s.

In this program a team of scientists and engineers is engaged in the development of laser-related components that could be used in the laser source and optical subsystem of a laser weapon system. Members of this team have been interacting with high-ranking military and political R&D managers, notably the Commander-in-Chief of the PVO Strany and a member of the Communist Party Secretariat. This team is believed to be under contract to a special electronics design bureau [redacted] which evidently has overall responsibility for this laser weapon program. Part of the development team is based at the Institute of Atomic Energy facility at Krasnaya Pakhra; the team is led by Ye. P. Velikhov, a leading magnetohydrodynamicist, with support from A. M. Prokhorov. The latter also serves as a scientific advisor to the Soviet SALT delegation regarding scientific feasibility problems, probably including laser beam weapons.

Research, development, and testing of such laser energy source components as power sources, nozzles, optical cavities, and diffusers are being conducted in this program, but the specific type of laser to which these components relate cannot yet be determined. The components being tested appear to be electric power sources which could be applied to magnetohydrodynamic powered elec-

[redacted]

trically excited lasers, to magnetohydrodynamic lasers, and/or to gas dynamic lasers augmented with magnetohydrodynamic pumping. In a related project, the Soviets are developing modular devices that are similar in many respects to US gas dynamic laser components. It is estimated that these Soviet modular units could be scaled up and combined to produce hundreds of kilowatts of continuous laser power within the next 3 years. Scaling to multimegawatt power and achieving the necessary laser beam quality at these high power levels could take considerably longer.

The available intelligence has been examined for evidence of the development of optical and precision tracking subsystems, as well as atmospheric propagation and target damage investigations, all of which are fundamental to a laser weapon program. Optical resonators, mirror components, and possibly beam directing mirrors being developed by *Strela* and Krasnaya Pakhra scientists appear to be intended for this probable laser weapon program. There is, however, no evidence of the development of the necessary precision optical pointing and tracking fire control subsystem. Nevertheless, *Strela* missile guidance and control experts are believed capable of developing components of such a subsystem.

Soviet research in the propagation of high-power laser beams in the atmosphere and knowledge of laser-induced damage effects on such target materials as titanium, aluminum, and plexiglass place the Soviet state-of-the-art on a level with that of the US. There is, however, no direct evidence connecting atmospheric propagation tests with the described laser weapon program. The latter is not surprising at this stage of development. Similarly there is no evidence of target damage tests directly related to this military laser program. Tests actively utilizing full-scale system hardware would not be expected to surface at this stage of devlopment.

[redacted]

[redacted]

[redacted]

ABM WEAPONS—It is unlikely that the Soviets could develop a laser ABM weapon system employing directed energy for kill in the next 10 years. Before such a system could be developed, solutions would be required in the technological problem areas of achieving laser output powers on the order of hundreds of megawatts, very large primary mirrors of two to three meters in diameter, and the capability to point and track the laser beam to accuracies approaching those achieved by astronomical telescopes.

COMMUNICATIONS—At least 10 laser communication links for voice and TV have been built and evaluated at various locations in the USSR. Systems reported to date include 24- and 96-channel voice, single-channel video, and two commercial single-channel voice systems with ranges of the order of 5 kilometers. These links, some of which have been integrated into the commercial telephone system, provide a potential military capability to extend the commercial communication systems quickly in times of military emergency and/or to set up optical links to replace interrupted segments of communications systems or to extend their coverage on an interim basis. Further developments could provide wideband optical satellite communications systems, a secure military command and control system, and/or real-time transmission to the ground of high resolution optical imagery from reconnaissance satellites.

The Soviets are among the leaders in semiconductor laser technology. Their research in this area has been of excellent quality and broad scope involving both theoretical and experimental work. Semiconductor laser systems for communications and ranging have been built and there is a substantial Soviet effort in utilizing semiconductor lasers in computer switching/logic circuits.

RANGEFINDERS AND GUIDED BOMBS—There is evidence that the Soviets are producing military airborne neodymium glass laser (wavelength, 1.06 micrometers) rangefinders in Moscow and Sverdlovsk and are probably testing them at major aircraft and weapon test ranges. The rangefinders weigh about 10 and 40 kilograms, with the 10 kilogram device having a 2.5 meter accuracy at a range of 5 to 6 kilometers. Current US airborne laser devices operate both as rangefinders for the accurate delivery of "dumb" ordnance at low attack angles and as target designators for the delivery of "smart" ordnance (laser guided bombs). Based on the weight and type of lasers the Soviets are using, it appears unlikely that the laser rangefinders have a designator capability. Although evidence of such a development is lacking, the Soviets are well aware of the success of US laser guided bombs, and probably have developed their own.

Laser-initiated fusion

In May 1968 the Soviets were first to report laser-induced fusion when they observed the generation of neutrons from a lithium deuteride target. This experiment demonstrated that large amounts of laser energy could heat atoms sufficiently to cause them to fuse. Potential applications of laser-induced fusion include its use as a trigger for nuclear explosions, controlled source of energy for nuclear power generation and space propulsion, and simulator of some of the effects of nuclear explosions. The Soviet laser used for the 1968 experiment was a large multistage neodymium glass system emitting at a wavelength of 1.06 micrometers. Since then, the Soviets have invested substantial resources in this effort, building a succession of these very large neodymium glass systems to study the initiation of thermonuclear reactions by lasers. The Soviets are also involved in the development of electron beam high pressure carbon dioxide and xenon lasers, apparently for laser-induced fusion, although there are reports that the Soviets are considering the use of xenon lasers in space applications because of the advantageous short laser wavelength of around 0.17 micrometer. These lasers have the advantage of being much more efficient than the neodymium glass laser. The Institute of Atomic Energy facility at Krasnaya Pakhra is believed to be conducting laser-initiated fusion experiments in conjunction with the Lebedev Institute, and there is some indication that portions of this program may be classified.

Depending on the type of laser and target materials, laser-induced fusion at the energy breakeven level is estimated to require a minimum input energy on the order of 10^4–10^6 joules delivered in pulse lengths of less than a nanosecond (10^{-9} sec). To date these energy and time requirements have not been achieved, but the Soviets have achieved pulse energies in excess of 1,000 joules in tens of nanoseconds. Success in reaching the laser-initiated fusion breakeven level is a complex matter that depends on the right combination of laser wavelength, pulse duration, shape, amount of energy delivered to the target, and target characteristics. The Soviets claim that laser-induced fusion at breakeven can be feasible within the next 5 to 10 years.

Soviet infrared optical technology

Soviet infrared (IR) optics technology is good and is supported by strong background work in theoretical and applied optics at the State Optical Institute in Leningrad. Much activity at this institute, one of the world's outstanding optical R&D facility, is probably related to military or other highly classified programs. The Soviets have been particularly active in the areas of IR detectors and image intensifiers. Soviet activity in investigating materials for possible high-power laser windows has also been noted. Recent information indicates the probable Soviet use of zinc selenide for carbon dioxide lasers. US investigations on this material substantiate the potential of zinc selenide as a high-power laser window candidate.

Soviet research and development of semiconductor radiation detectors has advanced considerably in the last several years. The Soviets are still conducting fundamental research on the lead chalcogenide detector materials (lead sulfide, lead selenide, and lead telluride). They have also conducted basic research on indium antimonide and indium arsenide for use in the 3 to 5 micrometer wavelength region. They have performed extensive studies on mercury-cadmium-telluride and doped silicon and germanium in the 5 to 25 micrometer region. It would also appear that the Soviets concentrate a greater proportion of their total far IR detector R&D work on pyroelectric materials than is done in the United States. Pyroelectric materials do not require cooling as do other materials used in the far IR region, although sensitivities are relatively low. They have also done some work on lead-tin-telluride.

The Soviets appear to have an across-the-board capability equal to or better than that of the US in the area of basic detector research and development, although there is a difference in the emphasis placed on the various types of detector materials. Soviet scientists seem more interested in the basic detector physics than are their US counterparts. With few exceptions, we have not seen a strong Soviet desire or ability to exploit the lab work by developing devices for infrared applications.

The possibility of using LWIR sensors in the 8 to 14 micrometer region to detect, track, and/or discriminate passively reentry vehicles from chaff and decoys as part of an ABM system is currently of high interest in the US and possibly in the USSR. This application requires development of cooled optics and detector arrays incorporating many elements. The Soviets have disclosed that in 1968 they had an operational 10-element cooled detector array which operated in the middle infrared (3-6 micrometers) region. The open-cycle type of cooling used in this device might also be useful for an LWIR discriminator system. A closed-cycle system, however, would be much more desirable. The Soviets could probably, at the present time, make such a cooler or copy a US closed-cycle system with a little effort, and they are believed to have the basic capability to design and develop an LWIR discrimination system. There is no evidence that the Soviets have a directed effort toward developing an LWIR sensor for ABM applications. Their biggest problem is the area in which the US probably enjoys the greatest technological advantage, that is, in the development of many element (50 or more) linear and/or planar arrays of LWIR detectors.

For many years Soviet scientists have been involved in R&D in areas of technology which would be applicable to development of image intensification devices to be used under conditions of low light for such applications as fire control, surveillance, and reconnaissance. There is no firm evidence that there is operational military low-light-level equipment in the USSR, although it is anticipated that practical military applications of such devices, incorporating a sensitivity to the near IR as well as to visible light, will be made by the Soviets within the next 5 years. The requisite technologies in photocathodes, fiber optics, and multistage image converters are well advanced in the USSR. Future refinements will come from new photocathode structures and microchannel electron multiplier plate development. In the field of photoemission, Soviet research in the visible spectrum is comparable with that of the West. Numerous photoemissive materials have been studied and developed to a high degree of sophistication. Soviet researchers are paying considerable attention to obtaining low-noise levels in photomultiplier photocathodes. Multistage, fiber optic coupled image converter tubes have been used in astronomy and high-speed photography. This capability would be directly applicable to the development and manufacture of night observation devices for military applications.

GROUND-BASED ELECTRO-OPTICAL APPLICATIONS—The Soviet ground forces have active IR devices in wide use for night driving, fire control, and surveillance. There is evidence of continued reliance on existing IR technology for the conduct of night ground warfare and of widespread deployment of relatively unsophisticated near-IR devices that significantly increase Soviet capability to conduct night operations and also to detect enemy use of IR for similar purposes. Optical tracking on missile and gun fire control radars is also used as a countermeasure to jamming. The Soviets also have at least one operational short-range IR homing SAM (SA-7). Efforts to develop passive night viewing equipment will continue, thus enabling the Soviets to supplement their active systems with passive devices within the 1972-77 period. There is no evidence of operational low-light level or passive infrared surveillance or fire-control systems, but the Soviets probably have the capability to fabricate such systems. The Soviets are also believed to have a current capability to field laser rangefinders and short-range tactical laser communication devices. Improved versions of SAMs incorporating cooled detectors will probably be developed.

NAVAL ELECTRO-OPTICAL APPLICATIONS—The Soviet Navy is using electro-optical devices on fire-control radars that direct both SAMs and antiaircraft guns. Some of these devices are probably television, but others could be infrared trackers or laser rangefinders. At least one ship-launched infrared antiship homing missile has been under development by the Soviets since about 1963, but it is still not certain whether such a system is deployed. Other electro-optical devices frequently observed are probably for passive day/night surveillance and/or navigation.

Some evidence of infrared suppression is indicated by construction details of the smokestacks of certain Soviet ships. The effectiveness of this technique is uncertain, and there is no corollary evidence that indicates the suppression has been deliberate.

We believe the Soviets will continue to work on additional infrared antiship missiles and that infrared guided systems for SSM and SAM roles possibly in a dual mode (radar/IR) missile version may appear within the next 5 to 10 years. The Soviets can be expected to continue development of television for day/night use and of passive infrared systems for surveillance and fire control. Laser rangefinders and target designators may appear in fire control and missile guidance systems in the next 5 years.

There is a single isolated incident during Soviet naval night operations in 1968 that included cooperative activities by a submarine, a destroyer, and an aircraft suggestive of a Soviet effort to develop an airborne nonacoustical ASW system, possibly an electro-optical system. Such a system is probably not yet deployed, but efforts along these lines are expected to continue. An airborne electro-optical ASW system of an IR radiometer type might appear within the next 10 years. The Soviets have developed airborne IR radiometers for surveying and mapping terrain, sea surface, and icefields. The technology used in these systems could possibly be carried over to ASW systems for detecting the thermal wake at the sea surface caused either by submerged submarines or their floating wire antennas. IR detectors with sensitivities on the order of 0.1°C to 0.001°C are considered necessary for such detection. It is not known whether the Soviets have any operational IR equipment for ASW, but there is some evidence that test flights have been made.

AIRBORNE ELECTRO-OPTICAL APPLICATIONS—Soviet airborne electro-optical reconnaissance capability appears to be limited when compared with that of the US. There is no indication of Soviet development of sophisticated air-to-ground IR reconnaissance sensors. Nevertheless, a potential capability in this area is apparent through a series of reports relating to imagery of volcanoes and icefields obtained from aircraft. Some of the imagery was derived with a line scanner operating at wave lengths of 3-5 micrometers and utilizing liquid-nitrogen-cooled lead selenide detectors. The Soviets are believed to be capable of developing and deploying, prior to 1975, airborne LWIR (8-14 micrometers) line scanners for a variety of applications including low- and high-altitude IR reconnaissance.

There is some evidence indicating Soviet military use of television aboard aircraft. Although television has limited resolution capabilities, it does have certain advantages for reconnaissance use with its potentially high sensitivity at low-light levels and capability for providing real-time video data. A television sensor system of this type is postulated as a possible complement or alternate to the photographic equipment in the Fishbed H reconnaissance pod. It is also significant that the Soviets are employing a radar-video system by which the radar picture obtained by an airborne radar is transmitted from the aircraft. This has the advantage of permitting units covered by the use of transponders to identify themselves in the picture. The Soviets will continue efforts to develop television equipment and systems with higher resolution, wider field of view, and less dependence on ideal light conditions. The Soviets could have aerial reconnaissance and target acquisition television equipment fully operational for use in aircraft within the next five years.

In an air-to-air role, the Soviet Atoll, Anab, Ash, and probably the AA-6 are produced in both IR and semiactive radar-guided versions. The Atoll seeker employs an uncooled lead sulfide detector similar to that of the US Sidewinder 1A. In the IR versions of the Anab, Ash, and the AA-6, the Soviets probably use a cooled IR detector. Such a system would take advantage of the intense jet exhaust emission centered around 4.3 micrometers and would also give better performance in the presence of flare countermeasures, sun glint, or reflections from clouds. Improved Soviet AAM homing heads using two-color infrared detectors for IR counter-countermeasures could be available by the late 1970s.

There is no evidence that the Soviets have IR, laser, or electro-optically guided ASMs. The Soviets have used the IR-guided Atoll in a tactical air-to-surface mode, but its effectivenes is limited by its relatively small warhead and requirement for very high contrast targets to insure accurate terminal guidance. Based on the requirement for highly accurate conventional ordnance for use against selected surface targets, it is estimated that the Soviets will develop ASM guidance systems (laser and TV) for operational use within the next five years.

The Soviets employ an unsophisticated IR sighting device in the optical fire-control system of the Fishbed C&E aircraft. On the Fiddler, a device located just forward of the canopy is postulated to be an IR sensor used as a passive fire-control system to support the IR-guided variant of the Ash missile. Continued development of cooled IR detectors and detector arrays could result in more advanced IR fire-control systems with forward hemispherical coverage and detection ranges in excess of 20 nautical miles against non-afterburning targets within the next three to five years.

The Soviet Army has a requirement for airborne real-time night vision systems for effective use of weapons installed on helicopters. During the mid-1970s, passive image intensifiers and night observation devices will probably be installed on Soviet rotary wing aircraft for combat surveillance and target acquisition. Infrared line-scan systems, operating in a forward-looking role, may be initially deployed by the mid-1970s. Multi-element infrared detector arrays will be used in conjunction with sophisticated recorder/display systems by this same period.

MILITARY MEDICINE

Military medical research and development in the USSR occupies a powerful position with respect to organizational control, structured planning, and access to the nation's most competent scientists. The medical research center for the Soviet armed forces is in Leningrad at the Military Medical Academy imeni S.M. Kirov (MMA), which is staffed by some of the nation's most competent medical experts. The MMA also has unrestricted use of civilian medical facilities. Thus, the military medical research program has the services of the finest medical research personnel in the USSR.

An excellent competence in surgery, especially for injuries, has been developed by physicians at the MMA and at the military faculties of several civilian medical colleges. For example, submarine physicians are trained in surgery as a primary specialization, and military physicians are the only surgeons in the USSR to execute sophisticated transplant operations. The successful development of an automatic blood vessel stapler is important under field surgery conditions. Progress has also been achieved in the development of procedures for the organization of hospital work under active war conditions, sorting of injured, delineation of the effort to be expended in treating individual phases or degrees of injury, and treatment of mass casualties.

Civilian hematologists and transfusion experts, heavily supported by Soviet military physicians, have created a national blood service system. This system has placed more emphasis on practical results than on the acquisition of modern techniques and equipment but, nonetheless, is now able to provide adequate supplies of blood. There is also a separate blood service which exists for military personnel with a non-reciprocal privilege of exploiting civilian facilities at will.

Soviet microbiologists have distinguished themselves by developing a program of predictive epidemiological surveys which enable them to anticipate potential infectious disease problems and apply prophylactic and therapeutic measures pertinent to the outbreak of such diseases of particular military significance as influenza, smallpox, cholera, and typhoid. Extensive research is being conducted on the effect of physiogeographic conditions in the development of vectors of diseases, hosts, and micro-organisms; regional pathologists are developing much knowledge on natural foci of infection which is directly applicable to miltiary field conditions and supports rapid detection, prophylaxis, protection, and treatment. This research is considerably more detailed and of longer range than Western research. The advantage to be conferred is important in view of the severe climatic conditions in individual sectors of the USSR which might possibly be theaters of future military conflict.

An aggressive civilian program has resulted in a successful emergency medical care system which is now operational in every metropolitan area. The system is set up to dispatch an appropriately equipped ambulance, manned by a supervisory physician and feldshers (auxiliary medical assistants) to a health emergency or accident site where the unit renders immediate assistance. The program could have increased value in military emergencies since it can be integrated into a national defense effort. On the international level an emergency unit to be dispatched to disaster areas has also been developed by the Ministry of Health. This is a 200-bed, multi-department, field hospital designed for air transport to a disaster site. The USSR completed clinical testing of the unit in Peru. In such hospitals, the USSR will have the experience to meet medical problems which occur at a considerable distance from Soviet centers on an emergency basis with a full complement of medical specialists and materiel. The Soviet Union will be capable in the event of large-scale warfare of exploiting this system to treat traumatic shock and burns, acute blood loss, and radiation exposure.

Radiation safety is one of the priority areas of substantive MMA activity, and military workers have extensively tested prophylactic chemical agents and therapeutic bone marrow transplantation in radiation injuries. While this work has been somewhat disappointing, the use of bone marrow radiation therapy is being used by the USSR to a limited degree and will probably find selective use within two years for workers in radiation research and for naval crews vulnerable to accidents in nuclear-powered vessels.

Both military and civilian research workers are currently devoting much attention to the effects of electromagnetic radiation. Military studies are centralized at the MMA and include efforts to protect the health of military and fleet personnel exposed to radio frequency (RF) radiation. The USSR continues to stress adherence to their national standards for maximum permissible exposure to RF radiation, a limit which is considerably lower than that generally accepted as safe in the West. The US accepted exposure of power flux density levels throughout the day is 10 mW/cm^2 as contrasted to Soviet standards of 0.01 mW/cm^2. But this policy is impossible for the USSR to maintain under the practical conditions of military operations and, thus, will create difficulty for medical specialists in the assignment and monitoring of communications personnel.

Soviet military scientists are studying injuries which body tissues as well as the eye can sustain during operation of lasers. The Soviets have the competence to maintain pertinent safety measures during applications of laser technology in medicine, industry, and communications and could participate in trials of laser devices as potential weapons.

Soviet military and civilian scientists are devoting much effort to research on acclimatization and training in mountainous areas and to the study of the adaptive reactions of the body to hypoxia, fatigue, and temperature stress, particularly in polar regions. Antarctic research has been described by Soviet sources to be supportive of the USSR space program.

Military pharmacological research is devoted to current military priority requirements, and efforts are under way in the development of antihypoxic agents, anti-chemical warfare agents, and antiviral chemotherapeutic agents for influenza. A capability is now being acquired to use antiviral agents to overcome the USSR's military and civilian influenza problem. It can also be assumed that the Soviet armed forces will have priority access to essential pharmaceuticals in wartime.

The Soviet drug industry has not had a good record in recent years in the discovery and development of new pharmaceutical products. The USSR has compensated in part for this deficiency by purchasing drugs produced in Hungary and Czechoslovakia. Agreements have also been set up with Hungary and Japan for those countries to use Soviet clinics for clinical testing of drugs. These arrangements will enable the USSR to acquire drugs of non-Soviet origin for its own use.

The USSR lags the United States in all areas of underwater medicine. But the level of Soviet work in this field is being raised through cooperation with the French and should equal the present level of US underwater medicine work within a few years. The USSR is now devoting priority attention to nuclear submarine, submersible and hyperbaric medicine in order to upgrade R&D in these areas.

CHEMICAL AND BIOLOGICAL WARFARE

Chemical warfare

The Soviet CW research and development effort has gradually expanded since World War I into an endeavor that encompasses all phases in the discovery and development of new agents and munitions from basic research to field testing. The Soviets have developed and standardized a large array of toxic agents with compatible dissemination systems and have also developed what is probably the world's best defensive CW capability. Research is continuing in CW defensive and offensive areas. Developmental work is continuing on items of protective materiel, as demonstrated by the frequency with which new items are reported, and is probably also continuing on agents and dissemination systems. In the absence of a CW treaty or if the Soviets were to violate the terms of any comprehensive CW treaty, existing weapons systems probably could be refined for increased effectiveness. Continuing research during the next decade could result in the development of new CW agents and munitions.

OFFENSIVE—Classified research on toxic agents is reportedly conducted at laboratories near Moscow, one of which has been identified as the Military Academy of Chemical Defense, and near Shikhany at the Central Chemical Proving Ground. The Proving Ground is the principal installation in the USSR for CW testing, evaluation, research and development. Both installations are under the control of the Chief of Chemical Troops. Researchers of these facilities have studied V-type agents and reportedly examined fluorophosphorylcholine compounds as well as agents derived from natural toxic compounds. [redacted]

[redacted]

In addition to the sparse information on classified research [redacted] there is a large amount of CW-related basic research that is reported in the scientific literature. Numerous articles have appeared which are related to the study of those organophosphorus compounds which, like the nerve agents, inhibit the enzyme cholinesterase. Methods of synthesizing these compounds and their physiological effects have been studied extensively.

Soviet scientists have investigated compounds that could have applications as incapacitating agents. They have studied both possible mental incapacitants with an action similar to the US agent, BZ, and possibly physical incapacitants such as ganglion blocking agents and neuromuscular blocking agents. The Soviets are not known to have developed an incapacitating agent for operational use.

There has been only a small amount of research reported on flame and incendiary agents. The research includes work on such self-igniting fuels as halogen fluorides (for example, chlorine trifluoride) and the trialkyl aluminums. Concerning the latter, the Soviets have successfully prepared triisobutyl aluminum (TBA) and have patented the process.

The Soviets probably have attenuating smokes against infrared and optical surveillance devices. They probably are conducting further research in this area.

The Soviets have adopted chemical-filled warheads for artillery weapons, tactical rockets, and missiles. Chemical warheads probably will be adopted for any new hardware that is suitable for the dissemination of chemical agents. There are no details available concerning the follow-on development of any such new weapons.

The Soviets are aware of the potential threat of chemical agents to naval vessels, landing parties, and shore installations and have conducted offensive and defensive exercises on naval CW employment. The extent of CW R&D specifically for naval use, however, is not known. Reportedly, they depend on the Ground Forces for such work; the Naval Chemical Directorate has liaison through the Chief, Naval Staff, with the Headquarters of Chemical Troops of the Ministry of Defense. Naval short-range rockets and cruise missiles may have chemical warhead options similar to those available to the ground forces.

Within the next 5 years the USSR probably will have considered a number of new types of CW agents for possible standardization as CW agents. For example, future military research on drugs probably will result in compounds that will be effective as physical or mental incapacitating CW agents. The Soviets presently have the technical competence to develop an incapacitating agent causing temporary physical, rather than mental, incapacitation and may have such an agent by the late 1970s. No major change in chemical warfare munitions delivery systems is anticipated within the next few years, but smokes for attenuating infrared and optical surveillance devices, consisting of plastic polymers seeded into smoke screens, will probably be adopted. The Soviets probably will continue to adapt existing toxic chemical agents to dissemination by new weapons. Self-igniting fuels will likely be standard for flame warfare in the distant future.

DEFENSIVE—The Soviets continue to supplement their excellent defensive CBW capability by developing new and improved items of materiel. Research and development is probably being conducted on protective clothing, decontaminants, and detection, as well as on prophylactics and antidotes for the prevention and treatment of CW casualties and for protection against biological agents. The Soviets have developed two new decontamination apparatuses (DKV and TMS-65), a new automatic alarm (GSP-II), and a new reconnaissance vehicle for operational use. They have also modified older equipment, such as the ARS-12U decontamination vehicle. Also, a new protective mask reportedly had been developed.

A significant amount of research is published in the open scientific literature related to defensive CW. Research concerned with the detection of organophosphorus pesticides in the air and cyanide in the water has direct application to the detection of chemical warfare agents. Colorimetric, spectroscopic, and electrochemical methods have been studied. More sensitive substrates have been studied for use in Schoenemann reaction which can be used to detect some nerve agents. Research related to prophylaxis and therapy is also being conducted. Studies on the action mechanism of poisoning by toxic compounds may aid in the development of more effective methods of prophylaxis and therapy. Compounds for use in combination with or for replacement of atropine have also been extensively studied. Antidotes for mental incapacitants probably are being developed.

Within 5 years the Soviets may have a new protective mask which will eliminate the hose of the current Shlem mask. This could be the Soviet PMG mask, which has an exterior mounted cheek canister and possibly a voicemitter, or the Czechoslovak M-10 type equipped with both an interior mounted cheek canister and voicemitter. The former choice is the more logical. Tanks as well as APCs could be equipped with effective CBR collective protection systems by this date. Detection equipment will be more sensitive and will probably include more items with a multi-agent detection capability. Antidotes for nerve agents may consist of mixtures designed to counteract the more serious physiological responses caused by the agent. No significant advances in protective clothing or decontamination equipment, however, are anticipated.

In the next 15 years specialized individual protective equipment will be designed to lessen the heat load and otherwise overcome the combat degradation imposed by the present bulky equipment. Research on detection equipment is expected to result in automatic field alarms with increased sensitivity and quicker response times, but no significant developments are expected in collective protection or decontamination equipment.

PRODUCTION TECHNOLOGY—The Soviets are familiar with the production processes for G agents that were developed by the Germans during World War II and probably are aware of more recent Western developments in the production of both G and V agents. This knowledge is supplemented by the Soviet expertise in organophosphorus chemistry. Articles dealing with possible intermediates for both G- and V-agent syntheses have appeared in the open literature.

Biological warfare

We continue to believe that the Soviet Union has had a BW research and development program under way for some years. Information on specific programs is virtually nonexistent, but open literature indicates continued R&D efforts in areas related to agent development. There are no reliable data on agent production, munitions development, stockpiling, or offensive troop training. Of prime concern is the fact that we are unable to determine which specific agents, if any, have been standardized for military use. There is ample evidence of medical or biological research on most of the candidate agents which were evaluated by the West, and of considerable civil and military concern about defense against biological attack.

The Soviet government has maintained a policy of complete secrecy on any offensive BW program of its own. The USSR has not admitted openly that such a program even exists and has gone to great lengths to castigate the West for its BW programs. A convention which prohibits the development, production, and stockpiling of bacteriological (biological) and toxin weapons was signed on 10 April 1972 by the United States, the USSR, and 68 other nations. Ratification by 22 governments will put it in force. The convention requires the destruction of existing stockpiles and weapons within nine months after ratification.

[redacted]

There is little direct or indirect evidence relating to the actual testing of BW munitions. We believe, however, that both the Soviet clandestine services and the military have tested various BW munitions and delivery systems. No large scale tests have been reported and there has been no firm evidence of a BW weapons system in the hands of troops. Actual testing could be undertaken at known CW testing sites or elsewhere with little risk of detection.

An experimental crop facility near Otar, USSR, may be conducting anticrop research. Located on the east side of the Otar Army Barracks [redacted] this facility is heavily secured and is believed to be associated with a large field test site consisting of several grids which could have been used for agent testing. The testing area is now inactive. Soviet scientists believed to have been associated with this research station have reported research on rice, wheat, corn, and soybeans, and their diseases. With the exception of wheat, the study of these crops is of little economic importance to the Soviets. Soviet work at this facility on wheat stem rust, rice blast, development of disease-resistant crops, rapid detection of plant disease, and biochemical analyses of crop disease has anticrop BW potential.

In research applicable to BW agent development, Soviet scientists continue to study the usual range of communicable diseases of humans and animals as part of their public health and veterinary medicine mission. Such studies could be used in offensive BW agent development and production, but classified research conducted on specific agents at military laboratories has never been identified. Defensive BW studies, however, appear to be published openly, and these may reflect work on actual agents which were being developed indigenously as well as those which were developed in the West. On this basis, there appears to be a long-standing Soviet concern with the agents causing botulism, anthrax, tularemia, brucellosis, plague, Q-fever, the encephalitides, typhus, and cholera.

Ancillary technologies which would support the development of biological weapons are fully understood by Soviet scientists. The physics of aerosol diffusion and cloud travel are treated mathematically in Soviet treatises of superior quality. Soviet military medical teams have been studying procedures for more than 10 years by which mass aerosol immunizations can be carried out. Although these programs have defensive applications, much data have been obtained on the generation, stabilization, and assessment of biological material in aerosols. More importantly, data were obtained concerning human dose responses under carefully controlled conditions.

Soviet investigators continue to show interest in modern techniques for the rapid detection and identification of microorganisms. Devices issued to Soviet field forces are inadequate, but modern sophisticated procedures (for example, the fluorescent antibody staining technique, air-sampling instruments, and particle-counting devices) are being explored. Soviet concepts applicable to the development of such materiel parallel approaches which have been studied in the West.

During the period under consideration, the Soviets will continue to improve the quality of microbiology and public health research. New viral strains will become available as a result of Soviet worldwide epidemiological studies. Within the next 10 to 15 years, methods will have been developed to improve the stability of microorganisms under storage conditions. Chemotherapy for many viral infections will also be available within this period. In addition, research on extremely toxic natural plant and animal toxins will be expanded because of their potential medical applications. Some of their achievements could have military applications if at some future date they were to withdraw from the convention.

NUCLEAR R&D

Weapons

The USSR has continued to carry out an active and vigorous nuclear weapon research, development, and test program. The main Soviet weapons development complexes at Sarova and Kasli are active; and the underground test program has continued at a steady pace. Although difficult to judge, the likely objectives of the test program probably are the development of thermonuclear warheads for new strategic systems; development of cleaner, lighter, and more flexible warheads for tactical applications; development of advanced warheads for ABM applications; and the investigation of pure fusion techniques.

INSTALLATIONS—The original Soviet nuclear weapons research and development facility is located at Sarova, about 250 miles east of Moscow. It is a sprawling complex of laboratories, fabrication facilities, a ballistic test facility, and 21 high-explosive test points. It probably became operational in 1949 and construction has continued to date, despite the reduced rate of weapons testing that followed the Limited Test Ban Treaty of 1963.

The second weapons R&D facility, at Kasli in the Urals, apparently did not become operational until about 1959. While large, it comprises fewer separate areas of activity than Sarova. It also lacks a ballistic test facility and has about half the number of high-explosive test points as Sarova. It may have somewhat more extensive production facilities than Sarova, although a direct comparison of the two installations is difficult. As at Sarova, expansion has continued at Kasli in recent years.

UNDERGROUND TESTING—Since the Limited Test Ban Treaty was signed in 1963, the Soviets have conducted a series of underground nuclear tests, primarily at their two principal proving grounds: one near Semipalatinsk in Siberia and one on Novaya Zemlya in the Arctic. A new intermediate- or high-yield test site at Kushata, between the Caspian and Aral Seas, was used for three tests but was apparently abandoned thereafter. They also have conducted over 20 peaceful nuclear explosions (PNEs) at various locations in the western half of the country.

About two-thirds of the underground tests conducted by the Soviet Union since the Limited Test Ban Treaty have been conducted at the Degelen Test Area of Semipalatinsk, where devices are emplaced in horizontal tunnels. Lately an increasing percentage (25 percent in 1971) of tests have occurred at the Shagan and Konystan Areas of Semipalatinsk where vertically drilled holes are used for device emplacement. For high-yield testing, the Soviets have available the Novaya Zemlya Underground Test Area, where devices [redacted] have been tested at a one-a-year pace since 1966. A new test site at Kushata (between the Caspian and Aral Seas), which probably was intended to serve as a supplementary intermediate- or high-yield test area, was developed in 1969 and 1970. Problems apparently developed at the site, however, and it was abandoned after three tests had been conducted.

The Soviet program for peaceful uses of nuclear explosives has been more vigorous than the US program both in experimental development and practical applications. The Soviets have investigated a wide variety of peaceful uses for nuclear explosives, including controlling wild gas wells, creating underground storage cavities, and stimulating oilfields and gasfields. Also, at least five cratering tests for PNE research have been conducted at the Semipalatinsk proving grounds, and in 1971, a [redacted] cratering test was conducted on the route of the proposed Pechora-Kama canal project. Plans for this canal project envision the use of 250 nuclear explosives [redacted] to excavate a 65-kilometer portion of the 112-kilometer canal.

REQUIREMENTS—Any assessment of Soviet aims in their nuclear weapons R&D effort must be largely speculative and based on analogy with current US efforts. The following are areas where there are probably Soviet R&D requirements:

a. Development of thermonuclear warheads for new strategic systems. Improvements in thermonuclear warheads having yields up to several megatons could be made through underground testing. In particular, Soviet warheads below three megatons could have performances improved significantly over those of 1961-62. The Soviets probably have already improved these warheads to some extent. The Soviets could also be developing optimized warheads for specific high-performance reentry bodies for new strategic systems.

b. Development of low-yield and special purpose warheads for tactical systems, including clean, lightweight, minimum cost warheads with increased flexiblity for tactical applications.

c. Development of advanced warheads for ballistic missile defense, including warheads of output tailored for exoatmospheric and endoatmospheric defense modes as well as of specialized nuclear devices to be used as radiation sources for underground experiments to study weapons effects.

d. Projects directed toward pure fusion device development. The objectives could include the initiation of thermonuclear reactions by either laser or relativistic electron beam heating systems or high-explosive implosion.

EFFECTS OF ARMS CONTROL AGREEMENT—Future arms control agreements could have a significant effect on the course of nuclear weapons research in the Soviet Union. Two areas which figure prominently in the world political arena are the Strategic Arms Limitation Talks and the Comprehensive Test Ban. The present SAL agreements should have little impact on nuclear research except possibly to increase the efforts in specific directions such as development of smaller, more compact warheads for MIRVs or warheads for limited ABM deployment that achieve maximum effectiveness in whatever mode they are used. If future SAL agreements place significant limitations on the number and type of weapons carriers, we would expect the Soviets to increase their nuclear weapons research program to attempt to compensate for these limitations by making improvements in warhead design.

On the other hand, a comprehensive test ban would have a very detrimental effect on nuclear weapons research if the Soviets adhered to the treaty. New warhead development would be constrained to modifications of tested designs, and such warheads could be stockpiled only at a reduced confidence. Without testing, nuclear design capabilities would deteriorate over a period of time through loss of experienced design teams. Soviet laboratories could be expected to increase their activities in such areas as weapons effects simulation since effects testing would not be allowed. Eventually, however, weapons design and testing capabilities would be required to achieve a pre-CTB capability after a prolonged test ban.

Controlled thermonuclear reactions

The Soviet controlled thermonuclear reaction (CTR) research program is the largest in the world and continues to expand. [redacted] In the late 1960s, the Soviet program concentrated on research with toroidal machines; since 1970 the program has become more diversified and includes studies of laser and relativistic beam induced fusion.

A large portion of the Soviet CTR research continues to be directed toward the Tokamak concept. The best combination of confinement times and plasma density has been obtained with these toroidal devices. These results have made scientists more optimistic that the technical feasibility of the controlled release of fusion energy may be demonstrated by 1980. Augmenting a major effort with toroidal devices is Soviet work on linear systems. This research provides a hedge against any failure of the Tokamak concept and also may result in a simpler fusion reactor.

Certain developments in CTR could have other important applications, such as high-altitude nuclear weapons effect simulation. The CTR program at Novosibirsk, which in the past has been important in possible weapons effects simulation, has now been practically eliminated and many of the leading plasma research personnel have been transferred to other institutes. Soviet theoretical plasma studies continue to be excellent and are providing the best understanding of basic plasma phenomena.

Military applications

The Unidentified Research and Development Facility No 3 at Semipalatinsk represents a major effort by the Soviets that could lead to an unexpected major military system. Its location at the Semipalatinsk Nuclear Weapons Proving Ground suggests a military nuclear connotation. [redacted] Some possible functions which have been proposed are: (i) advanced reactor test facility (i.e., nuclear rocket, ramjet and gas core reactors); (ii) intense neutron generator for producing fissionable materials or transuranic elements; (iii) collective linear accelerator for protons designed to test the feasibility of establishing a high-current charge particle beam weapon; and (iv) a multiple-purpose, highly versatile neutron gamma irradiation test facility for nuclear weapons effects studies.

Soviet nuclear technological development appears to be progressing at about the same pace as in the West. After several decades of R&D, the use of nuclear reactors to power such large military systems as exoatmospheric missile detection and tracking systems using lasers instead of radar and/or ABM systems using such kill concepts as MHD-lasers or MHD-electron beams are possibilities; however, these systems, based on present technology, would be far too ponderous for space applications. Unexpected advances leading to improved nuclear-powered military systems could probably result from the development of new materials permitting advances in such areas as: miniaturization of control systems, the design of magnets, and high-capacity energy storage systems. The likelihood of the Soviets meeting all prerequisites without being detected 5 to 10 years before their application is believed to be remote.

LONG-RANGE THREAT

Soviet leaders have stated repeatedly that they will ultimately achieve worldwide military and economic superiority by developing and exploiting their S&T potential. Scientific and technical parity with the leading nations of the West in certain areas of military significance and leadership in a few areas have already been achieved. Although there is no evidence to indicate that their S&T capabilities are growing faster than those of the West, the size and quality of the Soviet S&T effort as a whole allow exploration of innovative weapons concepts that could lead to revolutionary new systems.

A long-range threat* against the West may increase as a result of (i) the growth of the USSR's S&T resources, including physical R&D facilities and scientific and engineering manpower; (ii) improvements in Soviet S&T industrial management that would facilitate the manufacture of new weapons systems and military materiel; (iii) Soviet development of new weapons of unusual types or of substantially greater effectiveness than existing ones arising from S&T discoveries of a radical and unexpected nature.

The USSR is continuing to expand its S&T resources at a rapid pace. This expansion has included facilities for research and development, many of which support military programs. The number of scientists and engineers graduated in the USSR annually is already more than twice the number graduated in the United States, and the total continues to rise. The quality of Soviet S&T graduates is believed to compare favorably with that of the West. The majority of the new facilities and scientific and technical personnel will be required to meet the vast non-military needs of the USSR, but a substantial portion of the best facilities and personnel are involved with military problems. Thus, the growth in Soviet S&T resources could add to the long-range threat against the West.

For decades the USSR has, in general, been slow and inefficient in applying the results of its basic R&D work. To overcome this weakness, the Soviets have engaged for several years in a multifaceted, S&T industrial management reform program, but they have found it extremely difficult to reorient S&T and to redirect associated industrial managements throughout the vast bureaucracy. Despite both the R&D and managerial successes in Soviet space and military programs, there has been very little spillover of management techniques and R&D results into the civilian sector. This condition stems from the tight security barrier which surrounds the military sector and from the fact that the existing incentive system has been inadequate to stimulate the application of such innovations in management and R&D on the scale required. It is likely that the existing drive to acquire new techniques from the West to improve their R&D and industrial establishment will be intensified, and that efforts to increase the spin-off of defense R&D results will occur. [redacted] available evidence indicates that at least high-priority defense R&D projects are managed and coordinated much better than is non-defense R&D, due in large part to (i) the tighter management exercised over priority defense projects by top-level Party and Government officials, (ii) the availability of resources where military purposes are involved, and (iii) more pressure for innovative management coupled with higher incentives for achievements.

The USSR continues to follow a generally conservative approach in the development and production of weapons systems and military materiel, but new and unusual concepts as solutions to defense problems have often been tried. The Soviets have not always attempted to match US developments but at times have deployed unique, though far from ideal, systems. The fractional orbit bombardment system (FOBS) and the Moskva-class

*A threat to the security of the West that could arise 10 or more years in the future.

vessels are recent examples, and the Caspian Sea Monster may represent another. In the future the Soviets will continue to explore avenues that seem to offer military advantages. Although the Soviets have depended heavily upon weapons that are relatively simple and rugged in design, more complex system will become commonplace. Some of these new weapons, when coupled with the massive existing military resources of the Soviet Union, will increase the long-range threat to the West.

Like any highly industrialized nation that is engaged in military R&D, the USSR could make a major S&T discovery that would suddenly increase its military potential. Such a discovery is more likely in an area where R&D is intense. But such basic discoveries almost always require years of development before a practical product is achieved, and this reduces the possibility of capitalizing on the discovery much before its nature becomes known. In view of these factors, the possibility, timing, nature, or significance of any potential Soviet breakthrough cannot be forecast. Such an event is probably no more likely in the USSR than in the West.

The most serious long-range threat from the Soviet Union probably will come from the routine process of weapons system and military materiel development that attempts to exploit many known physical phenomena for practical applications. The possibilities most likely to have a long-range effect on the balance of power are military applications of technology to such areas as advanced ballistic missile systems; advanced antisubmarine warfare systems; advanced antiballistic missile and antisatellite defensive systems; surveillance, command, and control systems; and advanced air defense systems.

Advances in the ballistic missile field probably will involve systems having increased accuracy, possibly through the use of mid-course guidance and terminal homing, increased survivability, operational flexibility, and improved defense penetration. This latter improvement could involve use of sophisticated active or passive decoys as well as incorporation of maneuvering RVs. Advanced antisubmarine warfare systems probably will involve improved open ocean search and surveillance capabilities from surface or overhead platforms. Such platforms might be outfitted with various active as well as passive nonacoustic sensors. Advanced antiballistic missile and antisatellite systems will aim toward improved early warning and discrimination techniques, including such techniques as IR, LWIR, and UV sensors mounted on satellite platforms and reliable over-the-horizon radar. Data handling, more accurate tracking, and greatly improved weapons for both exoatmospheric and endoatmospheric intercept would also be features of such advanced systems. Surveillance, command, and control systems of the future will probably involve the real-time transmission of data at extremely high rates in a completely secure fashion. Electro-optic imaging, laser communications links, and communication satellites employing sophisticated anti-jam features and sophisticated modulation techniques such as spread spectrum will most likely be used. Advanced air defense systems would incorporate improved early warning and improved ECCMs from surface or airborne platforms, improved interceptors with a look-down shoot-down capability, and even more sophisticated radar capabilities. There is evidence, as noted above, that the Soviets have an R&D program to develop a high-energy laser weapon system.

Development of the above system concepts with the characteristics indicated will call for significant improvements over a broad base in the Soviet state of technology. Technological areas where improvements would be required will continue to include the broad military spectrum: radar, communications, guidance and control, fuels and propulsion, materials, signal processing and data transmission, computers, electro-optics including infrared, long-wave infrared, and lasers.

Top Secret

[redacted]

Top Secret