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MILITARY SUPPORT SPACE SYSTEMS—USSR (U)

PREPARED BY
U.S. AIR FORCE
AIR FORCE SYSTEMS COMMAND
FOREIGN TECHNOLOGY DIVISION

28 OCTOBER 1983

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MILITARY SUPPORT SPACE SYSTEMS—USSR (U)

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PREFACE

(S) This study describes the characteristics and capabilities of Soviet satellites that have military support or military support-related missions. These spacecraft include Soviet naval support, navigation, geodetic, meteorological, Earth resources, oceanographic research, radar support, and [redacted] [redacted] satellites. The launch vehicle, spacecraft, and mission control facilities used by the systems are described in detail. This study is updated biennially. (b)(1);1.4 (c)

(U) The support and contributions from Foreign Technology Division Branches SDSY (Space Subsystems), SDSS (Space Systems), SQTA (Telemetry Analysis), and WE (Meteorology) are hereby acknowledged.

(U) Comments on improving the usefulness of this document are invited and should be forwarded to the Assistant Chief of Staff, Intelligence, Department of the Air Force (ATTN: INET), Washington, D.C. 20330.

(U) The intelligence cutoff date for assessments made in this study is 31 March 1983.

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TABLE OF CONTENTS

TABLE OF CONTENTS (Cont)

TABLE OF CONTENTS (Cont)

Page No.

TABLE OF CONTENTS (Cont)

Page No.

TABLE OF CONTENTS (Cont)

LIST OF FIGURES

(b)(1);(b)(3):10 USC 424;(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

LIST OF FIGURES (Cont)

Page No.

LIST OF FIGURES (Cont)

LIST OF FIGURES (Cont)

LIST OF TABLES

LIST OF TABLES (Cont)

SUMMARY

(S) This study presents the technical assessment of the capabilities and limitations of Soviet military support space systems. Included in these systems are naval support, navigation, geodetic, meteorological, Earth resources, oceanographic research, radar support, and some satellites with undefined, but suspect, military-support missions. Each of these satellite systems has a military support-related mission and, in addition, may have scientific applications. Summaries of system development, function, and current status are discussed in the following paragraphs.

Naval Support Satellites (U)

(S) The Soviets have developed [redacted] (b)(1);1.4 (c) naval support satellite (NAVSAT) networks to serve different users—the [redacted] (b)(1);1.4 (c) networks are currently operational and are used by the Soviet military. The Soviet merchant and fishing fleets use only the [redacted] (b)(1);1.4 (c) network.

(S) [redacted] (b)(1);1.4 (c) The NAVSATs use a passive gravity-gradient attitude control system and Doppler navigation principles incorporating tracking beacons and broadcasted position, velocity, and time data. [redacted] (b)(1);1.4 (c)

[redacted] (b)(1);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(S) [redacted] These spacecraft are [redacted] is the only publicly acknowledged Soviet NAVSAT system. [redacted] (b)(1);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i) (b)(1);1.4 (c)

GLONASS Satellites (U)

(U) The Soviets are developing a global navigation system similar to the US NAVSTAR system. The Soviets have designated the system GLONASS (Global Navigation Satellite System). They stated that the system would be used by aircraft for navigation. In addition to aircraft, the system could also be used by land-based or marine users.

(S) The Soviets launched the first developmental GLONASS satellites in October 1982. A single SL-12 booster launched Cosmos 1413, 1414, and 1415 into a 20,000 km, 12-hour orbit inclined at 64.8 degrees. GLONASS will probably incorporate a passive navigation signal, which will include a broadcast of satellite position and velocity. The GLONASS network will consist of nine to 12 satellites placed in three orbital planes 60 degrees apart in right ascension. The GLONASS network will probably become operational in the 1986 time frame.

Geodetic Satellites (U)

(S) [redacted] (b)(1);1.4 (c) the Soviets [redacted] (b)(1);1.4 (c) geodetic satellites [redacted] (b)(1);1.4 (c) both Doppler beacons and flashing lights to acquire precise geodetic information on a global basis [redacted] (b)(1);1.4 (c)

(S) No GEOSAT 1 satellites have been launched since December 1978. Only one GEOSAT 1, Cosmos 1067, showed any evidence of activity by the end of 1980. The Soviets also satisfy their geodetic requirements using other methods, such as Soviet navigational satellites, Western geodetic satellites equipped with laser reflectors, [redacted] (b)(1);1.4 (c)

[redacted] (b)(1);1.4 (c)

Meteorological Satellites (U)

(S) The Soviets began developing meteorological satellites (METSATs) during the early 1960's. On many occasions, the Soviets announced their intention to develop a three-tier weather system—a low-altitude tier using manned spacecraft, a medium-altitude tier of Meteor spacecraft, and a high-altitude geostationary tier. They have consistently announced the use of meteorological sensors on their low-altitude manned missions. The medium-altitude Meteor system, which provides most of their spaceborne meteorological data, is fully operational. Their first geostationary operational meteorological satellite (GOMS), which was to support the First GARP (Global Atmospheric Research Program) Global Experiment (FGGE) from September 1977 to August 1979, has been delayed until after 1983 because of technical problems.

(S) The Soviet METSAT program enjoys a high priority within the Soviet space program. The Soviets usually maintain five to six operational Meteor satellites in orbit, averaging four Meteor launches each year through 1977. Since 1977, Meteor launches have averaged two launches each year. This decrease in the annual Meteor launch rate indicates extended satellite lifetimes rather than any de-emphasis of the program.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

Meteor-Priroda Satellites (U)

(S) In June 1977, Meteor 1/28 became the first Soviet satellite launched into a retrograde orbit (inclination greater than 90 degrees). The Soviets announced Meteor 1/28 would obtain information needed for research into the Earth's natural resources in addition to meteorological data. This satellite was the first in the Soviets' sun-synchronous Meteor-Priroda (Meteor-Nature) satellites.

(U) The sun-synchronous orbit of the Meteor-Priroda series is ideal for Earth resources applications; because each spacecraft passes over a particular region at the same solar time each day, it obtains successive imagery under identical lighting conditions for study of soils, vegetation, crops, etc. The Soviets state they use the Meteor-Priroda program to support the sciences of hydrology and geology, maritime fleet operations, and forest management.

(U) The individual Meteor-Priroda satellites use a variety of sensors to obtain Earth resources imagery, including the MSU-M and MSU-S from the Meteor 2 series. The Soviets have also tested in orbit two

(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

Oceanographic Research Satellites (U)

(U) The Soviets launched their first dedicated oceanographic research satellite (OCEAN) in February 1979. The announced mission of OCEAN satellites is to obtain data from the world's oceans to chart optimum shipping routes, locate the best fishing fields, and expand the Soviets' meteorological data base.

(S) (b)(1);1.4 (c) Deployed solar panels provide power to the satellite subsystems.

(S) The OCEAN satellites use visible, IR, and microwave sensors for evaluating the characteristics of the ocean surface. In addition, the Soviets announced that the second oceanographic research satellite, Cosmos 1151 launched in January 1980, carried an active sensor for determining wave-heights. Soviet scientists also stated OCEAN satellites, along with certain Meteor and Intercosmos spacecraft, have interrogated oceanographic sea buoys and ground-based automated weather stations.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

Radar Support Satellites (U)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

Soviets also launched [redacted] RADSAT 2 spacecraft into the same 83-degree inclined orbit used by the [redacted] RADSAT 1.

(S) During 1976, the Soviets launched the first third-generation RADSAT, RADSAT 3. This spacecraft performs one undefined mission by deploying up to 24 small objects over a 3- to 4-month period. Several appropriately equipped RADSAT 3 spacecraft have been used [redacted]

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(b)(1);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

[redacted]

INTRODUCTION

(S) This study contains intelligence estimates of Soviet military support space systems. Included in these space systems are Soviet naval support, navigation, geodetic, meteorological, Earth resources, oceanographic, radar support, [redacted] satellites. The purpose of this study is to provide a detailed description of these systems and their capabilities and limitations.

(b)(1);1.4 (c)

(S) The Soviet NAVSATs provide timely navigational data to a growing number of marine users. A navigation system independent of foreign aids is essential to the efficient operation of their expanding deep-water fleet, especially during hostile conditions.

(S) The Soviet GLONASS network will provide near-continuous velocity and navigational data to all types of users. The system will probably become operational sometime after 1986.

(b)(1);1.4 (c)

(S) The Soviets used GEOSAT [redacted] satellites to determine precisely the size and shape of the Earth and also the distribution of the Earth's gravitational field. This directly contributed to an accurate solution to the ballistic missile targeting problem. [redacted]

(b)(1);1.4 (c)

[redacted]

(b)(1);1.4 (c)

(S) Military meteorological requirements are divided into two categories. First, a synoptic requirement exists to provide long-range, worldwide forecasts (12-72 hours) for strategic planning. Second, a tactical requirement is essential to provide detailed, short-term forecasts (1-3 hours) for areas as small as an individual airfield. Presently, Soviet METSATs provide data primarily for synoptic requirements. However, limited tactical inputs such as cloud and ice-cover are available.

(S) The Meteor-Priroda Earth resources satellite system is an outgrowth of the Meteor meteorological satellite program. In addition to providing valuable data on natural resources, [redacted]

(b)(1);1.4 (c)

(S) The Soviet OCEAN satellite program provides the Soviet military and scientists with extensive data on ocean conditions that were formerly obtained only through ship reports and buoy measurements. OCEAN satellite data have direct applications in oceanographic research, in the shipping and fishing industries, and in understanding the meteorological processes that occur in the remote ocean areas. The Soviet OCEAN satellites have the potential to provide real-time monitoring of ocean parameters on a global scale.

(S) The Soviet RADSAT system is a multimission program that supports a variety of military customers.

[redacted]

(U) A chronological presentation of the design, development, test, and operational milestones of the Soviet military support satellites is shown by Figures 1 through 7.

(b)(1);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

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Page 018 of 171

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(b)(1):1.4 (c)

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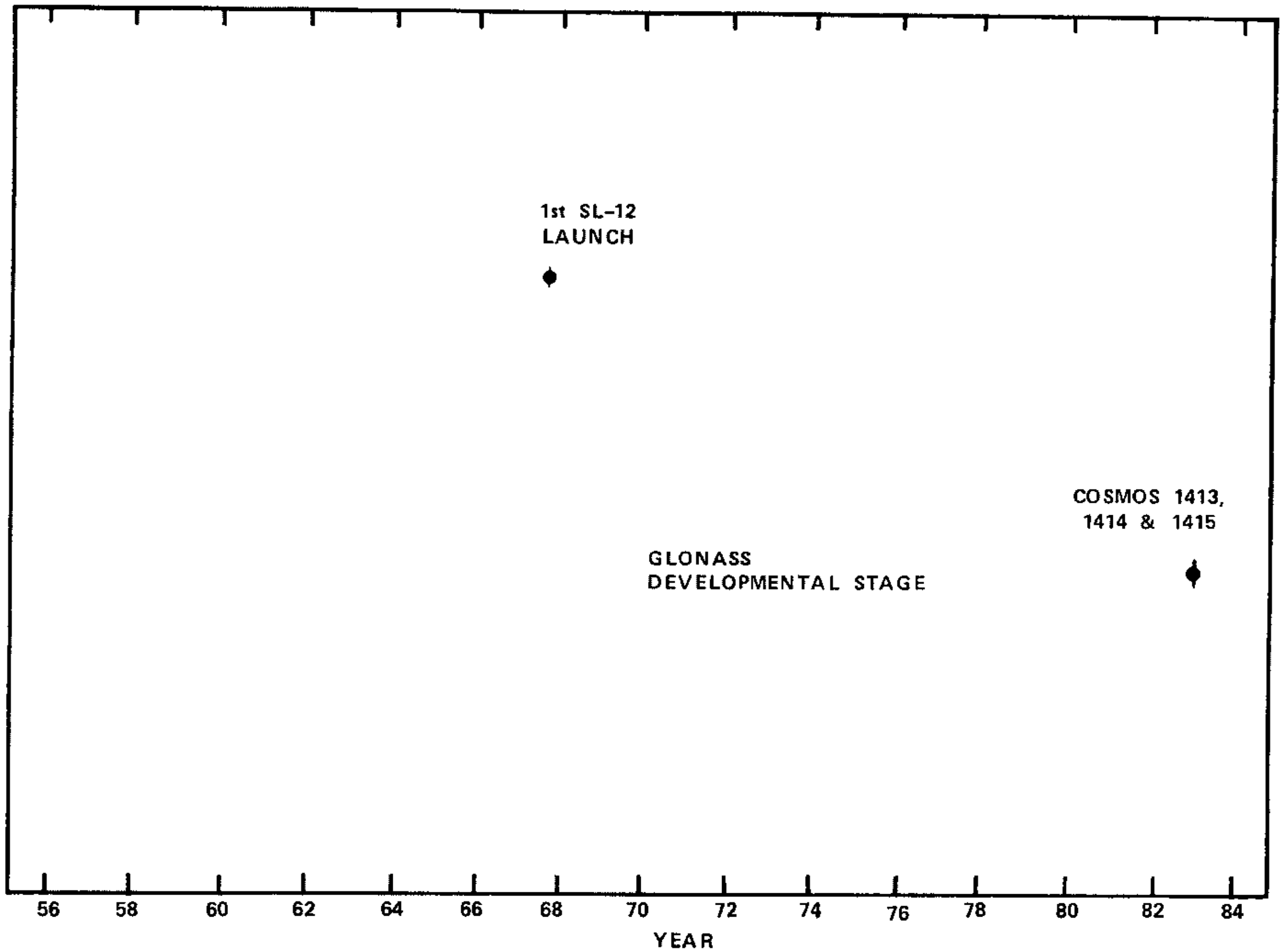

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Fig. 2 (U) GLONASS Milestones

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Page 020 of 171

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(b)(1):(b)(3):50 USC 3024(i):1.4 (c)

of the Freedom of Information and Privacy Act

Page 021 of 171

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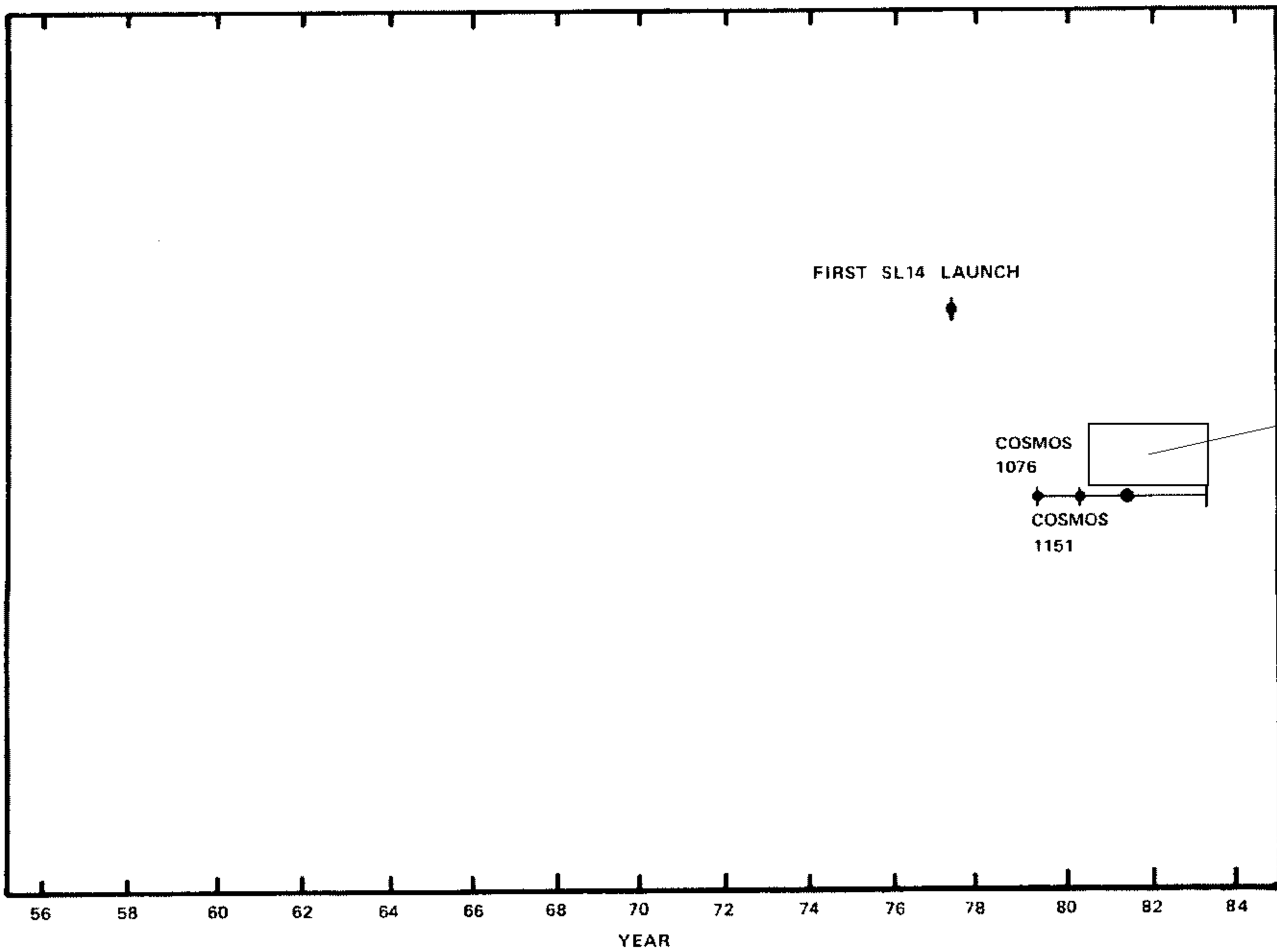
(b)(1):(b)(3):50 USC 3024(i):1.4 (c)

of the Freedom of Information and Privacy Act



(b)(1);1.4 (c)

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Fig. 5 (U) OCEAN Milestones

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Page 023 of 171

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(b)(1):Sec. 1.4(c):(b)(3):P.L. 86-36:(b)(3):50 USC 3024(i)

of the Freedom of Information and Privacy Act

Page 024 of 171

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(b)(1):1.4 (c)

of the Freedom of Information and Privacy Act

FAC-2A1: In column 2 para 3, it appears we inadvertently extended DOE's redaction in one line of text when we prepared the REF DIR to USAF. Since NASIC approved the markup, the redaction was left in. NSA also redacted the para.

FAC2A1: title redacted consistent with SME markup of table of contents

SECTION I

(b)(1);1.4 (c) NAVAL SUPPORT SATELLITE SYSTEM (S)

1. Background (U)

(S) The mission of the Soviet Naval Support Satellites, designated NAVSAT, is to provide accurate geopositioning data for ocean navigation and geodetic purposes.

(S) The Soviets, in an attempt to facilitate the global operation of their expanding navy, have developed an evolutionary spaceborne navigation system.

(b)(1);1.4 (c)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(S) The Soviet requirement for the NAVSAT system is based primarily on the needs of the submarine fleet. Submarines have unique navigation requirements. Surface exposure while obtaining a navigation fix must be limited to enhance survivability, so the navigation system must be constantly available, (or nearly so). The system must function worldwide, even in remote ocean areas. It must function 24 hours a day, unaffected by weather conditions. It must be exceptionally accurate; launcher geoposition is just as vital for an accurate SLBM trajectory as it is for an ICBM and is much more difficult to obtain.

(b)(1);1.4 (c)

(S) Other users also benefit from the NAVSAT system. These users include guided missile cruisers, missile range instrumentation ships, and oceanographic research vessels. Land-based mobile elements, such as IRBM launchers, could also find such a system useful. Aircraft generally would not benefit from the Soviet NAVSAT system.

(b)(1);1.4 (c)

(S) A Doppler-type NAVSAT system has inherent geodetic applications. Although such a system generally provides less accuracy on a single pass than optical tracking, the use of multiple passes can greatly improve accuracy. For example, the location of a fixed station can be determined to within 10 m of its true location by use of no more than 100 successive fixes. This degree of accuracy plus the simplicity of the Doppler technique makes a NAVSAT system particularly attractive for geodetic functions.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(S)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

FAC-2A1: See note above re: this para

(b)(1);(b)(3):50 USC 3024(i);1.4 (c)

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Page 026 of 171

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(b)(1):Sec. 1.4(c):(b)(3):P.L. 86-36:(b)(3):50 USC 3024(i)

of the Freedom of Information and Privacy Act

Page 027 of 171

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(b)(1):(b)(3):P.L. 86-36:(b)(3):50 USC 3024(i)

of the Freedom of Information and Privacy Act

Page 028 of 171

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(b)(1):(b)(3):P.L. 86-36:(b)(3):50 USC 3024(i)

of the Freedom of Information and Privacy Act

(b)(1);(b)(3):50 USC 3024(i);1.4 (c)

[redacted]

2.d. Users (U)

(b)(1);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

[redacted]

(b)(1);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

[redacted]

3. System Capabilities and Limitations (U)

3.a. Position Fix Accuracy (U)

(U) The position fix accuracy of any navigation system is the accuracy with which a user can determine his location relative to some reference coordinate system. This accuracy may be specified as the distance between the true location and the location as determined from the navigation system being used. Table III lists the advantages and disadvantages of navigating using a satellite Doppler system.

(S) The accuracy achievable by any Doppler NAVSAT is a function of several error factors. The paragraphs below briefly describe the nature of these factors and their contributions to the accuracy of Soviet Doppler NAVSATs. [redacted]

(b)(1);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

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TABLE II

(b)(1);1.4 (c)

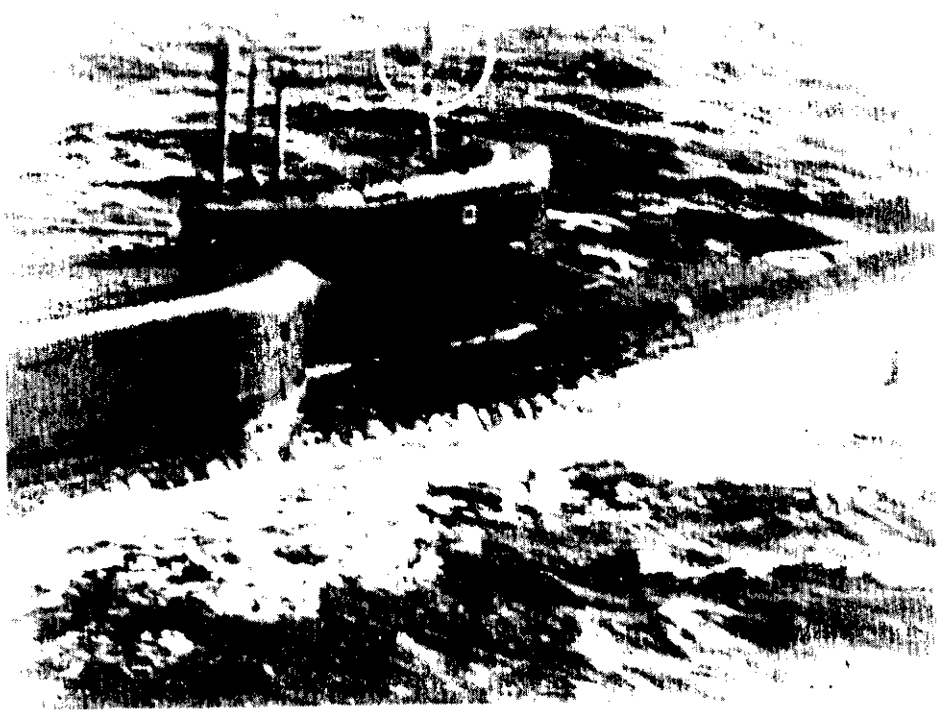

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Fig. 15 (U) PERT SPRING F on DELTA III-Class SSBN

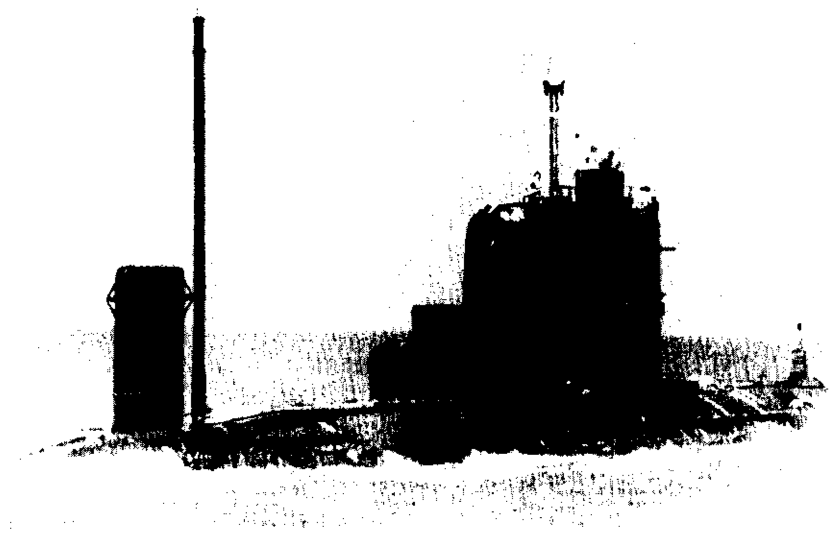

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Fig. 16 (U) PERT SPRING on GOLF-Class SS

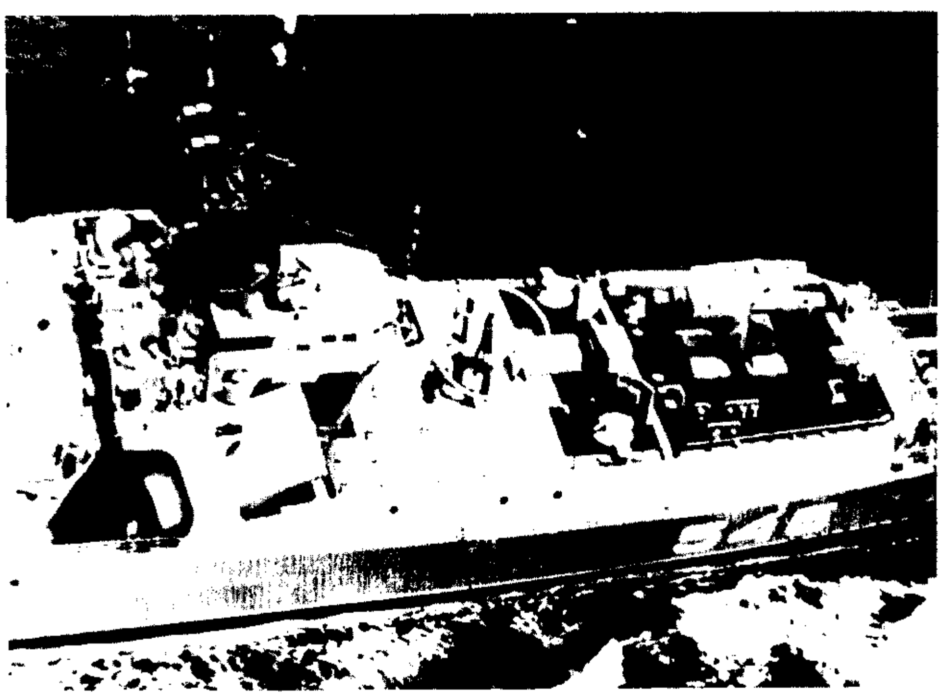

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Fig. 17 (U) PERT SPRING on KRESTA II-Class CG

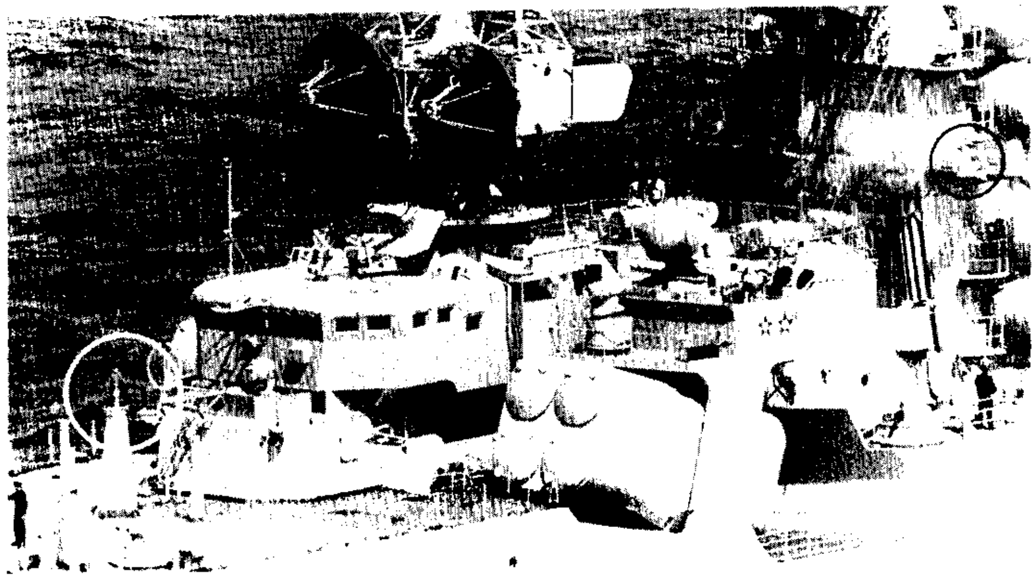

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Fig. 18 (U) PRIM WHEEL and PERT SPRING on a KRESTA II-Class CG

TABLE III

(U) ADVANTAGES AND LIMITATIONS OF A DOPPLER NAVSAT IN VARIOUS APPLICATIONS

USER APPLICATION	ADVANTAGES	LIMITATIONS
Fixed		
Mobile missile launcher	No velocity error—improved accuracy. Can use multiple position fixes to reduce position error.	Lack of accurate knowledge of antenna height above geoid.
Tactical field element man-pack portable	No velocity error—improved accuracy. Can use multiple position fixes to reduce position error.	Requires access to a computer located separately from receiver. Equipment miniaturization.
Geodetic mapping	No velocity error—improved accuracy. Can use multiple position fixes to reduce position error.	Requires ephemeris update on each orbit.
Moving		
Surface ships or submarines	More accurate than other methods. Generally more available than other methods. All-weather capability. Antenna height error reduced.	Velocity uncertainty always present reduces position accuracy. Cannot employ multiple fixes.
Aircraft	No apparent advantage. More accurate methods are available.	Outage duration between successive fixes too large for all but long-range flights. Velocity uncertainties are very large compared to ships—severely degrades fix accuracy.

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3.a.(1) Instrumentation Noise (U)

(S) This error factor arises from electrical noise in the receiving equipment, and it generates uncertainty in the measurement of received frequency and, hence, the Doppler shift. The magnitude of the uncertainty is generally small;

(b)(1);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3605

3.a.(2) Oscillator Instability (U)

(S) This factor introduces inaccuracy in the determination of the Doppler shift, since frequency depends on the condition of the satellite oscillator, and in the determination of the precise time of

(b)(1);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

3.a.(4) Geodetic Uncertainties (U)

(S) After a user computes position on the Earth, there still exists an error associated with imprecise knowledge of the Earth's shape.

(b)(1);1.4 (c)

3.a.(5) Orbital Data Inaccuracy (U)

(S) The ability of a user to precisely compute position depends upon the accuracy of the satellite orbital data available since the user employs the satellite as a reference point. For nonmoving users, this source generates the largest single error, especially when the data used have been projected several hours ahead.

(b)(1);1.4 (c)

3.a.(6) User Velocity Uncertainties (U)

(S) A moving user always encounters some uncertainty in velocity. This uncertainty influences positioning accuracy in two ways: (1) it causes an uncorrectable deviation in Doppler shift and (2) it represents a direct error that accumulates over the duration of the signal reception period and the subsequent computation period. The error from this source generally represents the largest error experienced by a moving user;

(b)(1);1.4 (c)

(b)(1);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

3.b. System Coverage and System Availability (U)

(S) "System coverage" refers to the geographic distribution of satellite availability to a user.

(b)(1);1.4 (c)

(U) "System availability" expresses how frequently a prospective user can obtain access to the Doppler navigation satellite system for position fix estimation purposes. System availability may be characterized in terms of average waiting time and the probability of immediate visibility. "Average waiting time" is the average time between the end of a successful satellite visibility period and the beginning of the next period. "Probability of immediate visibility" refers to the likelihood, at any random time, that a user will have access to a satellite. These parameters are a function of the minimum elevation angle at which the satellites are usable to an observer, the minimum required pass duration, the latitude of the user, the number of satellites in the system, and the orbital parameters of the satellites.

Pages 22-32 are denied in full and not provided

SECTION II

(b)(1);1.4 (c) [redacted] SUPPORT SATELLITE SYSTEM (S)

1. Background (U)

(S) The mission of the Soviet NAVSAT systems is to provide accurate geopositioning data for ocean navigation and geodetic purposes.

(b)(1);1.4 (c)

(b)(1);1.4 (c)
(b)(1);1.4 (c)
(b)(1);1.4 (c)

(S) [redacted] the Soviets commemorated the launch of Cosmos 1000, [redacted] by announcing the navigational mission of that spacecraft. Subsequent NAVSAT [redacted] launches were not accompanied by a Soviet announcement indicating their navigational role, although the Soviets did mention that Cosmos 1383, the first satellite to carry a COSPAS search and rescue satellite package, was a navigation satellite. (b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i) The NAVSAT [redacted] network supports Soviet fishing and merchant fleets as well as military users.

(b)(1);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

2. System Description (U)

2.a. Spacecraft Configuration (U)

(S) The Soviets first displayed a mock-up of Cosmos 1000, designated Tsicada, at the 1979 Paris Air Show. (See Figure 25.)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

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Fig. 25 (U) Tsicada NAVSAT at Paris Air Show

(S) Figure 27 shows two types of antennas on the nadir side of the NAVSAT [redacted] displayed at the 1979 Paris Air Show.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

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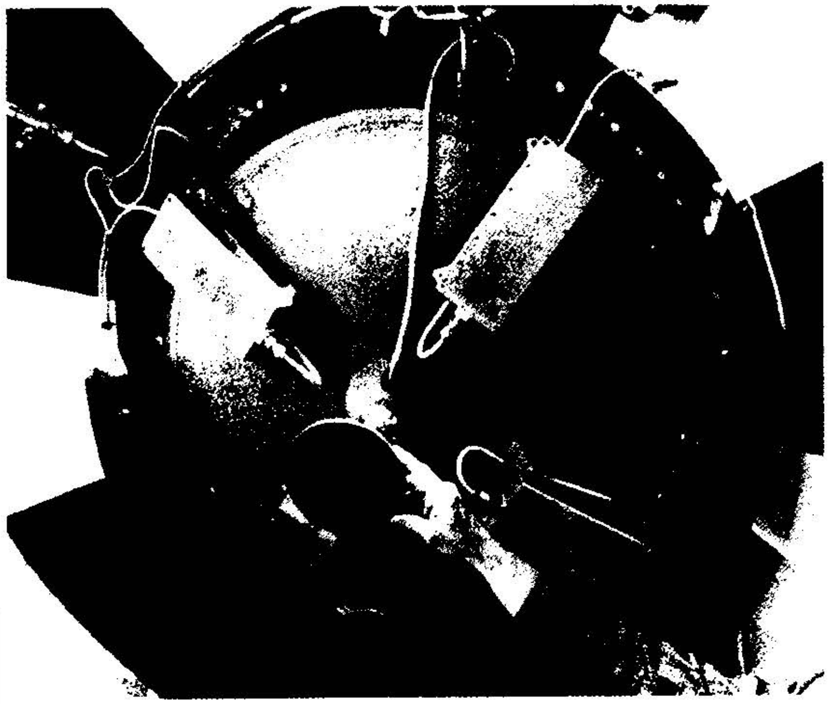

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Fig. 27 (S) [redacted] (b)(1);1.4 (c)

(b)(1);(b)(3):50 USC 3024(i);1.4 (c)

[redacted]

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024 (i)

[redacted] The TASS announcement accompanying the launch of Cosmos 1000 stated that the spacecraft would serve as a navigational beacon for the Soviet merchant and fishing fleets.

2.c. Operation, Command, and Control (U)

(b)(1);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

[redacted]

2.d. Users (U)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(S) The PERT SPRING antenna (discussed in Section I) is compatible with the NAVSAT [redacted] The Soviets announced publicly that the PERT SPRING-equipped ARKTIKA-Class AGBN Sibir used Cosmos 1000, a NAVSAT [redacted] on a 1978 exercise in the Arctic Ocean.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

[redacted]

Pages 36-39 are denied in full and not provided.

(b)(1);1.4 (c)

4.b.(7) COSPAS Search and Rescue Package (U)

~~(S)~~ Cosmos 1383, a NAVSAT [redacted] (Figure 33) launched in June 1982, carried the first COSPAS package of the COSPAS/SARSAT search and rescue satellite program. COSPAS/SARSAT is a multi-national project designed to use satellites to quickly locate ships and aircraft in distress. COSPAS is the Soviet term for their part of the project; the United States, Canada, France, and Norway are cooperating to build the Western half of the project, designated SARSAT from "search and rescue satellite."

(U) Each COSPAS/SARSAT satellite carries a package designed to receive signals from activated emergency beacons on downed aircraft and maritime vessels in distress. The satellite relays the signal to a Local User Terminal (LUT) in real-time. LUTs are or will be located at Scott Air Force Base, Illinois; Point Reyes, California; Kodiak, Alaska; Ottawa, Canada; Toulouse, France; and Tromso, Norway. Soviet LUTs will be in Vladivostok, Arkhangelsk, Moscow, and possibly at another location in Siberia. The LUT processes the signal to geolocate the emergency beacon using a Doppler shift principle nearly identical to that outlined in Appendix II. The LUT relays the position to a Mission Control Center at either Moscow or Scott AFB, which then notifies the nearest search and rescue unit.

(U) The COSPAS system (hardware, ground stations, satellite package, etc.) was developed by the Soviet Ministry of the Merchant Marine (MORFLOT); the SARSAT system was developed jointly by NASA, the Department of Communications (Canada), and the Centre National d'Etudes Spatiales (France). However, the individual program managers coordinated intensively during the development phase so that the two systems are entirely compatible; that is, the LUT at Scott AFB can use COSPAS satellites as easily as it can use Western SARSAT spacecraft.

(U) COSPAS satellites transpond emergency signals transmitted on the civil frequency of 121.5 MHz. SARSAT packages transpond signals transmitted on both 121.5 MHz and 243 MHz, the military emergency frequency. Using these emergency beacons, Cosmos 1383 has demonstrated an average position fix accuracy of 10 to 12 km. This accuracy is limited by the distress beacons themselves; developed long before the start of the COSPAS/SARSAT program, the beacons' carrier frequency is not stable enough for extremely accurate Doppler measurements. A new beacon system, being developed especially for COSPAS/SARSAT and operating at 406 MHz, will improve average accuracy to 2 to 5 km. The new beacon signal can also contain digital information identifying the aircraft or vessel in distress, the nature of the emergency, and the location of the accident. In cases where a COSPAS/SARSAT satellite hearing an emergency beacon is not at the moment within view of a LUT, the 406 MHz signal can be processed on board the satellite and the accident location stored in on-board recorders to be played back to a LUT later.

(U) Rescue authorities have credited Cosmos 1383 with saving at least 22 lives during its initial 9 months of operation. The second Soviet COSPAS satellite, was launched on 24 March 1983, 4 days before the launch of the first SARSAT satellite— a US weather satellite designated NOAA 8. The US plans to equip at least two more weather satellites, NOAA-F and NOAA-G, with SARSAT packages.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

[redacted]

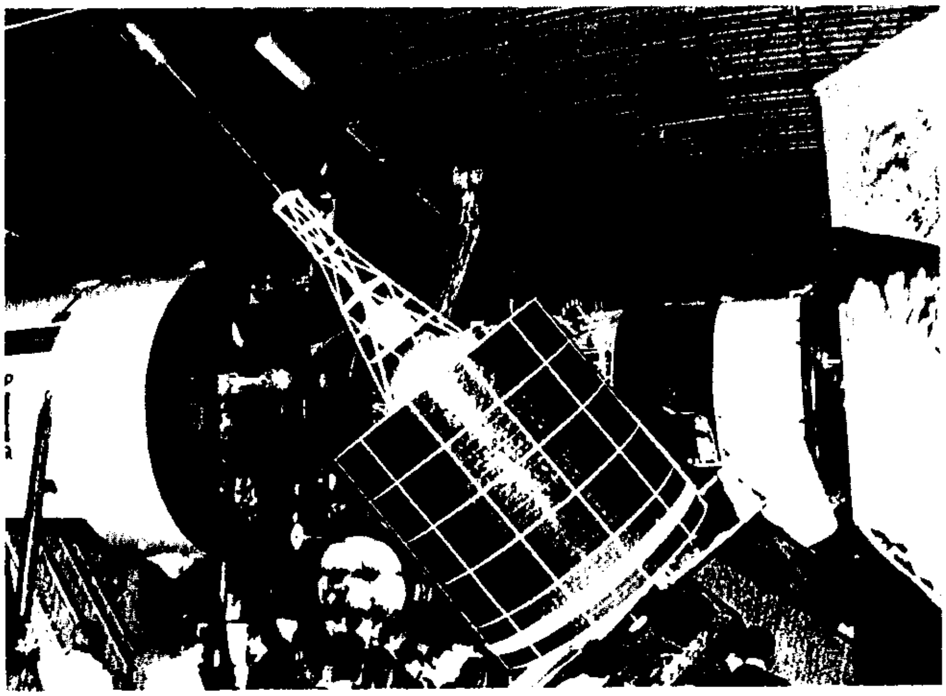

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Fig. 33 (U) Model of Soviet Satellite Equipped with COSPAS Package

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SECTION III

GLOBAL NAVIGATION SATELLITE SYSTEM (U)

1. Background (U)

(U) The Soviet Global Navigation Satellite System (GLONASS) will allow all types of users to obtain instantaneous, worldwide position and velocity fixes by accessing signals from at least three GLONASS satellites simultaneously. The Soviets apparently intend to construct a system similar to the US NAVSTAR network.

(U) The Soviets announced GLONASS in a February 1982 filing with the International Frequency Registration Board. The Soviets stated that the GLONASS network would consist of nine to 12 satellites placed in three orbital planes, with three or four satellites in each plane. The announced GLONASS orbit is 20,000 km circular, 12 hour orbit inclined at 63 degrees. The Soviets also stated that GLONASS was designed for worldwide aircraft navigation, and that the satellites in the system would be designated "GLONASS-1," "GLONASS-2," etc.

(U) The system as outlined by the Soviets could provide two-dimensional position fixes and velocity vectors. Users requiring a three-dimensional fix, such as aircraft, would have to determine the remaining coordinate, altitude, by other means, such as a radar altimeter.

(S) On 12 October 1982, the Soviets launched Cosmos 1413, 1414, and 1415 with an SL-12 launch vehicle from Tyuratam Missile and Space Center. TASS announced the satellites were in a 19,100-km near-circular orbit inclined at 64.8 degrees. According to TASS, the mission of the three satellites was to "improve the components and equipment of a space navigation system that is being developed to locate civilian planes and merchant marine and fishing ships of the Soviet Union."

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

[redacted]

solely to evaluate launch vehicle performance, it seems equally likely that they were identical to Cosmos 1414 and failed shortly after launch.

2. System Description (U)

(b)(1);(b)(3):50 USC 3024(i);1.4 (c)

[redacted]

2.b. Network Orbital Characteristics (U)

(S) Appendix I presents launch dates and initial orbital parameters of the experimental GLONASS satellites. According to the Soviets, the GLONASS network will consist of 9 to 12 satellites in 20,000-km circular orbits with 63-degree orbital inclinations. Three or four satellites will be in each one of the three orbital planes. The planes will probably be separated in right ascension by 120 degrees. The period of the orbit will be 12 hours, which means the ground trace of the satellite will repeat every 24 hours.

(S) The first three experimental GLONASS satellites have slightly different orbital parameters, than those announced by the Soviets. Cosmos 1413, 1414, and 1415 are in an approximately 19,100 km circular orbit with 64.8-degree orbital inclination. The lower orbit yields a shorter period of 11 hours 13 minutes.

(S) Figure 35 shows the proposed network configuration. Initial operating capability of the 9- to 12-satellite network (as proposed by the Soviets) may be achieved in 1986 or 1987.

(S) It is not certain that the Soviets will limit themselves to the 9- to 12-satellites network as mentioned in their IFRB filing. With such a system, only three satellites would normally be within view to a user at any one time, limiting location fixes to only two dimensions. However, there is little to preclude the Soviets, despite their announced intentions, from placing 18 or even 24 satellites into the GLONASS network, ensuring four satellites in simultaneous view and, thus, providing a three-dimensional positioning capability. [redacted]

(b)(1);1.4 (c)

(b)(1);1.4 (c)

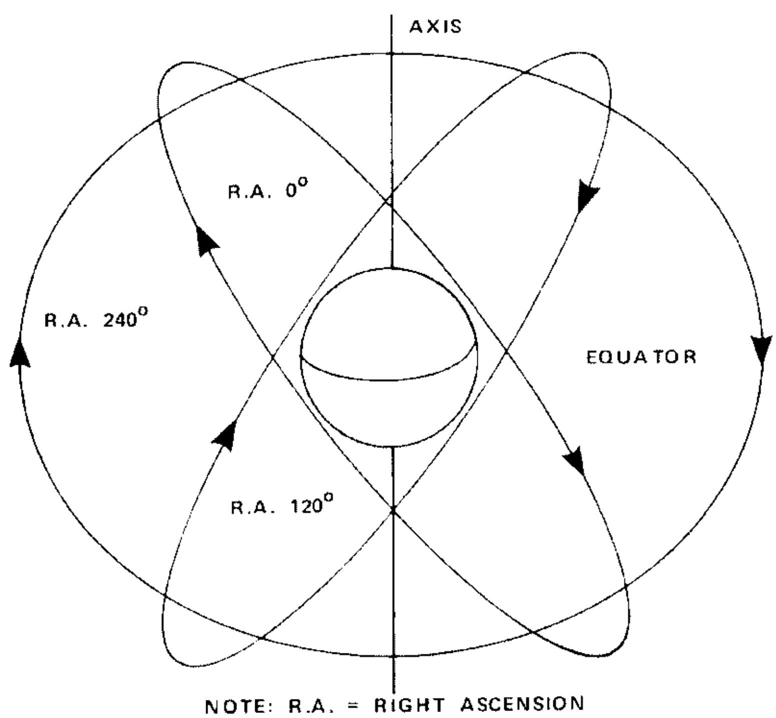

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Fig. 35 (U) Orbital Plane Arrangement of Proposed GLONASS Network

2.c. Operation, Command, and Control (U)

(b)(1);1.4 (c)

(S) Like Soviet NAVSAT [redacted] customers, GLONASS users will probably determine position and velocity using a continuous passive measurement combined with satellite ephemeris data. In contrast to other Soviet navigation satellites, GLONASS users will receive signals from three satellites simultaneously instead of using multiple successive fixes like NAVSAT [redacted] satellites. The use of three satellites allows the user to determine three unknown parameters (usually latitude, longitude, and user clock bias). This allows the user to determine three-dimensional position and velocity if altitude is known. Altitude may be determined by instruments such as a radar altimeter, pressure altimeter, or laser altimeter.

(b)(1);1.4 (c)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

[redacted]

2.d. Users (U)

(U) The Soviets have stated that GLONASS will provide navigation support to aircraft and merchant marine and fishing ships. This announcement indicates the Soviets intend to develop the civil aspects of the GLONASS system. The possibility also exists that the Soviets will offer GLONASS receivers on a commercial basis, in competition with GPS. They would certainly have a captive market in the Bloc countries, and, with government funding, the Soviets could offer GLONASS services at a price less than GPS.

(S) It is inconceivable that the Soviets would ignore the military aspects of GLONASS. GLONASS, or a variant of GLONASS, will certainly be primarily a military system, with civil navigation support a secondary mission. With an expanded (three-dimensional) capability, GLONASS could provide navigation support to cargo aircraft, bombers, tankers, fighters, cruise missiles, ballistic missiles and spacecraft; in short, support equivalent to GPS.

3. System Capabilities and Limitations (U)

3.a. Accuracy (U)

(S) GLONASS accuracy will be affected by most of the same error factors that effect the NAVSAT spacecraft. An accurate assessment of the accuracy of the GLONASS system cannot be made until the system is nearer its operational stage (b)(1);1.4 (c) [redacted] Because of the similarity to the US GPS systems, GLONASS could have a comparable position fix accuracy that is, on the order of 5 to 10 meters. [redacted]

(b)(1);1.4 (c)

3.b. System Coverage and Availability (U)

(U) A network of nine satellites could provide nearly continuous two-dimensional coverage to all parts of the Earth except areas near the equator. A network consisting of 12 satellites could provide complete two-dimensional coverage over the entire Earth surface. A minimum of 18 satellites would be required to provide continuous three-dimensional coverage to all parts of the Earth.

3.c. Mutual Usability of US-Soviet Systems (U)

(S) (b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024 (i)

[redacted] The Soviets' public announcement of the GLONASS System, however, indicates they may depend more heavily on GLONASS for civil navigation than they have on their low-altitude, Doppler NAVSAT system. Certainly their military systems will use GLONASS rather than the civilian (degraded accuracy) GPS.

4. Subsystems (U)

4.a. Launch System (U)

(S) Cosmos 1413, 1414, and 1415, the developmental GLONASS satellites, were launched from TTMTC using an SL-12 launch vehicle. (See Figure 36.) The fourth stage was constructed to carry and

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deploy three satellites and to make orbital plane inclination changes.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024 (i)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(b)(1);(b)(3):50 USC 3024(i);1.4 (c)

4.b.(4) Signals (U)

(U) The Soviets announced that each GLONASS satellite would transmit navigation signals in two of three possible frequency ranges, two signals to compensate for ionospheric refraction. The announced ranges were 1240-1260, 1597-1610, and 1610-1617 MHz. Maximum spectral power density was listed as −44 dBW/Hz (1597-1617 MHz) and −57 dBW/Hz (1240-1260 MHz) with satellite axial antenna gains of 13.3 dB (1597-1617 MHz) and 11.8 dB (1240-1260 MHz).

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

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SECTION IV

FIRST-GENERATION GEODETIC SATELLITE SYSTEM (U)

1. Background (U)

(U) Geodesy is defined as "that branch of mathematics which determines exact positions of points and the figures and areas of large portions of the Earth's surface, or the shape and size of the Earth, and the variations of terrestrial gravity."

(S) From this definition and the objectives of the US geodesy program, it is assumed that, through the use of man-made Earth satellites, the Soviets desire to establish a set of worldwide control points to fix a unified datum system referenced to an Earth-centered coordinate system and to establish the coefficients required in the spherical harmonic development of a description of the Earth's gravitational field.

(S) Although it is difficult to assess the intentions of the Soviets concerning the military applications of their geodetic program, there are several direct beneficiaries of accurate geodetic modeling. The ballistic missile targeting problem requires accurate geopositioning of both the launch site and the target area as well as precise determination of the influence of the Earth's gravitational field on the missile flight path.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3605

2. System Description (U)

(b)(1);(b)(3):50 USC 3024(i);1.4 (c)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(b)(1);1.4 (c)

(b)(1);Sec. 1.4(c);(b)(3):18 USC 798;(b)(3):50 USC 3024 (i)

(S) The Soviets also are satisfying their geodetic requirements using other means, such as navigational satellites, Western geodetic satellites equipped with laser reflectors (b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(S) The NAVSAT can provide comparable geopositioning accuracy to GEOSAT with multiple Doppler passes. Open-source literature indicates a Warsaw Pact country is constructing Doppler receivers that can be used for geopositioning using the Doppler passes of the US Navy Navigation Satellite System (NNSS).

3. System Capabilities and Limitations (U)

3.a. Position Fix Accuracy (U)

(U) The accuracy of position location depends upon the error associated with determining the location of a fixed position relative to the Earth's center of mass.

Once the user of GEOSAT data has geolocated a number of positions on the Earth, he can make ties between the positions. Conversely, by assuming or by independently determining the position of a tracking station and observing the position of the GEOSAT versus its predicted position, it is then possible to construct a gravitational model. With a worldwide network of stations, local anomalies and zonal harmonics can also be determined. This gravitational model and local/zonal variance are direct inputs in ballistic missile trajectory calculations.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

3.e. Mutual Usability of US-Soviet Systems (U)

~~(S)~~ The Soviets have constant access to and do make use of US GEOSATs. The US, however, has never expressed an interest in using Soviet GEOSAT 1 satellites. The US GEOSATs either have continuously transmitted Doppler beacons or else have reflective surfaces that can be tracked when illuminated,

(b)(1);1.4 (c)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

Pages 52-53 are denied in full and not provided.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024 (i)

[redacted]

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

[redacted]

4.c.(2) Equipment (U)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

[redacted]

(U) The Soviets appear to be phasing from optical tracking methods to laser tracking on cooperative satellites equipped with laser reflectors. Increased reliance on laser tracking of satellites is probably related to lower operations and maintenance costs, fewer operating personnel, increased real-time accuracy, and the ability to replace multiple optical sites with a single laser range finder.

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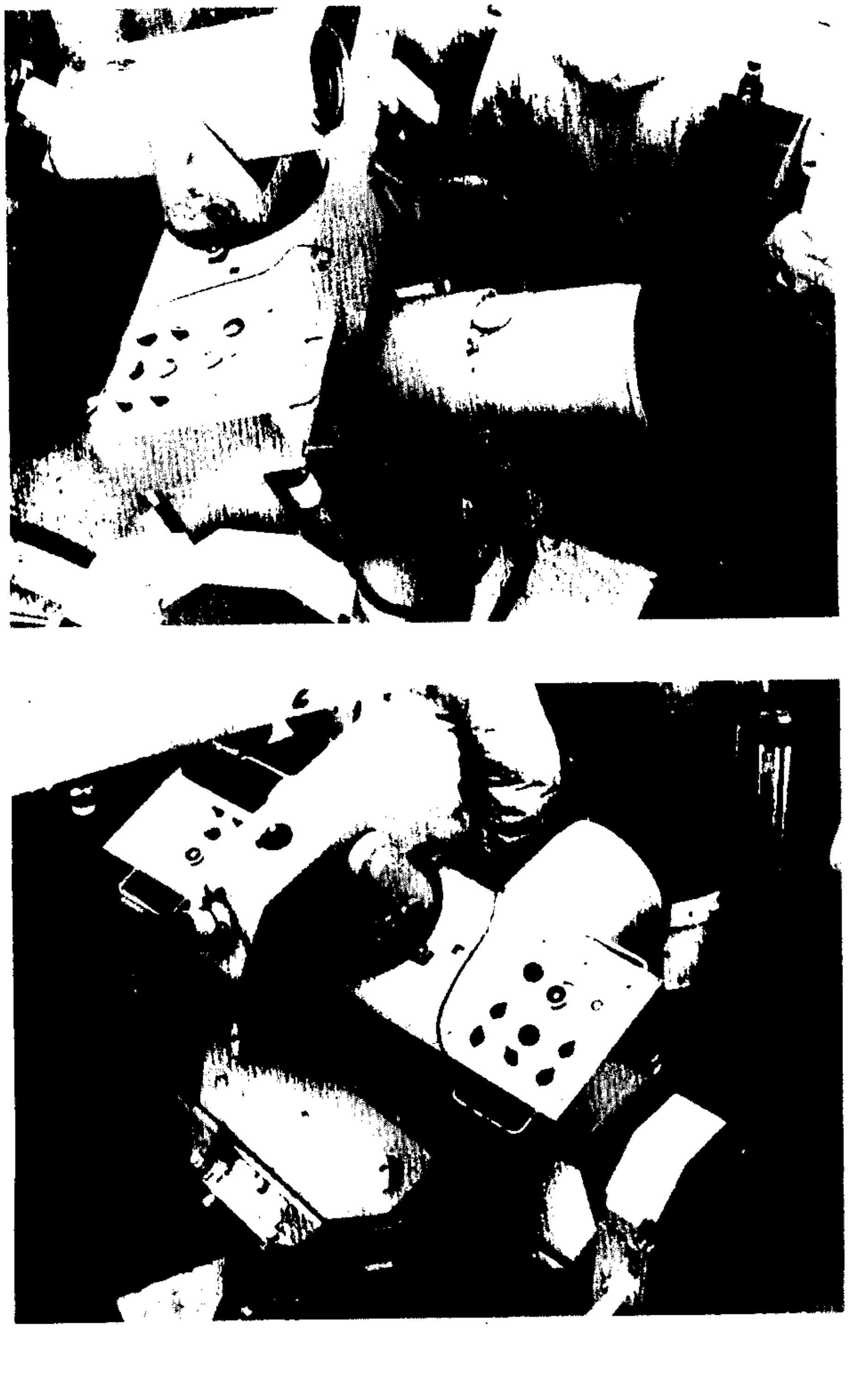

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Fig. 45 (U) FAU-2 Optical Satellite Tracking Camera

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Fig. 46 (U) FAS Ballistic Tracking Camera

FTD A81-1824 ~~FOR OFFICIAL USE ONLY~~

Fig. 47 (U) AFU-75 Tracking Camera

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Fig. 48 (U) FAS and AFU-75 Cameras

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Fig. 49 (U) VAU Optical Tracking Camera System

(b)(1);1.4 (c)

(U) Figure 50 shows a technician from the Central Geophysics Institute of the Potsdam Academy of Sciencies (GDR) adjusting a new laser ranger/camera built by the East German firm of Carl Zeiss Jena. This laser ranger is of the second generation type.

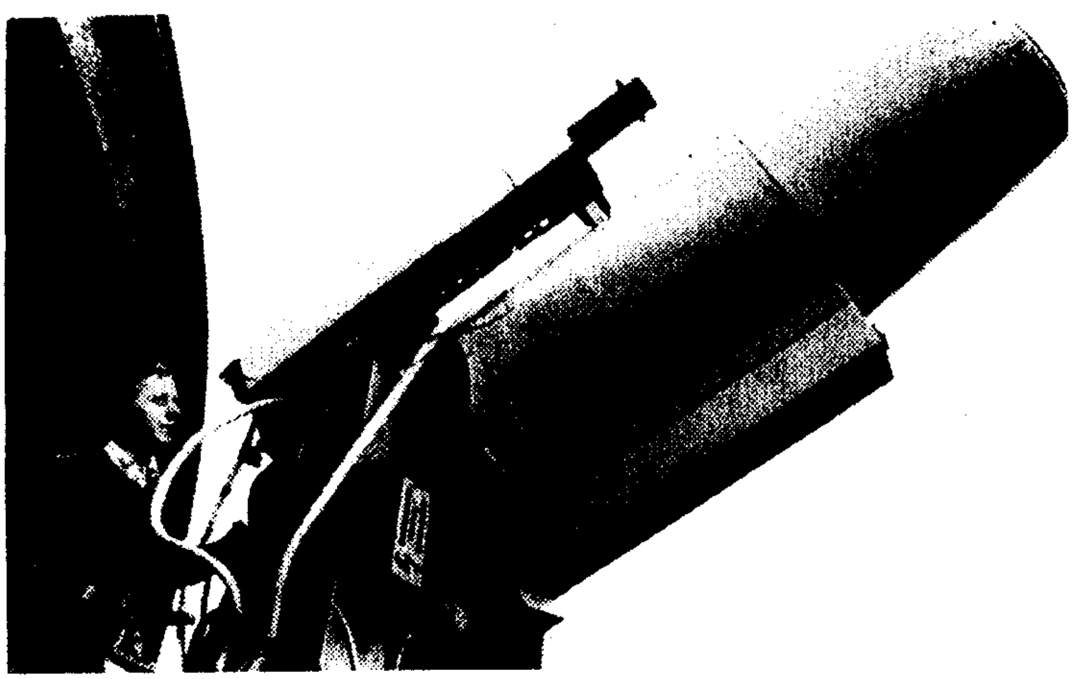
5. Current Geodetic Space Systems (U)

(b)(1);(b)(3):10 USC 424;1.4 (c)

(b)(1);1.4 (c)

~~(S)~~ The Soviets have announced the presence of laser retroreflectors on their two lunar rovers and on Salyut 4, Intercosmos 17, and Bulgaria 1300. Figure 52 shows the laser retroreflector carried by Bulgaria 1300. (See Figure 53.) Retroreflectors were probably also present on Salyut 6 and on Salyut 7.

(b)(1);1.4 (c)



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~~FOR OFFICIAL USE ONLY~~

Fig. 50 (U) Carl Zeiss Jena Laser Range Finder Camera

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TABLE X

(b)(1);1.4 (c)

~~SECRET~~

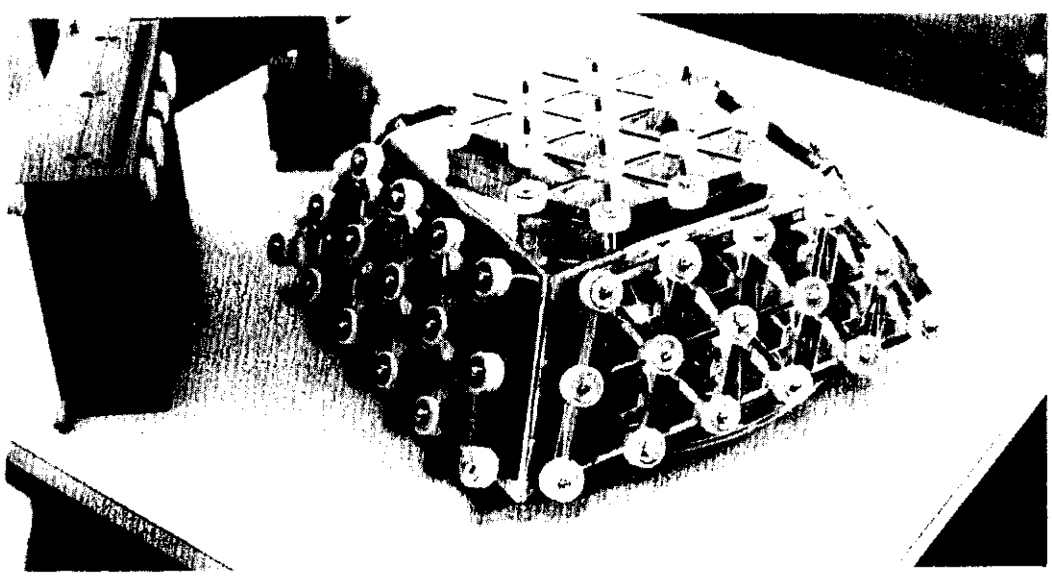

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Fig. 52 (U) Laser Retroreflector on Bulgaria 1300

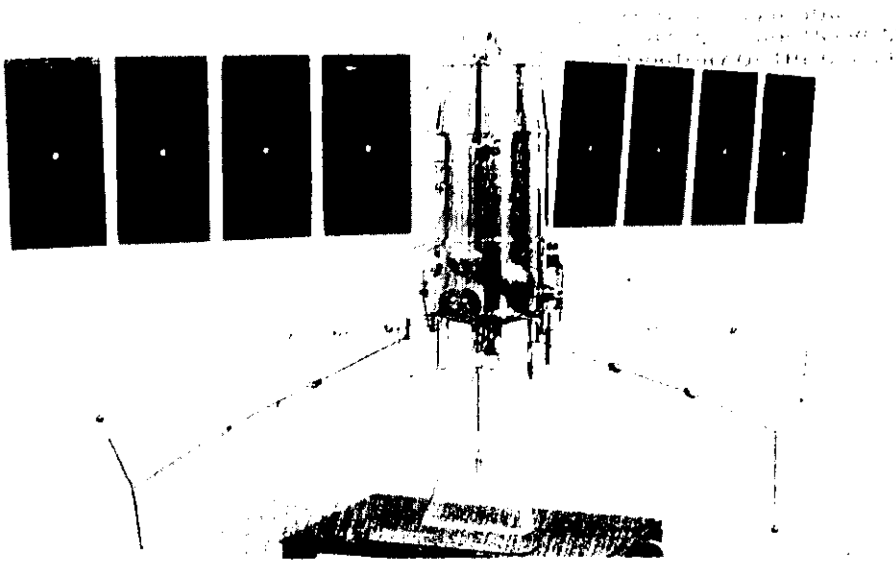

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Fig. 53 (U) Model of Bulgaria 1300

~~(C NOFORN)~~ The Intercosmos Council has often discussed a geodetic satellite, supposedly now in the developmental phase, called DIDEX (Differential Doppler Experiment). DIDEX would consist of a mother satellite that ejects two small subsatellites and then tracks the subsatellites with a laser range finder to map gravitational perturbations. [redacted] The first launch was originally scheduled for 1985 or 1986. However, DIDEX, an ambitious project in itself, has been delayed by the political situation in Poland, which is the primary contributor of much of the DIDEX hardware. The status of the program is currently uncertain.

(b)(1);1.4 (c)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

[redacted]

SECTION V

SECOND-GENERATION GEODETIC SATELLITES (U)

1. Background (U)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(S) The direction of the Soviet space geodesy program became unclear with the demise of the last GEOSAT I (b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024 (i) There had been speculation that the Soviets, having access to updated geodetic models supplied by the US, had no need to continue their space geodesy program. The launch of (b)(1);1.4 (c) indicates that the Soviets have continuing military requirements for satellite-provided geodetic data.

2. System Description (U)

(b)(1);(b)(3):50 USC 3024(i);1.4 (c)

2.b. Orbital Characteristics (U)

(b)(1);1.4 (c)

(S) (b)(1);1.4 (c) The increased visibility to ground stations produced by the high altitude, high inclination orbit is useful for geodetic purposes.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

2.d. Users (U)

(b)(1);1.4 (c)

(S) However, the Soviets continue to discuss in open source literature their efforts to refine their geodetic Earth model, despite having access to recent, accurate US models. With increasing US consideration of super-hardened Minuteman/MX silos, the Soviets may be attempting to decrease their ICBM or even their SLBM circular error probability by further reducing geodetic errors.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

Pages 70-72 are denied in full and not provided.

SECTION VI

METEOR 2 SATELLITE SYSTEM (U)

1. Background (U)

1.a. General (U)

(U) The military meteorologist must be ready to support military operations anywhere in the world, to describe and forecast weather on a global basis as well as for certain specified areas. To fulfill this task, the meteorologist needs global observations of atmospheric variables such as pressure, temperature, wind, precipitation, humidity, clouds, and aerosols.

(U) Conventional observations can supply some of this needed data, but have two major limitations—(1) the network of these observations is relatively sparse except over continental areas, and (2) conventional observations over the territory of a particular country may be withheld from other nations.

(U) The METSATs can overcome some of the limitations of conventional observations. Satellites can observe the Earth's atmosphere on a global basis, unlike the conventional observations network. In addition, no country can easily obstruct meteorological observation of its atmosphere from satellites. Indeed, satellites may provide the only meteorological data from a particular country if conventional data is withheld.

~~(S)~~ The METSATs are versatile systems capable of carrying experimental payloads and conducting missions other than dedicated meteorological data acquisition. [redacted] (b)(1);1.4 (c) The Soviets have announced retrograde METSATs are also used for Earth resources exploration and meteorological data acquisition.

(U) Meteorological sensors on satellites basically measure electromagnetic energy emitted or scattered from the Earth or atmosphere. Some observations, such as cloud cover pictures at visual or IR wavelengths can be directly interpreted by the meteorologist. Most types of sensor data, however, are not as easily interpreted, and observed radiation must be processed through complex computer algorithms to retrieve estimates of the properties of atmospheric variables.

1.b. METSAT Launches (U)

~~(S)~~ The Soviets first publicly acknowledged an interest in developing METSATs shortly after the launch of Sputnik 1 in October 1957. [redacted] (b)(1);1.4 (c)

[redacted] (b)(1);1.4 (c)

~~(S)~~ With the launch of Cosmos 144 in February 1967, the Soviets initiated a new series of METSAT launches. [redacted] (b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i) These vehicles included Cosmos 156, 184, 206, and 226. The Soviets announced the operation of three two-satellite systems called Meteor—Cosmos 144 and 156, Cosmos 144 and 184, and Cosmos 184 and 206. A METSAT launch failure precluded establishing a fourth Meteor system.

~~(S)~~ The launch of the first Meteor, later designated Meteor 1/1 from Plesetsk on 26 March 1969 indicated a long-range Soviet commitment to a satellite meteorological program. Meteors 1/5 and 1/10 through 1/27 were launched into higher, 900-km, near-circular orbits.

~~(S)~~ On 11 July 1975, the Soviets initiated an advanced METSAT network with the launch of a Meteor 2 type satellite. Since then the Soviets have launched the Meteor 2 satellites from Plesetsk into the standard 900 km, 81-degree inclined orbit at a rate of about one per year. The Meteor 2 spacecraft replaced the older, posigrade Meteor 1 satellites.

1.c. Soviet Meteorological Related Satellites (U)

~~(S)~~ [redacted] (b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024 (i) During 1975 the Soviets established the State Scientific Research Center for the study of the Environment and Natural Resources, often called Priroda (Nature) in Soviet literature. When Meteor 1/25 was launched in May 1976, [redacted] (b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024 (i)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(U) The Soviets continued to develop and use the low-altitude manned tier of their METSAT network. Such manned flights are not dedicated to meteorological observations, but the flights do provide an opportunity for special measurements and for testing new instruments. In addition, the lower altitude of these flights can provide much higher resolution than is available from their Meteor series. The crew also provides mission flexibility, the opportunity to repair or adjust instruments, and availability of direct human observations.

~~(S)~~ A geostationary operational meteorological satellite (GOMS) was scheduled to be launched in support of the 1978-1979 First GARP (Global Atmospheric Research Program) Global Experiment (FGGE). The Soviets delayed the launch date several times; the current estimate of the first GOMS launch data is 1985. The Soviets attributed these delays to the inability of a geostationary METSAT located over the equator to image adequately the extreme northern regions. More likely reasons for the delay are technical problems in data processing or in obtaining adequate sensor resolution from geostationary altitude.

~~(S)~~ The Soviets stated their intention to place the GOMS at 70° E, but they reserved the right to change its location at a later time. The expected lifetime of the first GOMS is 24-36 months. The satellite will be three-axis stabilized and will carry a scanning radiometer in the visible and IR ranges.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(U) The Soviets are also launching METSATs in a cooperative program with other socialist countries. Intercosmos 20, launched on 1 November 1979, carried instruments for Earth resources, meteorological, and oceanographic observations. Some of the instruments included were a multichannel spectrometer, a double-polarization radiometer R-225, and a magnetometer for measuring the three components of the Earth's magnetic field. Organizations involved in the experiments included the following:

Institute of Space Research of the USSR Academy of Sciences

Marine Hydrophysics Institute of the Ukrainian Academy of Sciences

Institute of Earth Magnetism, the Ionosphere and Propagation and Radio Waves of the USSR Academy of Sciences

Electronics Institute of the Academy of Sciences of the GDR

Dresden Polytechnical Institute of the Academy of Sciences of the GDR

Budapest Polytechnical University

Tesla Enterprise of Czechoslovakia

An unidentified Romanian organization

(U) Soviet meteorologists recognize and acknowledge the limitations of meteorological satellite observations. Cloud imagery from space may not always correspond to visual or radar observations, and an atmospheric sounding from space may in fact be an average based upon numerous observations over a large area but reported as the profile for one location. Observational data obtained from meteorological satellites are inherently less accurate than, and are not necessarily simultaneous with, conventional ground-based and upper-air observations. The Soviets have undertaken programs to assess, and possibly to compensate for, these limitations.

For FAC2A1 RE: column 2 para 2: when we REF DIR to USAF, we sent highlighted version reflecting DOE's markup. It seems we inadvertently withheld all of this para though DOE stopped 5 lines from bottom. NASIC concurred with highlights thus we will retain the redaction but reconsider if appealed. (NSA redacted too)

(U) The Scientific Research Institute of Hydrometeorological Instrument Building in Moscow is evaluating cloud observations within 200 km of Tashkent and Borispol. They are comparing three parameters—cloud observations collected visually, data obtained from Soviet radars, and simultaneous satellite imagery. The Nature Resources Space Research Institute of the Academy of Sciences of Azerbaydzhan has deployed a mobile laboratory called Priroda (Nature) to compare data collected via aircraft and satellite remote-sensing techniques with observations obtained at the Earth's surface. Meteorologists at the Main Geophysical Observatory in Leningrad propose that remote sensing accuracy can be improved by measuring cloud-free atmospheric radio-thermal emission, a technique currently receiving increased emphasis within the Soviet Union.

1.d. Military Use of Meteor Data (U)

(C) In general, only a limited amount of information on the development of military systems is available because results become classified once research and development programs begin to show military potential. Consequently, it is necessary to infer possible military applications of current METSAT programs.

(C) Meteorological data is vital to military commanders at all levels. Soviet military services are almost certainly receiving better meteorological support than is the civilian sector, primarily on the basis of their higher priority. Satellite derived data provide important weather support to the Soviet military.

(S) The existence of a single Soviet meteorological service organization, similar to the USAF Air Weather Service, may only be surmised at best; no hard evidence has yet been uncovered to verify such an organization. However, evidence indicates the existence of military meteorological platoons, sections, or units that are organic to the combat units they support. The detailed organizational structure of these military weather services and units is not fully known. It seems likely, however, that these weather units use satellite-derived weather information to brief commanders and staff from the highest to the lowest levels.

1.d.(1) Theater/Front Forces (U)

(b)(1);1.4 (c) [redacted]

(b)(1);1.4 (c) [redacted] In addition to cloud imagery, soil moisture content, as an example, could be of importance to theater commanders. [redacted] (b)(1);1.4 (c) [redacted] A Soviet division commander, after a heavy rain, would be very interested in whether the terrain is too wet to support his tanks and other motorized equipment.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i) [redacted]

1.d.(3) Soviet Naval Forces (U)

(S) Weather stations on board military vessels are probably equipped to receive facsimile cloud imagery over radio links from shore transmitters. [redacted] (b)(1);1.4 (c)

1.d.(4) General (U)

(b)(1);1.4 (c) [redacted]

(U) A Soviet journal stated that information obtained by means of the Meteor space system and used by the Hydrometeorological Service for the long term forecasting of various weather phenomena makes it possible to preserve annually material resources amounting from 600 to 750 million rubles. Resources conserved in this manner may be applied to the Soviets predominantly military economy.

(U) There are numerous military applications for the geomagnetic data collected by Soviet satellites. Extensive information on these applications may be found in DST-1820S-475-82, "Environmental Warfare—USSR and China (U)."

1.e. Expanded Use of Meteor Satellite Data (U)

(U) The Soviets are expanding their use of Meteor satellite data to other-than-conventional observations of cloud cover, temperature and water vapor profiles, surface radiation, and measurments of ozone and other atmospheric constituents.

1.e.(1) Satellite Climatology (U)

(U) Soviet climatologists are using meteorological satellite observations to help develop new models of the global climate and to help verify existing climate theories. The Main Geophysical Observatory in Leningrad and the All-Union Scientific Research Institute of Hydrometeorology in Moscow are among the organizations within the Soviet Union attempting to include satellite data in climate analysis. Soviet plans for additional global satellite climatology programs imitate those already implemented by the US.

1.e.(2) Contributions to GARP (U)

(U) A total of 150 member nations of the World Meteorological Organizations (WMO) carried out the first worldwide Global Atmospheric Research Program (GARP) from December 1978 through November 1979. Observations from Meteor 2 spacecraft were included within the large data base that the WMO systematically collected during this program.

1.e.(3) Agriculture (U)

(U) Satellite infrared (IR) observations have successfully identified moist and arid agricultural regions within the Soviet Union. Soviet scientists are also studying both visible and IR imagery to better understand the dynamics of melting snow cover in Northern and Central Siberia. This snow cover is an important source of moisture reserve for agriculture.

1.e.(4) Severe Weather (U)

(U) Meteorologists at the Hydrometeorological Scientific Research Center in Moscow are developing techniques to apply meteorological satellite imagery to supplement synoptic and radar observations for detecting and/or predicting heavy rain storms, thunderstorms, dust storms, and hail storms. Meteorological satellite data also provides otherwise unavailable weather observations to Arctic and Antarctic research expeditions and to high-latitude stations.

1.e.(5) Aeronomy and the Upper Atmosphere (U)

~~(C)~~ [redacted] (b)(1);1.4 (c)

High energy particle research conducted at the Institute of Applied Geophysics in Moscow addresses the effects that such radiation may have upon cosmonauts, space systems, and the ionosphere.

(U) Soviet cosmonauts have conducted research on visible radiation emitted in the Earth's upper atmosphere. Analysis of these observations has led to various theories and models for the different sources of electromagnetic radiation emitted from the upper atmospheric layers.

1.e.(6) Geophysical Prospecting (U)

(U) Meteor satellite imagery is used to identify geophysical formations that are known to correlate with the presence of mineral deposits. The Institute of Geophysics of the USSR Academy of Sciences, with the cooperation of several other institutes within the Soviet Union, successfully located tectonic fractures over large territories with the help of Meteor satellites and other remote sensing observations.

1.e.(7) Pollution and Environmental Protection (U)

(U) Visual wavelength observations obtained from Meteor 2 and manned Soviet spacecraft are used to locate atmospheric pollution, particularly in the vicinity of large industrial centers. The Soviets have developed techniques for estimating the extent and density of the aerosols and for determining the chemical composition of the offending pollutants. They are using this information to develop plans for atmospheric environmental protection.

(b)(1);(b)(3):50 USC 3024(i);1.4 (c)

[redacted]

1.f. Prospects and Limitations (U)

(b)(1);1.4 (c)

~~(C NOFORN WNINTEL)~~ The Soviets have acknowledged inadequate computer support of their remote sensing program. [redacted] country is at least 3-4 years behind the US in machine processing of remotely sensed data, and, therefore, the Soviets are emphasizing optical rather than digital data analysis.

(U) Soviet meteorologists are developing and evaluating new techniques to mesh microwave radio frequency, IR, and visual meteorological satellite observations, and they are attempting to improve their satellite-derived assessments of cloud type, cloud moisture content, and precipitation. Meteor 1/18 carried an ultrahigh frequency polarimeter as well as visual and IR detectors, and the later Meteor spacecraft are continuing the role supporting technique development.

2. System Description (U)

2.a. Spacecraft Configuration (U)

~~(S)~~ The characteristics of the Soviet METSAT vehicles are assessed on the basis of information from several sources. These include photographs of publicly displayed vehicles, statements of Soviet officials, [redacted] and the characteristics of data sent over the Moscow-Suitland line.[1]

(b)(1);1.4 (c)

~~(S)~~ The Soviets have displayed models of Cosmos 122, 144, and 156 and a Meteor 2 series satellite at various international exhibitions. Essentially the same basic spacecraft has prevailed from the outset of the program. The main body is cylindrical in shape with the long axis pointed toward the Earth via an active three-axis flywheel stabilization system. Power is provided by two large sun-oriented solar panels.

(b)(1);1.4 (c)

~~(S)~~ The Soviets announced the Meteor 1/10 payload weight, including solar panels, as 1,300 kg. [redacted] Since the spacecraft is basically configured the same as Meteor 1 satellites, best estimates place the weight of Meteor 2 satellites at 1,500 kg. The increase in weight is caused by spacecraft body modifications and additional sensor payloads on Meteor 2 satellites.

~~(S)~~ The Meteor 2 displayed at the Paris Air Show in 1977 is shown in Figure 55. Dimensions based on analysis of this display are shown in Figure 56.

2.b. Network Orbital Characteristics (U)

(b)(1);1.4 (c)

[redacted]

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

[redacted]

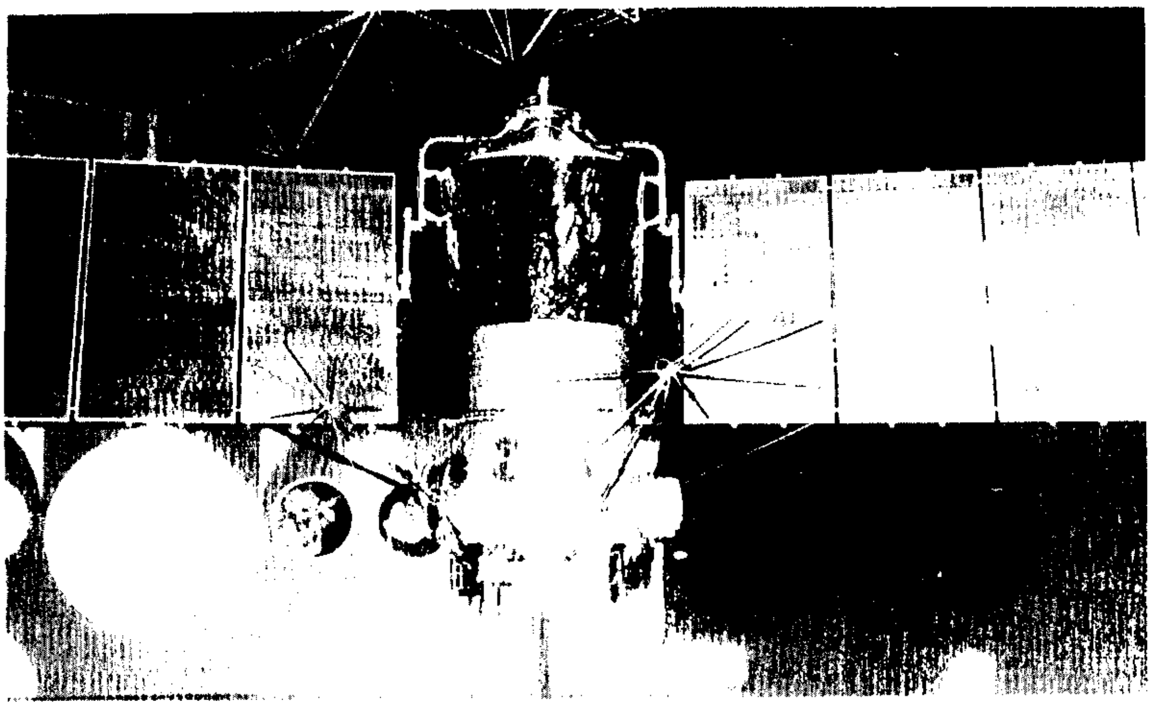
~~(S)~~ The Meteor 2 spacecraft are all placed into 900-km circular orbits inclined at 81 degrees. [redacted]

(b)(1);1.4 (c)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

[redacted]

[1](U) Moscow-Suitland line (Cold Line) is a communications link established during 1966 for the exchange of meteorological data between the US and USSR.



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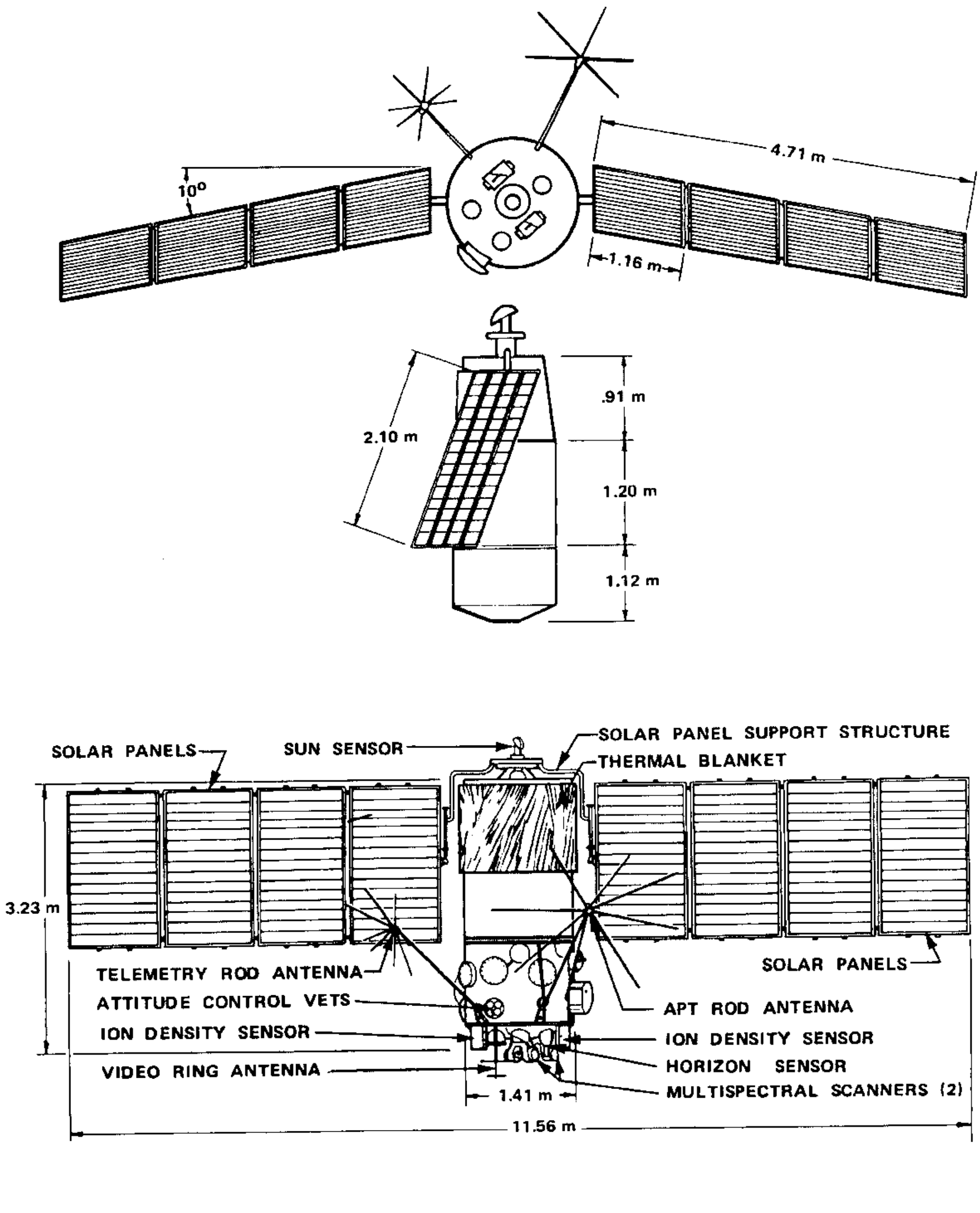
UNCLASSIFIED

Fig. 55 (U) Meteor 2/XX Series Display



FTD A80-076

UNCLASSIFIED

Fig. 56 (U) Meteor 2/XX Configuration

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024 (i) [redacted] Figure 57 is a Soviet diagram that presents the division of responsibilities in Meteor operations.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i) [redacted]

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i) [redacted]

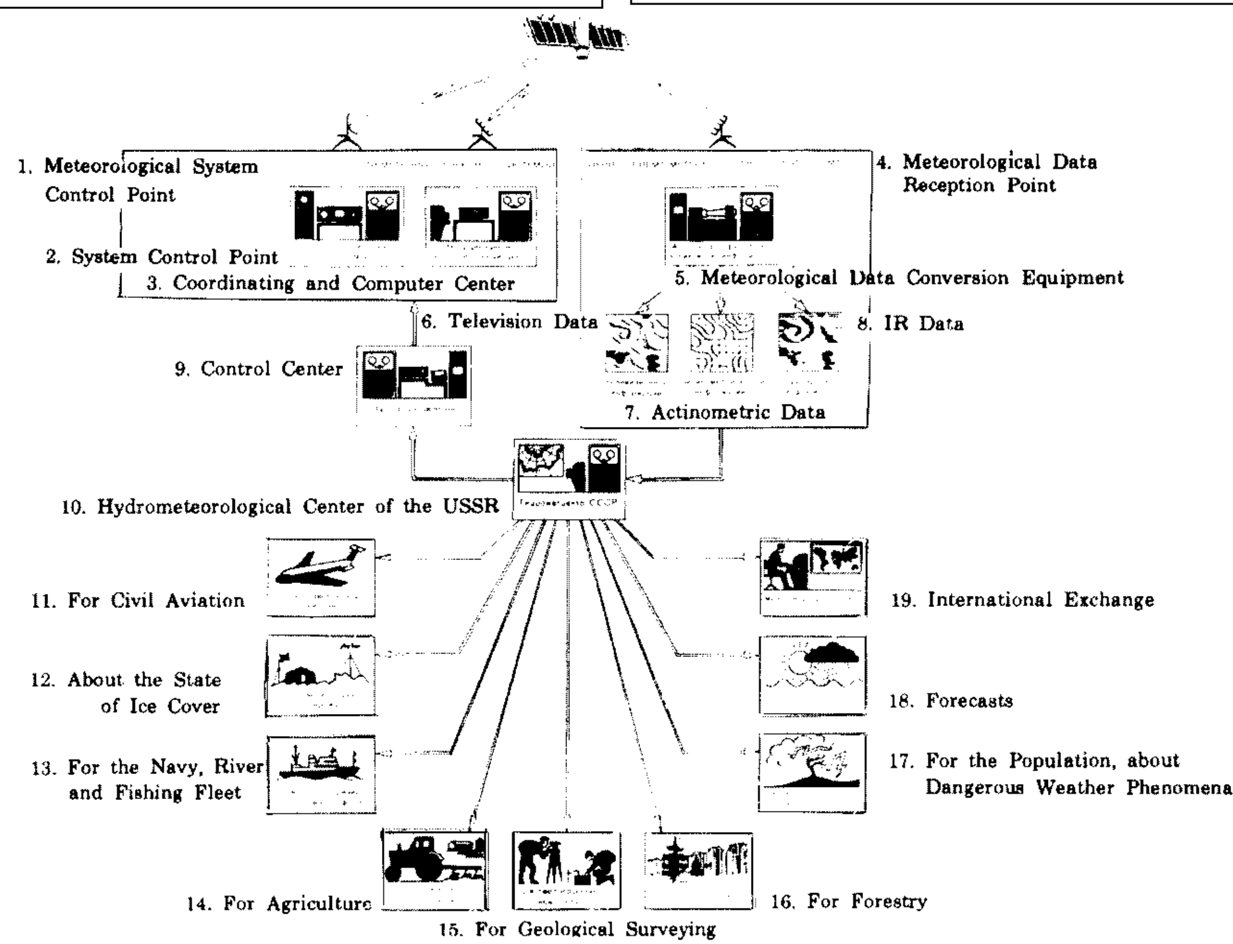


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Fig. 57 (U) Meteor Command Diagram

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

2.d. Users (U)

(U) Figure 57 lists many of the civil customers of meteorological satellite data. Military use of Meteor data is outlined in paragraph 1.d. of this section.

3. System Capabilities and Limitations (U)

3.a. Spacecraft Sensors (U)

~~(S)~~

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024 (i)

Figures 58 and 59 show views of the sensors on the Meteor 2 series display. The display model may not show the complete Meteor 2 sensor complement.

3.a.(1) Multispectral Scanner (U)

(U) The primary sensor package on board the Meteor 2 is the radio-television complex. The RTVK is composed of two sets of dual (redundant) multispectral scanners, the MSU-M and the MSU-S. These MSU units are optical-mechanical systems using single-line scan and single element receivers. The low-resolution MSU-M operates in four spectral bands, three visible and one IR. The medium-resolution MSU-S operates in two spectral bands, one visible and one IR. A 1977 article by A. S. Selivanov, V. P. Chemodanov, et al. diagrammed the MSS (Figure 60) and provided the following description of its operation.

(U) The radiation flux, being reflected from the mirror 1 (MSU-M) or from one of the edges of pyramid 1' and mirror 1" (MSU-S) and passing through objective 2, is directed by a mirror 3 to an interference mirror 4. The latter reflects the radiation flux in the visible band to the diaphragm 5 while the radiation in the IR band is passed to diaphragm 6. Passing through it, this flux is collected by a lens 7 and with the aid of a mirror 8 with an interference coating is directed to a photomultiplier (FEU) 9. After diaphragm 5 and collecting lens 10, the visible radiation is directed to the FEU 13 by interference mirrors 11 and 12. Only the optical elements for two channels and the FEUs (9 and 13) are installed in the MSU-S instrument.

(U) To separate the radiation of the visible band into three channels, additional optical elements are introduced into the optical system of the MSU-M, interference filters 14 and 15 and interference mirror 16. They accomplish the separation of the radiation on the FEUs (17, 18).

(U) The photometric calibration of the instruments is accomplished by closing the main light flux using a "riser" on the obturator 19; in this case, a light beam of the calibrated channel goes to the FEU through a window 20, which is closed by an optical wedge. The obturator rotates cophasally with the line scan. The calibration channel consists of an incandescent lamp SMN-10-50 (21), diaphragm 22, lens 23, turning prism 24, collecting lens 25, and light pipes 26, which direct the calibration flux to the FEU.

~~(S)~~ The MSS package flown on Meteor 1/18 produced data of value to Earth resources studies. However, the Soviets stated that because of limitations of the tape recorder, only four of eight channels could be operated. Three of the operable channels were 0.6-0.7, 0.7-0.8, and 0.8-1.1 μm in the visible and near-IR spectral region with a resolution of approximately 1 km. The fourth channel operated at 8-12 μm with a resolution of about 30 km. Figure 61 presents imaging of a dust storm in the Aral Sea region in the 0.8-1.1 μm range. This image was obtained on 22 May 1975 from the MSS aboard Meteor 1/18. Apparently, this MSS could image and record only two channels simultaneously.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

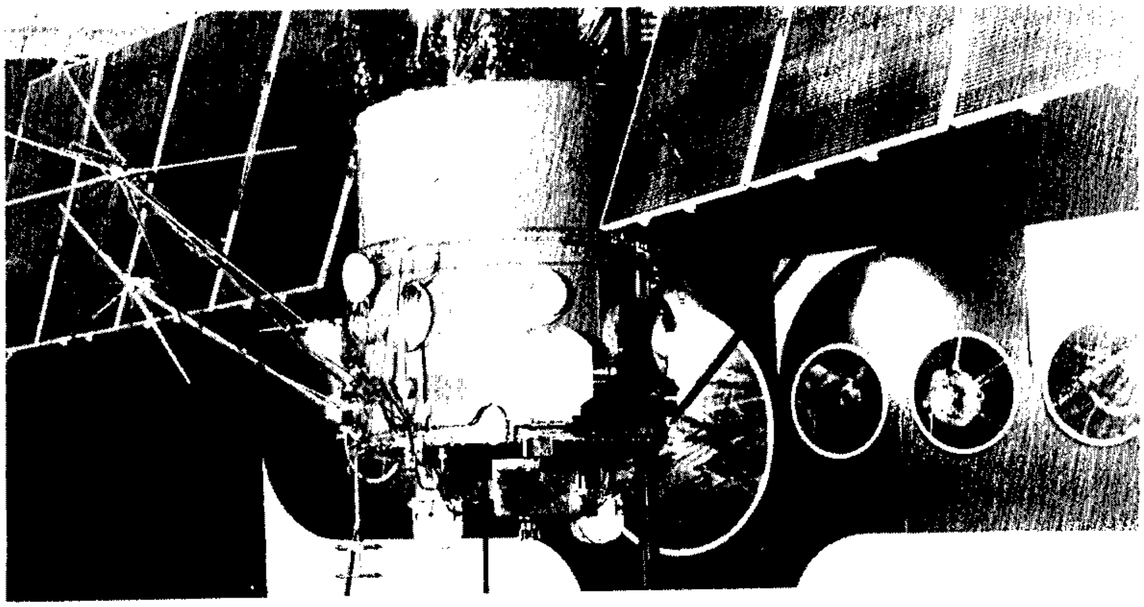

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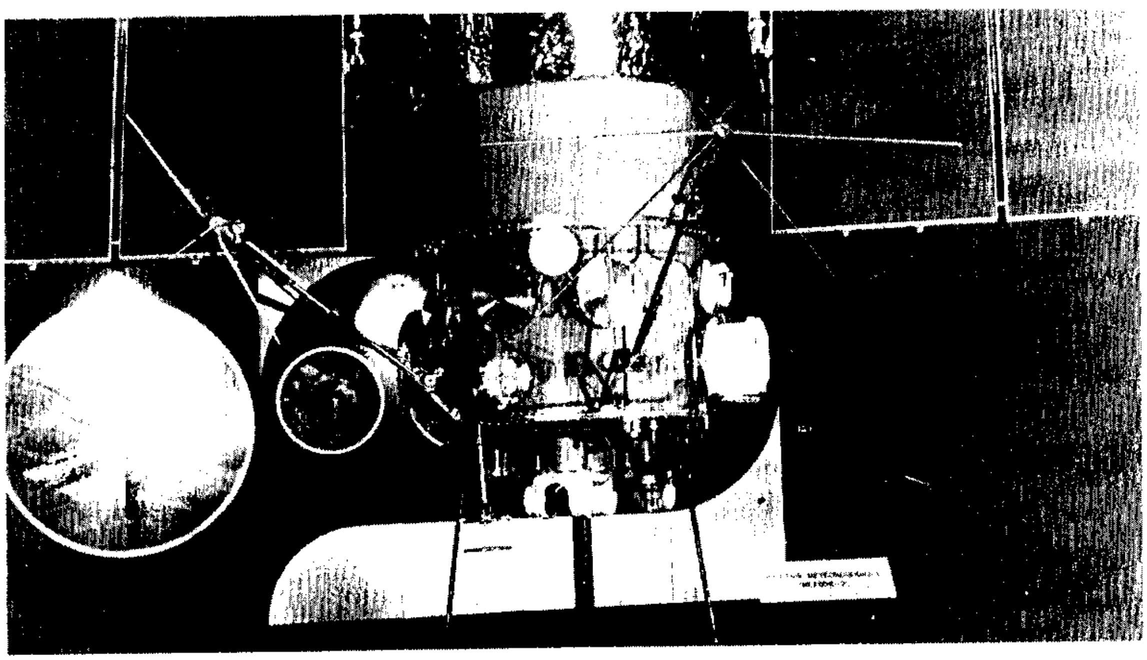
Fig. 58 (U) Meteor 2/XX Series Display, Close View of Sensors



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UNCLASSIFIED

Fig. 59 (U) Meteor 2/XX Series Display, Close View of Sensors

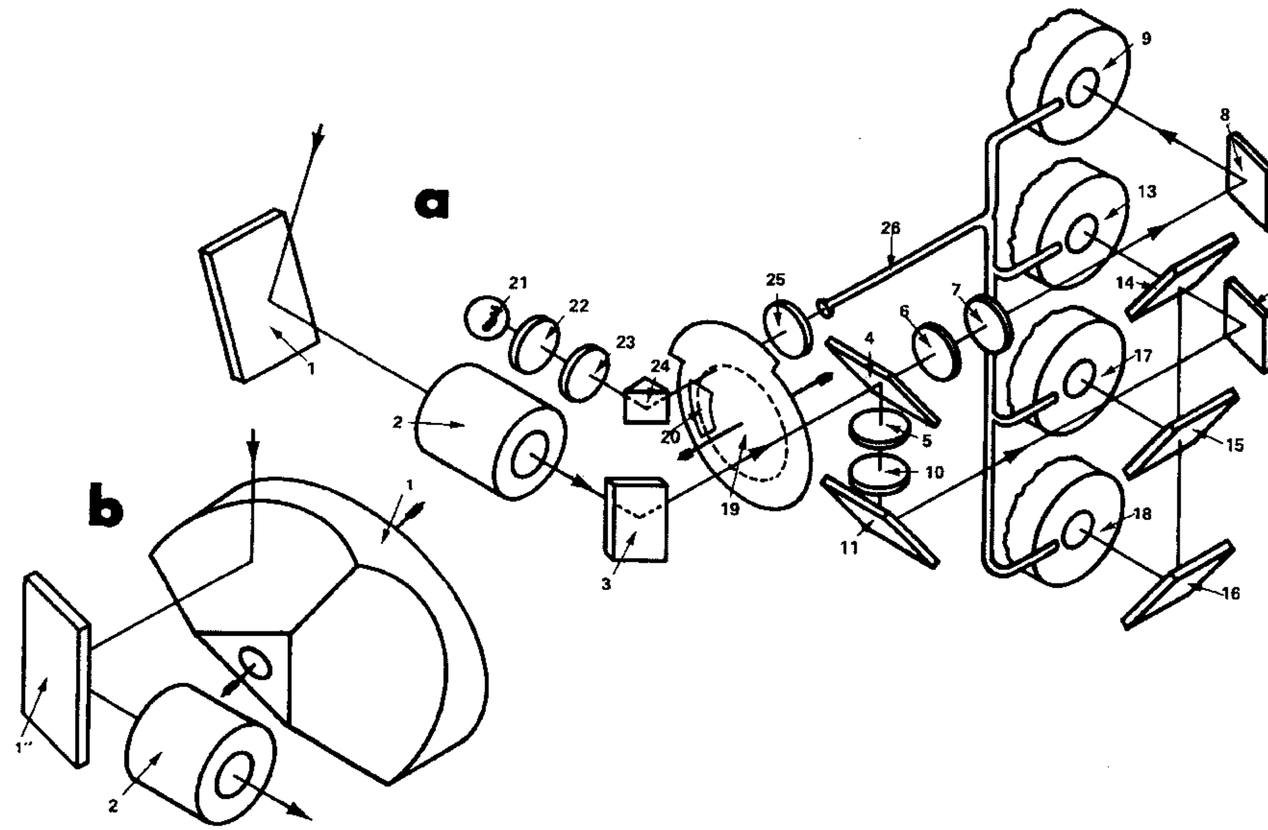

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Fig. 60 (U) Optical Schemes of MSU-M(a) and MSU-S(b)

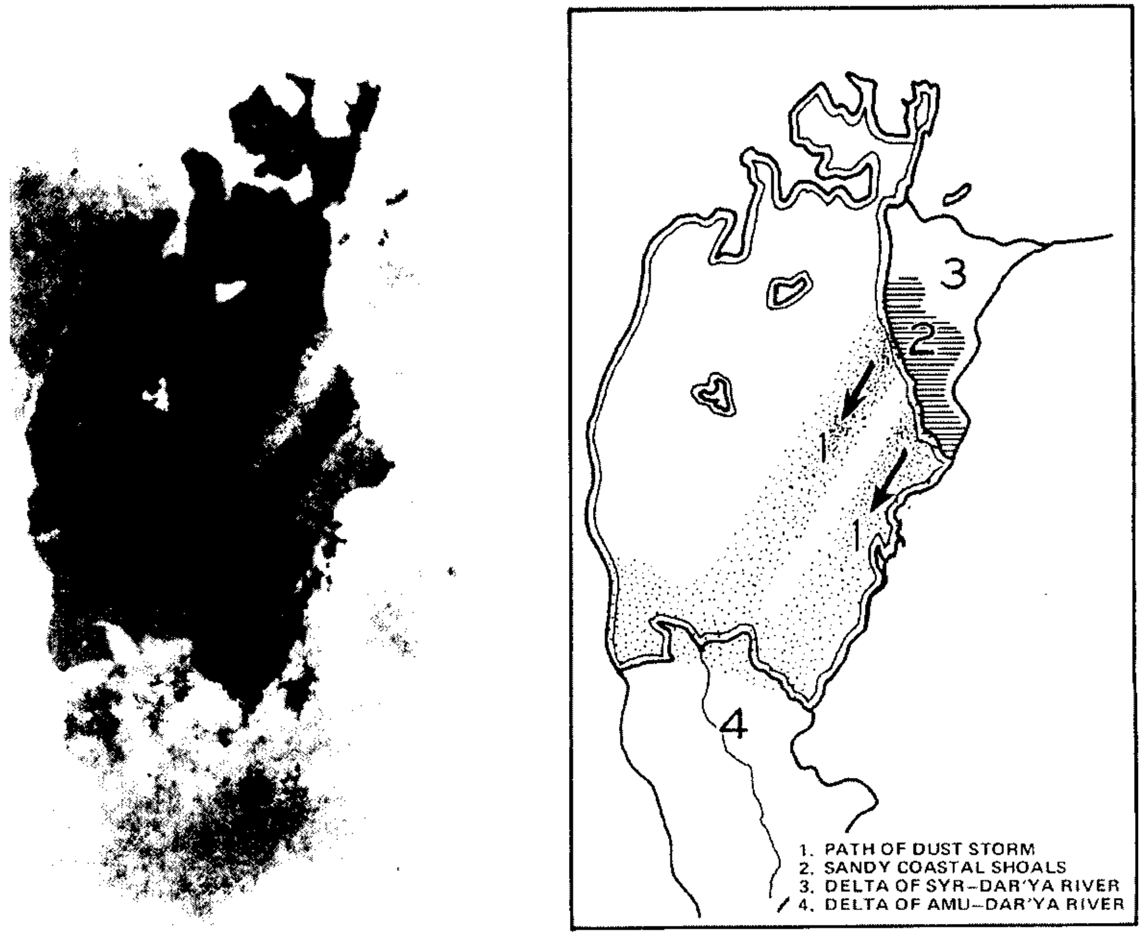

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Fig. 61 (U) Output of MSS Aboard Meteor 1/18

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

[redacted]

3.a.(2) Automatic Picture Transmission (U)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024 (i) [redacted] The Soviets announced APT for Meteors 1/10, 1/18, and all Meteor 2 series satellites.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

[redacted]

(U) Until late July 1977, the Soviets operated their APT system only within their own boundaries, denying the Western countries access to this information. However, NASA's Goddard Space Flight Center (GSFC) detected in July 1971 that the Soviets were routinely transmitting APT signals over the US. The reason is unknown, but it probably was in support of Soviet

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

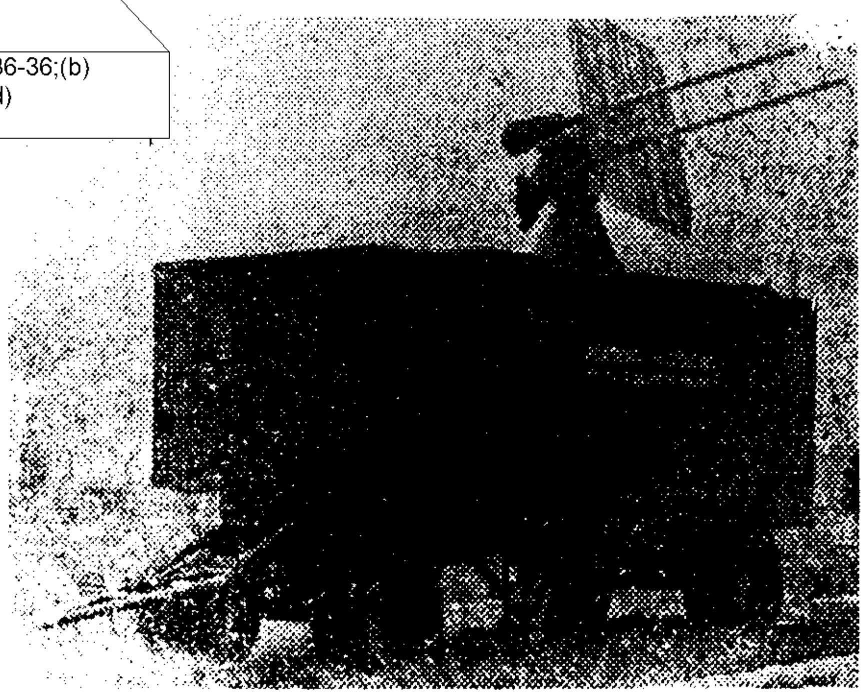
[redacted]

operations in the vicinity of Cuba. After GSFC processed several Meteor passes, information concerning the transmission was given to the Air Force Weather Facility at Cape Canaveral, Florida. Observations by this facility were made on the data receipt, processing, and subsequent picture quality of the Meteor APT system. Overall, these data were a welcome addition to other freely accessible meteorological data with the exception that all data could not be processed simultaneously, thus making it difficult to determine important parameters like cloud heights.

(S) The Cuban newspaper El Mundo contained a series of pictures in the 25 March 1969 issue showing one of four announced Soviet-built, mobile meteorological satellite data receiving vans (Figure 62) stationed in Cuba. According to the article, the van shown in Figure 63 became operational on 16 March 1969 at the Institute of Meteorology of the Cuban Academy of Sciences in Casablanca. The twin helix antenna mounted on the receiving vans is very similar to the [redacted] APT antenna found on some Soviet space support ships, such as the Kosmonaut Yuri Gagarin and Kosmonaut Pavel Belyayev. (See Figure 64.) The [redacted]

(b)(1);1.4 (c)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i);Sec. 1.4(d)



FTD A81-1833 UNCLASSIFIED

Fig. 62 (U) Meteorological Satellite Data Receiving Van

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Fig. 63 (U) Meteorological Satellite Data Receiving Van UNCLASSIFIED

(b)(1);(b)(3):50 USC 3024(i);1.4 (c)

[redacted]

on-board rectification. The data is rectified on board the spacecraft to correct the imagery for Earth curvature. This correction provides a minimal amount of skewing at the picture's edge, which facilitates the location of geographical features in comparison to surface synoptic weather charts.

(U) A description of Soviet APT collection equipment was given in a 1977 document. The first stations had a spiral eight-turn antenna with a gain of at least 10 dB for linearly polarized waves and 12 dB for circularly polarized waves. The length of the spiral was 4.24 m, the radius of the spiral was 0.34 m, and the diameter of the reflector was 1.75 m. Input impedance was 140 ohms. Rather than one eight-turn spiral, some antennas like the BED SPRING APT collection antenna (Figure 64) have used two four-turn spirals. The preamplifier, connected between the antenna and receiver, transmitted 2-3 MHz bandwidth signals with a gain of at least 20 dB. The receiver is a superheterodyne with a sensitivity of 6 μV and a bandwidth of 30 kHz. Picture recording used a drum phototelegraph that revolved at 120 rpm for Meteor APT or 48 rpm for NOAA satellite APT. Newer equipment likely operates at 240 rpm.

(b)(1);1.4 (c)

[redacted]

(b)(1);1.4 (c)

[redacted]

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

[redacted]

(C) Statements made by the Soviets in numerous publications indicate they have used microwave radiometers to measure open water and ice pack boundaries and atmospheric humidity.

(U) Reports from the open literature mentioned previous satellite microwave instruments. Cosmos 243, launched in 1970, contained microwave radiometers working at wavelengths of 0.8, 3.4, 8.5, and 1.35 cm. These sensors were used to study the sea surface temperature and the effect of sea foam on thermal emission from the surface. In addition, these radiometers were likely used to measure other parameters. Terrestrial emission in the 8.5-cm range is affected by atmospheric precipitation and clouds, heavy precipitation absorbs emission in the 3-cm wavelength range, the variation in 1.35-cm radiation is sensitive to atmospheric water vapor content, and a 0.8-cm wavelength detector can sense the radiation emitted by clouds and thus can be used in estimating their water vapor content. Cosmos 669, a photoreconnaissance satellite, apparently contained a submillimeter radiometer with two channels. Operating in the wavelength band of 0.08-0.143 and 0.4-0.667 mm, the radiometer was used to study moisture content in the atmosphere at middle and upper atmospheric levels.

(C) According to L. A. Alexandrov, a prominent scientist in the Soviet METSAT program, Meteor 1/18 carried a microwave radiometer. The instrument, which was downward pointing and nonscanning, sensed microwave radiation at a wavelength of 0.8 cm. Designed primarily to study precipitation, the instrument reportedly performed satisfactorily. In addition to delineating areas of precipitation, microwave observations are useful for determining sea states, surface wind fields, and ice conditions.

(C) According to L. A. Pakhomov, Chief of Section, State Scientific and Research Center for the Study of Earth Resources, two of the three channels of the passive microwave radiometer aboard Meteor 1/25 failed, one channel almost immediately after the mission began and the other shortly thereafter.

(C) Meteor 1/28 probably contained a microwave radiometer operating in three bands: 0.8, 1.35, and 8 cm. Reported resolution is 24 × 30 km for the 0.8 cm scanning channel, 90 × 90 km for the nonscanning 1.35 cm channel, and 100 × 100 km for the 8.5 cm nonscanning channel. Determination of atmospheric moisture and ice cover is the reported purpose of the instrument.

(U) The Soviets are interested in using microwave radiometry to observe soil moisture. Such observations would be useful in planning and monitoring their agricultural production. Both aircraft and satellite-borne instruments have been proposed, although most of the significant experiments through 1979 have used aircraft as the instrument platform.

(U) Oleg Prokovsky and Yuriy Timofeyev at Leningrad State University are reported to be analyzing the design of satellite microwave radiometry experiments. The reported purpose of the experiments is remote sensing of sea state and surface moisture.

(C) The Main Geophysical Observatory (MGO) is also probably involved in soil moisture studies with satellite microwave radiometry. MGO personnel were major participants in the joint US-USSR aircraft microwave radiometric study of the Bering Sea, and the Observatory's researchers reportedly were analyzing microwave data from the Meteor 1/25 satellite.

(S) The Soviets have encountered sensor problems in their microwave remote sensing efforts. Unreliability is a major problem; microwave data exchanged between the US and Soviet Union indicates that some microwave channels often do not function at all or fail shortly after launch. In discussions with US scientists, L. A. Alexandrov, of the State Committee for Hydrometeorology and Control of the Natural Environment, admitted that the USSR is having problems with the signal-to-noise ratio in their passive microwave remote sensing of the sea. This lack of data quality is further illustrated by the results of a cooperative US-USSR program in which microwave sensors were flown over the Bering Sea on US and Soviet aircraft. The Soviet data was so inferior that, according to one US scientist, there was no point in analyzing it. The Soviets seem embarrassed about their weakness in microwave technology and will probably continue to test improved microwave sensors (b)(1);1.4 (c)

(U) The Institute of Space Research (IKI) in Moscow has been developing a large space-based radio telescope since the early 1970's. In addition to extraterrestrial observations the most likely application for a large space-based radio telescope is mapping the Earth's surface; detailed temperature mapping has potentially significant military, as well as meteorological, applications.

3.a.(4) Infrared Spectrometer (U)

(b)(1);1.4 (c)

(S) A 12 May 1971 TASS announcement indicated that Meteor 1/8 carried an IR spectrometer used to produce temperature profiles. Representatives of the Hydromet reportedly revealed details of the instrument during an August 1971 exchange in Moscow. This spectrometer used a single detector with a grating scan from 10.5 to 15.0 μm and a spectral resolution of approximately 0.4 μm. Observations were in the direction of nadir with no spatial scanning accomplished. The Soviets stated that for temperature retrieval measurements, the five center wavelengths of 13.3, 13.7, 14.3, 14.4, and 14.7 μm were used. The instrument accuracy was said to be 1%, based upon comparison with data gathered by meteorological rockets.

(C) The Soviets announced that Meteor 1/25 carried a nonscanning spectral interferometer or Fourier spectrometer, developed and built in the German Democratic Republic (GDR), for conducting joint experiments within the framework of international cooperation under the Intercosmos Program. The GDR instrument was designed to operate from 6.3 μm, the water vapor band, up to and including 15 μm, the carbon dioxide band.

(U) An IR telescope-spectrometer apparently was used on board Salyut 5 to gather water vapor and ozone information. The device, labeled ITS-5, reportedly measured atmospheric transmission and was probably used in a limb-scanning mode. Measurements taken in the 6.3 μm water vapor band and the 9.6 μm ozone band allowed inference of water vapor and ozone concentrations at altitudes of 20-70 km.

(b)(1);1.4 (c) [redacted]

(b)(1);1.4 (c) [redacted]

(C) Additional details of construction of the Salyut 4 telescope-spectrometer (ITS-K) have been reported as follows: telescope and spectrometer were jointly constructed and the nitrogen cryostat was joined to the telescope, detector temperature was maintained at 50° K in the cryostat, volume of the cryostat was 19.1 liters, weight of the equipment was 70 kg, diameter of the telescope mirror was 300 mm and angular resolution was 8 × 16 minutes, and spectral range was 1-8 μm.

(b)(1);1.4 (c)

(C) The Soviets apparently encountered difficulty with the satellite-borne spectrometer instruments. Since [redacted] It is probable that most of the early spectrometers did not function correctly because no Soviet METSAT spectrometer results appeared in the open literature until June 1978, when a paper on the Meteor 1/28 interferometer-spectrometer data was presented at a COSPAR meeting. During this period, Soviet scientists did not publish papers on remote sensing of temperature and water vapor, but the papers were either theoretical or used data from American satellite spectrometers. In addition, the Soviets openly reported results from their satellite microwave instruments during the same period when they were silent about their spectrometer results.

(C) [redacted] (b)(1);1.4 (c)

All indications point to the conclusion that Soviet METSAT spectrometers have been generally unreliable or inaccurate or both.

3.a.(5) Particle Sensors (U)

(b)(1);1.4 (c)

(S) [redacted] However, the Soviets stated that Meteor 1/18 carried a solar proton-electron thermometer.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

3.e. Mutual Usability of US-Soviet Systems (U)

(U) Soviet use of US satellite data grants important dimensions to their total weather measuring and forecasting capabilities in the operational areas as well as in the research areas. They frequently use US data in their publications, and they acknowledge direct reception of American METSAT data (and many other places).

(U) There are many US satellite programs from which the Soviets probably receive and process APT data. These include the NOAA and GOES satellites.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(U) Undoubtedly, the Soviets are heavy subscribers to the US weather and LANDSAT data distribution centers.

~~(S)~~ During joint experiments, the Soviets lean heavily upon US weather satellite data. One example is the GARP program. The Soviets were unable to launch their planned geostationary satellite, and the US used one of its own satellites to cover the gap created by the Soviet failure.

(U) Use of Soviet APT by US customers is also possible with slight modification of the US APT receivers. However, Soviet APT operation is sporadic and simultaneous transmission of visible and IR imagery is not possible, so Soviet imagery is not routinely used in the US.

4. Subsystems (U)

(b)(1);(b)(3):50 USC 3024(i);1.4 (c)

(b)(1);(b)(3):50 USC 3024(i);1.4 (c)

4.b. Spacecraft Subsystems (U)

4.b.(1) Attitude Control System (U)

(U) Accurate control and exact knowledge of the attitude of the Meteor spacecraft are essential to reduce and interpret precisely the transmitted data. The Meteor ACS includes the following systems: (1) three orthogonally aligned flywheels to accomplish long-term orientation, (2) an electromagnetic damping system to unload excess momentum from the flywheels, (3) a cold gas jet system necessary to provide initial stabilization and to provide attitude correction or change impulses that exceed the limits of the flywheel system, (4) horizon and sun seekers and rate gyros to provide the proper attitude reference, and (5) a logic system necessary to link the various control subsystems into a coherent unity.

(U) Soviet sources stated that the total Meteor ACS weighs 150 kg and consumes 50 W for the electronics, the flywheels, and the magnetic dumping or desaturation of the flywheels.

(C) According to N. N. Sheremet'yevskiy, a Soviet scientist, the single axis flywheels are used as the main control elements, and the extra momentum of the flywheels is reduced by use of jet microengines or two magnetic torque motors. This creates functional redundancy of the system and ensures reliability. Control logic was chosen such that the jet unloading system switches off the flywheels and the magnetic torque motors provide the initial satellite damping.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(U) Sheremet'yevskiy identified the following ACS problems: (1) developing reliable and low-power electrochemechanical control elements, (2) synthesis of magnetic dump systems, (3) optimization of reactive dump systems, and (4) control organization providing an automatic change of system operating modes.

4.b.(2) Power System (U)

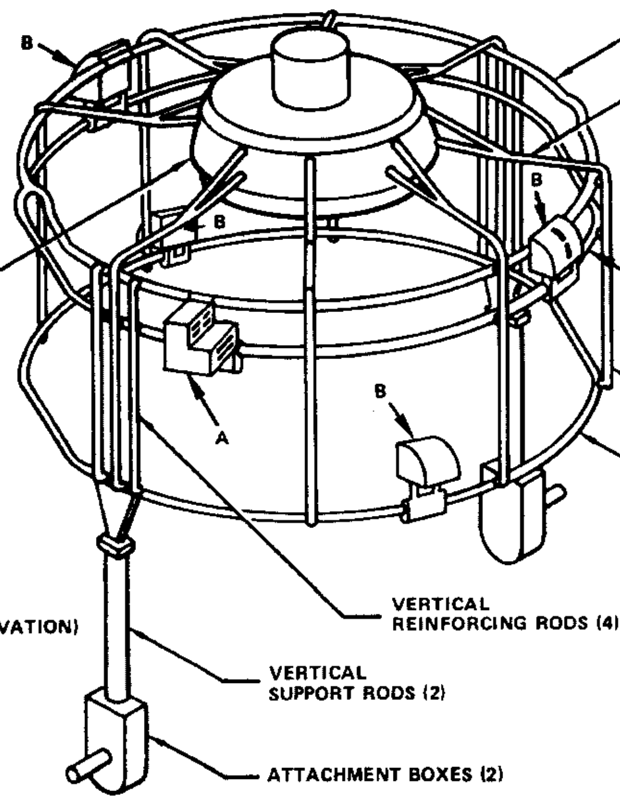
(U) The Soviet Meteor 1 and Meteor 2 spacecraft are equipped with solar panels to provide a long-lifetime electrical system. Ideally, a solar array should have two degree-of-freedom movements (azimuth and elevation) to maximize power by maintaining the array perpendicular to the sun direction.

(C) Cosmos 144, a precursor to the Meteor 1 series METSAT, was publicly displayed by the Soviets. Analysis of photographs taken at these displays indicates that the solar panel support structure allowed two-axis movements in azimuth and elevation. (See Figure 66.)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(C) N. N. Sheremet'yevskiy wrote a paper on the advantages of a single degree-of-freedom solar panel tracking system. He stated that fixing the solar panels in elevation would result in an efficiency loss of not more than 17 percent at Meteor orbital altitudes. (See Figure 67.) The use of oversized panels could compensate for this loss in efficiency. Examination of METSAT revealed that the Soviets did increase the METSAT solar panel size by one-third beginning with Cosmos 144. The significance of this modification is not known with certainty, but it may have indicated Soviet intentions to rely on the single-axis system. Among the advantages of a single-axis system, according to Sheremet'yevskiy, are satellite physical symmetry to minimize external disturbance torques, provision of a stable FOV for the Earth-pointing sensors, and elimination of distortion to the antenna-lobing patterns caused by two-axis panel motion.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)



8 SPOKES ARE EQUALLY SPACED (45° APART WHEN VIEWED FROM TOP)

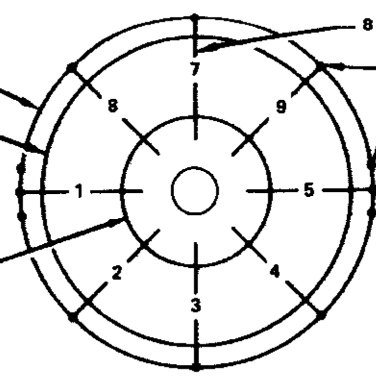


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Fig. 66 (U) Solar Panel Support Structure System

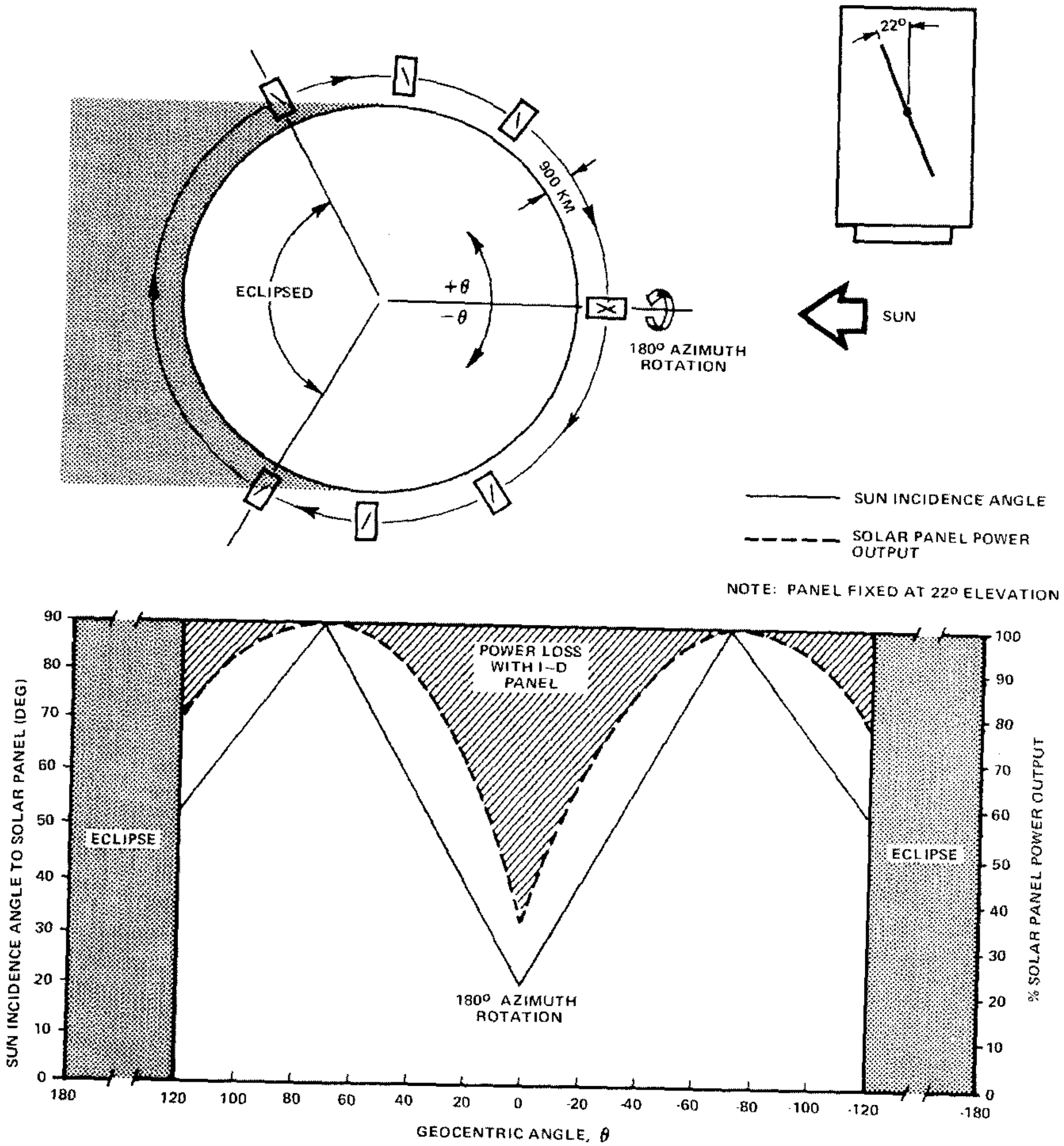

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Fig. 67 (U) Power Output of Single-Degree-of-Freedom Solar Panel

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

A Meteor 2 spacecraft on display at the Paris Air Show in 1977 had its solar panels fixed at 22 degrees elevation. Although the solar panel support structure allows articulation about the pitch axis, this may allow only a one-time deployment from the stowed position. Sun sensors detect the sun's azimuth and command yaw reorientation of the panels. The solar panel output history suggests that pitch attitude of the panels is fixed throughout the orbit.

(S) The Meteor 2 solar panels have an area of approximately 19.5 m^2. Using a mid-life solar cell conversion efficiency factor of 90 W/m^2, the Meteor 2 maximum power output could be 1,755 W during periods of ideal sun incidence angle. (b)(1);1.4 (c)

(b)(1);1.4 (c)

(S) During periods of solar eclipse, batteries provide spacecraft power. Therefore, during sunlight, power from the solar panels that is in excess of equipment needs charges the batteries.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(S) Detailed information concerning the Hydromet receiving station at Novosibirsk resulted from the visit of US scientists in 1970. The facility is located near Academgorodok (Academy City). The site is a fenced-in compound containing several antenna installations and a two-story control building. (See Figure 68.)This (b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(S) The antennas seen in Figure 68 include a tower upon which a microwave antenna reportedly is mounted, two dual helix antennas on the building roof, and a large 384-element (16 × 24) steerable array. The (b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024 (i) Pictures of the large planar array were first published in Izvestiya of 31 October 1969. This antenna, which the Soviets refer to as the FOBOS antenna, is used for receiving the (b)(1):1.4 (c) Analysis of the Izvestiya picture (Figure 69) reveals dimensions of 8 × 12 m, an operating range of roughly 315-515 MHz, and a gain approaching 40 dB if all 385 elements are active. US scientists reported the array could be operated electrically from the building; however, in actual operation, ". . .the satellites provide command signals to the antenna." The last item appears to mean the antenna uses an autotrack capability.

(S) The control building, which has base dimensions of approximately 15 × 30 m, provides about 900 m^2 of space. In addition to equipment associated with the antennas, it reportedly contained a MINSK-22 computer. That machine was reportedly used to "check" data.

(S) The Hydrometeorological Center in Novosibirsk was reported to be housed in a large five-story building. The center employed approximately 500 people and is supported by a computer center in Academgorodok. The Soviets stated that the Moscow center will have a similar computer capability.

(U) METSAT receiving equipment in the Moscow area is probably divided between the Hydromet building in Moscow and Hydromet facilities in Obninsk. A FOBOS antenna used to collect data from Meteor 2 and some other experimental satellites is located in the Hydromet facilities in Obninsk. The State Scientific Research Center for the Study of Natural Resources

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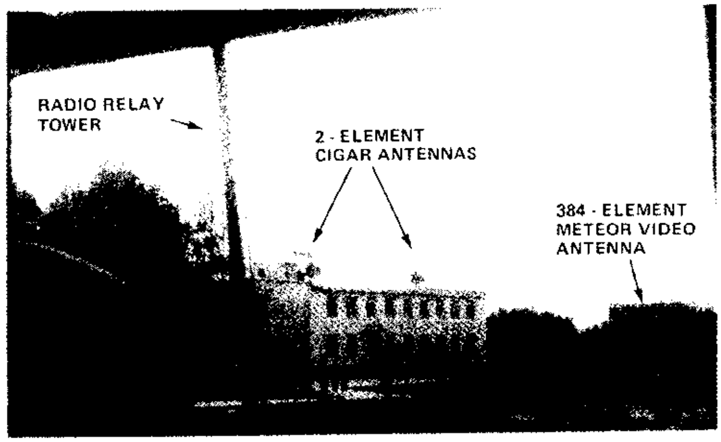

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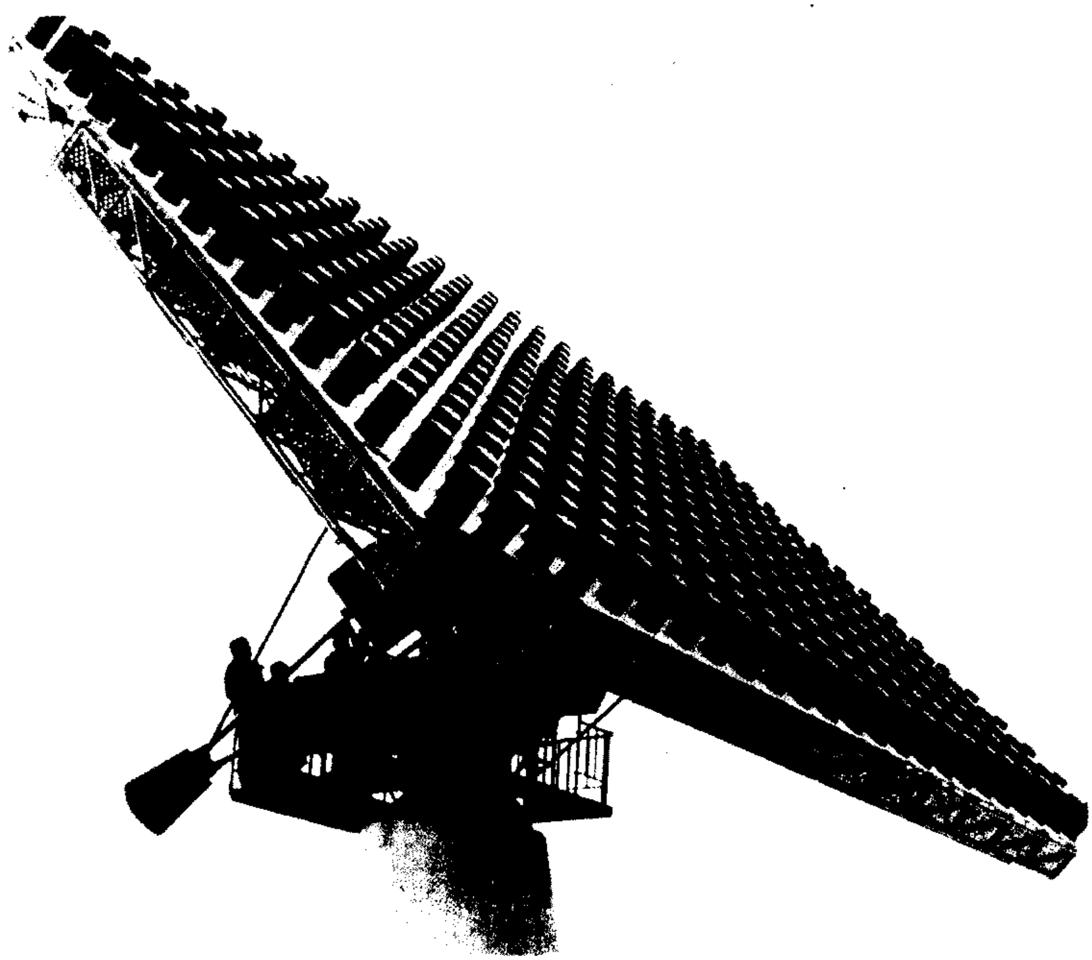
Fig. 68 (U) Photograph of Receiving Site



(GOSNITSIPR) reportedly uses this antenna and a terminal in the Hydromet Center building in Moscow to collect METSAT data.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

~~(S)~~ (b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i) the Soviets have announced the existence of over 60 APT receiving sites in the USSR.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

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SECTION VII

METEOR-PRIRODA SATELLITE SYSTEM (U)

1. Background (U)

(U) Interest is increasing in the field of Earth resources as the economic benefits of research in this area become more apparent. The Soviets have recognize the utility of space systems in remote sounding of natural resources. Satellite-provided imagery of the Earth's surface in the visible, infrared, and microwave spectrums plays a vital role in their development of this science.

~~(S)~~ The Soviets have developed their Earth resources satellite program in two directions. The first involves obtaining imagery on photographic film, then returning the film to Earth. This program uses cameras on the unmanned Earth Resources Photographic Satellites and the manned Soyuz and Salyut spacecraft. One disadvantage of this system is the data is not available in real-time; the film must be deorbited, recovered, and processed before it is usable. This disadvantage is not present in the second part of the Soviet Earth resources satellite program; the Meteor-Priroda satellites transmit imagery over radio links in real-time or near-real-time to ground sites in the Soviet Union.

(U) The Soviets used the early Meteor 1 satellites and sensors for unsophisticated Earth resources experiments. The first sensor designed especially for Earth resources applications, a multispectral scanner unit (MSU), was flown on Meteor 1/18 launched in July 1974. The Soviets improved this sensor and flew it on Meteor 1/25 in May 1976. The latest version of this sensor is the radio-television complex (RTVK) consisting of dual low-(MSU-M) and medium-(MSU-S) resolution multispectral scanners. The RTVK is the primary imaging meteorological sensor package on the Meteor 2 satellites and has flown on every Meteor-Priroda satellite to date. The Soviets introduced, on Meteor 1/30, two new sensors, BIK-E and Fragment, developed especially for Earth resources applications.

(U) The Soviets began their Meteor-Priroda satellite program with the launch of Meteor 1/28 in June 1977. Yu. V. Trifonov, in the September-October 1981 issue of *Earth Research From Space*, described the main goals of the Meteor-Priroda program as, "the development of equipment and techniques for obtaining and processing satellite data on the Earth's surface for the purpose of studying natural resources, developing equipment for correcting spacecraft trajectories to obtain special orbits and to guide spacecraft over test ranges, and to gain experience in using spacecraft to develop the Earth's natural resources."

2. System Description (U)

2.a. Spacecraft Configuration (U)

(U) The Soviets use the Meteor 2 spacecraft body as the body for the Meteor-Priroda satellites. According to the Soviets, the Meteor 2 body possesses the high reliability, pointing accuracy, orbit adjust capability, and available power required for the Earth resources mission. An exception is the Meteor-P satellite, launched 10 July 1981. Although the Soviets consider this satellite a part of the Meteor-Priroda program, there are a number of differences, including the fact that the Soviets evidently used an old Meteor 1-style body for Meteor-P. (See Figure 72.) The older body was probably used because Meteor-P was a cooperative effort between the Soviet Union and Bulgaria and carried, in place of the normal Meteor-Priroda sensors (Fragment and BIK-E), a number of Earth resources sensors built by Bulgaria.

~~(C)~~ The weights of the satellites will vary somewhat, depending on which sensors each carries. In addition to the standard RTVK package carried on all Meteor Priroda satellites; open source indicates Meteor 1/30, with Fragment and BIK-E packages weighs about 1,700 kg.

2.b. Network Orbital Characteristics (U)

(U) The Meteor-Priroda satellites are the only Soviet satellites launched into retrograde orbits. The Soviets launch these spacecraft into 650-km circular orbits inclined at 98 degrees. This orbit is Sun-synchronous; that is, the angle between the orbital plane and a line between the centers of the Earth and the Sun does not change with time. Therefore, it is the same local solar time each time the satellite passes over a particular location.

(U) The Soviets do not seem to be trying to establish a particular Meteor-Priroda network. (See Figure 73.) The orbits of Meteor 1/30 and Meteor-P, while relatively close in right ascension, are still further apart than the maximum error the Soviets have demonstrated in orbit placement. The current "network" provides two relatively close (in time) ascending passes at about 2200 local time and two close descending passes at about 1000 local time.

~~(S)~~ According to N. N. Sheremet'yevskiy in a Soviet technical paper presented at the 1978

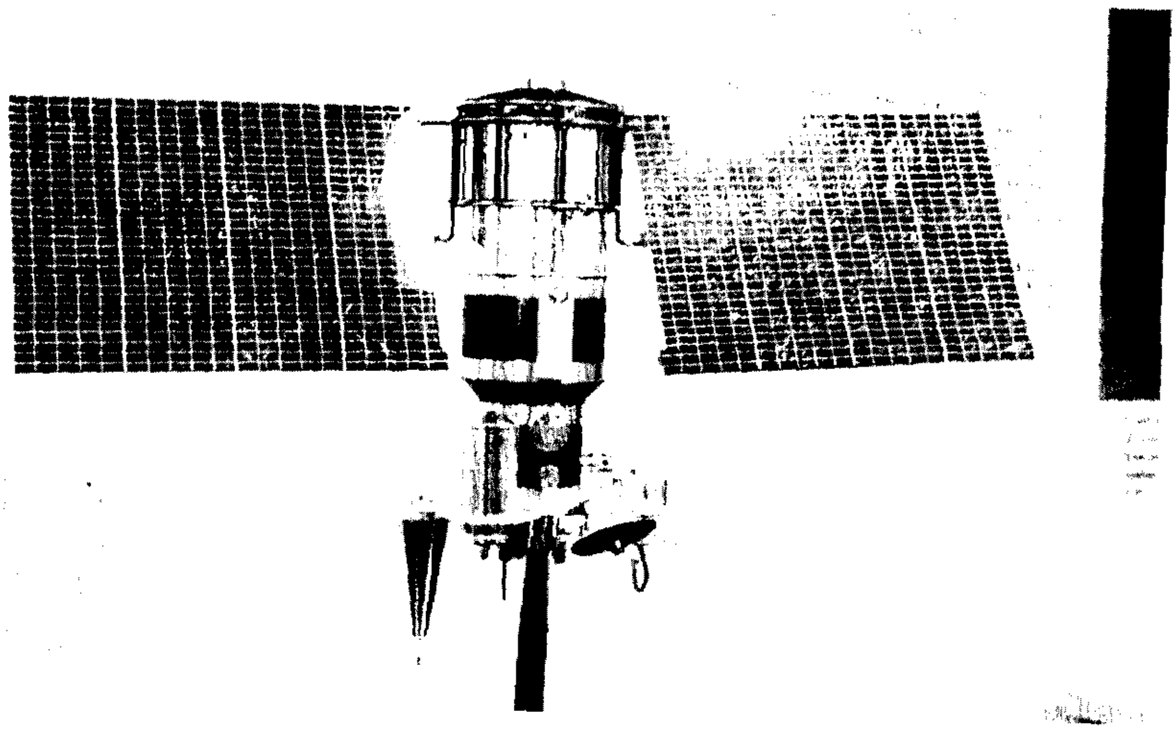

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Fig. 72 (U) Model of Meteor-P Satellite

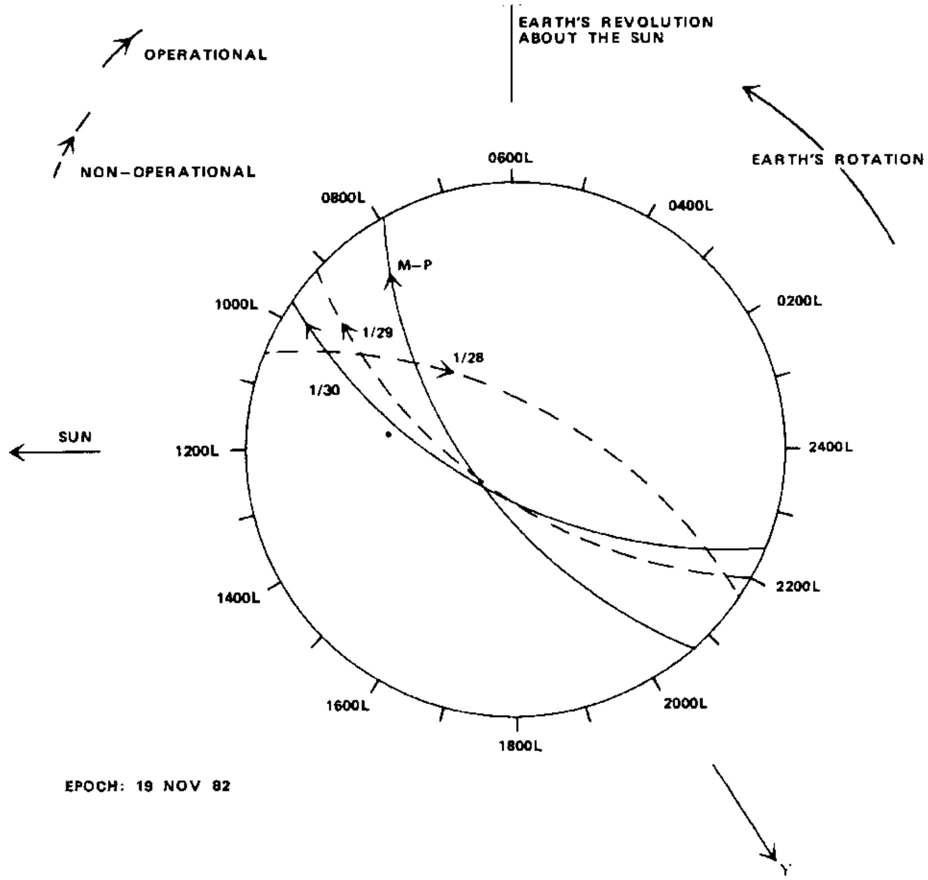

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Fig. 73 (U) Meteor-Priroda Orbital Arrangement

International Astronautical Federation (IAF) Conference, Meteor 1/28 has used an on-board plasma engine to apply a 10-second correction to its orbital period. This orbital period correction enabled Meteor 1/28 to complete exactly 74 orbits every 5 days. Therefore, Meteor 1/28 repeated its ground track on a 5-day cycle. The Soviets have also stated that Meteor 1/30 repeats its ground track every 15 days. It is almost certain all Meteor-Priroda satellites have electric reaction engines to perform similar orbit adjustments so that a single satellite can obtain repeated imagery of the same place on the Earth's surface, separated by a whole number of days.

2.c. Operation, Command, and Control (U)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

FAC-2A1: para 1 column 2 DOE redaction ended at "Meteor-Priroda." Unknown why we redacted the remainder of that line. Per RM, case previously QCed and CCO-2's hard copy review missing so leave as is. (NSA redacted entire column)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(U) According to the September-October 1981 issue of *Earth Research From Space*, data on the S345Z signal are recorded on both magnetic tape and photographic film at the three Hydromet reception sites. Photographs of the RTVK imagery are duplicated and sent directly to consumers. The BIK-E data are sent to GosNITsIPR for primary processing. Fragment data are received at the MEI OKB and are processed at both IKI and GosNITsIPR.

2.d. Users (U)

(U) Customers of Meteor-Priroda imagery are diverse and numerous. IKI and GosNITsIPR use Fragment data to develop sophisticated new processing techniques. The USSR Ministry of Geology, one of the main consumers of Meteor-Priroda imagery, uses RTVK data to investigate regional tectonic structures in the Earth's crust. Geologists use this data to predict potential oil-, gas-, and gold ore-bearing geological structures. The RTVK information is also used to define ice characteristics in ocean areas for the merchant marine and fishing fleets. Hydrologists use satellite imagery to estimate snow cover and water reserves in mountainous areas. Oceanographers use the Meteor-Priroda satellites to observe such phenomena as ocean vortices, internal waves, and river discharges and to locate fish breeding grounds. Agronomists evaluate the health of agricultural crops with satellite imagery. Forest management specialists have used satellite data to detect and monitor forest fires. Distribution of Meteor-Priroda data seems to be very open throughout the Soviet Union.

(S) The Soviets have stated their Institute of Foreign Geology examines imagery of foreign countries for natural resource studies.

(S) Although there is no evidence the Soviets intend to make Meteor-Priroda data available to Soviet Bloc or Free-World countries, perhaps as a commercial competitor to LANDSAT, the potential exists. The Soviets have a captive market for this valuable product in the Bloc countries and could, to achieve a significant political coup, supply Western countries with imagery roughly comparable to LANDSAT at a price much less than LANDSAT requires or even at no cost. RTVK data is currently available to anyone willing to invest in an inexpensive APT receiver, although the higher resolution BIK-E and Fragment imagery of course requires more sophisticated receivers and processors.

3. System Capabilities and Limitations (U)

3.a. Spacecraft Sensors (U)

(U) The Meteor program has always involved the development, testing, and eventual replacement of a continuous series of new sensors. The Meteor-Priroda program has started out the same way. The initial Meteor-Priroda satellites, Meteor 1/28 and 1/29, carried the RTVK package as the primary sensors (Figure 74), although these sensors appear externally different than the multispectral scanners on the Meteor 2. (Compare Figure 74 with Figure 58.) Meteor 1/30 (Figure 75) introduced a new generation of Earth resources sensors, the BIK-E and Fragment. Meteor-P carries an experimental sensor package designated Bulgaria 1300-2 built by Bulgarian scientists. Fragment and BIK-E will probably become the primary Earth resources sensors.

3.a.(1) RTVK (U)

(U) The RTVK package has been carried on every Meteor-Priroda satellite launched to date. Figure 76 shows the RTVK on a Meteor 1/28/ /1/29-Type display model. Figure 77 shows the sensor heads for the MSU-M and MSU-S. Figure 78 shows the entire RTVK sensor system.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

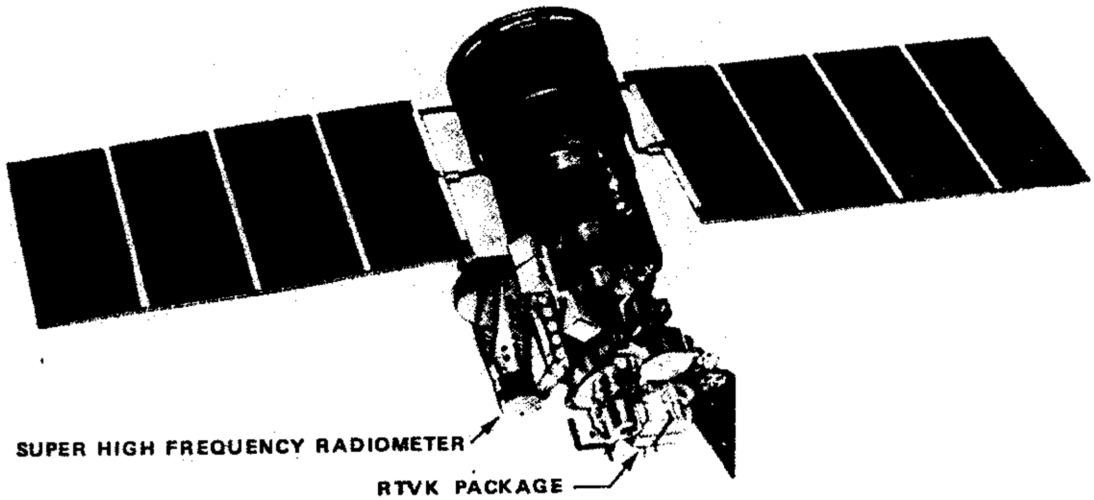

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Fig. 74 (U) Meteor 1/28/ /1/29-Type Satellite

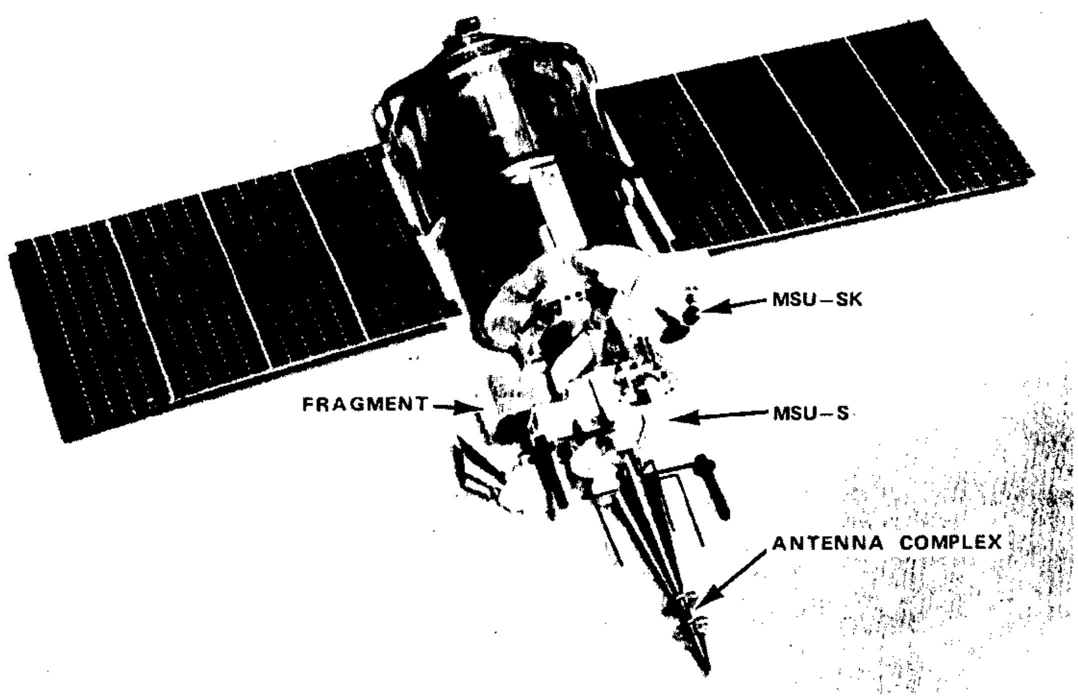

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Fig. 75 (U) Model of Meteor 1/30 Spacecraft

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Fig. 76 (U) RTVK Sensor System on Meteor Display

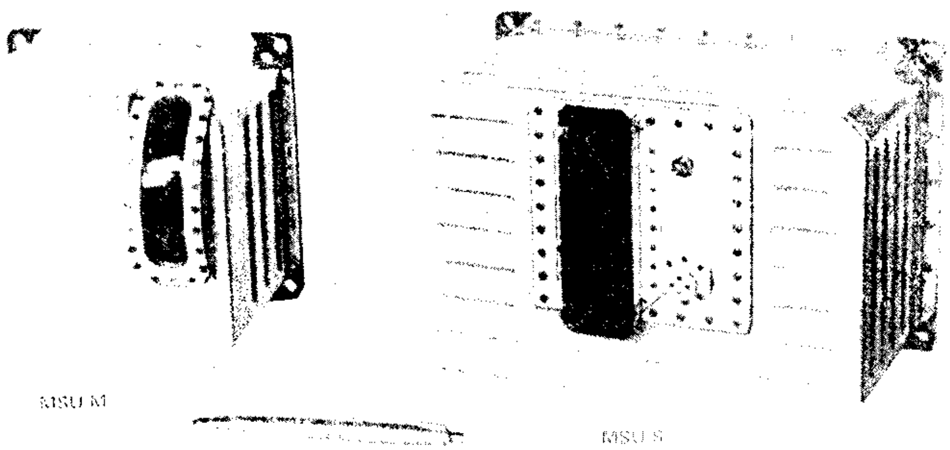

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Fig. 77 (U) MSU-M and MSU-S Sensor Heads

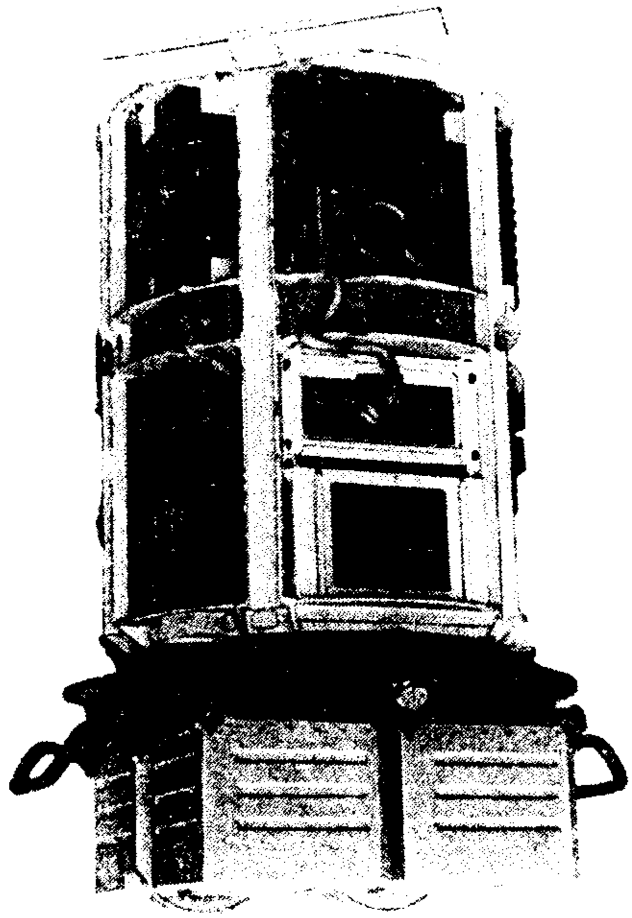

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Fig. 78 (U) RTVK Sensor System

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

3.a.(2) BIK-E (U)

(U) The BIK-E complex is composed of two multispectral scanners, the medium-resolution MSU-SK and the high-resolution MSU-E. This sensor was developed especially for Earth resources applications and was flown for the first and only time on Meteor 1/30.

3.a.(2)(a) MSU-SK (U)

(U) The MSU-SK is a wide-angle, medium-resolution, four channel sensor using a conical scan technique. The diameter of the MSU-SK optics is 200 mm. The following description of the sensor comes from the September-October 1981 issue of *Investigation of Earth From Space*. "According to a simplified diagram of the MSU-SK (Figure 79), it functions in the following manner: at an angle of 39 degrees to the vertical, radiation from the underlying surface is gathered by the spherical mirror (1) and directed to one of the four optical arms (2) that are located on scanning wheel (3), which rotates around a vertical axis. In the optical arm the radiation flow is focused with the help of a number of optical assemblies and a flow corresponding to a single television element is separated from it, directed toward the scanning wheel's axis of rotation, refracted, and then split in the spectrum-separation system (4). Photoreceivers (5) convert it into a video signal that, after shaping in amplifiers (6), is sent to the instrument's output."

"Four lines of the image are "drawn" during one revolution of the scanning wheel, it being the case that the sighting axis describes a conical surface in space, while its trace on the Earth's surface (a line) is a circular arc with a central angle of about 66 degrees.

"Channel calibration is carried out both according to an internal standard and with respect to the sun. The MSU-SK's spectral characteristics are presented in Figure 80."

(U) The MSU-SK has a swath width of 600 km, much less than the MSU-M and MSU-S and a nadir resolution of 175 by 243 meters. (See Table XIII.)

3.a.(2)(b) MSU-E (U)

(U) The MSU-E is a high-resolution, three channel scanner designed for problems requiring high resolutions over comparatively small observed areas. The MSU-E incorporates a very advanced detector system using charged couple device (CCD) arrays. (See Figure 81.) The image of the Earth's surface enters through the objective lens (1) and is projected through a spectrum splitter (2) onto three CCD arrays (3). Each array consists of 1,024 elements and operates in its own spectral band. (See Figure 82.) The video signals generated by the CCD arrays enter channel amplification and shaping units (4). Each of the CCD arrays are perpendicular to the direction of the spacecraft's flight. Line scanning is done electronically; frame scanning is done by satellite velocity.

(U) A radiative-type refrigerating unit cools the CCD arrays to a range of −30 to −50 degrees centigrade. The Soviets have not yet added an on-board calibration system for the MSU-E. According to the Soviets, their scientists are considering increasing the swath width by increasing the number of elements in each CCD array.

3.a.(3) Fragment (U)

(U) The Soviets encountered a need in their Earth resources program for an operational system that would acquire and process multispectral video data characterized by high spectral accuracy and which depicts in real-time, with good spatial resolution and high data rate (digital), the rapidly occurring changes in target areas on the Earth's surface. This need resulted in the experimental "Fragment" system.

(U) Fragment, rather than being merely a sensor, is an entire data transmission system. According to

TABLE XIII

(U) METEOR-PRIRODA SENSOR CHARACTERISTICS

	RTVK		BIK-E		FRAGMENT
	MSU-M	MSU-S	MSU-SK	MSU-E	
Swath Width (km)	1,930	1,390	600	28	85
Scan Rate (lines/sec)	4	48	48	218	87
Weight (kg)	4.5	5.5	47	17	280
Power Consumption (W)					200
Number of Channels	4	2	4	3	8
Spectral Intervals (μm)	0.5-0.6 0.6-0.7	0.5-0.7 0.7-1.1	0.5-0.6 0.6-0.7	0.5-0.7 0.6-0.8	0.4-0.7 0.5-0.6 0.6-0.7 0.7-0.8
	0.7-0.8		0.7-0.8	0.7-1.1	0.8-1.1 1.2-1.3
	0.8-1.0		0.8-1.1		1.5-1.8 2.1-2.4
Nadir Resolution (m)	1,000 × 1,600	140 × 240	175 × 243	28	80 (0.4-0.7) (0.5-0.6) (0.6-0.7) (0.7-0.8) (0.8-1.1) 240 (1.2-1.3) (1.5-1.8) 480 (2.1-2.4)

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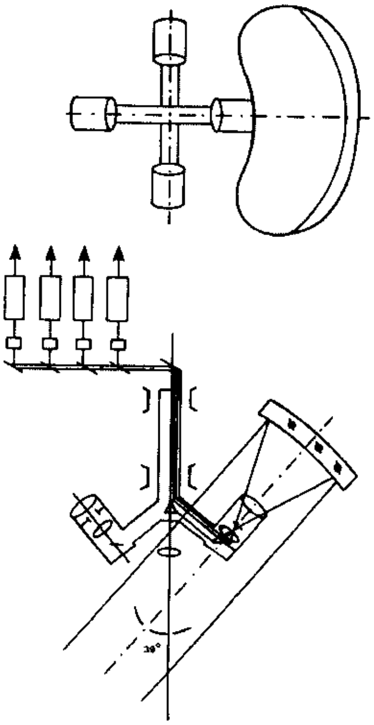

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Fig. 79 (U) Structural Diagram of the MSU-SK

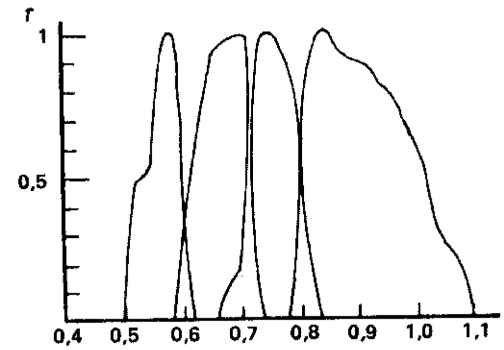

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Fig. 80 (U) Spectral Characteristics of the MSU-SK

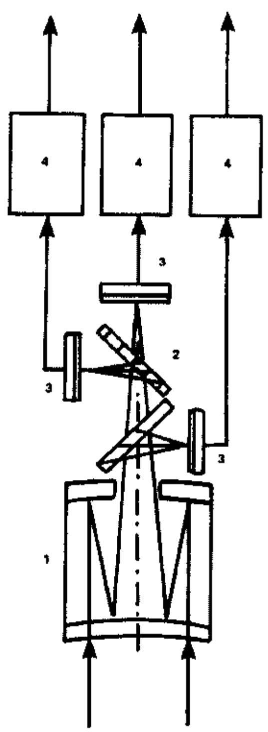

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Fig. 81 (U) Structural Diagram of the MSU-E

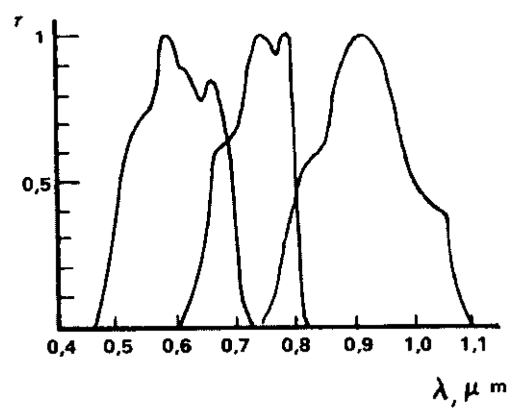

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Fig. 82 (U) Spectral Characteristics of the MSU-E the Soviets, the Fragment system consists of a scanning unit, a complex of photodetectors with a fibre-optics collector, an analog-to-digital converter, a digital radio transmitter unit, and receiving and processing equipment.

(U) Figure 83 is a cutaway of the Fragment sensor. The East German Karl Zeiss-Jena Company developed the optical system (3), consisting of a 0.24 meter-aperture Cassegrain lens with a focal length of 1 meter. The rest of the sensor was build by the Institute for Cosmic Research. Worthy of particular note are the fibre-optics splitter (6), the cooling radiators (13), and especially the analog-to-digital conversion unit (10). The digital aspect of the Fragment system is extremely interesting.

(U) Sophisticated, high-resolution, real-time sensors almost require the high reliability, low noise sensitivity, and high data rate of a digital radio data link. According to the Soviets, the Fragment radio link is a 1000-MHz, phase modulated signal with a capacity of 3.840 megabits per second. The total information content (video, synchronization, calibration, etc. data) of all eight of the Fragment sensor channels is 5.60 megabits per second, so the Fragment radio link can transmit data from four to six of the eight Fragment sensor channels simultaneously. The Fragment transmitter power is about 5 W through a highly-directional antenna.

(U) According to the Soviets, the Fragment ground reception site, the Special Design Office of the MEI, uses an Orbita-type antenna with an effective area of about 50 m^2 to receive the 1000-MHz data link. The antenna tracks the satellite with look angles provided by GosNITsIPR. The digital data is recorded using a complex composed of several low-, medium-, and high-speed magnetic memory units and is sent to IKI and GosNITsIPR for processing. The Soviets also mention that they are considering methods to create a radio link with a capacity of up to 100 megabits per second.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

3.a.(4) Experimental Sensors (U)

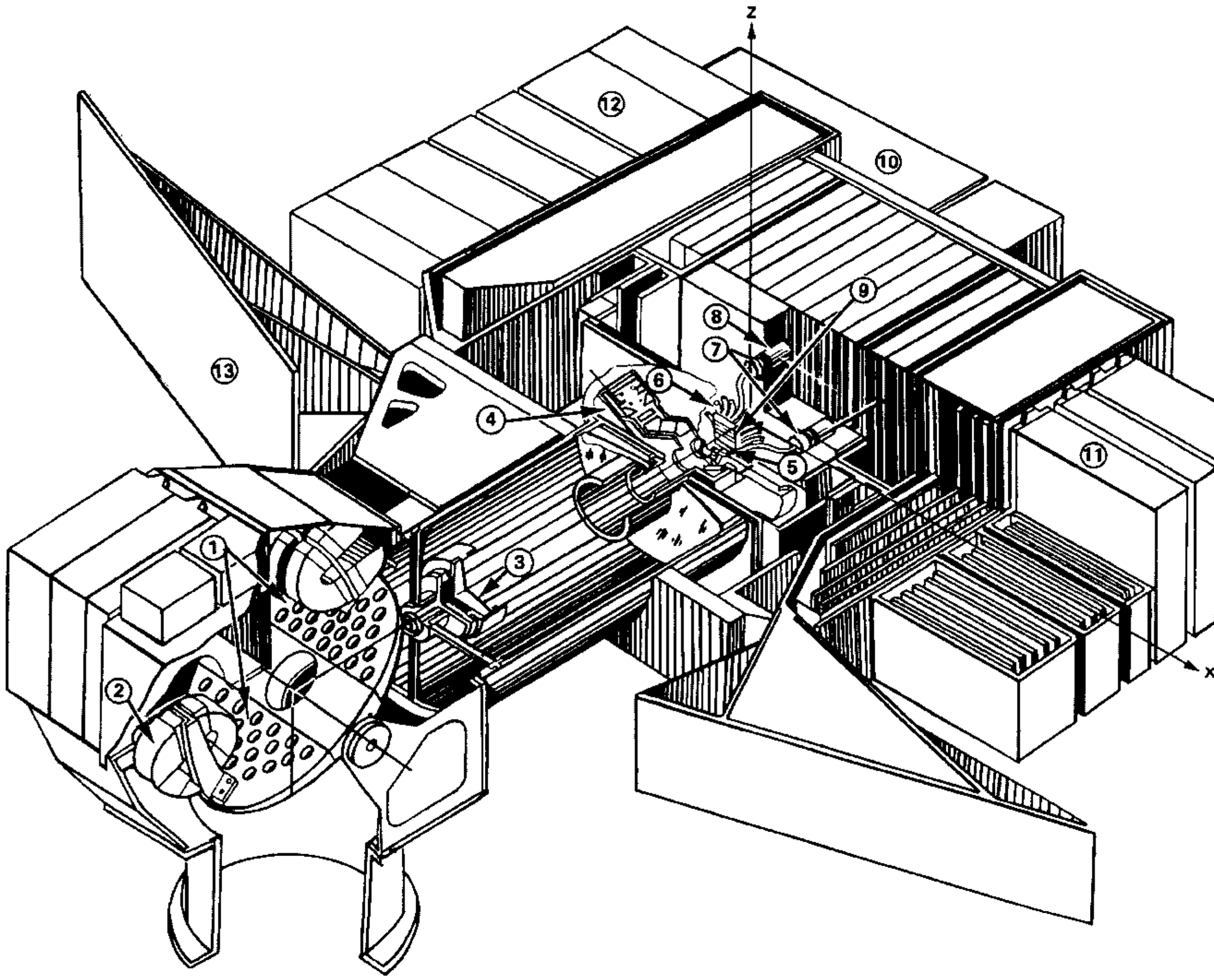
(U) The Meteor-Priroda satellites also carry a number of experimental sensors, some one of a kind. Examples include:

- A three-channel microwave radiometer operating at 0.8 cm (scanning), 1.35 cm, and 8.5 cm; carried on Meteor 1/28.
- A spectrometer-interferometer, developed in the GDR and operating at 6.25-25.0 m; carried on Meteor 1/28, 1/29 and 1/30.
- A four-channel spectrometer for measuring corpuscular radiation flow, operating at 0.3-30 keV; carried on Meteor 1/28.
- A scanning IR radiometer for slant sounding of upper atmosphere radiant heat, operating 0.3-30 μm; carried on Meteor 1/28.

3.a.(5) Meteor-P Sensors (U)

(U) Meteor-P was the result of a cooperative effort between the USSR and Bulgaria and was intended to commemorate the 1300th Anniversary of the founding of Bulgaria. In addition to the RTVK complex, Meteor-P carried an infrared sensor, Lastochka-65, operating between 8 and 12 μm with a 15 $\times$ 15 km resolution. Meteor-P also carried a sensor package, designated Bulgaria 1300-2 and composed of a number of Earth resources/meteorological sensors built by Bulgaria. (See Figure 84.)

(U) The SMP-32 is a 32 channel programmable spectrometer operating in the visible and near-IR spectrums (0.4-0.9 μm). Resolution is 280 $\times$ 280 meters. The RM-1 is a single channel microwave radiometer operating at 4 cm with an angular antenna resolution of 3 degrees. The three-channel RM-2 microwave radiometer operates at 0.8, 1.35, and 1.6 cm with an angular antenna resolution of 5 degrees.



1 SCANNING MIRROR
2 MIRROR DRIVE
3 LENS
4 REFERENCE LIGHT SOURCES
5 OPTICOMECHANICAL COMMUTATOR
6 FIBER-OPTIC SPLITTER
7 SPECTRAL BANDPASS FILTERS
8 PHOTORECEIVERS
9 BLOCKS OF AMPLIFIERS FOR DIRECT CURRENT AND HIGH-VOLTAGE POWER SOURCES FOR PHOTORECEIVERS
10 ANALOG-TO-DIGITAL CONVERSION UNIT
11 CONTROL AND INFORMATION COLLECTION AND PROCESSING SYSTEM UNITS
12 ELECTRIC POWER SYSTEM UNITS
13 COOLING RADIATORS FOR PHOTORECEIVERS

FTD A83-2494

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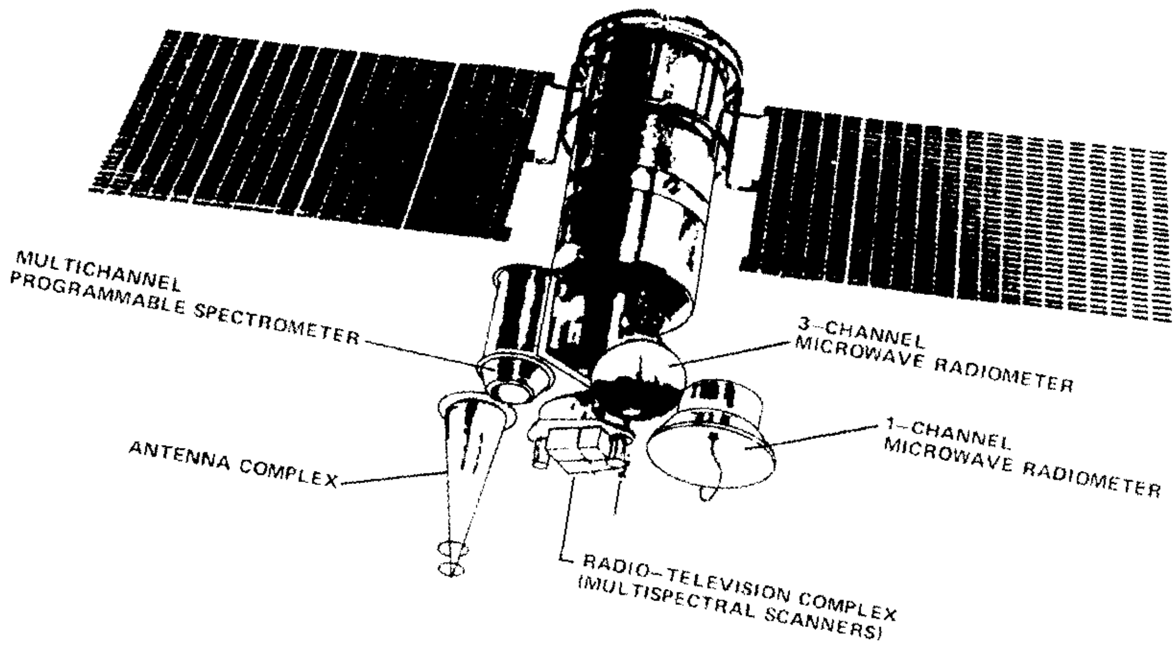
Fig. 83 (U) General View of "Fragment" Multispectral Scanning System



FTD A82-2058

Fig. 84 (U) Meteor-P Satellite and Sensor

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(U) Data from all three Bulgaria 1300-2 sensors can be simultaneously transmitted directly over the APT link. In addition, up to 6 minutes of SMP-32 data and 90 minutes of RM-1/RM-2 data can be recorded and transmitted later over the APT link. This capability allows MSU-M or MSU-S visible/IR imagery to be collected simultaneously with the Bulgaria 1300-2 data; visible/IR imagery aids considerably in interpreting the Bulgaria 1300-2 data. Bulgarian ground stations can receive the APT downlink directly.

3.b. System Coverage (U)

(U) The Soviets are apparently not interested in obtaining complete, continuous Earth coverage with the Meteor-Priroda satellites. For example, on Meteor 1/30, MSU-SK coverage is not continuously complete south (north) of 77° N (77° S). Rather, the Soviets seem interested in obtaining sets of data on the same particular areas separated by a number of days. This practice, while not very useful for meteorological applications, is appropriate for natural resources research.

(b)(1);(b)(3):50 USC 3024(i);1.4 (c)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

4.b.(2) Recorders (U)

(U) Out-of-country data from all four channels of the MSU-M and both channels of the MSU-S can be recorded by on-board magnetic memory units for playback later over the Soviet Union. Each of two recorders carried by each satellite has a capacity of 6 minutes.

4.b.(3) Payload Signals (U)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(U) In addition, the real-time data from the MSU-E and MSU-SK sensors are transmitted over a 466.5-MHz digital signal. According to the Soviets, the digital 463-MHz link has a capacity of 7.68 megabits per second. The MSU-E and MSU-SK cannot operate simultaneously.

(U) Real-time Fragment data is downlinked on a 1000-MHz digital signal. According to the Soviets, this signal uses phase modulation and has a capacity of 3.840 megabits per second. Fragment transmitter power is about 5 W, and the transmitting antenna has a directivity factor of about 2.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

4.c. Ground Stations (U)

(S) (b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024 (i) According to the Soviets, the BIK-E data are transmitted over the 466-MHz digital signal to an experimental information discrimination system at Obninsk that uses the FOBOS antenna fitted with a low-noise receiver. (b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024 (i)

Page 114 is denied in full and not provided.

(U) According to the Soviets, Fragment data is downlinked on the 1000-MHz digital signal to a Special Design Office of the Moscow Power Engineering Institute in Moscow Oblast.

(U) Data transmitted on the APT link can be received by any APT ground station within view of the satellite. For example, Bulgarian scientists are able to receive Bulgaria 1300-2 data directly from Meteor-P through an APT station in Bulgaria.

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SECTION VIII

OCEANOGRAPHIC RESEARCH SATELLITE SYSTEM (U)

1. Background (U)

(U) Oceanographic research has always been hampered by the relative inaccessibility of the ocean. Oceanographers were formerly restricted to data gathered from a small number of oceanographic research vessels, weather reports infrequently transmitted from ships, and information gathered and relayed by automated ocean buoys.

(U) Compared with the number of meteorological and geophysical monitoring stations established on land, the number of ocean-monitoring platforms is insignificant. The expense of an observation network of oceanographic ships and buoys, dense enough to provide a contiguous data picture and large enough to cover the ocean regions, has until now been prohibitive. Recent international programs, such as the first Global Atmospheric Research Program (GARP), are spreading the cost of establishing a large observation network among many nations. However, large gaps in data coverage still exist.

(U) Soviet oceanographic research satellites (OCEANs) have the potential to provide real-time monitoring of ocean parameters on a global scale. Ship and buoy reports will continue to play a major role in oceanography through the next decade; satellite oceanography will become increasingly important as spaceborne sensors and data interpretation techniques improve.

(S) OCEANs can provide data on internal ocean waves; estimate sea state and wind velocity, measure the vertical distribution of water vapor over the ocean and its affects on the transmission characteristics of the atmosphere, determine ice-water boundaries and ice thickness and age to provide safe routes for ships and submarines through and under icy waters, and interrogate buoys and relay buoy data. OCEAN data can be extremely valuable for Soviet global naval operations.

(U) The Soviets have conducted a variety of oceanographic experiments using a number of different satellites since the late 1960's. Cosmos 243 and Cosmos 384, launched in 1968 and 1970, respectively, carried microwave radiometers for experiments involving emitted radiation from the ocean surface. Cosmos 243 was used in an international experiment in 1973 to study ice-water boundaries, ice-pack characteristics, and wind waviness using emitted microwave radiation.

(S) The Soviet Meteor satellites were used extensively in oceanographic research. In one instance in 1974, during an international experiment called GATE-74, maps of sea surface radiation temperatures derived from data from Meteor 1/17 and NOAA-3 were compared with actual observations from ships. Because of the experimental nature of many instruments carried on the Meteor series spacecraft, it is likely that the OCEAN satellite sensors in at least their theoretical aspects, were first evaluated on Meteors.

(U) The Soviets are also using their manned space program for oceanographic research. The cosmonauts on-board Salyut 6 provided data on fishing beds, probably derived from visual observation of plankton concentration, to the All-Union Scientific Research Institute of Sea Fisheries and Oceanography. Multispectral photography of the Caspian Sea, taken from Soyuz 12, was used in an oil pollution detection experiment. The Soviets will likely continue to use manned vehicles as low altitude observational platforms for oceanographic as well as meteorological purposes.

(S) Intercosmos 20 was launched on 1 November 1979 with an announced oceanographic research mission. In addition to the Soviet Union, four countries of the Intercosmos organization—Hungary, East Germany, Romania, and Czechoslovakia—participated in the development of Intercosmos 20. The Soviets stated the satellite would be used to study the feasibility of detecting areas of increased biological production and of ocean pollution. Intercosmos 20 also carried an ocean buoy or automated ground station interrogation system. The satellite, passing over an ocean buoy, collects scientific data stored by the buoy and transmits it to a ground station. Intercosmos 20 is capable of transmitting scientific data directly to ground stations of the Unifed Telemetry System of the Socialist States (YETMS) in the USSR, East Germany, Bulgaria, Hungary, Czechoslovakia, and Cuba. On 6 February 1981, another Intercosmos satellite, Intercosmos 21, was launched with an identical payload as Intercosmos 20.

(U) According to the Soviets, the Meteor and the OCEAN types of satellites also have a buoy and/or automated ground station interrogation capability.

(b)(1);(b)(3):50 USC 3024(i);1.4 (c)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

3. System Capabilities and Limitations (U)

3.a. Spacecraft Sensors (U)

(S) The OCEAN satellites carry a variety of sensors to examine the conditions of the ocean and the atmosphere at the air-water interface. A number of the sensors were tested on earlier Meteor spacecraft, such as Meteor 1/18, 1/25, and 1/28. These ocean sensors were used during various international oceanographic projects such as the "Bering" experiment, and Global Atlantic Tropical Experiment (GARP).

(S) Several open-source Soviet articles have revealed the presence of visual, infrared, and microwave radiometers on-board the OCEAN satellite.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024 (i)

3.a.(1) Visual Radiometer (U)

(S) Open-source literature has indicated the presence of a six channel nonscanning visible radiometer.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024 (i)

(U) Different masses of water have different optical characteristics. The visible radiometer is used to determine the boundaries of different water masses, continental runoff water, ocean currents such as the Gulf Stream, and zones of upwelling. It provides information on internal ocean waves and aids in mapping the distribution of chlorophyll and plankton in the ocean. Data on plankton concentration is very important to the fishing industry.

(U) The resolution requirements of oceanographic sensors are quite different from those of meteorological or reconnaissance sensors. The large size of the water masses involved make very high spatial resolution unnecessary. However, the contrasts between different water masses in a particular spectrum range are very small. For instance, the bands of maximum absorption of ocean chlorophyll have a range of approximately 40 nm. Therefore, a very high spectral resolution is required for these measurements. The OCEAN type visible radiometer, according to open-source material, matches the required spatial and spectral resolutions.

3.a.(2) Infrared Radiometer (U)

(S) According to Soviet publications a 10-channel infrared radiometer is on board the OCEAN satellites.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

Pp. 119 is denied in full

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(U) The nadir-looking infrared radiometer could be used to measure ocean surface temperature, atmospheric parameters such as water vapor profiles, and heat transfer functions between ocean surface and atmosphere.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024 (i)

3.a.(3) Microwave Radiometer (U)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(S) and open sources indicate that there are two sets of microwave radiometers on board the OCEAN satellite.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024 (i)

(S)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024 (i)

The footprint is on the order of 85 km, according to open source material. Several Soviet articles state that the microwave radiometers on OCEAN satellites are used to determine surface temperature, ice cover characteristics, atmospheric humidity, water reserves in clouds, and intensity of precipitation.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(U) The microwave radiometers when used to study ice fields can determine ice-water boundaries, the rating of the ice pack, and the thickness and the age of the ice.

3.a.(4) Unidentified Sensor (U)

(S) Soviet open source articles indicate that Cosmos 1151 is carrying an active radar system designed for collecting information on the magnitude of waves on the sea surface.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(U) Several articles that preceded to the launch of Cosmos 1151 indicated the desire of the Soviets to place an active radar on board the satellite for the purpose of evaluating wind speed and direction in addition to wave height. After the launch one article mentioned the presence of an active radar on board Cosmos 1151.

(U) A similar US satellite, SEASAT, carried three types of active radar on board, a radar scatterometer, a radar altimeter, and a synthetic aperture radar.

(S)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024 (i)

Historically, the Soviets seldom talk about technical failures; they just simply ignore them.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

A radar scatterometer would provide the Soviets with a way of collecting the data required to determine sea surface conditions as they indicated they desired to in open source articles on the ocean satellites.

3.b. Buoy and Ship Interrogation (U)

(S) Open source literature has revealed the presence of a buoy data relay system on board the OCEAN satellites.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

~~(S)~~ Open source articles on Cosmos 1076 and Cosmos 1151 have stated that the buoys along with Soviet ships "constitute a system of reference points and make direct measurements in the ocean for the purpose of monitoring and calibrating the satellite's equipment."

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

From here to end task to NGA upon appeal. Material had to be withheld because NGA's response ended at p. 121. Apparently our referral copy excluded the final 39 pages and NGA did not inform us that the document abruptly ended.

Refer to "NSA/CIA/NGA added" layer for redactions up to p. 121 that were placed prior to this DIF action.

3.f. Mutual Usability of US-Soviet Systems (U)

(U) The Soviets make extensive use of oceanographic data from US satellites for research purposes. They have acknowledged that data from the Nimbus, ESSA, NOAA, GEOS, LANDSAT, and SEASAT spacecraft are used in the Soviet Union for research purposes. The wide availability of these data through organizations like the World Data Center make it unlikely that the Soviets receive oceanographic data directly from US satellites.

(U) Use of Soviet oceanographic satellites, through either data exchange or direct reception, by US scientists is extremely infrequent. US researchers will occasionally use Soviet data, most often in joint experiments, but the practice is not common for a number of reasons. Soviet data is frequently inferior to data from US satellites, as the Soviets are still several years behind the US in satellite oceanography. Soviet satellites are programmed to gather data over areas of interest to Soviet researchers, but these may not necessarily offer the same interest to US scientists. Finally, the Soviets appear reluctant to release scientific data, possibly for security reasons or from a desire to avoid comparison with US data.

4. Subsystems (U)

(b)(1);(b)(3):50 USC 3024(i);1.4 (c)

4.b. Spacecraft Subsystems (U)

4.b.(1) Attitude Determination and Control System (U)

~~(S)~~ Accurate sensor orientation requires precise knowledge and control of the spacecraft's attitude.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

4.b.(2) Power Systems (U)

~~(S)~~ The OCEAN satellites are equipped with a pair of solar panels to provide electrical power to the spacecraft system and batteries.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024 (i)

~~(S)~~ The total area of the solar panels is about 4.7 m^2. Using a mid-life solar cell efficiency of 90 W/m^2, the maximum solar panel output is about 423 W at ideal sun incidence angle.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

Page 123 is denied in full and not provided.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

4.c. Ground Stations (U)

(U) The sensor data from the OCEAN satellites are used by several different scientific agencies in the Soviet Union and can be used by the Soviet military. The primary user seems to be the Marine Hydrophysics Institute of the Ukrainian Academy of Sciences at Sevastopol. The Marine Institute was involved in the design and construction of the OCEAN sensors, and many of the public announcements concerning the OCEAN satellites are issued by the Institute's Director, Academician Boris Nelepo.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

Pages 125, 127 and 128 are denied in full and not provided. Page 126 is blank and not provided.

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

[redacted]

(b)(1);(b)(3):50 USC 3024(i);1.4 (c)

[redacted] high orbits are ideal for density measurements in the upper atmosphere. Soviet scientists have stated in open literature that highly inclined [redacted] satellites were involved in ionospheric research. [redacted] the [redacted] may be involved in similar scientific research. [redacted]

(b)(1);(b)(3):50 USC 3024(i);1.4 (c)

[redacted]

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

[redacted]

Page 130 is denied in full and not provided.

SECTION X

(b)(1);1.4 (c) [redacted] SATELLITE SYSTEM (S)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i) [redacted]

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024 (i) [redacted]

3.a.(1) Faceted Objects (U)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i) [redacted]

(S) [redacted] A retroreflector uses multiple internal reflective surfaces to reflect an incident laser beam directly back along its original path. The Soviets have placed retroreflectors on their Salyut spacecraft, their lunar rovers, and certain scientific satellites. Figure 54 shows the laser retroreflector on Bulgaria 1300, launched 7 August 1981. The Soviets (b)(1);1.4 (c) [redacted]

(b)(1);1.4 (c)

also use for geodetic purposes an extensive ground network of laser range finders with retroreflector equipped Western satellites.

(b)(1);1.4 (c)

(b)(1);(b)(3):50 USC 3024(i);1.4 (c)

Pages 133-135 are denied in full, page 136 is blank, pages 137-147 are also denied in full and page 148 is blank. None are provided.

APPENDIX II

POSITION FIXING BY DOPPLER NAVSAT (U)

(U) For a NAVSAT user to determine his position he must solve the problem in three steps:

1. Determine the position of the NAVSAT.

2. Determine the range from the user to the NAVSAT.

3. Determine the user's position from the information obtained in steps 1 and 2 above.

1. Determination of NAVSAT Position (U)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(U) The value of the NAVSAT radius vector R is:

$$R = X^2 + Y^2 + Z^2$$

The longitude of the NAVSAT subpoint is the angle

$$= \arctan (Y/X) = \text{longitude}$$

The latitude of the NAVSAT subpoint is the angle

$$= \arcsin (Z/R) = \text{latitude}$$

The height of the NAVSAT above the Earth is h

$$h = R - \text{Earth radius}$$

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

(U) The error associated with determining the satellite position is the largest contributing factor to the total error associated with the navigation fix. This satellite position error is composed of uncertainties in the satellite's orbit and geodetic errors. (See Appendix III.)

2. Determination of Range from Users to NAVSAT (U)

(b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

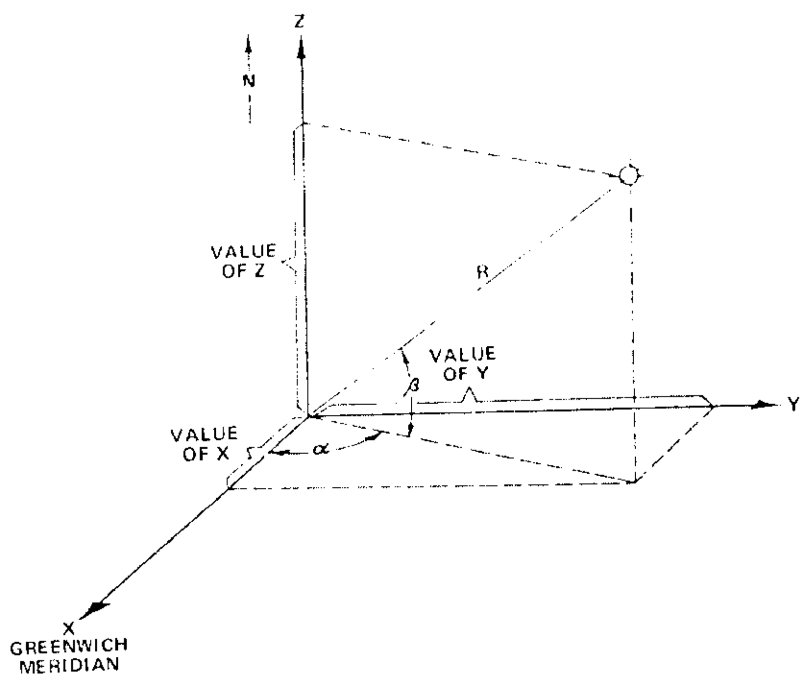

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Fig. A-1 (b)(1);Sec. 1.4(c);(b)(3):P.L. 86-36;(b)(3):50 USC 3024(i)

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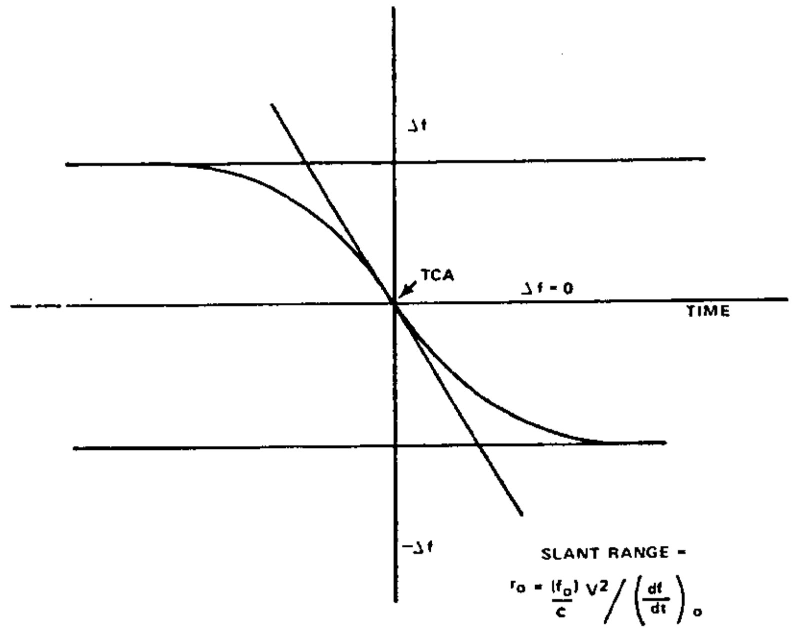

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Fig. A-2 (U) Doppler Shift Curve

(U) From this curve the user can calculate the range to the NAVSAT at the time when the radio frequency he receives equals that emitted by the NAVSAT. This range will be the range of closest approach, r, and is given by the following equation:

$$r = (-f_o/c)\ (V^2)/df/dt)$$

where

r = range of closest approach

f_o = frequency emitted by NAVSAT

V = NAVSAT velocity

c = speed of light in vacuum

f = frequency received by the NAVSAT user

(df/dt) = slope of the Doppler curve when $f = f_o$

3. Determination of the Position of the User (U)

(U) First, the great circle cross track angle must be determined. (See Figure A-3.)

(U) By the law of cosines:

$$\cos(s) = \frac{(R^2 + (er)^2 - r^2)}{2\ (R)\ (er)}$$

Therefore:

$$S = \arccos \frac{(R^2 + (er)^2 - r^2)}{2\ (R)\ (er)}$$

(U) Then the off-meridian angle of Earth trace, K, must next be determined.

$K = \cos(i)/\sin(S)$, where i is the inclination

(U) If the orbital inclination is not known, then K can be found by the method shown in Figure A-4.

(U) From spherical trigonometry, it can be shown that:

$$\tan(K) = \tan(A)/\sin(B)$$

(U) The overall geometry is shown in Figure A-5. If the satellite inclination is known, then from spherical trigonometry it can be shown that:

$$\cos(C) = \cos(S)\cos(C') + \sin(S)\cos(C')\cos(90 + K)$$

$$= \cos(S)\cos(C') + \sin(S)\cos(i)$$

$$C = \arccos \cos(S)\cos(C') + \sin(S)\cos(i)$$

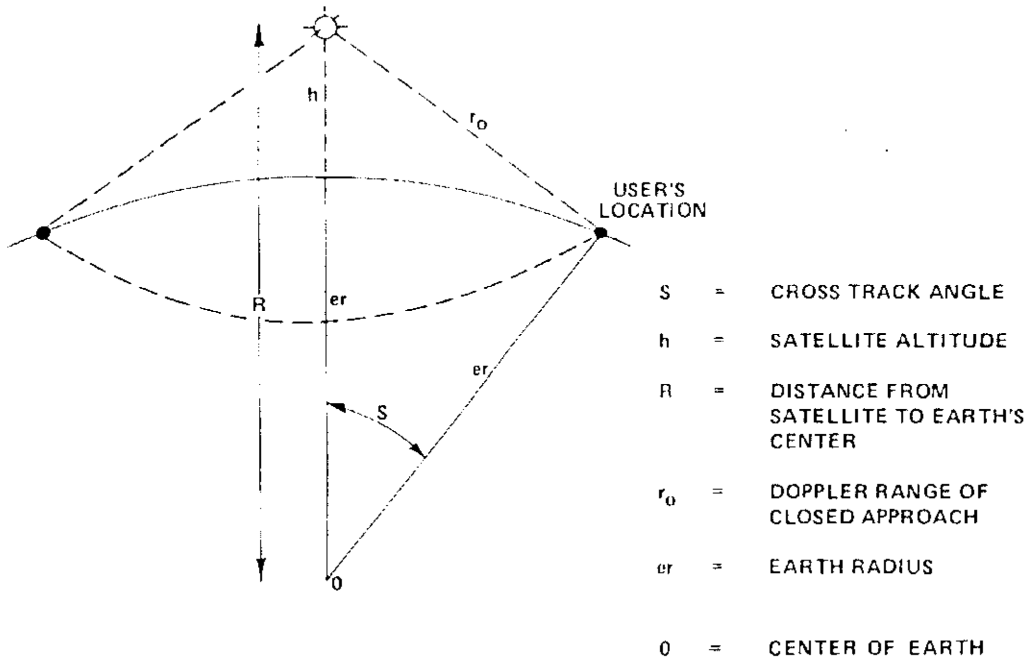

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Fig. A-3 (U) Determination of Cross-Track Angle

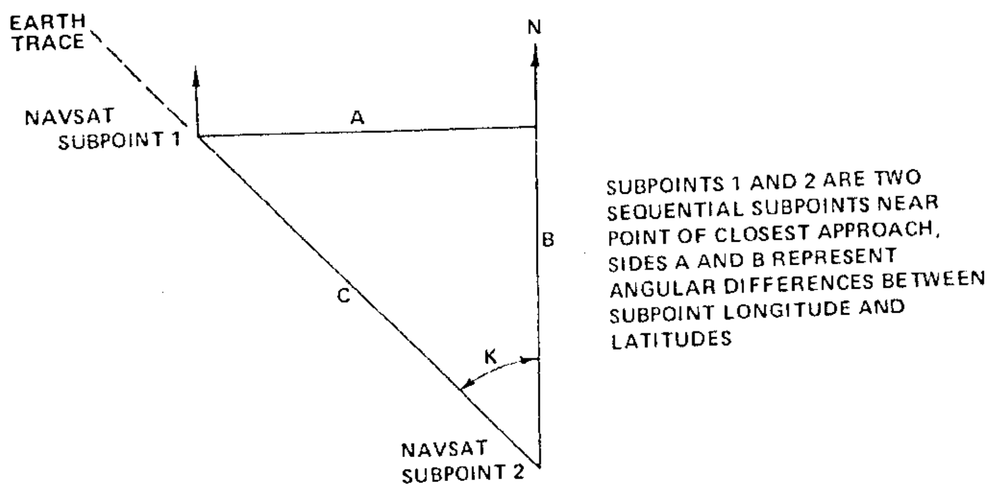

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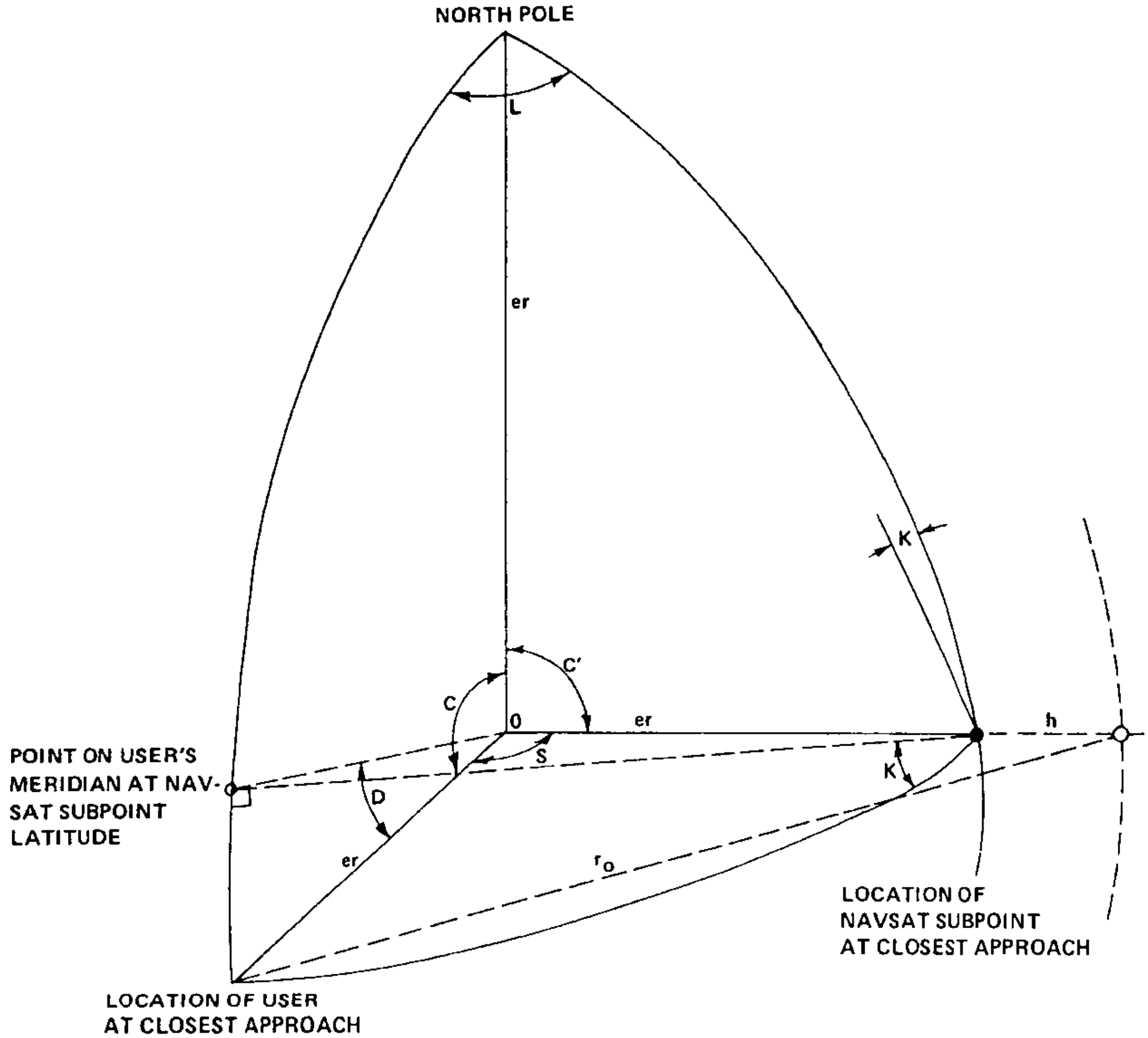
Fig. A-4 (U) Determination of Off-Meridian Angle



O	=	EARTH'S CENTER	S	=	CROSS TRACK ANGLE
er	=	EARTH'S RADIUS	D	=	DIFFERENCE BETWEEN NAVSAT AND USER'S COLATITUDES
L	=	DIFFERENCE IN LONGITUDE BETWEEN NAVSAT AND USER	K	=	OFF-MERIDIAN ANGLE OF EARTH TRACE
C	=	USER'S COLATITUDE			
C'	=	NAVSAT COLATITUDE			

Fig. A-5 (U) Overall Geometry for Doppler NAVSATs

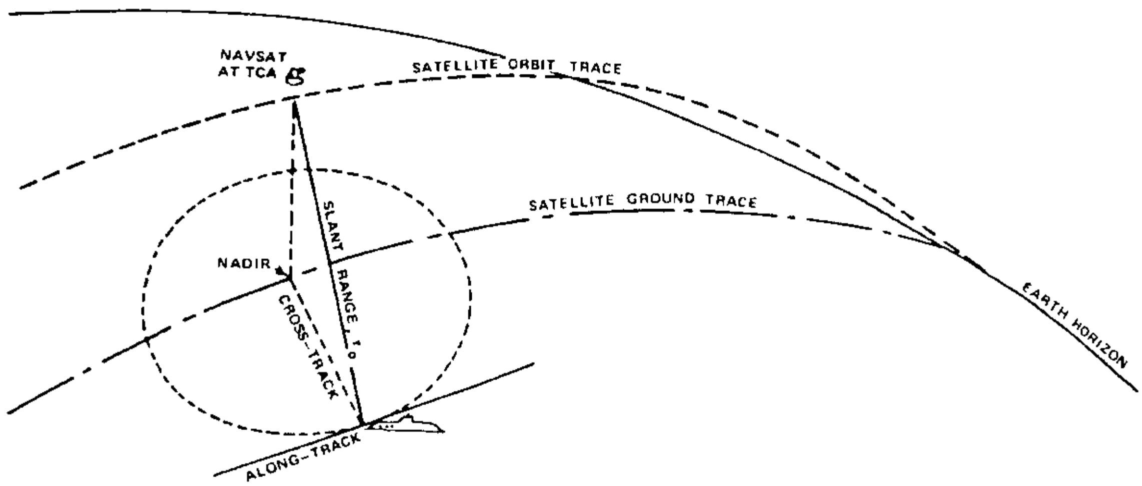


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Fig. A-6 (U) Doppler Navigation

(U) The user's latitude is then equal to 90 degrees − C.

(U) Further:

$$\sin(L) = \frac{\cos(K)\ \sin(S)}{\sin(C)}$$

$$L = \arcsin \frac{\cos(K)\ \sin(S)}{\sin(C)}$$

(U) User's longitude = satellite longitude ± L.

(U) From Figure A-5 and the law of sines:

$$\sin(K) = \sin(D)/\sin(S)$$

$$D = \arcsin\ (\sin(K)/\sin(S))$$

(U) Therefore, user's latitude = 90 degrees − (C' ± D).

(U) Further, from the law of cosines:

$$\mathrm{con}(K) = \tan(L)/\tan(S)$$

$$L = \arctan\ \cos(K)/\tan(S)$$

(U) Therefore, user's longitude = satellite longitude ± L.

Pages 155-163 (final page of the paper) withheld in full, and not provided.

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