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STARING AT THE SEA: THE SOVIET RORSAT AND EORSAT PROGRAMMES

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The Soviet Union developed a number of satellite systems that were closely integrated with military weapons systems. Their RORSAT and EORSAT satellite systems, intended to target American naval vessels for attack, are the best example of using satellites as a direct extension of military missions. Although much about these programmes remains classified, it is now possible to discuss many previously unknown details of their history.

1. INTRODUCTION

The Soviet ocean reconnaissance satellite programmes were among the most enigmatic components of Soviet military space programmes during the Cold War. Dozens of satellites in the effort were launched under the catchall "Kosmos" designation beginning in the mid-1960s to support one of the most central components of Soviet military strategy, i.e. to target United States naval vessels during conditions of potential hostilities. Unlike most other Soviet military programmes, little was forthcoming from official Russian sources on the history behind the ocean reconnaissance programmes. While Westerners now freely talk of Soviet photo-reconnaissance systems such as *Zenit* and *Yantar*, the ocean surveillance programmes have retained their Cold War-era Western designations, Radar Ocean Reconnaissance Satellite (RORSAT) and ELINT (electronic intelligence) Ocean Reconnaissance Satellite (EORSAT). In 1997, during the 300th anniversary of the formation of the Russian Navy, the Russians finally began to declassify these two parallel efforts. At the same time, the CIA has also declassified many Cold War era National Intelligence Estimates related to the Soviet space programme. This current article is an early attempt to summarise some of the new revelations and shed light on the origins, motivations, and history of the RORSAT and EORSAT programmes.

2. ORGANISATIONAL BACKDROP

In the history of the overall Soviet space effort, a small number of personalities are associated with the creation of important space systems. They include: Korolev, Chelomey, Glushko, Yangel, Babakin, and Mishin. Despite the unprecedented revelations in recent years about the structure and organisation of the former Soviet space programme, two names have been almost completely absent from this history although they were responsible for developing four of the most important Soviet military systems. They were Aleksandr Andreyevich Raspletin (1908-1967) and Anatoliy Ivanovich Savin (1920-). Their respective organisations, the KB-1 and the OKB-41, still remain relatively unknown. Raspletin and Savin were collectively responsible for developing:

(1) the Soviet anti-satellite (ASAT) system;

(2) the Soviet RORSAT system;

(3) the Soviet EORSAT system; and

(4) the Soviet space-based missile early warning system.

Aleksandr Andreyevich Raspletin, Director of the KB-1. Raspletin was responsible for early development of both the RORSAT/EORSAT programmes, as well as the co-orbital ASAT.

Anatoliy Ivanovich Savin, the Chief Designer of the OKB-41. Savin was directly responsible for the US-A/RORSAT and US-P/EORSAT programmes, as well as the co-orbital ASAT and space-based early warning systems.

2.1 The Design Bureau-1 (KB-1)

Raspletin's KB-1 traced its lineage back to the immediate post-war era. On 8 September 1947, the USSR Ministry of Armaments established the Special Bureau-1 (SB-1) in Moscow to develop radio-guided cruise missiles [1]. One of the more infamous engineers at the SB-1 was its Chief Engineer Sergey L. Beriya, the son of the dreaded Soviet secret police chief Lavrentiy P. Beriya. The SB-1's primary goal for the next few years was the development of the Kometa missile system which was, in fact, based on the younger Beriya's university diploma project. Later, in August 1950, the SB-1 was reorganised into the larger KB-1, a new Design Bureau specifically tasked with the creation of an effective air defence system for Moscow, initially known as the Berkut and later as the S-25 (known in the West as the SA-1 Guild).

It was in February-March 1955 that there was a large-scale reorganisation at the KB-1 that led to the creation of three main subdivisions which would go on to play significant roles in major Soviet strategic weapons systems. They were:

(1) the SKB-30 for anti-ballistic missile (ABM) systems (headed by Chief Designer Grigoriy V. Kisunko);

(2) the SKB-31 for surface-to-air missile (SAM) systems (headed by Chief Designer Aleksandr A. Raspletin); and

(3) the SKB-41 for airborne intelligence collection systems (headed by Chief Designer A.A. Kolosov). [2]

By 1960, Raspletin was 'promoted' to the position of Director of the KB-1, leaving the day-to-day activities of the SAM division to Chief Designer Boris V. Bunkin. Thus, by the early 1960s, Raspletin was overseeing a large organisation focusing on the development of a wide variety of important Soviet strategic weapons systems. In the late 1950s and early 1960s, the lion's share of work at the KB-1 was dedicated to the development of the System A, the first Soviet ABM weapon. The programme came to fruition on 4 March 1961 with the world's first interception of a ballistic missile by an ABM. The effort was directed by General Designer Kisunko [3].

The KB-1's first forays into the development of high priority space-based military systems came around this time during discussions for early Soviet anti-satellite proposals. At the time, the KB-1 proposed a joint anti-satellite project in cooperation with Sergey P. Korolev and aviation designer Artem I. Mikoyan using a variant of the famous R-7 ICBM. The idea never progressed beyond the proposal stage since the Soviet leadership favoured an alternative proposal from Vladimir N. Chelomey designated the Satellite Destroyer (IS) which eventually formed the basis of the Soviet co-orbital ASAT system [4]. There appears to have been a great deal of conflict between factions within the KB-1 and Chelomey, who was beginning to exert a dominant influence on the Soviet space programme at the time. A major portion of the work at the KB-1 was, in fact, redirected for Chelomey's interests around 1960: KB-1 Director and General Designer Raspletin became a subcontractor for Chelomey, while KB-1 subordinate departments such as the OKB-41 (formerly the SKB-41) were ordered to focus exclusively on Chelomey's pet projects such as the IS programme.

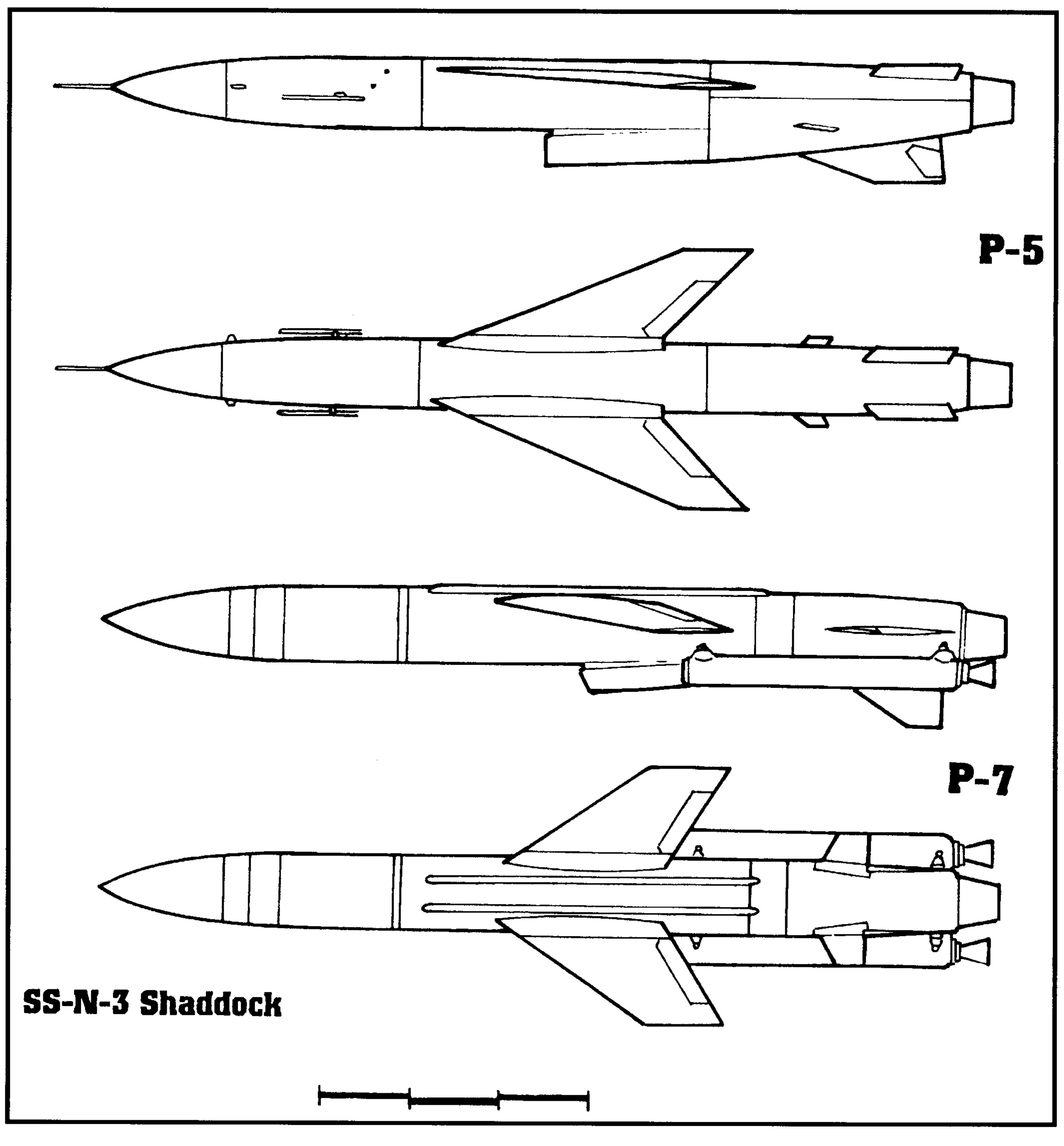
Kisunko, as ambitious as Chelomey himself, was reluctant to work for Chelomey, and the conflict eventually culminated in a major reorganisation at the KB-1. In early 1962, Kisunko's team separated from the KB-1 and became the independent OKB-30, which focused exclusively on ABM systems [5]. Through the following three decades, Kisunko and his successors at the OKB-30 have directed the development of all operational Soviet and Russian ABM systems. The OKB-30 is known today as the MAK Vympel.

The divisions remaining behind at the KB-1 expanded their reach from SAMs and airborne reconnaissance systems to the arena of space. In 1962, Anatoliy I. Savin took over as the Chief Designer of the OKB-41 subdivision and directed it toward what would eventually become its main thrust of work: high-priority offensive and defensive space-based systems [6].

3. EARLY CONCEPTION

3.1 Requirements For The System

In the post-Stalin era, there was a major shift in Soviet naval military strategy from a large cumbersome surface fleet to a smaller force comprising submarines, destroyers, and patrol boats equipped with tactical long-range cruise missiles with nuclear tipped warheads. One of the earliest such missiles was the P-5 (better known as the SS-N-3c Shaddock in the West) developed by the OKB-52 under Chelomey. Intended as a counterpart to the United States' Regulus strategic cruise missile, the P-5 had a nominal flight range of about 500 kilometres and carried a 650 kiloton warhead. The P-5 system was declared officially operational by the Central Committee and the Council of Ministers on 19 June 1959 [7]. Unable and unwilling to compete with the United States in the open oceans by developing extensive naval forces—particularly aircraft carriers—the Soviets instead chose to invest heavility in anti-ship missiles. They mounted these on many large surface combatants such as the Kynda and Kresta I class cruisers which entered service beginning in the early 1960s. The P-5 served as the foundation for several other anti-ship variants such as the P-6 (the SS-N-3a Shaddock), the P-35 (the SS-N-3b Shaddock), and the P-7 (the SS-N-3c Shaddock) which used a combination of inertial guidance with mid-course corrections provided by reconnaissance aircraft or surface ships (see Table 1). Terminal guidance against ship targets was provided either by infrared or active radar.



Soviet P-5 and P-7 anti-ship cruise missiles, designated SS-N-3 Shaddock by NATO.

(Illustrations courtesy Steven J. Zaloga)

Targeting for these missiles posed a major challenge since the location of American naval targets would have to be correctly determined prior to launch of the missiles. This matter was complicated by the fact that in most cases the missiles would be fired against targets which were beyond the range of the firing ship's radars. In the late 1950s, the Soviets began development of a system to ensure accurate targeting for a new generation of strategic naval cruise missiles which was

TABLE 1: *Soviet Tactical and Strategic Naval Cruise Missiles.*

Soviet Name	DoD/NATO Names	Index	Range	Design Bureau	Type	First Flight	Operational
P-5	SS-N-3c *Shaddock*	4K95	500 km	Chelomey	SLS	Aug 28 1957	Jun 19 1959
P-5D			c. 600 km	Chelomey	SLS	Sep 1959	Mar 2 1962
P-7	SS-N-3c *Shaddock*		1000 km	Chelomey	SLS	Apr 21 1961	*Aug 2 1965*
P-6	SS-N-3a *Shaddock*	4K48	500 km	Chelomey	SLS	Dec 23 1959	Jun 23 1964
P-10			600 km	Beriyev	SLS	1956	program term.
P-15	SS-N-2a *Styx*	4K40	8-40 km	Bereznyak	SLSH	Oct 1956	1960
P-15U / P-15TG *Termit*	SS-N-2b *Styx*	4K40U	40 km	Bereznyak	SLSH	Aug 29 1959	1972
P-15M *Termit-M*	SS-N-2c *Styx*		80 km	Bereznyak	SLSH		1972
P-20			3000 km	Ilyushin	SLS		*1960*
P-25		4K70		Chelomey	SLSH	1961	*1963*
P-27 *Termit-R*	SS-N-2d *Styx*			Bereznyak	SLSH		*Late 1980s*
P-35	SS-N-3b *Shaddock*	4K44	<300 km	Chelomey	SLSH	Oct 21 1959	1963
P-35 *Redut*			300 km	Chelomey	CLT	Sep 7 1963	Aug 11 1966
P-35 *Redut* (w/ *Utes*)			300 km	Chelomey	CLT	May 30 1971	Apr 28 1973
P-35 *Progress*		3M44	300 km	Chelomey	CLT	1976	1982
P-70 *Ametist*	SS-N-7 *Starbright*	4K66	80 km	Chelomey	ULS	Aug 1960	Jun 3 1968
P-120 *Malakhit*	SS-N-9 *Siren*	4K85	110-150 km	Chelomey	ULS	Sep 25 1968	Mar 17 1972
P-500 *Bazalt*	SS-N-12 *Sandbox*	4K80	550 km	Chelomey	SLS/SLSH	Oct 1969	1975
P-700 *Granit*	SS-N-19 *Shipwreck*		550 km	Chelomey	ULS	Nov 1975	Mar 12 1983
P-750 *Grom*	SS-N-24 *Scorpion*		3000 km	Chelomey	ULS	1986	
Meteorit		3M25	5000 km	Chelomey	ULS	May 20 1980	*late 1984*
Meteorit-M			5000 km	Chelomey	ULS	Dec 26 1983	
Vulkan		3M70		Chelomey	ULS	Jul 1982	Dec 18 1987
Oniks	SS-NX-26	3K55	300 km	Chelomey	ULS/SLS/SLSH		
Bastion			300 km	Chelomey	coastal *Oniks*		
Rubezh-A			80 km	Bereznyak	coastal		Oct 22 1978
Moskit	SS-N-22 *Sunburn*	3M80	10-120 km	Bereznyak	SLSH		1984
Moskit-M		3M82	120 km	Bereznyak	SLSH		
Kh-35 *Uran*	SS-N-25	3M24	130 km	Zvezda	SLSH		
Granat	SS-N-21 *Sampson*	3K10	3000 km	Novator	ULS		1987

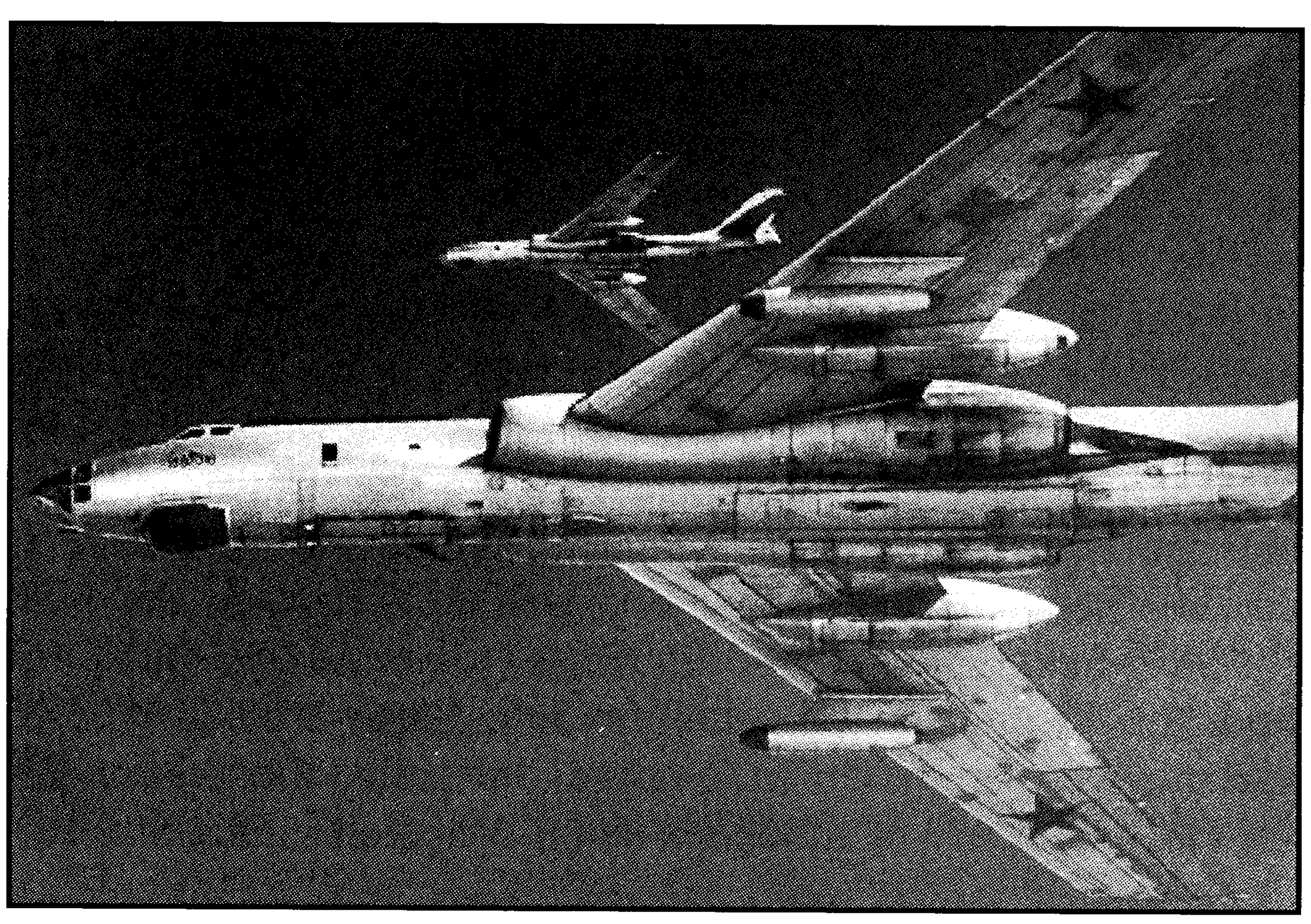
Notes:
In the "Operational" column, a date in italics denotes the date when the program was terminated.

Sources:
1. Aleksandr Shirokorad, "Missiles Over the Sea" (in Russian), *Tekhnika i vooruzheniye*, November-December 1997.

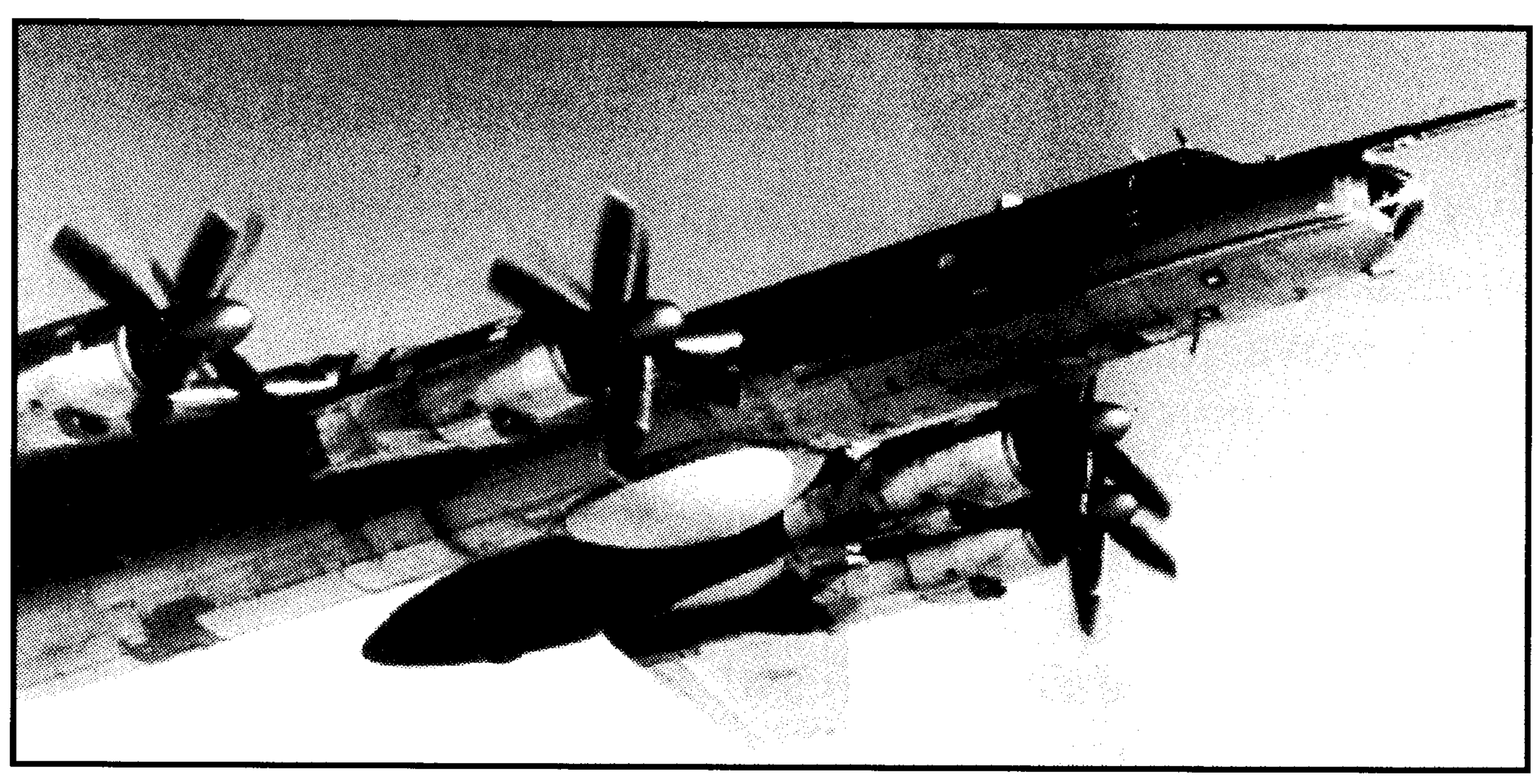
Abbreviations:

CLT coastal, launched from truck
SLSH surface-launched from ships
SLB surface-launched from boats
ULS underwater-launched from submarines
SLS surface-launched from submarines

comprised of airborne systems installed on specially equipped Tu-16RTs (Badger) and Tu-95RTs (Bear-D) aircraft, and later the Ka-25RTs (Hormone) helicopter. These aircraft carried systems for detecting American naval targets and transmitting their location data to Soviet warships equipped with anti-ship missiles. Initial models of a side-looking radar, called Uspekh, were designed at the NII-132 based at Kiev under Chief Designer I.V. Kudriavtsev for targeting the P-5 and P-35 missiles. The airborne detection system, presumably directed as a whole by the KB-1, was declared operational in 1965. Russian sources have claimed that the Tu-95RTs had a radar reach up to 7000 kilometres range [8]. These claims notwithstanding, airborne ocean reconnaissance systems suffered from being vulnerable to the target ship's defensive weapons systems. For many of the same reasons that airborne photo-reconnaissance eventually progressed to space-based photo-reconnaissance, the Soviet Navy also began exploring expanding their intelligence collection systems into space.



Tu-16RTs "Badger" maritime reconnaissance aircraft. The limitations of aircraft, such as their range, restricted search capabilities, and vulnerability to attack by aircraft from the very aircraft carriers they are supposed to detect, make them less than ideal surveillance platforms. Spacecraft are not nearly as vulnerable and can cover far more area.



Tu-95RTs "Bear-D" maritime reconnaissance aircraft. This aircraft is used to detect U.S. Navy ships at sea.

In 1959-60, the Soviet Navy developed some of the early requirements for an ocean reconnaissance system, officially called the Space-Based Sea Reconnaissance and Detection

System (known in its Russian abbreviation as MKRTs). Two Design Bureaus, Chelomey's OKB-52 based at Reutov and Raspletin's KB-1 in Moscow joined forces with the Navy to meet the latter's requirements. Chelomey had the leading role in the programme with the KB-1 essentially as a subcontractor [9].

The three parties formulated six basic requirements for the system:

(1) radar and electronic intelligence systems for all-weather reconnaissance of the ocean surface from space, with an ability to work automatically and distinguish a surface ship accurately from background interference from the ocean's surface and report back its exact location;

(2) a spacecraft equipped with all-weather reconnaissance systems, having automatically operating attitude control systems with a sufficiently powerful power source and the ability to correct its orbit on command from the Earth;

(3) a radio-control system on the spacecraft for precisely ensuring and predicting the orbital movement of the spacecraft from commands issued for ensuring the nominal operation of the vehicle's on-board systems during orbital flight;

(4) automated ground systems for controlling the spacecraft, and for receiving and transmitting the necessary information;

(5) naval ship-based reconnaissance and detection systems capable of processing information, selecting the main targets from the incoming information, and inputting that information to the firing complexes of the anti-ship cruise missiles; and

(6) a booster for launching the spacecraft into orbit with rigid requirements for short preparation times and the capability of precise orbital insertion into the required orbit. [10]

Clearly two of the most important requirements of the system were time-criticality and all-weather capability. Since ships move relatively fast, transmission of their position to offensive ships needs to be made before the target changes course. Secondly, adverse weather such as fog or rain squalls can make accurate location and identification a very difficult process. Both of these factors played very important roles in the eventual design of the system and its operational characteristics.

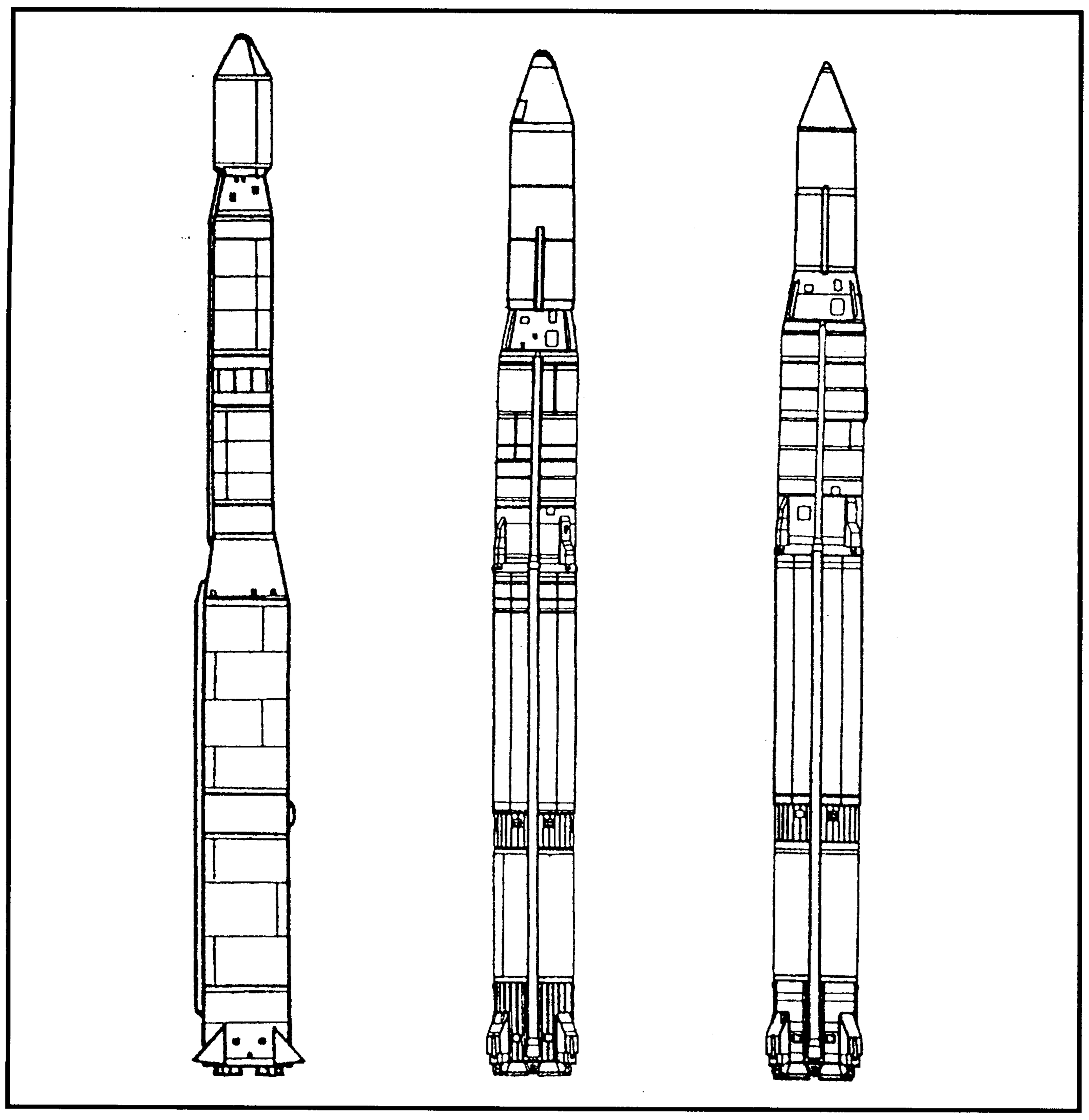
3.2 Prime Contractors

The ocean reconnaissance programme received formal approval on 16 March 1961 with the issuance of an official Central Committee and Council of Ministers decree (no. 420-174). A second decree on 3 June 1962 further defined details of the system as a whole including the role of prime and secondary contractors [11]. The effort had the technical designation "US," standing for the Russian abbreviation of "Controlled Satellite." A special Ministry of Defence order dated 18 June 1964 included the programme as part of its new five-year plan for space-based reconnaissance. At the time, the US satellite programme was given the codename Morya-1 (Seas-1) [12]. Quite likely Morya may have been the official Soviet designation for the programme, although by the time the system was declared operational, it inherited the name Legenda (Legend). In the initial stages of the work, the prime contractor for the entire satellite system was Chelomey's OKB-52. The Design Bureau was also responsible for developing a space launch version of the UR-200 ICBM, designated the UR-200K, for launching the satellites.

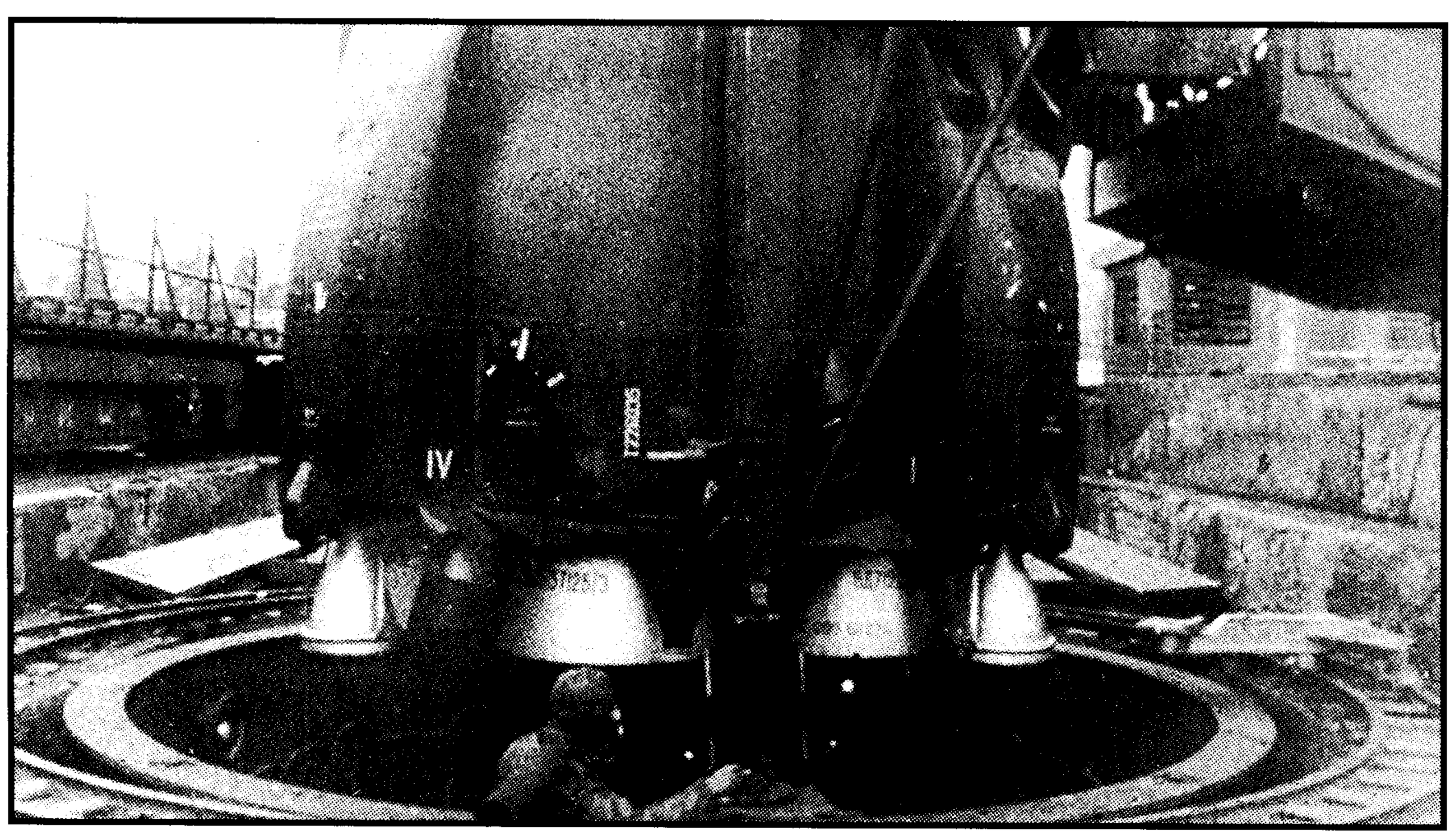
Much of the early work on the US programme was carried out in parallel with the Soviet co-orbital anti-satellite programme, called Satellite Destroyer ("IS" in its Russian abbreviation). In fact, the US and IS had major common elements, such as the UR-200K launcher, the same satellite bus, and many of the same contractors. Development of the UR-200K booster had been delegated to Chelomey's Branch No. 1 based at Moscow, which was collocated with the giant Khrunichev Machine Building Plant. The two-stage rocket was to have a mass of about 140 tonnes and was to be capable of launching 4.0 tonnes into a low Earth orbit, sufficient for satellites of both the US and IS classes. The KB-1 initially served as the main subcontractor for the radio-electronic and guidance systems for the spacecraft. The roles of the OKB-52 and the KB-1 reversed in the mid-1960s soon after the termination of the UR-200 ICBM programme. Many of Chelomey's projects were cancelled at the time, evidently because his chief sponsor, Nikita S. Khrushchev, lost his hold on power in the Soviet Union. In 1965, the KB-1 took over as the overall systems integrator for both the US and IS satellite systems, leaving Chelomey's OKB-52 as the provider for the satellite buses. The KB-1 was thus responsible for the design of the satellite, integration with its launcher, and overall development of control and guidance systems. Within the KB-1 itself, although General Designer Raspletin retained overall leadership of the two programmes, the subordinate OKB-41 under Chief Designer Savin was directly responsible for implementation of the projects. Perhaps because Savin's work at the KB-1 was beginning to encompass a huge array of space projects by this time, the OKB-41 separated from the KB-1 in 1973 and became the independent Kometa Central Scientific-Research Institute (TsNII Kometa) [13]. The KB-1 meanwhile continued its work on tactical and strategic surface-to-air missiles for the Soviet Air Defence Forces. The KB-1 is today known as the Almaz Central Design Bureau (TsKB Almaz).

Within the OKB-41 itself, there were several men under Savin chiefly responsible for creating the US system. These included M.K. Serov (chief of the thematic department) who later became the Chief Designer of the MKRTs, Yu.Ye. Petrushchenko (chief of the laboratory for ground-based systems), Gleb F. Zotov (chief of the laboratory for on-board systems), I.G. Ropoport (chief of the theoretical department), and V.V. Britvin (chief of the thematic-theoretical laboratory).

After the loss of Chelomey's UR-200K launcher for the US system, the KB-1 subcontracted Chief Designer Mikhail K. Yangel's Yuzhnoye Design Bureau to provide the services for a launch vehicle. On 24 August 1965, the Central Committee and the USSR Council of Ministers issued a joint decree to create a new two-stage space booster on the basis of the R-36 (or SS-9 Scarp) ICBM whose primary job would be to deposit both the IS and the US satellites into Earth orbit [14]. Two variants were on the drawing board, one called the Tsiklon-2A for early launches of mockups and test vehicles and an operational model called the Tsiklon-2. They were distinguished primarily by the length of their respective payload fairings (See Table 3 on p. 406). In an interesting historical aside, the lead designer for these launch vehicles at the Yangel Design Bureau was Leonid D. Kuchma, who is currently the President of Ukraine. Yangel's engineers completed the so-called Draft Plan for both boosters by March 1966. Launch facilities, earlier



From left to right: the cancelled UR-200K space launch vehicle, the Tsiklon-2A (or 11K67) configured for early launches of the US system, and the Tsiklon-2 (or 11K69) configures for operational launches of both US-A/RORSAT and US-P/EORSAT satellites.



Rocket nozzles of the large R-36 ICBM, designated the SS-9 Scarp by NATO. The R-36 was developed into the Tsyklon series of space launch vehicles.

created for the UR-200 at the Tyura-Tam launch range, were also turned over for use by the Tsiklon-class rockets. These included two launch pads at site 90 located about 70 kilometres north-west of the original town of Leninsk (recently renamed Baykonur) which was part of the so-called "Left Flank" of the missile range [15]. The fully-automated launch complexes were created by the Design Bureau of Transport Machine Building (KB TransMash) led by Chief Designer Vsevolod N. Solovyev, modified from their original use for the UR-200K rocket.

Originally, the primary operating organisations for the US ocean reconnaissance system were the Directorate of Missile-Artillery Armaments (URAV) and the Armaments Institute (IV VMF), both subordinate to the Soviet Navy [16]. One of the leading architects of the US ocean reconnaissance system was Captain 1st Rank (the United States Navy equivalent of Captain) Konstantin K. Frants of the IV VMF who laid much of the foundation of Soviet naval strategy in the new space era. Frants would personally brief Soviet leaders such as Khrushchev on the utility of the US system. Eventually, operational duties of the US system were inherited by the Russian Military Space Forces (VKS, which recently ceased to exist as an independent entity having been absorbed by the Strategic Missile Forces) [17]. The primary client for information from the ocean reconnaissance system has probably been the Department of Satellite Intelligence of the Naval Intelligence Directorate of the Main Navy Staff, Naval Headquarters [18].

4. DEVELOPMENT AND DESIGN

4.1 Variants

The US programme was one of the first space projects from the OKB-52, and General Designer Chelomey made good use of his experience in the aviation industry—his background had primarily been in the development of naval cruise missiles. In this respect, the development of the US satellites differed from concurrent Soviet space projects such as Vostok and Zenit since Chelomey almost completely bypassed the conventional set of subcontractors and manufacturing plants that had dominated the field with Korolev's spacecraft. This in turn meant that Chelomey's design decisions were, in many ways, completely different for a spacecraft than they might have been had he chosen to go the conventional route.

Initially, Chelomey had conceived the US satellite as having a single variant, carrying both a powerful radar as the primary means for detecting ships on the ocean's surface, as well as electronic intelligence (ELINT) systems to monitor and detect transmissions from ships to supplement the radar information. Due to mass limitations, underlined especially by the change of the launch vehicle from the more powerful UR-200K to the less powerful Tsiklon-2, there was a revision of this approach relatively late in the programme, probably in 1964-65. Petr S. Pleshakov, the Director of the Central Scientific-Research Institute-108 (TsNII-108) and Chief Designer Raspletin, together proposed developing two different classes of US satellites:

(1) an "active" spacecraft with radar systems, called the US-A; and

(2) a "passive" spacecraft with ELINT systems, called the US-P. [19]

Pleshakov, who later would rise to become USSR Minister of Radio Industries, oversaw the TsNII-108, one of the leading research institutes in the country developing ELINT and radar systems for the military. This institute was also the overall systems integrator for Soviet ELINT satellites of the Tselina-class whose buses were created by the Yuzhnoye Design Bureau.

Radar resolution had to be sufficiently high so as to differentiate between various types of American surface vessels, which would all show up as "blobs" from the radar echos. While radar was preferable, particularly due to the necessity for all-weather operation, the use of radar also raised associated operational problems. Obtaining the kind of resolution achieved by conventional photo-reconnaissance satellites was out of the question, since that would require radars of massive size impossible to launch into space at the time. But a modest sized radar about eight metres in length could theoretically detect vessels on the ocean's surface down to a resolution of 20-30 metres. In order to increase resolution as much as possible, engineers proposed adopting an operating orbit as low as possible, down to about 265 x 250 kilometres. Given the attendant atmospheric density at that level, technically it would not be efficient to use large flat solar panels to power the spacecraft. Additionally, given the large amounts of electricity needed to operate the radar, it was necessary to explore power sources other than solar panels to provide power. As a result, Chelomey and Raspletin agreed to use a compact nuclear reactor on board the US-A spacecraft, a design decision which affected other characteristics of the vehicle such as the need for radiation counters on the satellite, and the need to introduce radiation safety measures during preparation of the satellite prior to launch. The US-P spacecraft, operating in a slightly higher orbit, would use solar panels to power its ELINT systems. Both spacecraft would use a common bus that was similar to the one designed for the parallel IS ASAT system. In a recent history of the US programmes, Savin himself noted that parallel but inter-related development of the US and IS systems significantly reduced the amount of work committed to both programmes [20].

4.2 US-A / RORSAT Design

4.2.1 The Reactor

For obvious reasons, the development of the nuclear reactor was one of the most challenging elements of the US-A programme. Chelomey's OKB-52 had, even prior to work on the US-A, begun to explore the possibility of using nuclear reactors for powering its new generation of spacecraft. A Central Committee and USSR Council of Ministers decree dated 23 June 1960 had approved exploratory work on a winged spacecraft generically called the Kosmoplan for voyages to the Moon and the inner planets. The first design plans for this ambitious vehicle had emerged by early 1961 when Chelomey conceptualised a vehicle capable of automated flight to the Moon, Mars, and Venus and capable of returning to the Earth and landing on a conventional airfield [21]. Having initially explored the possibility of using chemical liquid propellant rocket engines, nuclear rocket engines, and electric rocket engines, Chelomey's engineers settled on the use of an electric rocket engine powered by a small compact nuclear power-station for the Kosmoplan. The unit as a whole consisted of a small nuclear reactor with a turbine to convert the reactor's power into electrical power, a tubular radiator to dissipate heat, and plasma rocket engines. Although the Kosmoplan programme never received firm support from the Soviet government, these early studies on nuclear power sources were no doubt instrumental in the early development of the US-A satellite.

Initial research on space-based nuclear powered units was carried out by the Physical-Power Institute (FEI) at Obninsk and the Kurchatov Institute of Atomic Energy (IAE) in Moscow. Each institution supported and pursued different approaches. The FEI focused on using a semiconductor converter for transforming the thermal energy of a nuclear reactor into electricity, while the IAE explored the more advanced thermo-emission converter concept. The two are also known as thermo-electric and thermionic reactors respectively. Overall supervision was entrusted to the governmental Committee for the Use of Atomic Energy although in later years development of the reactors was overseen by the Ministry of Medium Machine Building, the same ministry responsible for the manufacture of all Soviet nuclear warheads [22].

There was evidently some degree of discord over which type of reactor to install on flight versions of the US-A satellite. According to Sergey N. Khrushchev, the Soviet leader's son, Academician A.I. Leypunskiy from the FEI favoured "a fast-neutron reactor" while Academician Anatoliy P. Aleksandrov from the IAE preferred "a thermal reactor." Aleksandrov evidently took the matter directly to Nikita S. Khrushchev, who was none too pleased to be drawn into a technical decision outside his competence [23]. In the end both directions were pursued in parallel by the two different institutes.

Actual engineering and manufacturing work on the US-A's nuclear reactor was undertaken progressively by a series of different organisations, the work being transferred from one to another in line with institutional changes in the Soviet defence industry. Initial development began in 1960 at the Moscow-based OKB-300 headed by General Designer Sergey K. Tumanskiy, a Design Bureau whose primary focus up to that point had been creating engines for jet aircraft [24]. In December 1972 when all reactor work was moved to a single entity, the MKB Krasnaya zvezda, based in Moscow. The MKB Krasnaya zvezda had been originally established in 1950 as the OKB-670 under the famous Chief Designer Mark M. Bondaryuk and eventually became the most prolific ramjet developing entity in the USSR. When in 1972 its primary focus became the development of nuclear reactors, all of its ramjet-related work was transferred to the MKB Soyuz at Turayevo [25].

As per original specifications, these Design Bureaus engaged in parallel work on two types of space-based nuclear reactors, one with a semiconductor converter and the other with a thermionic converter. In the former case, thermal energy is non-magnetically transformed into electricity by means of the thermo-electric effect occurring when semiconductors or junctions of dissimilar metals develop a thermo-electromotive force caused by temperature disparities between them. The actual converter is heated by the nuclear reactor. Scientists at the FEI evidently achieved success quicker than their competitors, allowing the rapid development of the BES-5 reactor which had an original rated power output of about 5 kW [26]. All test and operational models of the US-A satellite evidently carried the BES-5, which probably had the operational designation Buk (Beech). According to official Soviet reports dating from the late 1980s, the operational version of the US-A satellite carried a reactor fuelled by U238 enriched with U235 which was encased in a beryllium reflector. In a report to the International Atomic Energy Agency, the Soviets described the reactor as consisting of 37 cylindrical fuel elements with 90% U235 enrichment with a total mass of 31.1 kilograms [27]. The reactor's fuel assembly had a mass of 53 kilograms, was 0.6 metres in length and 0.2 metres in diameter [28]. Control systems for the BES-5 reactor were developed by the OKB-12 under Chief Designer A.S. Abramov, who also produced propellant loading control systems for the giant N1 booster in the 1960s.

Later, in the 1980s, the MKB Krasnaya zvezda (then the NPO Krasnaya zvezda) completed work on the long-awaited multi-cell thermionic nuclear reactor model, designated the TEU-5 (the Russian abbreviation for "Thermionic Unit at 5 kW") or Topol, also rated at about 5 kW. In the case of thermionic converters, electrical energy is obtained directly from heat using the process of emission of electrons from a hot cathode into the inter-electrode space that is either evacuated or filled with the plasma of alkaline metals. One of the architects of these reactor programmes was Krasnaya zvezda Chief Designer V.I. Serbin, the son of the feared Chief of the Central Committee Defence Department Ivan D. Serbin, who exercised doctrinal control over the Soviet missile and space

TABLE 2a: *US-A/RORSAT Satellites.*

NAME	OKB NAME	INDUSTRY INDEX	NO.	LAUNCH DATE	LAUNCH VEHICLE	PERIOD OF OPERATION	END OF MISSION MANOEUVRE	REACTOR	COMMENTS
Kosmos-102	US-A		(n1)	Dec 27 1965	11A510		Jan 13 1966		model phase 1
Kosmos-125	US-A		(n2)	Jul 21 1966	11A510		Aug 2 1966	-	model phase 1
Kosmos-198	US-A		(n3)	Dec 27 1967	11K67	1 day	Dec 28 1967	-	model phase 2
Kosmos-209	US-A		(n4)	Mar 22 1968	11K67	1 day	Mar 23 1968	-	model phase 2
	US-A		(n5)	Jan 25 1969	11K67	-	-	-	launch failure
Kosmos-367	US-A		(n6)	Oct 3 1970	11K69	<3 hours	Oct 3 1970	-	model phase 3
Kosmos-402	US-A		(n7)	Apr 1 1971	11K69	<3 hours	Apr 1 1971	-	model phase 3
Kosmos-469	US-A		(n8)	Dec 25 1971	11K69	9 days	Jan 3 1972	-	model phase 3
Kosmos-516	US-A		(n9)	Aug 21 1972	11K69	32 days	Sep 22 1972	BES-5	
	US-A		(n10)	Apr 25 1973	11K69	-	-	BES-5	launch failure
Kosmos-626	US-A		(n11)	Dec 27 1973	11K69	45 days	Feb 9 1974	BES-5	
Kosmos-651	US-A		(n12)	May 15 1974	11K69	71 days	Jul 25 1974	BES-5	worked w/ K-654
Kosmos-654	US-A		(n13)	May 17 1974	11K69	74 days	Jul 30 1974	BES-5	worked w/ K-651
Kosmos-723	US-A		(n14)	Apr 2 1975	11K69	43 days	May 15 1975	BES-5	
Kosmos-724	US-A		(n15)	Apr 7 1975	11K69	65 days	Jun 11 1975	BES-5	
Kosmos-785	US-A		(n16)	Dec 12 1975	11K69	<3 hours	Dec 12 1975	BES-5	
Kosmos-860	US-A		(n17)	Oct 17 1976	11K69	24 days	Nov 10 1976	BES-5	
Kosmos-861	US-A		(n18)	Oct 21 1976	11K69	60 days	Dec 20 1976	BES-5	
Kosmos-952	US-A		(n19)	Sep 16 1977	11K69	21 days	Oct 7 1977	BES-5	
Kosmos-954	US-A		(n20)	Sep 18 1977	11K69	c.43 days	Oct 31 1977	BES-5	reactor reentered
Kosmos-1176	US-AM?	17F16?	(n21)	Apr 29 1980	11K69	134 days	Sep 10 1980	BES-5 mod	test flight
Kosmos-1249	US-AM?	17F16?	(n22)	Mar 5 1981	11K69	105 days	Jun 18 1981	BES-5 mod	
Kosmos-1266	US-AM?	17F16?	(n23)	Apr 21 1981	11K69	8 days	Apr 28 1981	BES-5 mod	failed early
Kosmos-1299	US-AM?	17F16?	(n24)	Aug 24 1981	11K69	12 days	Sep 5 1981	BES-5 mod	failed early
Kosmos-1365	US-AM?	17F16?	(n25)	May 14 1982	11K69	135 days	Sep 26 1982	BES-5 mod	
Kosmos-1372	US-AM?	17F16?	(n26)	Jun 1 1982	11K69	70 days	Aug 10 1982	BES-5 mod	
Kosmos-1402	US-AM?	17F16?	(n27)	Aug 30 1982	11K69	120 days	Dec 28 1982	BES-5 mod	reactor reentered
Kosmos-1412	US-AM?	17F16?	(n28)	Oct 2 1982	11K69	39 days	Nov 10 1982	BES-5 mod	
Kosmos-1579	US-AM?	17F16?	(n29)	Jun 29 1984	11K69	90 days	Sep 26 1984	BES-5 mod	
Kosmos-1607	US-AM?	17F16?	(n30)	Oct 31 1984	11K69	93 days	Feb 1 1985	BES-5 mod	
Kosmos-1670	US-AM?	17F16?	(n31)	Aug 1 1985	11K69	83 days	Oct 22 1985	BES-5 mod	
Kosmos-1677	US-AM?	17F16?	(n32)	Aug 23 1985	11K69	60 days	Oct 23 1985	BES-5 mod	
Kosmos-1736	US-AM?	17F16?	(n33)	Mar 21 1986	11K69	92 days	Jun 21 1986	BES-5 mod	
Kosmos-1771	US-AM?	17F16?	(n34)	Aug 20 1986	11K69	56 days	Oct 15 1986	BES-5 mod	
Kosmos-1818			(n35)	Feb 2 1987	11K69	-	-	TEU-5	work w/ K-1867
Kosmos-1860	US-AM?	17F16?	(n36)	Jun 18 1987	11K69	40 days	Jul 28 1987	BES-5 mod	work w/ K-1834
Kosmos-1867			(n37)	Jul 10 1987	11K69	-	-	TEU-5	work w/ K-1818
Kosmos-1900	US-AM?	17F16?	(n38)	Dec 12 1987	11K69	c.124 days	Apr 14 1987	BES-5 mod	work w/ K-1834 & K-1890
Kosmos-1932	US-AM?	17F16?	(n39)	Mar 14 1988	11K69	66 days	May 19 1988	BES-5 mod	work w/ K-1900

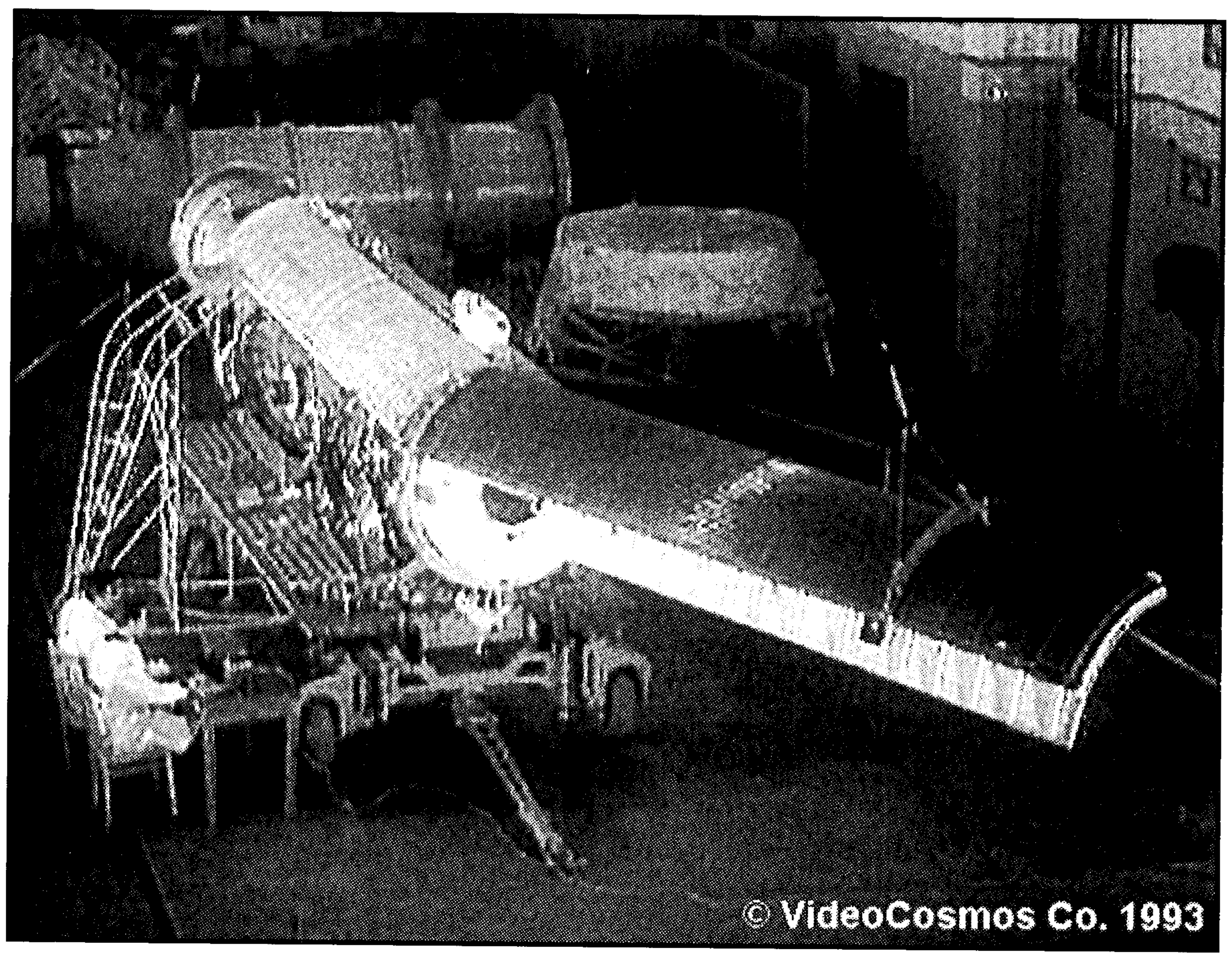
Sources:
1. Nicholas L. Johnson, *The Soviet Year In Space 1988*, Teledyne Brown Engineering, Colorado Springs, CO, 1989, p. 74.

Notes:
1. The end of mission manoeuvre refers to the date that the reactor (or mockup) was boosted out of the satellite's operational orbits into a safekeeping orbit.
2. The end of mission manoeuvres for Kosmos-102 and Kosmos-125 denote the date of decay.

programmes for nearly a quarter century in the 1960s and 1970s [29].

There was a third reactor programme that also reached a gestation period in the 1980s after a long development period. The Leningrad-based Central Design Bureau of Machine Building (TsKBM) in cooperation with the Kurchatov Institute of Atomic Energy produced a 6 kW reactor designated the Yenisey [30]. The Yenisey used a single-cell design with a uranium crystal fuel element. Unlike the Buk or the Topol, the single-cell thermionic design allowed designers to fully test the reactor on the ground without using radioactive fuel. The multi-cell design mounted the reactor fuel cells in units one on top of the other, like batteries in a flashlight. The single-cell design used a single long fuel cell. Tungsten heaters acting as surrogates were inserted into spaces where the fuel elements would traditionally be mounted, thus generating sufficient heat for the reactor to be tested for its efficiency [31]. The Yenisey was evidently not earmarked for any US-A type spacecraft, but rather for a much heavier satellite designed by the NPO Prikladnoy mekhaniki based at Krasnoyarsk-26. Although details still remain sketchy, it appears that the Yenisey-equipped spacecraft was set for launch by a Proton booster in the 1980s, but the programme was delayed and eventually cancelled by the late 1980s [32].

When the Soviets began publicising their reactor programmes beginning in 1989, they used a confusing set of designations for public consumption: the Topol was called the Topaz while the Yenisey was called the Topaz-2, even though the two designs had little in common and were developed by unconnected Design Bureaus. Topaz is the Russian acronym for "Thermionic Experimental Conversion in the Active Zone." Partly due to the misleading designation system, and partly as a result of Soviet efforts to obfuscate the issue, most Western analysts believed that all US-A RORSATs used a thermionic



Soviet US-A/RORSAT satellite. The large side-looking radar antenna is being deployed during a ground test. The antenna is folded flush against the satellite's side during launch and unfolds to essentially double its length. The reactor would be mounted to the back of the satellite in this photo.

(Photo courtesy VideoCosmos Co., via Igor Lissov).

design, when in fact the thermionic design was not introduced until 1987 [33]. Additionally, although the Yenisey/Topaz-2 reactor had little connection with the US-A RORSAT programme, Western analysts have continued to make a connection between the two, although the Topaz-2 was probably designed for a military mission that had nothing to do with ocean reconnaissance.

One of the most well-known aspects of the Soviet radar ocean reconnaissance satellite programme was its unusual mission profile. Since the US-A spacecraft was intended to fly in a relatively low orbit, it meant that the vehicle with its dangerous reactor would decay in a short time and fall to the Earth. In order to preclude any accidental re-entry leading to contamination of the Earth's landmass, KB-1 and OKB-52 engineers co-operatively devised a flight profile whereby after a nominal mission of about 45 days, a secondary solid-propellant rocket engine would boost the Radiation-Dangerous Part (ROCh), i.e. the reactor and core, to a safe orbit approximately 900-1000 kilometres high that would ensure that the satellite would remain in orbit for 400 years or so. By the time of its reentry in the 24th century, the radioactive fuel would have decayed naturally, posing no threat to the inhabitants of the Earth. The spacecraft's on-board control complex included an automated system comprising orientation, stabilisation, and timing systems to independently boost the ROCh to a safe orbit not only at the end of nominal missions, but also in cases of an "irreversible failure" of the spacecraft [34].

4.2.2 The Radar

The primary payload of the US-A satellite was a powerful phased-array X-band radar developed by the Moscow-based NII-17 under Chief Designers I.A. Brukhanskiy and Ya.B. Shapirovskiy. The radar antenna, semi-circular in shape, extended out from one end of the cylindrical satellite bus to its full length of about 4 metres. There was apparently a second side-looking radar antenna which was designed by P.O. Salaganik. An independent computer system controlled the radar during operational missions. One of the problems scientists and engineers faced in designing the radar systems for the US-A was the limited experimental data on such large systems for ocean reconnaissance. Due to the absence of information on distinguishing targets from background interference on the ocean's surface, KB-1 and NII-17 engineers devised airborne versions of the US-A radar for an extensive testing programme that continued parallel with testing of the space-based system [35].

According to recently declassified CIA reports dating from the 1970s, the US-A radar could "detect medium-sized and some small ships—such as cruisers and destroyers—under favorable conditions, and probably can detect large ships—such as aircraft carriers—even under adverse sea conditions" [36]. Submarine detection was neither an original goal of the system, nor apparently was it possible during operations of the US-A constellation.

4.2.3 Spacecraft Systems

The configuration of the US-A spacecraft has not been revealed in great detail in Russian sources, although it is evident that the actual bus was similar to the passive US-P satellite. The overall cylindrical-shaped satellite had a mass of 3800 kilograms and was 10 metres long and 1.3 metres wide. The nuclear reactor plus high altitude storage element accounted for 1250 kilograms of the mass and 5.8 metres of the length of the vehicle [37].

A major portion of the effort on the US-A and US-P was to minimise the level of interaction with ground control during operational missions. With this in mind, I.G. Ropoport, an engineer at the KB-1, proposed the so-called "single-point system of radio-guidance" which:

> ensured precise determination of the orbital parametres of the moving [spacecraft] and its prediction by two passages over a control point by issuing commands necessary for the daily functioning of the [spacecraft] with a precise connection to a synchronised system. [38]

The US-A bus apparently used specially developed preprogrammed "micromodules" with the best Soviet integrated microcircuits of the period, which were incorporated into onboard systems for radio-control and communications. The orientation and stabilisation systems for the satellite not only maintained correct attitude, but also were equipped to automatically position the satellite into correct orientation in case of a catastrophic failure of the nuclear reactor. This complex system was designed and developed by the OKB-36 at the KB-1 under Chief Designer P.M. Kirillov.

Due to the limited capability of the Tsiklon-2 launch vehicle, OKB-52 engineers adopted a mission profile where the two stages of the booster would insert the payload on a suborbital trajectory; at the apex of this trajectory, the US-A spacecraft would fire a self-contained powerful rocket engine to boost itself into an initial Earth orbit. Unlike most other Soviet spacecraft of the period, rocket engines for the US-A and US-P spacecraft were not designed by the Kaliningrad-based OKB-2. For the ocean reconnaissance satellites, the engine subcontractor was the Moscow-based OKB-300 headed by Chief Designer Tumanskiy, the same organisation initially responsible for the spacecraft's nuclear reactor. The OKB-300's "space" branch at Turayevo, established in 1964, was responsible for developing engines for these spacecraft. Note that this same branch, later known (after 1972) as the independent TMKB Soyuz, concurrently developed the tiny ullage motors for the famous Blok D rocket stage of the Proton and N1 rockets. The actual engine complex of the US satellite comprised three sets of engines:

(1) a "relatively powerful" engine for orbital insertion;

(2) medium thrust engines for orbital corrections and motion; and

(3) very "economical" low-thrust stabilisation engines. [39]

The last set of engines were evidently ion engines to counteract the relatively significant air drag at the low operational altitude of the US-A satellite. These probably produced a constant low level of thrust to prevent change in orbital parametres and to eliminate drift in the relative pairings of two US-A satellites.

4.3 US-P / EORSAT Design

4.3.1 Spacecraft Systems

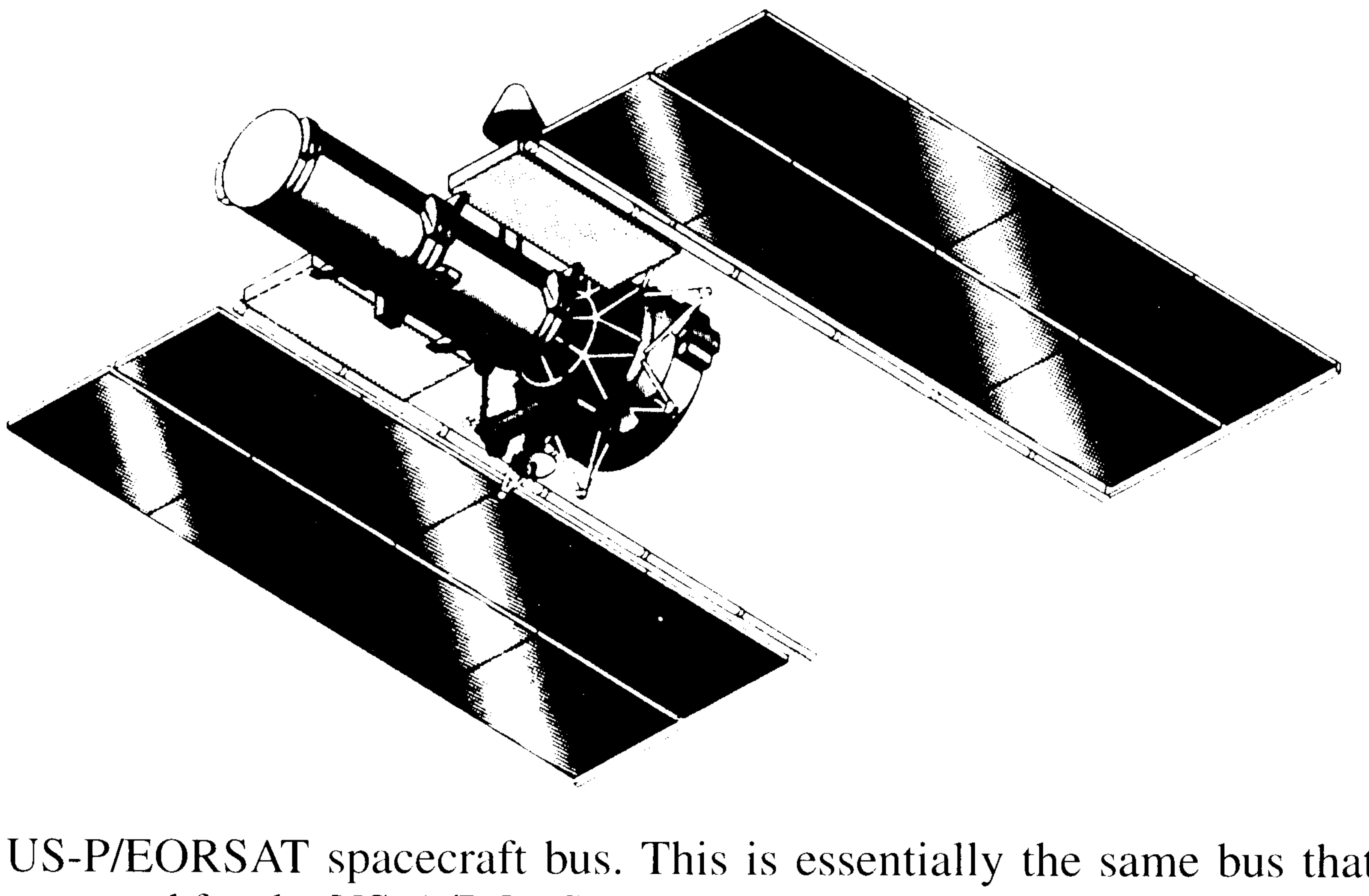
The US-P spacecraft, while using the same bus structure as its counterpart, differed in some respects. Data is only available on the most recent variant. The bus main body diameter is the same as the US-A vehicle, 1.3 metres, but it is far longer, up to 17.0 metres. Its total mass is 3000 kilograms. The cylindrical bus is framed by two large solar panels, about one-and-a-half times longer than the main body. The solar panels were designed and produced in-house at the OKB-52. The spacecraft has a pri-

TABLE 2b: *US-P/EORSAT Satellites.*

NAME	OKB NAME	INDUSTRY INDEX	NO.	LAUNCH DATE	LAUNCH VEHICLE	PERIOD OF OPERATION	LAST MANOEUVRE	DECAY	COMMENTS
Kosmos-699	US-P		(n1)	Dec 24 1974	11K69		Mar 1975	Oct 16 1977	
Kosmos-777	US-P		(n2)	Oct 29 1975	11K69		-	Jun 3 1976	
Kosmos-838	US-P		(n3)	Jul 2 1976	11K69		Nov 1976	Aug 23 1977	
Kosmos-868	US-P		(n4)	Nov 26 1976	11K69		Dec 1976	Jul 8 1978	
Kosmos-937	US-P		(n5)	Aug 24 1977	11K69	196 days	Mar 1978	Oct 19 1978	
Kosmos-1094	US-P		(n6)	Apr 18 1979	11K69		May 1979	Nov 7 1979	pair w/ K-1096
Kosmos-1096	US-P		(n7)	Apr 25 1979	11K69		Jun 1979	Nov 24 1979	pair w/ K-1094
Kosmos-1167	US-P		(n8)	Mar 14 1980	11K69	372 days	Mar 20 1981	Oct 1 1981	work w/ K-1176 & K-1220
Kosmos-1220	US-P		(n9)	Nov 4 1980	11K69	145 days	Apr 1981	-	work w/ K-1167
Kosmos-1260	US-P		(n10)	Mar 21 1981	11K69	176 days	Sep 13 1981	May 22 1982	work w/ K-1286
Kosmos-1286	US-P		(n11)	Aug 4 1981	11K69	224 days	Mar 1982	Oct 16 1982	work w/ K-1260 & K-1337
Kosmos-1306	US-P		(n12)	Sep 14 1981	11K69	150 days	Feb 3 1982	Jul 16 1982	incorrect orbit, replaced K-1260, work w/ K-1337
Kosmos-1337	US-P		(n13)	Feb 11 1982	11K69	8 days		Jul 25 1982	work w/ K-1286 & K-1306
Kosmos-1355	US-P		(n14)	Apr 29 1982	11K69	249 days	Feb 1983	Aug 27 1983	
Kosmos-1405	US-P		(n15)	Sep 4 1982	11K69	91 days	Nov 1982	Feb 5 1984	
Kosmos-1461	US-P		(n16)	Jul 5 1983	11K69	268 days	Jan 1984	-	
Kosmos-1507	US-P		(n17)	Oct 29 1983	11K69	222 days	Nov 1984	Aug 19 1987	work w/ K-1461
Kosmos-1567	US-P		(n18)	May 30 1984	11K69	538 days	Nov 19 1985	Apr 3 1988	
Kosmos-1588	US-P		(n19)	Aug 7 1984	11K69	341 days	Jul 14 1985	Feb 17 1988	
Kosmos-1625	US-P		(n20)	Jan 23 1985	11K69	0 days		Jan 25 1985	upper stage fail
Kosmos-1646	US-P		(n21)	Apr 18 1985	11K69	312 days	Feb 24 1986	May 2 1988	
Kosmos-1682	US-P		(n22)	Sep 19 1985	11K69	382 days	Oct 6 1986	May 17 1988	work w/ K-1769
Kosmos-1735	US-PM?	17F17?	(n1)	Feb 27 1986	11K69	576 days	Sep 26 1987	Nov 17 1988	work w/ K-1737
Kosmos-1737	US-P		(n23)	Mar 24 1986	11K69	254 days	Dec 3 1986	Dec 3 1986	work w/ K-1735
Kosmos-1769	US-P		(n24)	Aug 4 1986	11K69	367 days	Aug 6 1987	Feb 18 1988	work w/ K-1682
Kosmos-1834	US-PM?	17F17?	(n2)	Apr 8 1987	11K69	510 days	Aug 29 1988	Oct 13 1988	work w/ K-1735 & K-1860
Kosmos-1890	US-PM?	17F17?	(n3)	Oct 10 1987	11K69		Dec 1988	Dec 26 1988	work w/ K-1834
Kosmos-1949	US-PM?	17F17?	(n4)	May 28 1988	11K69	662 days	Mar 22 1990	Apr 23 1990	work w/ K-1900
Kosmos-1979	US-PM?	17F17?	(n5)	Nov 18 1988	11K69	374 days	Nov 27 1989	Dec 25 1989	work w/ K-1890 & K-1949
Kosmos-2033	US-PM?	17F17?	(n6)	Jul 24 1989	11K69	516 days	Dec 22 1990	Jan 6 1991	work w/ K-1949 & K-1979
Kosmos-2046	US-PM?	17F17?	(n7)	Sep 27 1989	11K69	560 days	Apr 11 1991	Apr 16 1991	work w/ K-1949, K-1949 & K-2033
Kosmos-2051	US-PM?	17F17?	(n8)	Nov 24 1989	11K69	260 days	Aug 11 1990	Jan 21 1991	work w/ K-2046
Kosmos-2060	US-PM?	17F17?	(n9)	Mar 14 1990	11K69	527 days	Aug 23 1991	Sep 1 1991	rep K-1949
Kosmos-2096	US-PM?	17F17?	(n10)	Aug 23 1990	11K69	710 days	Aug 2 1992	Aug 30 1992	rep K-2051
Kosmos-2103	US-PM?	17F17?	(n11)	Nov 14 1990	11K69	49 days	Jan 2 1991	Apr 3 1991	work w/ K-2107
Kosmos-2107	US-PM?	17F17?	(n12)	Dec 4 1990	11K69	461 days	Mar 10 1992	Apr 6 1992	work w/ K-2103
Kosmos-2122	US-PM?	17F17?	(n13)	Jan 18 1991	11K69	775 days	Mar 4 1993	Mar 28 1993	work w/ K-2107
Kosmos-2238	US-PM?	17F17?	(n14)	Mar 30 1993	11K69	540 days	Sep 21 1994	Dec 9 1994	
Kosmos-2244	US-PM?	17F17?	(n15)	Apr 28 1993	11K69	657 days	Feb 14 1995	Mar 18 1995	work w/ K-2258
Kosmos-2258	US-PM?	17F17?	(n16)	Jul 7 1993	11K69	603 days	Mar 2 1995	Jun 8 1995	work w/ K-2244
Kosmos-2264	US-PM?	17F17?	(n17)	Sep 17 1993	11K69	564 days	Apr 4 1995	Aug 7 1995	work w/ K-2293
Kosmos-2293	US-PM?	17F17?	(n18)	Nov 2 1994	11K69	509 days	Mar 26 1996	May 13 1996	work w/ K-2264
Kosmos-2313	US-PM?	17F17?	(n19)	Jun 8 1995	11K69	683 days	Apr 22 1997	Jul 11 1997	work w/ K-2335
Kosmos-2326	US-PM?	17F17?	(n20)	Dec 20 1995	11K69	659 days	Oct 10 1997	Nov 8 1997	
Kosmos-2335	US-PM?	17F17?	(n21)	Dec 11 1996	11K69	operational			work w/ K-2313 & K-2347
Kosmos-2347	US-PM?	17F17?	(n22)	Dec 9 1997	11K69	operational			work w/ K-2335

Sources:

1. Phillip S. Clark, "Soviet ELINT Satellites for Monitoring Naval Transmissions," *Jane's Soviet Intelligence Review*, August 1990, pp. 378-381.
2. Phillip S. Clark, ed., *Jane's Space Directory*, 1997-98, Jane's Information Group, Coulsdon, UK, 1997.
3. M.V. Tarasenko, *Voennyye aspekty Sovetskoi kosmonavtiki*, Nikol, Moscow, 1992.

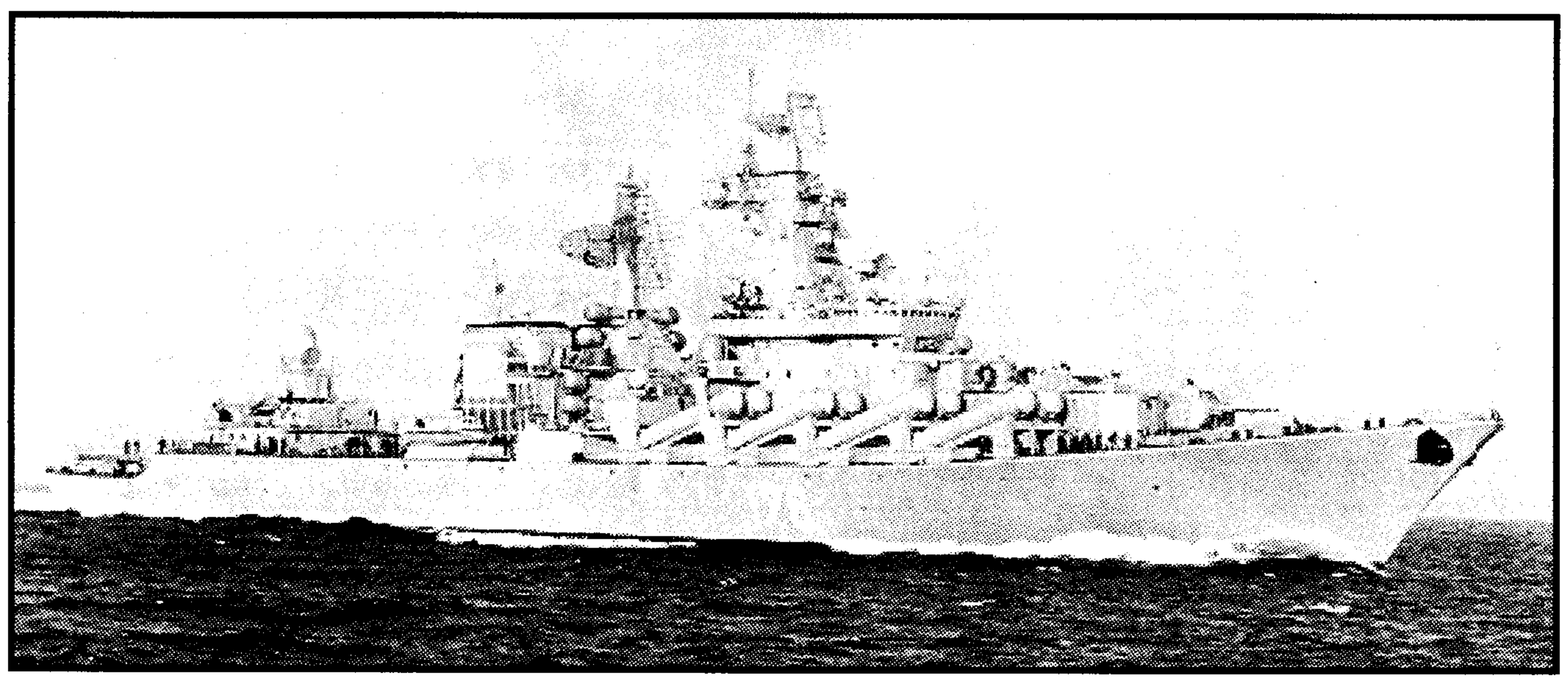


US-P/EORSAT spacecraft bus. This is essentially the same bus that was used for the US-A/RORSAT. The US-P was equipped with a large X-shaped antenna (not shown) for receiving electronic emissions from naval vessels and pinpointing their sources. The current manufacturer of the bus, the KB Arsenal, is now offering the spacecraft for piggy-back payloads for various civil applications. *(Illustration courtesy Europe & Asia in Space).*

mary orbital injection engine with a thrust of 300-600 kilograms, serving the same purpose as on the US-A vehicle. In the case of the US-P, the Tsiklon-2 inserts the spacecraft into a 120 x 415 kilometre transfer orbit, from whence this main engine boosts the vehicle into its circular working orbit. In addition to the main engine, the vehicle also carries a set of four 10 kilogram thrust attitude control engines, presumably also designed by the OKB-300 (later the MNPO Soyuz) and the Turayevo MKB Soyuz. Propellant for both engine systems, unsymmetrical dimethyl hydrazine and nitrogen tetroxide, is carried in eight 60-litre tanks. The main and attitude control propulsion systems are probably identical to the ones used on the US-A satellite [40].

4.3.2 *ELINT Systems*

The passive electronic intelligence (ELINT) systems on board the US-P were developed by the Kaluga Branch of the TsNII-108 under Director S.I. Baburin (initially) and V.L. Grechki (later). This primary payload for the US-P satellite is an 'X'-



Soviet Slava class guided missile cruiser in the 1980s. The Slava was essentially designed as an anti-ship cruiser. Note the eight cylindrical canisters for P-500 "Bazalt" (NATO designation: SS-N-12) anti-ship cruise missiles on the starboard side. The Slava had two "Punch Bowl" satellite antennas. Soviet naval doctrine during the 1960-1980s eschewed aircraft carriers and emphasised using large numbers of anti-ship weapons to saturate American defences to attack the U.S. Navy's carriers. Weapons such as the P-500 received targeting information from aircraft, as well as orbiting EORSAT and RORSAT spacecraft.
(Courtesy U.S. Department of Defense via Soviet Military Power).

shaped antenna, similar to the one used on the civilian Okean spacecraft, which is carried on the Earth-facing side of the bus.

The reconnaissance and detection systems on board cruisers and submarines were designed by the NII-132 based at Kiev under Chief Designers I.V. Kudryavtsev and T.Ye. Stefanovich. The system comprised elements which received information directly from the satellites in a so-called "find-transmit" mode which introduced the coordinates of the selected target into systems for guiding the anti-ship missiles [41]. According to Western analysis, the system was capable of providing target data down to an accuracy of about two kilometres [42]. Soviet ships equipped with Punch Bowl (NATO codename) antennae were said to be able to receive US-A and US-P data directly from the satellites to guide long-range missiles such as the surface-launched P-500 Bazalt (or SS-N-12 Sandbox) anti-ship missiles [43]. Apart from real-time transmission of data, the satellites were also capable of storing information for later transmission to Moscow.

For both the IS and the US programmes, Chelomey and Raspletin had a specially built command and control facility established near the town of Noginsk which was independent from the primary military control centre in Moscow at the premises of the NII-4 military institute [44]. Initially, the Noginsk centre relied on the Bolshevo team for mission control support but eventually inherited full capabilities to control both the ASAT and ocean reconnaissance programmes, although ground stations across the Soviet Union were evidently leased from the Strategic Missile Forces. Officers from the Air Defence Forces and the Navy were on hand to oversee the two programmes respectively. The land-based complex at Noginsk for receiving and processing the incoming data was designed in a cooperative venture by the NII-648 under Chief Designers G.B. Petropavlovskiy, V.G. Shchetinin, and G.P. Videneyev, and the MNII-1 under Chief Designer V.M. Minayev. Most notably, the former institute, the NII-648, concurrently developed the famous Igla rendezvous system used on the Soyuz spacecraft in the 1960s and 1970s. The US-A and US-P satellites were equipped with a special communications antenna on top of the vehicle for real-time or near-real-time operation via Molniya-2 and Tsiklon satellite constellations. These systems were designed by the NII-695 based at Moscow under the leadership of Chief Designer M.S. Nemirovskiy [45].

5. MISSION PROFILES

Procedures for preparing the satellite payloads and implementing the launch cycle were developed by Savin's engineers. The prepared cyclogram included operations synchronised to a single schedule that led to a rapid-response launch that had minimal human involvement. Based on information from the three-stage Tsiklon-3 variant, it is clear that launch preparation time was reduced to an absolute minimum. Once at the pad, all operations were automatic. Propellant loading through the base required about one hour from T-75 minutes. In non-

TABLE 3: *Launch Vehicles for the US System.*

UR-200K (or 8K81K) DATA

	LENGTH / DIAMETER	PROPELLANTS	ENGINE	ENGINE CONTRACTOR	THRUST
STAGE I	20.0m / 3.0m	NT-UDMH	1 X RD-0202	OKB-154	204t (sl)
STAGE II	10.0m / 2.0m	NT-UDMH	1 X RD-0205	OKB-154	62.5t (v)
OVERALL	30.0m / 3.0m	-	-	-	-

NOTE: The RD-0202 unit comprised the RD-0203 and the RD-0204. The RD-0205 comprised the RD-0206 and the RD-0207.

***TSIKLON-2A* (or 11K67) DATA**

	LENGTH / DIAMETER	PROPELLANTS	ENGINE	ENGINE CONTRACTOR	THRUST
STAGE I	18.9m / 3.0m	NT-UDMH	1 X RD-251	OKB-456	270.4t (sl)
STAGE II	10.9m / 3.0m	NT-UDMH	1 X RD-252	OKB-456	96.0t (v)
OVERALL	39.7m / 3.0m	-	-	-	-

***TSIKLON-2* (or 11K69) DATA**

	LENGTH / DIAMETER	PROPELLANTS	ENGINE	ENGINE CONTRACTOR	THRUST
STAGE I	18.9m / 3.0m	NT-UDMH	1 X RD-251	OKB-456	270.4t (sl)
STAGE II	10.9m/ 3.0m	NT-UDMH	1 X RD-252	OKB-456	96.0t (v)
OVERALL	35.5m / 3.0m	-	-	-	-

emergency conditions, the same launch pads could handle about three launches per month, although a stored booster could be ready for launch within 72 hours of a request [46].

The CIA in their evaluation of the Soviet capability to establish a full network of US satellites, stated in a classified report in 1983 that there were storage facilities at Tyura-Tam for 22 Tsiklon-2 boosters and payloads, the majority of these being used for ASAT missions which also required the Tsiklon-2. In the case of US payloads, the CIA believed that as many as seven such satellites were possibly stored for launch with a maximum replenishment capacity of 6-10 launches per day [47]. Certainly, in crisis or wartime situations, the Ministry of Defence's General Staff would have had to weigh the requirements of the Air Defence Forces (for the ASATs) and the Navy (for the US satellites) given their common use of launch vehicles and pads at Tyura-Tam.

5.1 The US-A / RORSAT Mission Profile

The radar-equipped US-A satellites initially worked with a system of two satellites. They were placed in orbits that would allow one to follow another about 20-30 minutes later. By comparing the radar information from the two satellites, computers on the ground could determine the target's speed and course. A second set of passes about 90 minutes later on the succeeding orbit would allow verification of the predicted course changes. Overlap in coverage between ground tracks in the northern and southern latitudes was also used for the same purpose, serving a vital function to monitor Atlantic shipping lanes between the United States and Europe as well as oil tanker routes going around the southern tip of South America and Africa [48]. The US-A satellites normally operated at a mean altitude of 255 kilometres inclined, like the US-P, at 65 degrees.

By the late 1970s, the CIA correctly recognised that the US-A/RORSAT and US-P/EORSAT satellite systems were two of the most strategically important elements of the Soviet military

U.S. Navy aircraft carrier Enterprise making a high speed turn. The large carriers could be detected by US-A/RORSAT radars even in bad weather. However, their relatively high speed (nuclear carriers such as the Enterprise could reputedly travel in excess of 35 knots - faster than virtually any other naval vessel) meant that they could be far from their reported position by the time a missile arrived. This led to the requirement for constellations of US-A/RORSAT and US-P/EORSAT satellites working in cooperation.
(Courtesy United States Navy).

space programme. In a 1975 study, American intelligence believed that in both crisis and conflict situations, the Soviet military would have a moderate to high degree of dependence on the US-A system to engage in naval warfare, "high dependence" meaning there would be no practical substitute in the Soviet arsenal for performing the same mission [49]. This assessment was evidently revised by 1980, with the CIA estimating a current "low to moderate" dependence increasing to "high" by 1990 [50]. The CIA believed that the two systems reached initial operational capability in 1971 and 1975 respectively, much earlier than actual operations would suggest [51]. In a detailed 1985 report, U.S. intelligence correctly recognised that unlike other military assets, the RORSAT and EORSAT systems were primarily geared for use during hostilities:

> These two types of satellites are primarily wartime and crisis weapon targeting systems [deleted] for use against aircraft carriers and naval battle groups. The required coverage for nearly continuous targeting and the demonstrated orbital spacing indicate that prior to hostilities the Soviets will attempt to expand the satellite networks to four EORSATs and seven RORSATs [from two of each type during peacetime]. [52]

The CIA also hinted that both constellations would be prime targets for any potential American ASAT mission:

> The Soviets probably recognise that these satellites are vulnerable and would be short-lived once hostilities began. The satellites would be useful just before hostilities and as hostilities began. We expect the Soviets to attempt to complete a full EORSAT/RORSAT network with launches by SL-11s [i.e. Tsiklon-2] in a matter of days. [53]

The CIA predicted that in a crisis situation, a network of seven US-A satellites and four US-P satellites could provide targeting data for antiship missiles about every two hours in the 50 to 70-degree latitude region. Not surprisingly, targeting data more than two hours old was seen to be significantly inaccurate for combat situations. Table 4, adapted from the CIA report, shows the possible constellations required of US-A and US-P for sufficient coverage to provide accurate targeting data.

5.2 The US-P / EORSAT Mission Profile

The US-P system's primary mission was to detect sea-based electronic signals by recording the type of signal received, and determining the direction of the transmitter from the satellite's position. The information was then relayed to ground stations and sea-based vessels in near-real-time via data relay satellites. Quick analysis on the ground, either by computer or by analysts, then combined data from several satellites to pinpoint the location of the receiver and determine the type of emitter. Since the US-P's targets were usually mobile, the frequency of overflight was crucial to the upkeep of reliable information on the target's position. In the early years, the US-P satellites operated in orbits at a mean altitude of about 435 kilometres and an inclination of 65 degrees.

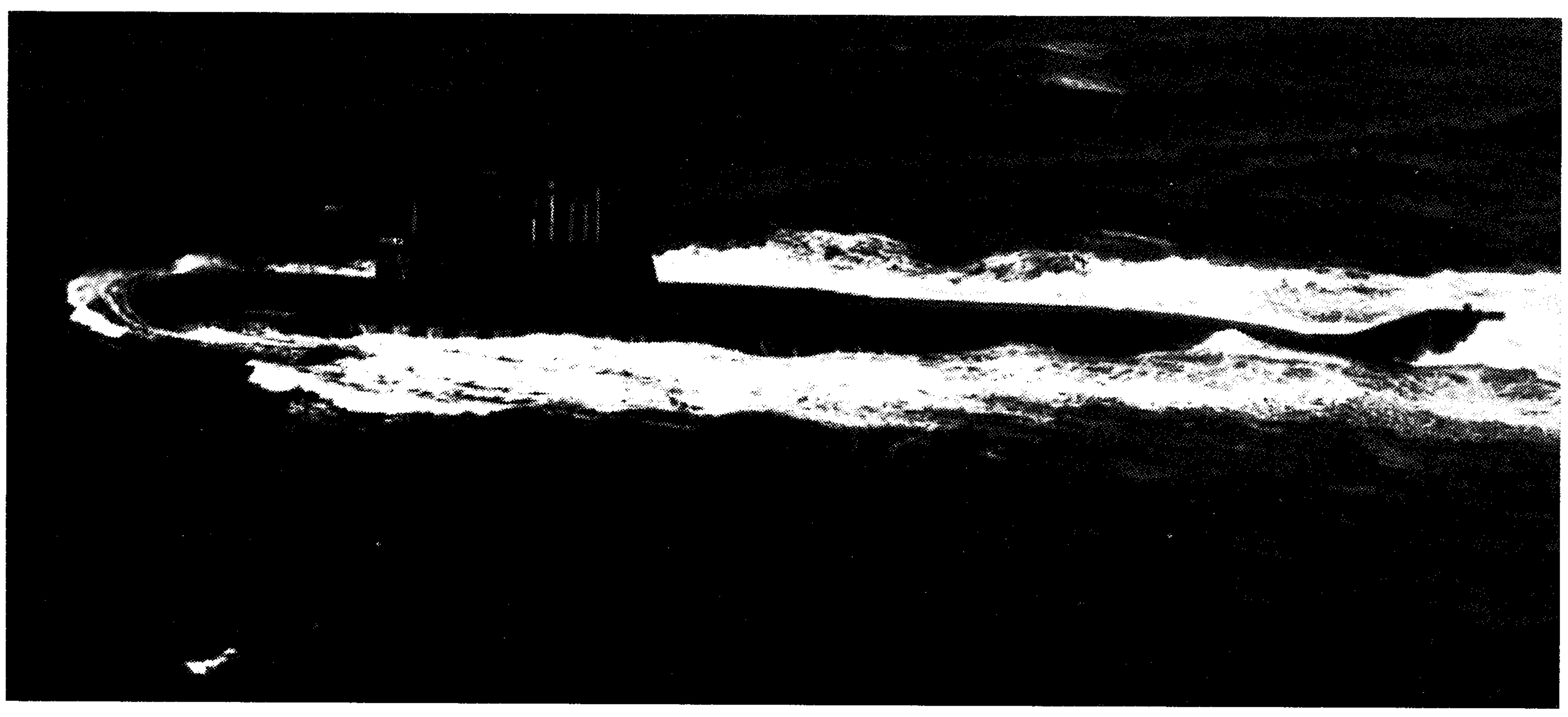
According to the 1983 CIA report, about 20 Soviet naval vessels were equipped at the time to receive data from the US-P satellite system. The same study also emphasised the primary limitations of the originally deployed system: failure to detect ships controlling their electronic emissions and the excessive time required for a single satellite to revisit the same target, i.e. from 6 to 14 hours at northern latitudes and about 28 hours at

TABLE 4: *US System Requirements for Adequate Target Coverage.*

	HOURS BETWEEN REVISIT TIMES AT VARIOUS LATITUDES									
NUMBER AND TYPE OF S/C	0°	10°	20°	30°	40°	50°	55°	60°	65°	70°
1 US-P	28	24	24	20	16	14	12	6	6	28
2 US-P	14	12	12	10	8	7	6	3	3	14
4 US-P	7	6	6	5	4	3.5	3	1.5	1.5	7
1 US-A	56	54	52	46	40	32	28	22	16	8
2 US-A	28	27	26	23	20	16	14	11	8	4
4 US-A	14	14	13	12	10	8	7	5	4	2
7 US-A	8	8	7	7	6	5	4	3	2	1
1 US-P & 1 US-A	19	17	16	14	11	10	8	5	4	6
2 US-P & 2 US-A	9	8	8	7	6	5	4	2.3	2.2	3
4 US-P & 4 US-A	5	4	4	4	2.9	2.4	2.1	1.2	1.1	1.6
4 US-P & 7 US-A	4	3	3	3	2.4	2.0	1.7	1.0	0.9	0.9

EXPLANATION:
By Western estimates, the effectiveness of targeting ships in the oceans would be completely neutralised if the US spacecraft were unable to overfly specific targets within two hours of each other. Thus, from the table it is possible to identify the latitudes and constellations of US-A and US-P spacecraft necessary for adequate targeting. These areas have been shaded. The final row lists the optimal constellation of these type of spacecraft which the Soviet Navy would deploy during crisis or battle conditions, thus affording adequate targeting data between latitudes of 50° and 70° in the world's oceans.

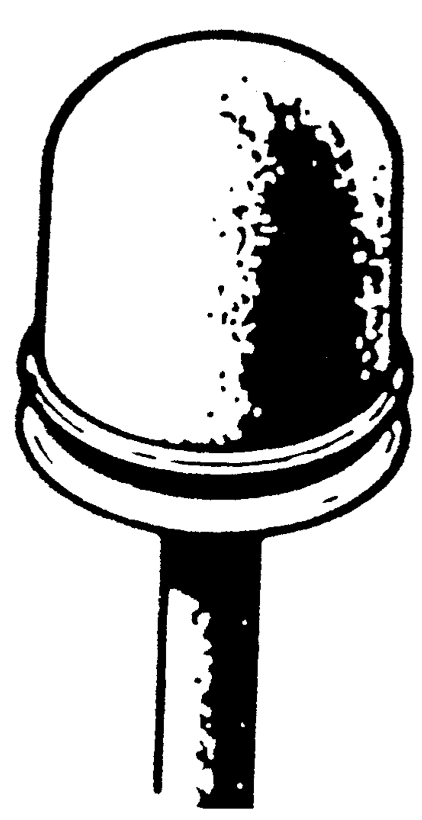
SOURCE:
The table is based on U.S. Central Intelligence Agency, *National Intelligence Estimate 11-1-83JX: The Soviet Space Program*, Washington, D.C., 19 July 1983, p. III-11 (declassified 1997 as part of the CIA Historical Review Program).



Soviet Oscar II ballistic missile submarine. The Oscar II is reputed to be very quiet and one of the most difficult submarine targets for the U.S. Navy to track. The submarine, which is still in service today, is equipped with 24 long-rang P-700 "Granit" (NATO designation: SS-N-19) missiles which receive their targeting information from aircraft and orbiting spacecraft.
(Courtesy U.S. Department of Defense via Soviet Military Power).

the equator. For ideal usage in the higher latitudes, the system required a network of at least four US-P satellites to provide continuous targeting data, i.e. data that was less than two hours old. The CIA predicted that such a full network would not be deployed in non-crisis situations. Future improvements expected in the late 1980s would include "improved receiver sensitivity, extended radio frequency coverage, and improved locating capabilities" and "fitting out more Soviet naval combatants to receive the collected data directly and increasing satellite lifetime" [54]. It would be surprising if most of these improvements, if not all, had not been incorporated into subsequent models of the US-A satellite system, still operating in the 1990s. Certainly, the Russians have achieved a remarkable increase in satellite lifetime over the models of the satellite deployed in the early 1980s.

Submarine detection by either the US-A or US-P constellation was not possible. There has been little information from Russian sources on Soviet-era experiments in space-based submarine detection programmes. Certainly, there were no operational systems of the kind in existence. The CIA themselves were unsure of the possibility that the Soviets would achieve a breakthrough by the mid-1990s in the field, but in a 1983 report stated that "research in space-based submarine detection has been conducted from Soviet space stations" [55].



"Punch Bowl" satellite receiving antenna. A parabolic antenna is underneath the protective cover. This antenna is mounted on some Soviet/Russian submarine periscope masts, such as those on the Oscar II. A similar version is mounted on surface vessels. It is used to receive transmissions from US-P/EORSAT spacecraft.

In 1993, journalists visiting the TsNPO Kometa were told that the organisation had been engaged in a dedicated programme for a space-based submarine detection system using a system known as Spektr-RM which "by means of a laser beam creates a [two-dimensional frequency] spectrum while a powerful computer identifies the parametres of an anomaly in the sea" [55a]. Elements of the system had evidently been tested in space yielding "excellent results" although its introduction to operation was hampered by financial difficulties at Kometa. Coincidentally or not, Kometa had also developed the Oktava military interceptor complex for the Spektr module of the Mir space station. The system, evidently to have been used for testing various new ABM systems, was deleted from the Spektr module in 1992 once the spacecraft was reconfigured to a more "civilian" nature [55b].

6. SUPPORT SYSTEMS

6.1 Molniya-2

In 1962, the Soviet Navy issued a Tactical-Technical Requirement, a document somewhat comparable to a Request For Proposal, to Soviet Design Bureaus for a communications-navigation satellite system to support future ocean reconnaissance satellite systems. With the introduction of long-range anti-ship missiles and an ocean reconnaissance satellite system, clearly there was a need for highly precise navigation and efficient communications between ships of the Soviet Navy. Chief Designer Korolev's OKB-1 evidently proposed a satellite system designated Molniya-2 to satisfy the requirements, which included facilitation of communications between Navy command posts and surface ships and submarines [56]. At some point soon after, for reasons that are unclear, the Molniya-2 Navy project was dropped in favour of what may have been a competitive proposal from the NII-695, a Moscow-based institute which had hitherto designed the voice communications systems for the piloted Vostok spacecraft. Confusingly, there was a later Soviet communications satellite called Molniya-2 which was flown between 1971 and 1977, but the flown variant appears not to have had much to do with the original early 1960s Navy proposal.

6.2 Tsiklon

The NII-695 proposal was called Tsiklon (Cyclone), confusingly the same name as the ocean reconnaissance system's launch vehicle. Tsiklon was a dual navigation-communications system with two modes of work:

(1) a "data transfer mode" for surface ships and submarines in any location in the world's oceans;

(2) a "direct transmission mode" which could be used simultaneously with navigation instruments for locating ships of the Soviet Navy.

The operational orbit of the Tsiklon system was to be limited to 800-1000 kilometres. The entire system was comprised of the ground communication points, the spacecraft communication systems, communications complexes on submarines, and control-measurement systems.

Launches in the Tsiklon communications-navigational satellite programme began in May 1967 with the flight of Kosmos-158. Concurrently, between 1967 and 1970, Project 640 type submarines were equipped with the Tsunami-M communications complex for testing the Tsiklon satellite system. As the system was declared experimentally operational in 1969, the Soviet Navy expanded its use by installing the systems on 613 and 611 submarines as well as the cruisers Admiral Senyavin and Tobol. These vessels were the very first Soviet naval ships to use space-based navigation and communications systems for sea-faring missions. The last Tsiklon satellite, Kosmos-1027, was launched in July 1978, ending a 28 launch series (including one launch failure). During the programme, the Soviets generally kept three such satellites active concurrently.

The Tsiklon system was superseded by an improved satellite, the Tsiklon-B which began flight testing with Kosmos-700 in December 1974. The Tsiklon-B system which used the Tsunami-AM complex on the satellites, was declared fully operational in 1976 and given its operational Navy designation Parus (Sail), which is the more commonly known name for the early Soviet navigation-communications satellite system [57]. All Parus satellites operate in the same orbital regime of 83 degrees inclination at approximately 980 x 1020 kilometres altitude. Usually the satellites operate in six orbital planes 30 degrees apart from each other. According to American intelligence reports, Soviet navigational satellites from the late 1970s and early 1980s were capable of providing location data to within 180 metres [58]. The Tsiklon-B satellites themselves are cylindrical in form, 2 metres in diameter, 2.1 metres in length and are equipped with a long gravity gradient boom. Mass is approximately 790-825 kilograms [59]. The Parus system has begat such "civilian" versions such as Tsikada (Cicada) and Nadezhda (Hope). (See also "Addendum".)

7. FLIGHT-TESTING

7.1 US-A / RORSAT Testing

The Soviet Navy carried out testing of the US-A satellite system in three stages. Phase 1, in 1965-66, consisted merely of testing the spacecraft's orientation, stabilisation, and propulsion systems. Instead of a nuclear reactor, the vehicles carried a chemical power source as a substitute. To evaluate the ability of the on-board systems to accurately determine the spacecraft's attitude, engineers installed the special Neptun (Neptune) astro-orientation system on these vehicles.

The launches of these early US-A vehicles occurred at a particularly transitional period for the programme as a whole. The UR-200K launch vehicle had been replaced by the Tsiklon-2 booster, while Chelomey lost his leading role in the programme, to be replaced by Raspletin and Savin. Since the Tsiklon-2 rocket was still unready at the time of these tests, Raspletin and Savin agreed to use a modified version of Korolev's old R-7 ICBM to launch the initial US-A models. In December 1965 and July 1966, this variant, the 11A510, launched Kosmos-102 and Kosmos-125 respectively, the first test models of the Soviet ocean reconnaissance satellite system. Both were launched from site 31 at Tyura-Tam, one of the two R-7-based pads at the space launch centre. Little is known of the results of the launch, although Savin later alluded that some "unique experimental data" was received [60]. In the case of Kosmos-125, communications were maintained with the spacecraft until its 52nd orbit, i.e. for about four days [61]. Both spacecraft remained in low orbits and did not manoeuvre to the higher "safing" orbit for the nuclear reactor. They decayed 17 and 13 days respectively after launch. Savin served as the Technical Director for the missions, while the Chairman of the State Commission was Major General A.M. Boytenko, a senior official at the Baykonur Cosmodrome. In its National Intelligence Estimate on the Soviet space programme dating from early 1967, the CIA was still unsure of the goals of these two seemingly mysterious missions, but was aware that "these vehicles employed a new propulsion device for injection of the payload into orbit. Another propulsion system was probably used to effect minor changes in the orbit" [62].

Phase 2 lasted from December 1967 to January 1969 and focused on testing of the radio-control systems, specially manufactured simulators of the nuclear reactor, and chemical sources of power for the US-A spacecraft. For the first time, the vehicle was equipped with its full complement of control systems for all operations. Under Boytenko and Savin's supervision, engineers flew three US-A spacecraft, one of which, on 25 January 1969 failed to reach orbit due to a second stage failure. Unusually for a concealed Soviet launch failure, that particular launch attempt was widely reported in the Western press [63]. The two vehicles that did reach orbit flew first into low Earth orbits at 280 x 260 kilometres at 65.1 degrees before manoeuvreing into high orbits at about 950 x 900 kilometres within 2-6 days after launch. Since the spacecraft did not carry reactors, the relatively rapid boost to a higher orbit was probably not the result of some catastrophic failures. By mid-1969, the CIA was still listing all the Phase 2 launches as part of a new manoeuvrable satellite programme with undetermined goals [64]. In its 1971 review of the Soviet space programme, the CIA did predict for the first time that:

> We estimate that if the Soviets choose to do so, they could have a 10 kilowatt thermionic reactor in space by the late 1970s. A reactor with this output would be adequate as a source of electrical power for a large space station or as power for electrical propulsion for planetary probes. [65]

Phase 3 began in October 1970. Underscoring the importance of the testing was the choice for the Chairman of the State Commission for testing the system: Admiral N.N. Amelko, the Deputy Commander-in-Chief of the Soviet Navy. There were six launches to the end of 1973, some of them failures. All of them for the first time carried operational versions of the BES-5 nuclear reactors. The first satellite, Kosmos-367, was boosted into a high storage orbit almost as soon as it reached orbit, indicating that there was a major failure in the reactor soon after launch. Subsequent missions in April 1971 and December 1971 were more successful, the former working in its low orbit for 18 days and the latter for 10 days. Performance continued to improve with Kosmos-516 in August 1972 which operated for 31 days before being boosted into its high orbit. This particular spacecraft also had the distinction of being the first vehicle to carry the full complement of the radar payload into orbit; all previous vehicles had evidently carried mockups [66].

There was a major failure on 25 April 1973 when the orbital insertion engine of the US-A satellite failed during ascent to orbit and the payload flew an arc that deposited it, nuclear reactor included, into the waters of the Pacific Ocean. United States Air Force planes flying high over the Pacific evidently sampled the upper atmosphere for signs of radiation [67]. According to former-Soviet sources, testing of the US-A system with its Tsiklon-2 launch vehicle ended in August 1973 [68]. The next flight, Kosmos-626 in December of the same year, was the first satellite to operate for a fully nominal mission. The nuclear reactor separated successfully from the main spacecraft and boosted itself into a safekeeping orbit 44 days after launch. Interestingly, the same year, Savin's division at the KB-1 became the independent TsNII Kometa, thus now solely responsible for the programme.

Coincidentally, it was at this time that the CIA for the first time positively identified the preceding launches as being part of a radar reconnaissance satellite system. In its December 1973 review of the Soviet space programme, the authors wrote that:

> The spacecraft uses a side-looking radar that can detect large surface ships, such as aircraft carriers. This system has a potential for providing targeting data to combatants at sea. The combination of data from such a system with data from other sources, such as ELINT satellite data, would be highly useful in targeting antiship missiles. [69]

The CIA correctly predicted that the system was headed for operational status sometime in the 1975-1977 period.

The first dual-operational missions of the system, meanwhile, began in May 1974 with the launches of Kosmos-651 and Kosmos-654. Both displayed the mission profile of suc-

TABLE 5: *Contractors for the US System.*

SYSTEM	CONTRACTOR	CURRENT DESIGNATION	CHIEF/GENERAL DESIGNER/ DIRECTORS	DATES OF WORK FOR CONTRACTORS
Overall US System	**OKB-52** **KB-1** **TsNII Kometa** **TsKB-7**	**NPOMashinostroyeniya** **TsKB Almaz** **TsNPO Kometa** **KB Arsenal**	**V. N. Chelomey** **A. A. Raspletin** **A. I. Savin** **P. A. Tyurin**	**1960-65** **1965-73** **1973-80s** **1980s-current**
Bus Design & Manufacture	OKB-52 TsKB-7	NPO Mashinostroyeniya KB Arsenal	V. N. Chelomey P. A. Tyurin	1960-72 1972-current
US Guidance Systems	OKB-41 of KB-1	TsNPO Kometa	A. I. Savin	n/a
US Attitude Control Systems	OKB-36 of KB-1	NPP Almaz	P. M. Kirillov	n/a
US Propulsion Systems	OKB-300 TMKB Soyuz	AMNTK Soyuz TMKB Soyuz	S. K. Tumanskiy V. G. Stepanov	1960-1972 1972-current
US-P solar panels	OKB-52	NPO Mashinostroyeniya	V. N. Chelomey	n/a
UR-200K Launch Vehicle	OKB-52	NPO Mashinostroyeniya	V. N. Chelomey	n/a
Tsiklon-2 Launch Vehicle	OKB-586	NPO Yuzhnoye	M. K. Yangel	n/a
Launch Complexes	TsKB TransMash	TsKB TransMash	V. N. Solovyev	n/a
US-A BES-5 reactor conception	FEI	FEI	A. I. Leypunskiy	n/a
US-A TEU-5 reactor conception	IAE imeni I. V. Kurchatova	IAE imeni I. V. Kurchatova	M. D. Millionshchikov & A. P. Aleksandrov	n/a
US-A reactor development	OKB-300 MKB Krasnaya zvezda	AMNTK Soyuz NPO Krasnaya zvezda	S. K. Tumanskiy M. M. Bondaryuk	1960-1972 1972-current
US-A radars	NII-17	MNII Priborostroyeniya / NPO Vega-M	I. A. Brukhanskiy & Ya. B. Shapirovskiy	n/a
US-P ELINT package	TsNII-108 Kaluga Branch	NII RTI	S. I. Baburin & V. L. Grechki	n/a
US Reconnaissance & Detection Systems on Naval Vessels	NII-132	NPO Kvant	I. V. Kudryavtsev & T. Ye. Stefanovich	n/a
US Ground-Based Processing Systems	NII-648 MNII-1	NPO Tochnykh priborov MNII Agat	G. B. Petropavlovskiy, V. G. Shchetinin & G. P. Videneyev V. M. Minayev	n/a
US Communications Systems	NII-695	MNII RS	M. S. Nemirovskiy	n/a

Source:
1. A.I. Savin, G.F. Zotov and Yu. Ye. Petrushchenko, "The Space-Based Reconnaissance and Detection System" (in Russian) in *Rossiyskaya nauka-voyenno-morskomy floty*, ed. A.A. Sarkisov, Nauka, Moscow, 1997, pp. 319-323.
2. Christian Lardier, "La Russie Devoile Certains Satellites Secrets" (in French), *Air & Cosmos* 1628, 44-45 (1997).

ceeding passes over the same target area. There do not appear to have been any major problems with the nuclear power source, as both reactors were boosted to high orbits 71 and 74 days after launch respectively, significantly exceeding the design lifetime of the spacecraft. A subsequent dual mission in April 1975 lasted for 43 and 64 days respectively, the latter again exceeding the design lifetime. The missions coincided with Phase 2 of the Okean 75 (Ocean 75) naval war games undertaken by the Soviet Navy on 15-17 April in the Atlantic, Mediterranean, Pacific, and Indian Oceans. The system was evidently given a thorough checkout in conjunction with airborne radars during the exercises [70]. In October of the same year, the Central Committee and the USSR Council of Ministers issued a joint decree declaring the US-A ocean reconnaissance satellite system operational [71]. While the system was evidently operational, Phase 3 of the testing programme did not officially end until 1978, suggesting that the US-A may have been adopted into full operation prior to elimination of all problems which had arisen in the test phase. In fact, the first post-testing phase mission in December 1975 may have been a complete disappointment when Kosmos-785's nuclear reactor failed immediately upon entering orbit. Within three hours of launch, the reactor was boosted to a higher orbit. The second US-A of the pair was never launched [71a]. A declassified CIA report from 1980 also hinted that there had been many failures in the test programme and that "the failures have been due to various causes, making it difficult for the Soviets to correct all problems and produce a reliable system" [72]. Unfortunately, details of all the failures still remain deleted from the report. By 1978, the Soviet Navy was flying the first models of the US-A satellite manufactured at the Leningrad-based Arsenal Design Bureau (KB Arsenal) which had been subcontracted by TsNII Kometa for serial production [73].

Prior to the end of Phase 3 testing, the US-A system suffered its most serious failure to date, one that escalated into an international incident. Kosmos-954, a US-A satellite launched in September 1977, had operated with its "partner" Kosmos-952 during its operational life, but instead of boosting its reactor into a safe orbit at the end of its mission, it remained in its low orbit, suggesting a major control system failure. By 6 January 1978 it had lost attitude control and naturally decayed, spreading radioactive debris over northern Canada on 24 January. The entire incident has already been covered extensively by Western analysts, but in recent years Russian sources have added some minor details to the story [74]. US-A system General Designer Savin wrote in 1997 that the problem was a "very significant malfunction in the control system for transferring the ROCh" of the spacecraft into its higher orbit [75]. The Soviet Air Defence Forces' Centre for Monitoring Cosmic Space (TsKKP), a component of the larger System for Monitoring Cosmic Space (SKKP) was called into action during the emergency. Controllers at the TsKKP continuously monitored the descent of Kosmos-954 beginning 20 December 1977, suggesting that the failure was apparent by mid-December. One participant claims that the TsKKP accurately predicted the time of decay for the dangerous satellite, 1512 hours on 24 January 1978, although this information was clearly not made public at the time [76].

Sergey N. Khrushchev, the Soviet leader's son, also describes the incident in his memoirs:

> There was a certain amount of panic in Moscow and an endless series of conferences, some searching for culprits, others insisting that the developers produce a document guaranteeing security...The reactor's Chief Designer [Mark M.] Bondaryuk, refrained from comment. Finally, Bondaryuk wrote that a nuclear explosion was ruled out, but that he would not presume to predict other consequences. In a postscript at the very end of the document, he admitted laconically that if the shielding was not destroyed, an extremely low-grade thermal explosion, no more than five kilotons, was possible. However, the likelihood of such an explosion was virtually nil. People in the Central Committee tore their hair and demanded that the postscript be withdrawn, but the Chief Designer held his ground, saying: you asked for my opinion. I described all the theoretical possibilities. You decide yourselves whether to make it public or not. They decided not to publish it. [77]

While the account may have traces of truth in it, Khrushchev erred on one point: Bondaryuk, who was indeed the original Chief Designer of the US-A reactor, died in 1969, well before the Kosmos-954 incident. For the time being at least, US-A launches were cancelled as Savin's engineers began a redesign process to preclude such an accident from occurring again.

7.2 US-P / EORSAT Testing

Testing of the passive US-P variant designed to detect transmissions from target American warships was conducted parallel to the radar version and was, in fact, overseen by the same governmental State Commission led by Admiral Amelko.

The first US-P was launched as Kosmos-699 in December 1974. This appears to have been an inert mockup which remained in orbit almost four months before disintegrating on 18 April 1975. Actual flight-testing of the US-P system began in October 1975 with the launch of Kosmos-777 [78]. The satellite flew into a standard orbit at 456 x 437 kilometres at 65 degrees inclination. Western observers monitoring transmissions from the vehicle were able to identify common frequencies between Kosmos-777 and the nuclear powered radar reconnaissance satellites. In the early stages, the State Commission established a pattern of launches of the US-A and the US-P: a solo ELINT mission would be launched between pairs of the radar variant. The sixth and seventh US-P satellites, launched in April 1979, appear to have introduced a new flight profile, perhaps prompted by the Kosmos-954 incident. The two spacecraft, instead of flying solo missions, flew one behind the other, phased about 60 degrees apart. The launches coincided with major Soviet naval manoeuvres at various locations including the Persian Gulf [79]. These two missions were the final test missions of the US-P system; in October 1979, the Central Committee and the Council of Ministers issued a joint decree declaring the US-P EORSAT as an operational element of the Soviet armed forces [80]. The entire ocean reconnaissance satellite system, consisting of the US-A and US-P spacecraft, was given the operational name Legenda or Ideogramma-Pirs [81]. It is quite likely that the much shorter time required to test the US-P system as compared with the US-A system had much to do with the use of common spacecraft systems which had already undergone a thorough checkout on the US-A satellite since the mid-1960s.

8. OPERATIONS OF THE IDEOGRAMMA-PIRS

8.1 US-A / RORSAT Operations

During the redesign process in the wake of the Kosmos-954 failure, the TsNII Kometa introduced a modified mission profile for the US-A system of satellites. In Savin's own words:

> Means for fully excluding the possibility of non-working of the transfer control system in analogous [to Kosmos-954] and other situations was developed as a result of the performed analysis. Simultaneously, changes were introduced in the design of the on-board atomic energy source, which would ensure complete burning up of the active zone of the nuclear reactor...during entry into the upper layers of the atmosphere. [82]

The modified safety system could now be triggered by active command from the ground, by loss of spacecraft pressurisation, by reactor power anomalies, or by loss of spacecraft stabilisation. With nominal operation, the spacecraft would separate into three component parts:

- the nuclear reactor with a self-contained booster rocket;
- the satellite's propulsion stage; and
- the satellite bus.

The reactor would boost itself into a high elliptical transfer orbit, leaving the two remaining objects in the lower orbit from which they would decay soon after. Less than an hour after reaching the transfer orbit, the reactor's rocket engine would fire once again to circularise the orbit to about 900 x 1000 kilometres. In that orbit, the fuel core of the reactor would be ejected from the reactor as an additional safety precaution. This final manoeuvre was first demonstrated on Kosmos-1176, the first post-Kosmos-954 mission [83].

In event that none of the four cases prompted the boosting of the reactor to a higher orbit, a backup mechanism would operate, activated by the onset of natural orbital decay. At an altitude of 114-120 kilometres, the increased density of the Earth's upper atmosphere would cause a corresponding increase in temperature, which in itself would trigger ejection of the fuel core from the reactor. Thus, just hours prior to re-entry, the hazardous material would dissipate with burnup in the atmosphere [84]. Savin wrote later:

> The effectiveness of these measures was confirmed in 1983 when there was a failure in the transfer of the ROCh of [the spacecraft] due to a failure in its execution profile...and the active zone of the reactor burnt up in the upper layers of the atmosphere. During the careful controlled [search] on the part of both the USSR as well as the USA, no radioactive contamination was detected on the Earth's surface. [85]

The incident Savin referred to was the re-entry of Kosmos-1402, which evidently suffered a similar failure to Kosmos-954. On 28 December 1982, after finishing its mission, the spacecraft was commanded to separate from its reactor, but separation never occurred. As per the safety measures instituted following the previous accident, the core was detached from the reactor unit; if all went well, the former would simply burn up in the upper atmosphere instead of being protected from a fiery re-entry by the reactor unit, thus raising the possibility of dangerous contamination on the Earth's surface. Since the reactor shell had been exposed to the core for a long period of time there was justified concern that parts of the reactor might survive entry into the atmosphere and pose a hazard to humans. The satellite plus reactor combination re-entered over the Indian Ocean on 23 January 1983 while the core hit the upper atmosphere on 7 February over the south Atlantic between Brazil and Africa. Fortunately, no contamination was apparent following either of the re-entries. Like Kosmos-954, the Soviets tracked Kosmos-1402's progress closely in its dying days. A high-ranking officer in the Air Defence Forces later claimed that "in both cases [i.e. Kosmos-954 and Kosmos-1402] our forecast [for re-entry] proved more accurate than that of the Americans" [86].

One of the few descriptions of US operations from Russian sources describes activities of the integrated US-A/US-P system during the Falklands conflict between the United Kingdom and Argentina in 1982. According to Savin:

> The high effectiveness of the...[ocean reconnaissance satellite] system was brilliantly displayed in flight in 1982 during the Anglo-Argentine conflict over the Falklands...Islands. The system allowed the complete evaluation of the situation on the sea, and from the information received from the system, the General Staff of the [Navy] was able to determine the exact moment of the commencement of the disembarkation of the English landing party. [87]

By the early 1980s, the US-A and US-P systems were part of larger Reconnaissance-Strike Complexes (RUK) which comprised not only the satellites, but also naval reconnaissance aircraft, ship-board helicopters, attack submarines, surface combatants, auxiliary intelligence-collection ships, merchant ships, fishing trawlers, land-based signals intelligence sites, and covert agents [87a].

Following the second emergency incident in the US-A programme in 1983, there was a hiatus of about one-and-a-half years before such nuclear-powered missions were resumed. As opposed to previous missions in the programme, Kosmos-1579 in June 1984 displayed mission operations that were clearly inter-related with the Kosmos-1567 satellite of the US-P series, emphasising increased integration of the two systems. The orbital planes of the two satellites were separated by 150 degrees, with their orbits intersecting over the North Atlantic. The two satellites made their passes over the same target area 45 minutes apart [88]. In future launches, the spacing between the US-A and US-P satellite planes was approximately 145 degrees, a spacing which gradually increased over time due to orbital perturbation effects [89].

In 1987, the US-A series displayed its first new mission profile in over 20 years of missions. Standard orbital profiles were limited to 250 x 265 kilometres at 65 degrees with a seven day repeating orbit (taking 111 Earth revolutions) over the same target. With the flight of Kosmos-1900 in December 1987, the satellite flew a six day repeating profile (taking 95 Earth revolutions) in a slightly modified orbit of 256 x 271 kilometres also at 65 degrees. Kosmos-1900 was also the first operational US-A satellite inserted into an orbital plane not 135-150 degrees behind the orbital planes of already flying US-P satellites [90]. The Kosmos-1900 satellite proved to be the only satellite utilising the new mission profile; the next US-A satellite was the very last nuclear-powered radar reconnaissance spacecraft launched by the Soviet Union. Kosmos-1932 in March 1988 reverted back to the original RORSAT profile with a mean orbital altitude of 257 kilometres. The mission was evidently timed, like many of the US-A series, to monitor naval manoeuvres spread all across the world. Ground controllers evidently lost control of Kosmos-1900 sometime in mid-April 1988. The last station-keeping manoeuvre on the vehicle was performed on 10 April, making it the third longest US-A mission in 20 years. Despite serious misgivings about yet another possible international incident involving a wayward space-based nuclear reactor, the redesign of the US-A satellite after the Kosmos-954 debacle proved effective. On 30 September 1988, just days before the onset of decay, Kosmos-1900 apparently triggered its nuclear reactor safety system due to loss of satellite stabilisation. The spacecraft separated into its component parts, and the reactor was boosted into a safe orbit of 695 x 763 kilometres. The remainder of the vehicle decayed the next day over the Indian Ocean [91].

Kosmos-1932 was the last operational US-A satellite launched. After three orbital failures and two launch failures, the Soviet Navy apparently dropped plans, or perhaps was forced to drop plans, for further launches in the series. The public outcry over the re-entry of the various failed reactors over the years was no doubt a major consideration in terminating the programme. Reactors from the US-A satellites were also causing interference with space-based gamma-ray detectors, such as those on NASA's Solar Maximum Mission (SMM), a problem which had been discovered as early as 1980 by the United States Department of Defence. While Russian-language sources have not contained any details of the internal deliberations on the decision to discontinue the US-A programme, it is possible that a decision to terminate the effort was drawn out over several years after the near-accident of Kosmos-1900 in 1988. Following the Kosmos-1900 incident, the Soviet news agency TASS reiterated that "At present there is no doubt about the advisability of the application of nuclear power plants in outer space" [92]. But throughout 1989-90, Soviet officials faced increased international pressure to curtail all further experiments with nuclear reactors in space. At the same time, in March 1990, the Soviet Union pledged to inform the United Nations of future launches with nuclear power sources on board, a promise that no doubt compromised much of the utility of the US-A programme. Finally, in January 1994, Vladimir Vasilovskiy, the Deputy Department Chief for nuclear reactors of the Russian Ministry of Atomic Energy, was quoted as saying that the Russian Federation had no plans to launch any more nuclear reactors into space in subsequent years [93].

8.2 US-P / EORSAT Operations

In 1986, the US-P series displayed two new mission profiles. Normally, the passive satellite flew at 430 x 445 kilometres at 65 degrees inclination with a profile that ensured groundtrack repetition every four days or 61 revolutions. With the flight of Kosmos-1735 in February 1986, the US-P satellites began flying at 405 x 420 kilometres at 65 degrees, i.e. a little lower than usual, but with a groundtrack repetition every three days or 46 revolutions. The new altitude regime eventually allowed the US-P satellite system to facilitate full target coverage with a three satellite constellation completed in May 1988, instead of the more complex four spacecraft system. A second profile was inaugurated with Kosmos-1737 in March 1986 which flew at 73.4 degrees instead of the standard 65 degrees, although the satellite maintained its three day groundtrack repetition lasting 46 days. Throughout their periods of operation, Kosmos-1735 and Kosmos-1737 co-ordinated their station-keeping manoeuvres to maintain a precise relationship that had the two satellites cross the equator in the northward direction at the same 46 locations [94]. Apart from the better polar coverage afforded by the higher inclination, the 73.4 degrees inclination was also preferable since pads for the Tsiklon-2 launcher at the Plesetsk launch site would then be available for such high priority missions.

As the US-A operations terminated in 1987-88, the Soviet Navy redirected much of its ocean reconnaissance efforts to the remaining US-P programme. By 1989, for the first time they established a constellation of four US-P vehicles in two orbital planes separated by 172 degrees at the equator. Thus, all four spacecraft shared a common set of 46 ascending nodes which were repeated every three days, allowing precise targeting of naval movements. Later, in 1990, the constellation was expanded to a record six spacecraft for a brief period, in a move probably timed to compensate for the lack of US-A operations [95]. The ideal constellation might consist of six US-P satellites with three evenly spaced apart in each of two orbital planes separated by 145 degrees. By the early 1990s, the operational orbit for the satellites was about 404 x 417 kilometres at 65 degrees inclination, an altitude regime rigidly maintained at +/-1 kilometres with frequent orbital manoeuvres.

9. MODERNISED VARIANTS

While the original models of the US-A and US-P satellites were created under the overall direction of the TsNII Kometa under General Designer Savin, development of newer versions were contracted out to other firms, principally the KB Arsenal. The latter organisation had been established in 1949 as the Central Design Bureau-7 (TsKB-7) at Leningrad [96]. In its initial years of existence, the Design Bureau had focused on developing artillery systems for Soviet ships, before migrating in 1958-60 to developing long-range solid-propellant ballistic missiles for the Strategic Missile Forces. Under the leadership of Chief Designer Petr A. Tyurin, by the mid-1960s, the organisation, then designated the KB Arsenal Named After M.V. Frunze, inherited some subcontracts to manufacture hardware for the L3 lunar spacecraft. In 1969, it began expanding its profiles to other space projects, eventually leading to manufacturing the US-A and US-P spacecraft for the TsNII Kometa beginning in 1972 [97].

In the 1970s, the TsNII Kometa in cooperation with the KB Arsenal began a widespread modernisation effort within the context of the US programme. According to Savin, this modernisation:

> facilitated the increased active lifetime of the [spacecraft] up to 4-6 times [over their predecessors] due to the incorporation of modern, for the mid-1970s, miniaturised elements in the on-board apparatus which substantially improved [tactical-technical characteristics] of the MKRTs system. [98]

Key roles in this effort were played by KB Arsenal Chief Designers V.G. Kalabin and Yu.F. Valov. Having reached operational status by the late 1980s, the KB Arsenal completely took over the US-A and US-P programmes from the TsNII Kometa, and continues to design and launch the passive US-P EORSAT version for the Soviet Navy at the time of writing. The current Chief Designer of the KB Arsenal is Boris I. Poletayev, who assumed his new post in April 1995.

9.1 US-A / RORSAT Variants And Designations

In 1987, the Soviets launched two nuclear-powered radar ocean reconnaissance satellites that belatedly introduced a new nuclear reactor for the US-A satellite, the TEU-5 Topol. The first one, Kosmos-1818, launched in February 1987, was put into a standard US-P insertion orbit of 115 x 425 kilometres before performing two manoeuvres that deposited it in high Earth orbit with a mean altitude of 800 kilometres, eventually settling into a seven day repeating pattern orbit. Its successor, Kosmos-1867, launched in July 1987, followed a similar flight profile, before reaching its operational orbit in an orbital plane 120 degrees away from Kosmos-1818 [99].

As later revealed by the Soviets, these missions were "the world's first space launches of nuclear energy units with thermionic transformers" [100]. Although Western analysts believed that the new Topol reactors were a follow-on programme to the original US-A reactor (the BES-5), it now appears that both development programmes were undertaken in parallel, with the thermionic design taking a much longer time to reach fruition. Although rated power was expected to be 5 kW, during the Kosmos-1818 mission, the 1000 kilogram Topol displayed an output of 2-3 kW. The satellite remained operational for six months. Its successor, Kosmos-1867, worked for almost a year. These missions were evidently tests of the new reactor with modified US-A buses for future radar ocean reconnaissance missions with a much more powerful radar capable of operations from the higher orbit. The higher altitudes not only extended the field of view to Arctic regions, but also put the US-A satellites further out of range of possible attacks from ground-based American ASAT systems. Finally, the higher orbit, with a lifetime of about 350 years, afforded better safety for the nuclear reactor, since there was no need for the satellite to function in a dangerous lower orbit. The strong international pressure to terminate further reactor tests in space appears to have given pause to the Soviets and there were no subsequent tests of the Topol in space.

Russian sources have generally identified two variants of the US-A satellite:

(1) the US-A (the original version);

(2) the US-AM (a modified version) also designated the "17F16." [101]

A third possible variant of the system has also been mentioned, although this may have been a typo referring to the US-AM:

(3) the US-M. [102]

A decree of the Central Committee and the USSR Council of Ministers in October 1989 declared the US-M system fully operational. Quite likely, the original US-A spacecraft was modified after the Kosmos-954 debacle in 1977-78, leading to flight-testing of the US-AM variant beginning with Kosmos-1176 in April 1980. Curiously, American intelligence sources noted that the newer variant had a configuration almost identical to the older flying models [103]. The bus probably remained the same, but internal instrumentation improvement allowed the dramatic increase in lifetimes for the new models. The uprated versions had significantly extended periods of operation, moving from the conservative 45 days on the original version well up to 120-130 days by the mid-1980s. It may have been this modernised version which was declared operational in October 1989, albeit after nuclear reactor-equipped flights had ceased due to international pressure. Conversely, the two Topol-equipped satellites launched in 1987 may have been either the US-AM or US-M versions. Without explicit confirmation from Russian sources, the association with specific designations remains conjectural.

9.2 US-P / EORSAT Variants And Designations

Kosmos-1735 in 1986, with its slightly lower operating orbit and different mission profile, appears to have been a new variant of the original US-P satellite. No further satellites after Kosmos-1769 in 1986 have used the old profile, suggesting that the flights of the old model were discontinued at that point. Apart from the flight profile, the new model also introduced a new method of mission termination. Earlier models had been simply boosted off-station out of the normal US-P orbital regime and then abandoned, which eventually led to disintegration in orbit. The new models terminated their mission using a manoeuvre to reduce the altitude of perigee, thus facilitating rapid decay [104]. All satellites of the newer series barring one have used the deorbit profile. The only exception has been Kosmos-2313 which partially disintegrated into 86 trackable pieces on 26 June 1997, the first such breakup since November 1987.

Russian literature has identified up to three variants of the US-P satellite:

(1) the US-P (the original version);

(2) the US-PU (a modified version) also designated "17F120"; and

(3) the US-PM (a modified version) also designated "17F17." [105]

While the US-P was probably the variant flown in 1974-86, the US-PM has probably been flown beginning with Kosmos-1735 in 1986. An official decree of the Central Committee and the USSR Council of Ministers declared the uprated US-PM variant operational in October 1989, suggesting a good fit with the new mission profile [106].

10. CONCLUSIONS

The Russian Federation has continued to operate two to four US-PM satellites in the mid-1990s although there was an unexpected break in March 1993 with the end of the Kosmos-2122 mission which terminated US-PM satellite activity for the first time since 1983. Notably, the satellite also set a record operational lifetime of 775 days, a duration which remains unbroken at the time of writing [107]. The programme resumed within days with the launch of Kosmos-2238 which began the establishment of a new three-satellite constellation. The last US-PM / EORSAT launch was in December 1997, bringing the system to a two satellite constellation, down from the heyday of the Soviet era of the 1980s.

The Soviet ocean reconnaissance satellite programme was one of the most important elements of Soviet wartime strategy during the Cold War. The system, now comprising the passive satellites, still remains an important component of the Russian Federation's future claims to maintaining an influence on the world's oceans. Despite the recent revelations from Russian sources on the history of the programme, the history reconstructed here has been at best, one with many gaps. For example, we know little about which weapons systems were targeted using data from the system. What kind of modifications were incorporated into newer models of the satellites? What was the effectiveness of joint EORSAT/RORSAT operations from the Soviet Navy's perspective? How important was information from the system in determining Soviet naval strategy? Would the Navy target their missiles based solely on information from the EORSAT/RORSAT system or would there be additional sources of data? What were the internal deliberations behind the cancellation of the nuclear-powered US-A programme? And why does the EORSAT constellation continue to fly at a time when other satellite constellations are severely depleted and the majority of the Russian Navy is rusting at port? These and other questions will serve to fill in the gaps in a very important but overlooked aspect of Soviet Cold War military strategy.

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ADDENDUM

Since submission of this article, some information has emerged from Russian sources clarifying some of the issues in the article:

1. The original goal of the US system, as formulated in May 1960, was to aid in targeting the P-6 (SS-N-3a Shaddock) cruise missile.

2. The Tsiklon-2 and Tsiklon-2A launch vehicles originally used the RD-261 and RD-262 engines on its first and second stages but switched to the RD-251 and RD-252 engines in the mid-1970s.

3. The Tsiklon navigation satellite system bus was developed by the OKB-10 (Chief Designer M.F. Reshetnev). Subsystems developers were, for its navigation and tracking instrumentation, the NII-885 (Chief Designer N. Ye. Ivanov and Director L.I. Gusev) and for its communications systems, the NII-695 (Chief Designers N.N. Nesvit, N.A. Pochtar, and I. Kh. Golschteiyn). The Chairman of the State Commission for testing the Tsiklon satellites was Vice-Admiral G.G. Tolstolutskiy, the Chief of the Communications Directorate of the Soviet Navy. Testing of the follow-on Tsiklon-B system was administered by the same State Commission.

   The second generation navigation system was the Tsikada system, whose development began in 1974. The prime contractor was the NPO Prikladnoy mekhaniki (Chief Designer M.F. Reshetnev), the bus was manufactured by the PO Polet (Chief Designer A.S. Klinyshnikov), and the radio-technical and navigation systems package was developed by the NII RadioPribor (Chief Designer N.Ye. Ivanov). Flight-testing began in 1976 and was overseen by a State Commission headed by Admiral A.I. Rassokho, the Chief of the Chief Directorate of Navigation and Oceanography of the Ministry of Defence.

4. There is still some confusion over the operational designations of she US-A and US-P satellite systems. Recent Russian sources suggest the overall ocean recconnaissance system was named "Ideogramma-Pirs' (Ideogram-Pier) which consisted of the 'Pirs-1" and "Pirs-2" complexes. Presumably, these were the US-A and US-P systems respectively. It is not clear how the names "Morya" and "Legenda" were used during the ocean reconnaissance programmes.

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48. Curtis Peebles, Guardians: *Strategic Reconnaissance Satellites*, (Novato, CA: Presidio, 1987), p.276.
49. *Soviet Dependence on Space Systems*, p.3.
50. U.S. Central Intelligence Agency, National Intelligence Estimate 11-1-80: Soviet Military Capabilities in Space, Washington, D.C., 6 August 1980, p.7.
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52. Ibid., p.III-8.
53. Ibid. Note that the United States did not have an operational ASAT at this time.
54. Ibid., p.III-9.
55. U.S. Central Intelligence Agency, National Intelligence Estimate 11-1-83: The Soviet Space Program, Washington, D.C., 19 July 1983, p.15 (declassified 1997 as part of the CIA Historical Review Program).

55a. "Secret Space," TV documentary, Videokosmos/Ostankino TV/Rudy Inc., broadcast 15 May 1993, 0750 GMT, Moscow on First Channel Network (in Russian).

55b. Steven J. Zaloga, "Red Star Wars," *Jane's Intelligence Review*, May 1997, pp.205-208.

56. Aleksandr B. Shirokorad, *Sovetskiye podvodnyye lodki poslevoyenooye postroyki*, (Moscow: Arsenal Press, 1997), p.24.
57. Ibid. As part of the Tsiklon-B system, submarines and surface ships carried the Tsunami-BM communications complexes while ground stations were equipped with the Tsunami-VM communications complexes.
58. National Intelligence Estimate 11-1-83JX: The Soviet Space Program, p.II-16.
59. P.S. Clark, *Jane's Space Directory*, 1997-98, p.156.
60. Anatoliy I. Savin, Gleb F. Zotov, and Yu.Ye. Petrushchenko, "The Space-Based Sea Reconnaissance and Detection System."
61. Mikhail Rudenko, "Designer Chelomey's Raketoplans" (in Russian), *Vozdushniy transport* **52**, 8-9 (1995).
62. U.S. Central Intelligence Agency, National Intelligence Estimate 11-1-67: The Soviet Space Program, Washington, D.C., 2 March 1967, p.8 (declassified 11 December 1992 as part of the CIA Historical Review Program). Note that the launcher variant used for the launches of Kosmos-102 and Kosmos-125 is listed in the source as the SL-5. All previous unclassified Western analysts had linked these launches to the SL-10, which in fact was used to launch Polet-1 (in 1963) and Polet-2 (in 1964). The Soviet designation for the SL-10 was the 11A59.
63. See for example, "Space Shot Failure In Soviet Reported By U.S. Observers," *The New York Times*, 31 January 1969, p.13.
64. U.S. Central Intelligence Agency, National Intelligence Estimate 11-1-69: The Soviet Space Program, Washington, D.C., 19 June 1969, pp.32-33 (declassified 16 January 1997 as part of the CIA Historical Review Program).
65. U.S. Central Intelligence Agency, National Intelligence Estimate 11-1-71: The Soviet Space Program, Washington, D.C., 1 July 1971, p. 16 (declassified 16 January 1997 as part of the CIA Historical Review Program).
66. *Soviet Dependence on Space Systems,* p.13.
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68. V. Pappo-Korystin, V. Platonov, and V. Pashchenko, *Dneprovskiy raketno-kosmicheskiy tsentr*, p.83.
69. U.S. Central Intelligence Agency, National Intelligence Estimate 11-1-73: The Soviet Space Program, Washington, D.C., 20 December 1973, p.6 (declassified 1997 as part of the CIA Historical Review Program).
70. C. Peebles, *Guardians*, p.280.
71. V. Pappo-Korystin, V. Platonov, and V. Pashchenko, *Dneprovskiy raketno-kosmicheskiy tsentr*, p.85.

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72. National Intelligence Estimate 11-1-80: Soviet Military Capabilities in Space, p.29.
73. Anatoliy I. Savin, Gleb F. Zotov, and Yu.Ye. Petrushchenko, "The Space-Based Sea Reconnaissance and Detection System."
74. For details of the Kosmos-954 incident, see for example Peebles, *Guardians*, pp.280-284.
75. Anatoliy I. Savin, Gleb F. Zotov, and Yu.Ye. Petrushchenko, "The Space-Based Sea Reconnaissance and Detection System."
76. Y. V. Votintsev, "Memoirs and Essays: Unknown Troops of an Extinct Superpower."
77. Khrushchev, Nikita Khrushchev: *The Creation of a Superpower*: **Volume II**, pp.211-212.
78. V. Pappo-Korystin, V. Platonov, and V. Pashchenko, *Dneprovskiy raketno-kosmicheskiy tsentr*, p.85.
79. C. Peebles, Guardians, p.285.
80. V. Pappo-Korystin, V. Platonov, and V. Pashchenko, Dneprovskiy raketno-kosmicheskiy tsentr, p.91.
81. Shirokorad, Sovetskiye podvodnyye lodki poslevoyenooye postroyki, op. cit., p.24.
82. Anatoliy I. Savin, Gleb F. Zotov, and Yu.Ye. Petrushchenko "The Space-Based Sea Reconnaissance and Detection System."
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86. Y. V. Votintsev, "Memoirs and Essays: Unknown Troops of an Extinct Superpower."
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