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SOVIET SPACE COMMAND & CONTROL

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The Soviet presence in space increases although their launch rate is declining and this places a growing demand on their Space Command & Control (SC&C) facilities. Literature research has been performed to establish the resources that make up the Soviet SC&C. A location and description of the land based, seaborne, airborne and space based resources is provided. The location of space support ships during the launch of the Kvant-2 module in 1989 has been established to give an overview of the then used seaborne resources.

1. INTRODUCTION

Although the annual number of Soviet launches is declining, the number of operational satellites and spacecraft in Earth' orbit slightly increases.[1] Effectively, the Soviet presence in space is increasing and this places a growing demand on their Space Command & Control (SC&C) facilities. The assessment of Soviet space capabilities should therefore not be limited to numbers of launches and satellites alone. Space surveillance, communication, and tracking, telemetry and control (TT&C) are vital to their space program. These parts of the Soviet space organization are still not affected by glasnost and are largely kept secret. This report on literature research, although not complete, presents an organization only partly analogous to the U.S. Space Command's world wide network. [2] Because of its vastness and high latitudes the Soviet Union is able to keep track of most low-altitude, high-inclination satellites from landbased ground stations on their own territory, but for the remainder some land based tracking stations within friendly countries and a fleet of ocean-going space support ships are operated. Space based resources are used to complement those on land and sea.

2. LAUNCH CENTRES

Soviet spacecraft are launched from the two main space launch centres: Plesetsk, located about 170 km South of Archangel, and Tyuratam (Baikonur) in Kazakhstan, East of the Aral Sea. (See Table 1 for exact locations and fig.1 for a general overview). A third centre, Kapustin Yar, is used only for occasional missions nowadays. The command bunkers within these centres (sometimes also referred to as 'Flight Control Centre' by the Soviets) are equipped with technical installations and measurement apparatus with radio systems to measure flight orbital data of the launch vehicle and to receive telemetry data.(fig.2)

Information on the prelaunch preparation and insertion of the spacecraft into orbit is sent to the Flight Control Centre, where it is processed and displayed on the common and individual screens in the control rooms. Control of the spacecraft is transferred from the launch complex to the Flight Control Centre immediately after the separation of the launch vehicle's last stage and the spacecraft. [3]

TABLE 1: *Latitude/longitude positions* [24]

Name	L/North	L/East
Angarsk	52.31	103.55
Archangel	64.32	40.40
Baku	40.22	49.53
Baranovichi	53.09	26.00
Chekhov	55.07	37.30
Dzhezkazgan	47.44	67.42
Dzhusaly	45.32	64.05
Irkutsk	52.18	104.15
Kaliningrad	55.56	37.55
Kapustin Yar	48.33	45.42
Kolpashevo	58.21	82.59
Komsomolsk-na-Amure	50.32	136.59
Krasnoyarsk	56.05	92.46
Leninsk	45.38	63.16
Lyaki	40.33	47.25
Medvezhiy Ozera	55.50	38.00
Minsk	53.51	27.30
Mishelevka	52.52	103.10
Moscow	55.45	37.42
Mukachevo	48.26	22.45
Naro-Fominsk	55.22	36.45
Nikolayev	46.57	32.00
Novosibirsk	55.04	83.05
Olenegorsk	68.04	33.15
Pechora	65.14	57.18
Petropavlovsk-K	53.03	158.43
Plesetsk	62.42	40.21
Pushkino	56.01	37.52
Sary-Shagan	46.08	73.32
Sevastopol	44.36	33.31
Simeiz	44.26	33.59
Simferopol	44.57	34.05
Skrunda	56.43	21.58
Tarusa	54.44	37.14
Tbilisi	41.43	44.48
Tselinograd	51.10	71.28
Tyuratam	46.00	63.00
Ulan-Bator	47.54	106.52
Ulan-Ude	51.55	107.40
Ussuriysk	43.48	131.59
Vladivostok	43.09	131.53
Yevpatoriya	45.12	33.20
Zvenigorod	55.40	36.50

3. FLIGHT CONTROL CENTRES

In the 1960's, on different occasions, reports in Soviet press unveiled information on the Flight Control Centres (FCC). Early pictures showed them to be very simple, but gradually in time they have shown considerable advances. FCC's are located in Kaliningrad near Moscow and in Yevpatoriya on the Crimea. The oldest FCC is the Yevpatoriya centre. Besides

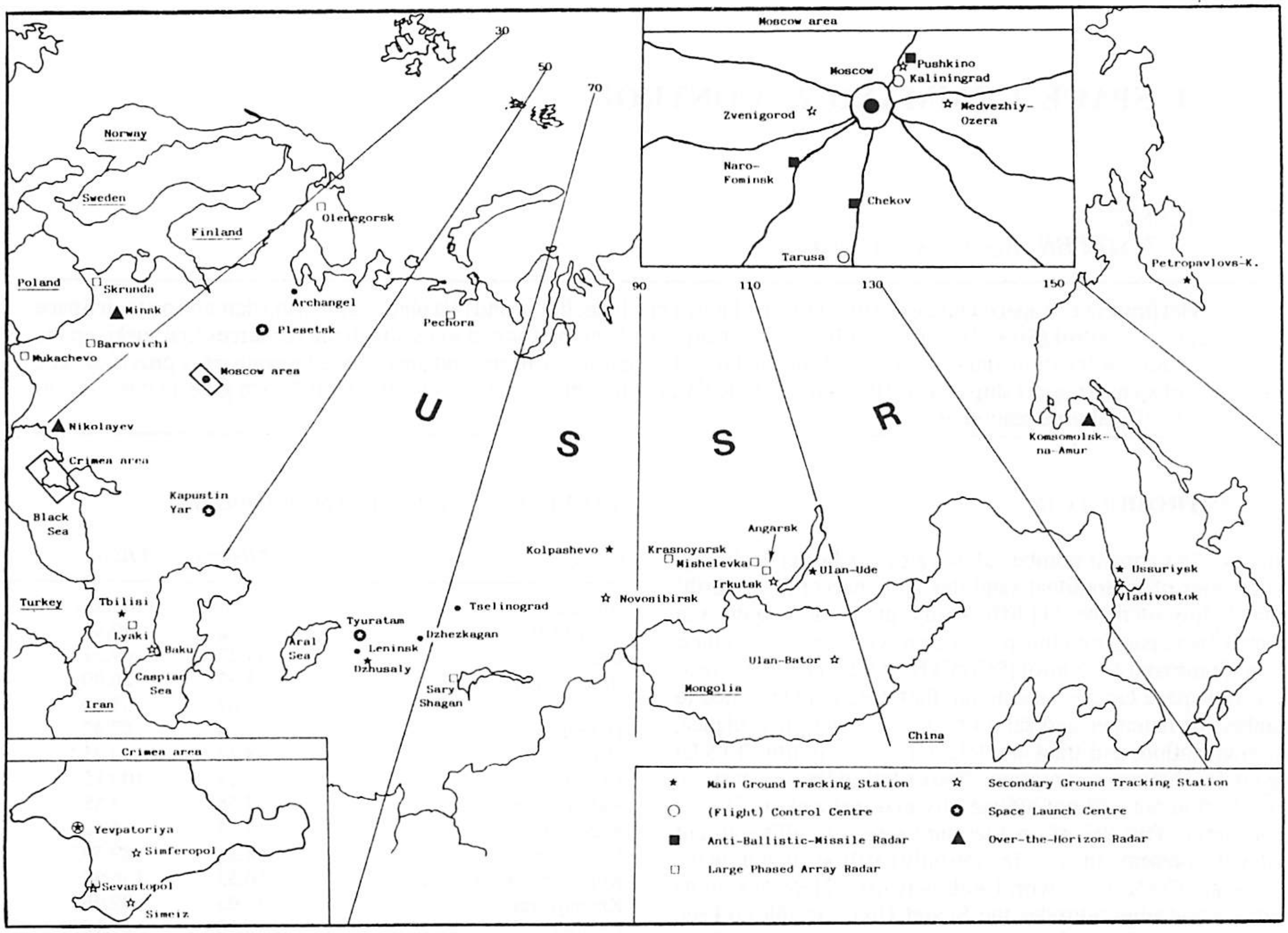

Fig. 1 Soviet Space Command and Control related locations.

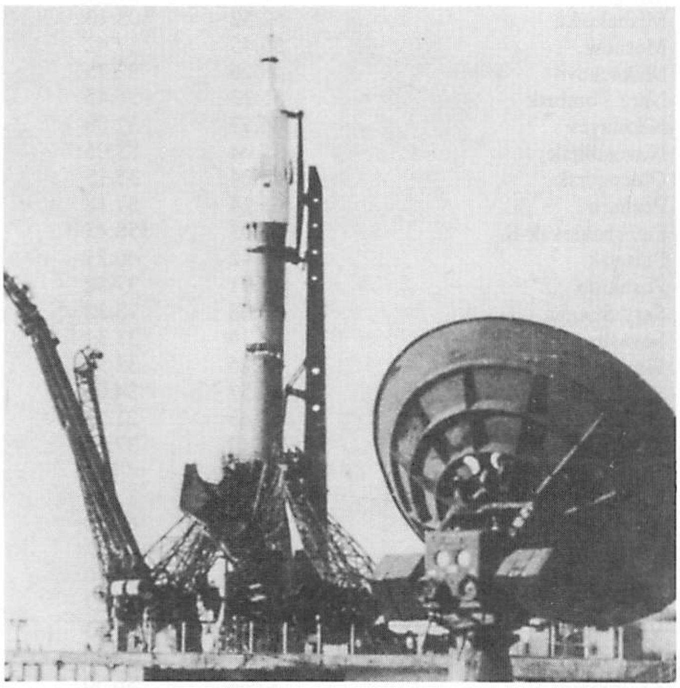

Fig. 2 Soviet SC & C antenna at space launch centre.

acting as a back-up for Kaliningrad, it is mainly used for interplanetary flights nowadays. However, the Phobos flights in 1988 were controlled in an annex to Kaliningrad FCC. Kaliningrad (Tsentr Upravleniya Poljotami, Ts.U.P.) is the FCC used for manned missions (callsign "Zarya", meaning "Morningred") and low-Earth-orbit missions, and has been operational since 1974. [4] It was built between older buildings and has four under-ground and six above-ground storeys. Several spacecraft can be controlled simultaneously from at least two control rooms. The control room to support flights of the country's space shuttle orbiter is located in Kaliningrad too. The facility is not unlike Western FCC's. In general the central wall display in a control room has an orbit ground track superimposed as a white trace on a world map. Black rings on the map indicate coverage zones of ground tracking stations located on Soviet territory, while white rings pinpoint coverage area of space support ships. Screens on each side project drawings, photographs or television images relevant to the mission. The strip above the central wall display provides information that is continually updated during a flight.

For some missions, control is delegated, e.g. the Institute of Biomedical Problems situated near Moscow has its own control room for handling the international Biosatellite missions.[5] Analogous, the 'Priroda State Scientific Research and Production Centre' might have its own control room.

Another centre which controls spacecraft is the Computing and Coordinating Centre (CCC), reportedly operated by the Soviet Academy of Sciences. It has a huge operations hall, with a large map of the world on which the computed trajectories of operational spacecraft are displayed. Illuminating panels on either side of the map carry principal steps of a launch count down or give status on Soviet spacecraft. The CCC collects data from all over the world which is processed, analyzed, evaluated and compared. The CCC may be collocated with Kaliningrad FCC.

4. GROUND TRACKING STATIONS

It is very likely that the early launch guidance employed by the Soviets was primarily by radio. Radar and optical means were employed along the corridor flown by satellites launched repetitively from the Tyuratam space launch centre. From there on more radio and theodolite tracking stations were added along subsequent corridors. These tracking stations were referred to as Komandno Izmeritelnyy Kompleks (K.I.K.)[6] i.e. Command and Measurement Complex.

In addition to these main ground tracking stations, the Soviet Union has supposedly established a ground based organization comprised of a master station and 12 smaller tracking stations [7] (Academy of Sciences computer centres). It appears that some or most of these stations are collocated with the main ground tracking stations and that the discrimination is more task than location related. They are equipped with apparatus for tracking Doppler shifts in radio signals, radar tracking (2.17 - 2.19 GHz) and phototheodolite tracking, and transmit their data to the CCC.

During a flight, the ground tracking stations provide trajectory measurements and receive telemetry data and television information from spacecraft. All the decisions in controlling the flight of the spacecraft are realized through these tracking stations by means of commands via radio links. Between an FCC and a ground tracking station there are telephone, telegraph and wide-band communications links. The ground tracking stations ensure the transmission of telemetry data to the FCC. Redundancies in the telemetry data are removed from the flow of telemetric information. This is done either mathematically, by computer or mechanically with the aid of specialized equipment. Equipment for transmitting data over telephone links is used to compress the flows of telemetry, and, trajectory and programmed command information.

In 1975 the first official Soviet acknowledgement and subsequent publications of ground based tracking stations appeared in connection with the Apollo-Soyuz-Test-Project [8]. A list with seven ground tracking stations was provided: Yevpatoriya, Tbilisi, Dzhusaly, Kolpashevo, Ulan-Ude, Ussuriysk and Petropavlovsk-Kamchatskiy. Irkutsk and Novosibirsk were mentioned later.

In 1979 preparations for the launch of the Indian satellite Bhaskara-2 produced an indication of another ground tracking station in Medvezhiy Ozera or Bears Lake. Indian experts were given an opportunity of using this facility for receiving information and controlling the satellite during the first phase of its mission. A similar announcement, following the launch of Bhaskara-2 in 1981, defined the duration of this period as being from 15 to 20 days. The Indian space research centre in Sriharikota, Moscow and the Monitoring Centre at Medvezhy Ozera were connected by telex and direct telephone lines.

5. OPTICAL TRACKING

Soviet public statements about their tracking capabilities for the early years made particular reference to optical tracking facilities (fig. 3). These were located in many parts of the Soviet Union and the main optical station was, and probably still is, in Zvenigorod near Moscow. In 1985, the world's largest satellite tracking camera - designed to track high altitude satellites, mainly in geostationary orbits - was installed there. It weighs about 25 tonnes and has a focal length of 75 centimetres. New electro-optical systems, like the U.S. GEODSS-type [9], probably have been introduced. In a paper presented at a symposium on balloon geodesy in 1978, the Soviets review experiments on simultaneous optical tracking of flashlights mounted on aircraft, at Zvenigorod tracking station and two such stations near Ulan-Bator (Mongolia) [10].

Since 1976 reports have surfaced about laser observation of satellites. A school on laser observation was established on the Crimea at one of the tracking stations. Similar installations that were used on this school, were later reportedly handed over to Bolivia, Cuba, Egypt, India and Poland. In 1988 negotiations were concluded with Angola, Ecuador, India, Mozambique and Vietnam to install laser range finders under the Interkosmos programme [11]. The early laser tracking programme was referred to as the Great Arc project in a Czechoslovakian broadcast in 1977. In 1980, Latvia was added to the network making

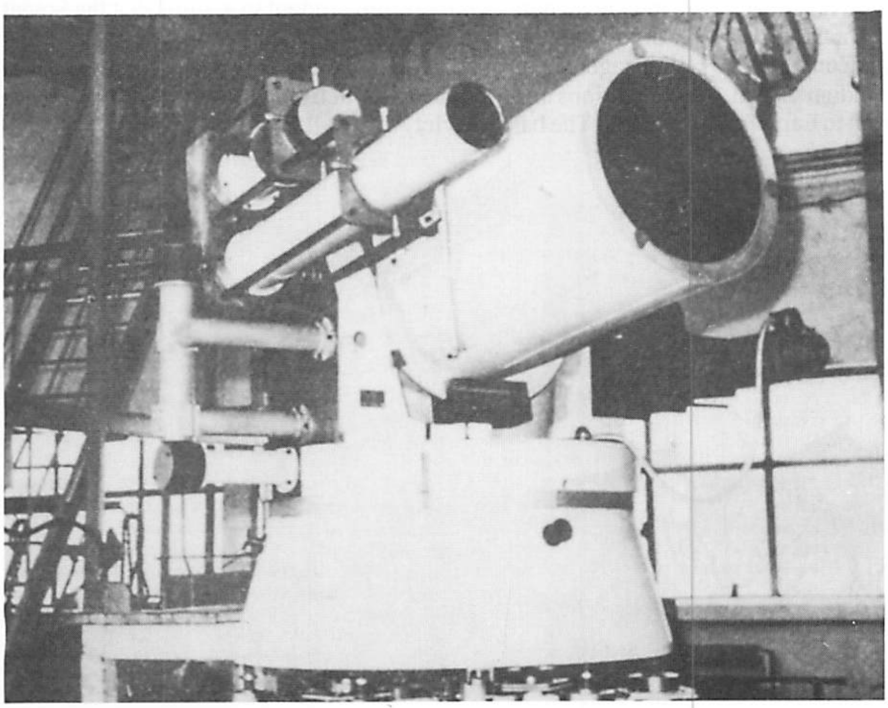

Fig. 3 Soviet optical equipment for space purposes.

regular observations of artificial satellites using laser rangefinders. Within scientific geodetic programmes, these laser tracking stations probably are being employed in the SC&C organization. Interkosmos-22 (7 Aug. 1981) was reported to have an angular laser reflector for geodetic studies using ground based lasers at 14 locations around the world.

6. TELEMETRY

With the introduction of the automatic universal orbital station (Interkosmos-15, 19 Jun. 1976) a new unified telemetric system (YeTMS) for digital data transmission was also tested. The YeTMS used an advanced computer, designed to process data before it was transmitted to ground stations. Data was received in Cuba, Bulgaria, Czechoslovakia and the Soviet Union. The data collection stations in the Soviet Union were located in the area around Moscow, Baku, Sevastopol and Vladivostok. The mission of Interkosmos-20 (1 nov. 1979) was oceanographic research, and the spacecraft served as an information relay between buoys and platforms placed in various parts of the ocean and the control centre at Tarusa, South of Moscow.

7. SEARCH AND RESCUE

Part of the Soviet SC&C is the organization that deals with the recovery of spacecraft or spacecapsules that return to Earth, and is called "the search and rescue complex" [12]. In general, its tasks are to locate the returning craft or capsules and evacuate cosmonauts and/or payloads. The main recovery area is situated between Tselinograd and Dzhezkazgan on the steppes of Kazakhstan. To re-enter, the spacecraft retrofires approximately at the equator over the Gulf of Guinea. Atmospheric re-entry starts over Egypt and continues through maximum heating and ionization communications blackout near the Caspian Sea. Thus landings occur normally northeast of Leninsk. The Soviets claim that, with aid of the space support ships, they could also recover spacecraft from the sea if they wish to do so. The first time they recovered a spacecraft from a deep space mission was also the first water recovery. Zond-5 (launched 14 Sep. 1968) swung around the Moon and returned to Earth after 7 days in space. The approach to Earth was over the South Pole and it landed in the Indian Ocean as it headed North. The landing at night complicated matters for the recovery team. Recovery was directed by the rescue service and tracking ship Borovichiy. The second Soviet water recovery was Zond-8, 725 km Southeast of the Chagos Archipelago in the Indian Ocean. This mission used a significantly different approach to Earth for re-entry, coming in over the North Pole instead of the South. The advantage was that Soviet ground stations could control the flight during most of the re-entry. The normal recovery force is equipped with aircraft, helicopters and all-terrain vehicles. Men and equipment are directed to where the returning craft or capsule is expected to land. Helicopters and aircraft use radio direction finding techniques to search for the spacecraft (19.995 MHz) and accompany it as it comes down for landing, and, in the case of returning cosmonauts, maintain two-way communications (121.75 MHz).

8. DEEP SPACE TRACKING

Deep space operations principally need 24 hour world-wide coverage. The Soviet Union could, with the breadth of the country and its space support ships, achieve such coverage but apparently chose not to. The only Soviet recourse is to rely upon automatic systems in their deep space craft, or if more (near)-real time data and commands must be exchanged, to plan their missions to have such crucial events take place when the antennae face the distant spacecraft. Yevpatoriya has been portrayed by the Soviets, on several occasions, as their deep space tracking station. Pictures of radiotelescopes with eight dishes in two rows of four (fig. 4), together with single dish antennae have been published in different books and magazines. Yevpatoriya probably is a collocation of a space flight centre - also referred to as Simferopol and as Simeiz; all three are located on the Crimea - a deep space radio telescope and a space ground tracking station. A Novosti Press Agency publishing on the Phobos mission in 1988 [13], described telescopes with diameters of 70 metres in Yevpatoriya and Ussuriysk and one with a dish with a diameter of 64 metres in Medvezhiy Ozera. This would make the two latter stations part of the deep space tracking system. Furthermore, radio interferometry is reportedly being conducted using Earth stations in Pushkino [14] and Ussuriysk [15].

9. SPACE RADARS

Radars, able to detect launches of intercontinental ballistic missiles and also able to discriminate between real re-entry vehicles and decoys, are equally capable to be used as space tracking radars. It is therefore prudent to assume that the Soviet Union will employ its extensive strategic warning and tactical management ground based radar network to support their space operations and to monitor the activities of spacecraft and space debris. The basic Soviet Anti-Ballistic-Missile (ABM) surveil-

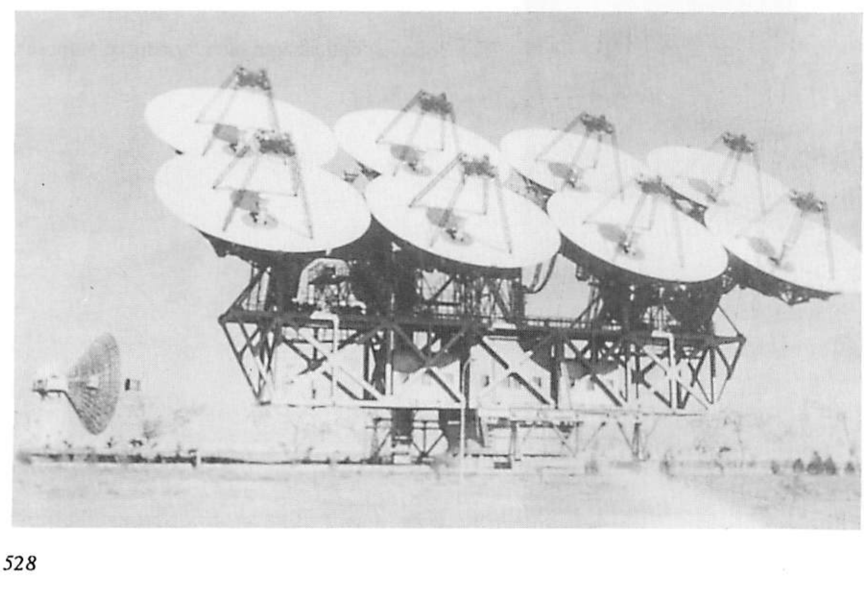

Fig. 4 Yevpatoriya radiotelescopes.

lance network consists of eleven Hen House detection and tracking radars at six locations on the periphery of the U.S.S.R.. These six locations have never been revealed but can be deduced from Soviet Military Power 1986 [16]. It is stated that "Five of these [LPAR] radars duplicate or supplement the coverage of the Hen House network, ...". Together with the information in fig. 5, locations of the Hen House radars are most probable in the following areas: Angarsk, Crimea, Mukachevo, Olenegorsk, Sary-Shagan and Skrunda.

The Pill Box four-sided phased array battle-management radar (located near Pushkino) will supplement and probably replace the older Dog House and Cat House ABM target tracking radars of which the locations also never have been revealed other than two locations South of Moscow. In Jane's Land based Air Defence [17] Chekhov is illustrated as the one location while the other is merely pinpointed in the area of Naro-Fominsk.

The Pechora type bi-static large phased-array radars (LPAR) may eventually replace the older Hen House radars. Deployment began in the late 1970's at Baranovichi, Krasnoyarsk, Lyaki, Mishelevka, Mukachevo, Olenegorsk, Pechora, Sary-Shagan and Skrunda [18]. Construction of two additional radars, at Sevastopol on the Crimea and in the Angarsk area, was reported in 1988. The Soviets put a moratorium on the construction of the Krasnoyarsk radar after US accusations that it was a breach of the ABM Treaty as was admitted by Soviet minister Shevardnadze in 1989. At the end of May 1990 the Soviets started to dismantle this radar. The other LPAR's probably will not be operational until the mid 1990's.

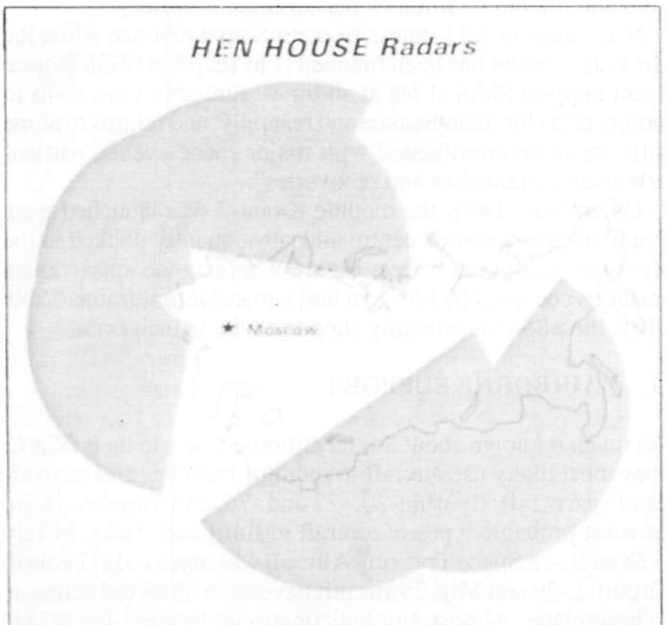

Fig. 5 Coverage of Hen House radars.

Three Over-the-Horizon radars which can be used also for space tracking purposes, are located in the area of Minsk, Nikolayev and Komsomolsk-na-Amure [19].

10. SPACE SUPPORT SHIPS

Once out of reach of landbased tracking stations - for only about 9 hours out of 24 spacecraft in Earth orbit are within field of view of landbased tracking stations on Soviet territory - control is exercised through space support ships (SSS). Possibly because of Soviet reluctance to become too dependent on foreign landbased stations, or perhaps because of unwillingness of some nations to be hosts for such stations, the Soviet Union has put considerable emphasis on developing their seaborne tracking and control system. Therefore several classes of ships have been developed. Besides a number of small tracking and signal relay ships, a fleet of dedicated SSS is operated by the Academy of Sciences (AoS).

The first dedicated SSS was the "Kosmonavt Vladimir Komarov" which was followed by the "Akademik Sergei Korolev" and the flagship "Kosmonavt Yuriy Gagarin". Eight smaller vessels (Vytegrales class) were refitted for the SSS role: "Pavel Belayev, Borovichi, Georgiy Dobrovolski, Kegostrov, Morzhovets, Nevel, Viktor Patsayev and Vladislav Volkov".

The Soviet navy is building two classes of SSS. Not being subordinated to the AoS, it probably means that the role of these ships is not purely civil anymore. They may support military missile test launches as well. The one class is named after the first of its ships, the "Marshal Nedelin", which is assigned to the Vladivostok based Pacific fleet (fig. 6). According to Rear Admiral Brooks of US Naval Intelligence [20], the second ship in this class, the "Marshal Krylov", is conducting sea trials.

A nuclear powered, and by far the largest class of SSS, is the

Fig. 6 "Marshal Nedelin" Space Support Ship.

Fig. 7 "SSV-33" Space Support Ship.

Fig. 8 Octagonal antennae (3) amidships the SSV-33.

other new class. With hull number SSV-33 it has one large radome on the bow and several smaller ones along the length of the ship (fig. 7). Additionally it has three flat faced octagonal antennae amidships that may well be a 3-D tracking radar.(fig. 8) It may have dual capabilities like the Nedelin. Again according to Brooks, the SSV-33 is equipped with advanced systems associated with space support and surveillance, including modified telemetry antennae, tracking radars and electro-optical sensors.

A new civilian SSS for the AoS is being built in Leningrad and already has been named the "Akademik Nikolay Pilyugin". It is too premature to tell what its specific fit will be, but it is assessed that it will be a Nedelin class.

SSS receive telemetry information from (mostly manned) spacecraft and transmit them to the FCC by means of the Molniya satellite relay network. Conversation between manned spacecraft and the SSS is also possible. Thus the use of SSS can increase the communications time between spacecraft and FCC from about 20 to 45 minutes per 90-minute-orbit.

N.L. Johnson [21] states: "Recent Soviet practice while the Mir space station has been manned is to keep 5-8 SESS [Space Event Support Ship] at sea at all times. Embarkations, visits to foreign ports for maintenance and resupply, and returns to home ports are often coordinated with major space events, particularly manned launches and recoveries".

On 26 Nov. 1989, the module Kvant-2 was launched from Tyuratam space launch centre and subsequently docked to the Mir space station on 8 Dec. Figure 9 depicts the approximate positions occupied by SSS's in that particular timeframe. Table 2 lists the SSS that probably supported the launch event.

11. AIRBORNE SUPPORT

Not much is known about Soviet airborne assets to their SC&C. They most likely use aircraft to monitor launches and recoveries of spacecraft. Ilyushin-20, -22 and -76, and Tupolev-16 are the most probable types of aircraft to fulfil such tasks. In July 1988 an IL-18 Space Tracking Aircraft was observed at Leninsk Airport. L-39 and Mig-25 aircraft have been observed acting as a chase-plane. Almost any helicopter can be used for SC&C purposes like search and rescue, airborne communications relay etc.

12. SUPPORT FROM SPACE

The first space systems used for SC&C communications and data relay links were Molniya satellites in highly elliptical orbits. "Orbita"-type ground stations and space support ships are connected through these Molniya satellites and in this way provide a communications link between FCC's, ground tracking stations and spacecraft. (fig. 10)

Although the Soviets used geostationary communications relay satellites for broadcast purposes and governmental data links since 1974, it took untill 1982 to launch a relay satellite for dedicated SC&C purposes. In 1981 the International Frequency Registration Board was informed of the Soviet intention to establish a Satellite Data Relay Network (SDRN). Since then probably two of such geostationary communications systems have been added to the assets of Soviet SC&C. Of a possible third system that has to be considered here, almost no information is available. For the sake of clearness these systems have been denominated Group A, B and C.

Group A started off with the launch of Kosmos-1366 (see Table 3) in May 1982. In this group satellites were sometimes

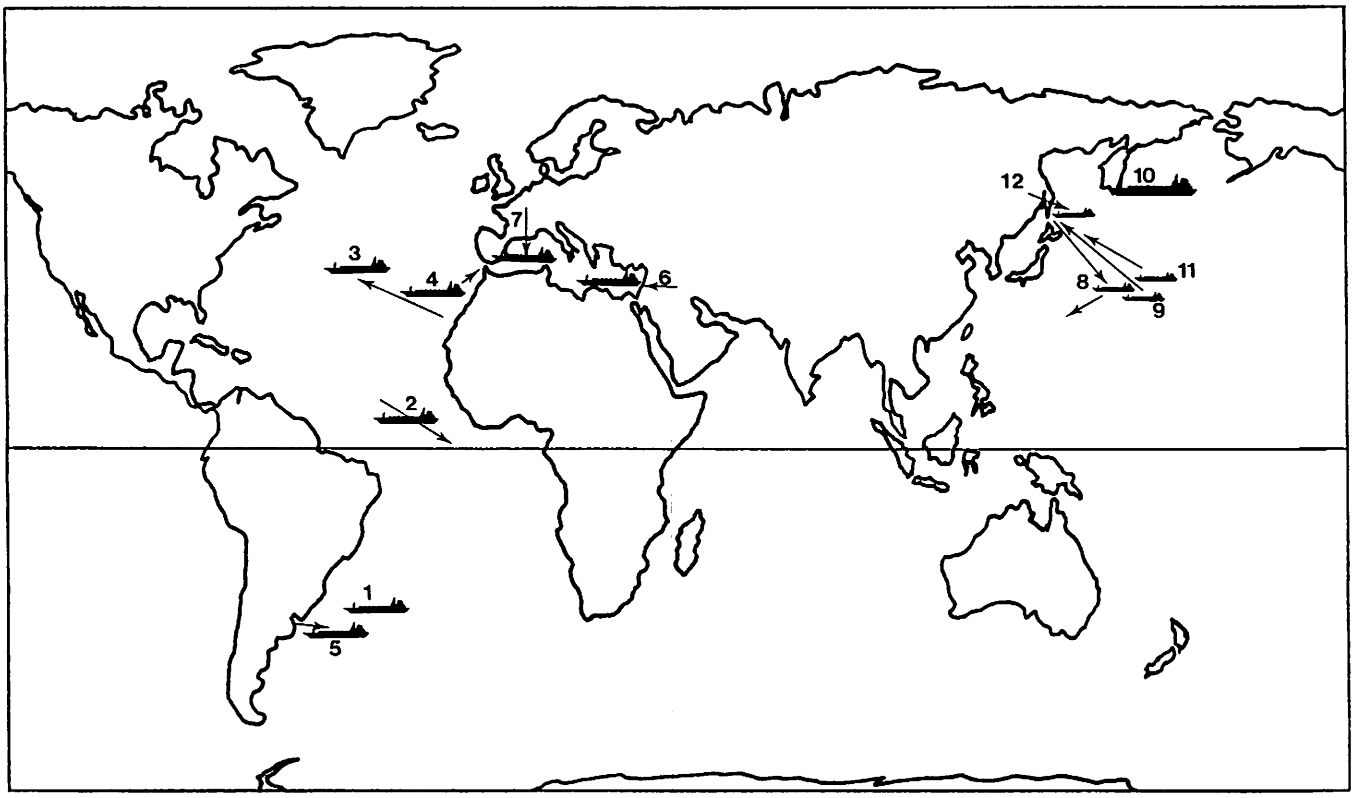

Fig. 9 Soviet space support ships in the (1989) timeframe of the Kvant-2 launch and subsequent docking to the space station Mir (see Table 2 for legend).

TABLE 2 : *Soviet space support ships that probably supported the launch and docking of Kvant-2.*

ATLANTIC OCEAN

1. **Kosmonavt Pavel Belayev**
   40.00S 45.00W: From 24 Nov. on, probably on station
2. **Kosmonavt Georgiy Dobrovolski**
   10.00N 35.00W: 24 - 26 Nov. enroute
   11.00N 27.00W: 26 Nov. - 7 Dec. probably on station
   09.00N 18.00W: From 7 Dec. on, probably on station
3. **Akademik Sergey Korolev**
   Las Palmas : Till 13 Nov.
   37.00N 30.00W: From 20 Nov. on, probably on station
4. **Kosmonavt Viktor Patsayev**
   35.00N 12.00W: 24 - 30 Nov. probably on station
5. **Kosmonavt Vladislav Volkov**
   Buenos Aires : Till 24 Nov. in port
   42.40S 46.30W: From 26 Nov. on, probably on station

MEDITERRANEAN

6. **Kosmonavt Vladimir Komarov**
   Eastern Mediterranean: Around 5 Dec. enroute
7. **Kosmonavt Viktor Patsayev**
   38.00N 04.00E: 2 - 8 Dec. probably on station

INDIAN OCEAN

No Soviet SC&C related activities

PACIFIC OCEAN

(Only small telemetry-relay ships active)

8. **Chazma**
   22 - 28 Nov. enroute from Vladivostok
   25.00N 158.00E: 28 Nov. - 2 Dec. probably on station
   23.00N 149.00E: From 8 Dec. on, probably on station
9. **Chukotka**
   18 - 24 Nov. From the central Pacific enroute to Vladivostok
10. **Marshal Nedelin**
   From 11 Nov. on in Petropavlovsk-K. after operations in the central Pacific
11. **Sakhalin**
   18 - 24 Nov. From the central Pacific enroute to Vladivostok
12. **Spassk**
   47.00N 144.00E: From 11 Dec. on, probably on station

launched without a Soviet mentioning of a mission at all. Missions therefore may range from covert operations data link to relay of data from remote sensing satellites or two-way communications between manned spacecraft and ground control. In April 1986 a satellite of this group, Kosmos-1738, was positioned at the geostationary location of 16°W for the first time.

Group B, the announced SDRN, started with the launch of Kosmos-1700 in October 1985. This satellite was positioned at 95°E and was labelled Eastern SDRN (ESDRN). Kosmos-1700 has been very distinctly used as a relay between the Mir space station and ground control. It was followed by Kosmos-1897 in November 1987. The move of this satellite from 95°E to 12°E in July/August 1988 was one of the then still not fully understood preparations for the spaceflight of the Buran space shuttle orbiter. The Central (CSDRN) 160°W location and the Western (WSDRN) 16°W location have up till now not been filled with

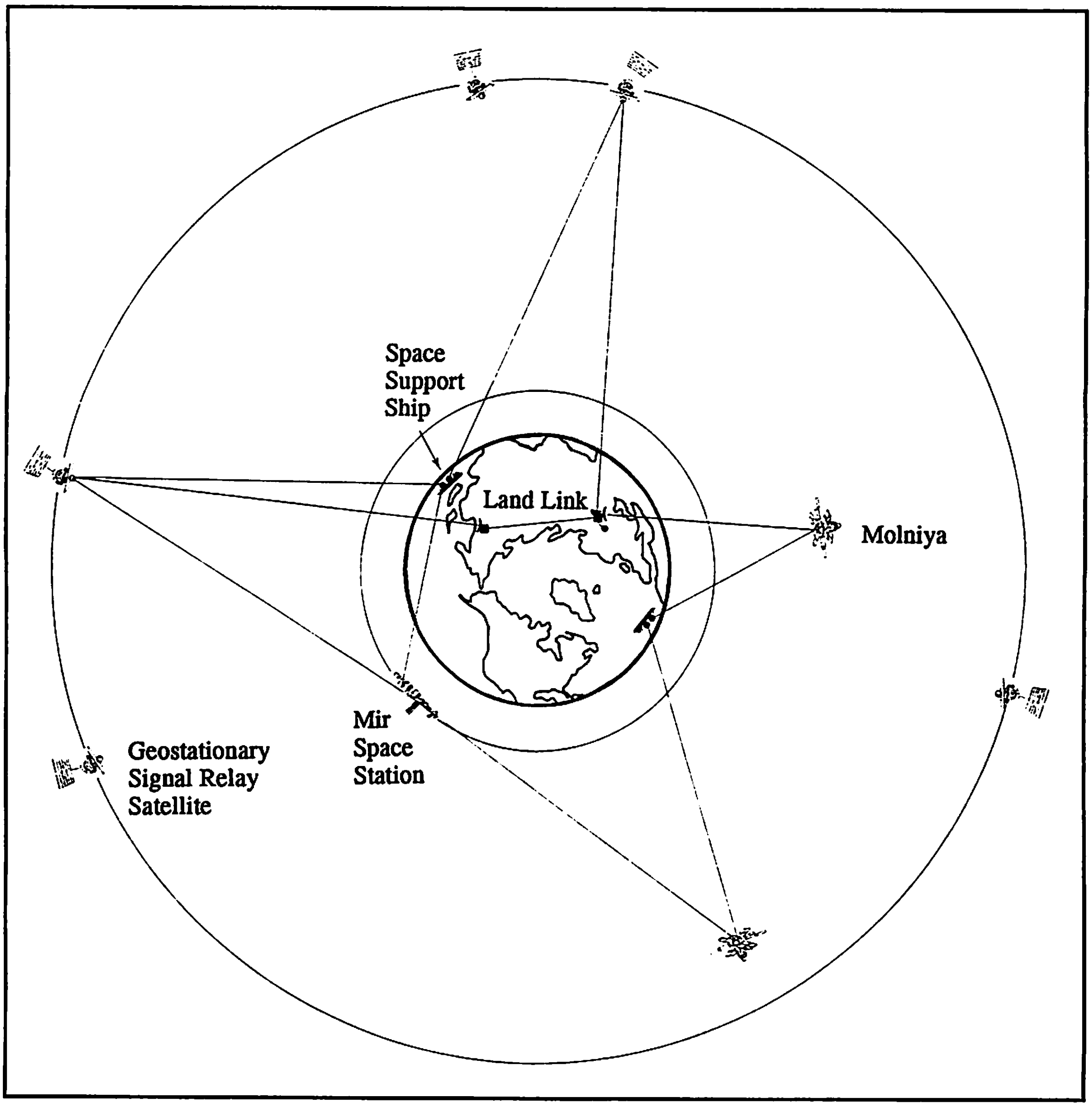

Fig. 10 Schematic overview of possible datalinks in (manned) space operations when out of reach of Soviet territory.

TABLE 3: *Geostationary positions of possible SC & C related relay satellites*

Group A		
Kosmos-1366	17 May 1982	77°E
Kosmos-1540	2 March 1984	79°E
Kosmos-1738	4 April 1986	16°W
Kosmos-1888	1 October 1987	80°E
Kosmos-1961	1 August 1988	16°W
Group B		
Kosmos-1700	25 October 1985	95°E (ESDRN)
Kosmos-1897	26 November 1987	95°E (ESDRN)
?		16°W (WSDRN)
?		160°W (CSDRN)
Group C		
Kosmos-1546	29 March 1984	23°W
Kosmos-1629	21 February 1985	25°W
Kosmos-1894	28 October 1987	25°W
Kosmos-1940	26 April 1988	24°W

dedicated relay satellites.

Group C is the most mysterious group. It consists of four satellites (Kosmos-1546, -1629, -1894 and -1940), initially at the 25°W geostationary location. Space logs label its function from missile early warning to data relay, while they also could be experimental Prognoz satellites.

To start with the latter, Prognoz is the name of an intentional geostationary satellite network designed to monitor the world's oceans and natural resources and to study atmospheric processes. One of the assigned geostationary locations is 24°W. The planned first launch was in 1982, but dedicated spacecraft under the Prognoz name have yet to be launched. Group C spacecraft therefore can be experimental (hence the Kosmos designation) Prognoz satellites.

If Group C spacecraft are missile early warning satellites, it explains the sparse information released. If these spacecraft are of the same design as the highly elliptical orbit spacecraft, they probably provide the Soviets with some additional back-up for their current missile early warning satellite system. On the other hand, a new missile early warning system in the correct geostationary locations may be targeted at U.S. submarine launched ballistic missiles. The orbital manoeuvering of Kosmos-1940 from 24°W to 12°E and subsequent continuous drifting in easterly heading may be some kind of operational determination of the best geostationary locations for such a system.

The assumption that Group C is a third geostationary data relay satellite system may therefore not be correct. If so, the Soviet SDRN may just consist of the satellites in the ESDRN (77°, 79°, 80° and 95° East) and WSDRN (16°W) locations with the CSDRN (160°W) location still to be filled.

13. CONTROL OF BURAN

In 1989, A. Maksimov [22] shed some light on Soviet SC&C related assets when he described the spaceflight of the Buran space shuttle orbiter (15 Nov. 1988). The Marshal Nedelin and the Kosmonavt Georgiy Dobrovolski SSS sailed in October 1988 to take positions at 45.00S and 133.00W. The data that was received by the Nedelin was retransmitted via Raduga-16 - which at that time was collocated with Gorizont-6 at about 130°W - to the ground station at Petropavlovsk-K and from there via land line to a K.I.K. command and measurement complex and the FCC. The data received by the Dobrovolski was analogously retransmitted via Gorizont-6, Petropavlovsk-K and Molniya-1 satellite to the Medvezhiy Ozera Orbita ground station and then through land lines to the FCC.

Additionally, the SSS Kosmonavt Vladislav Volkov (05.00N 30.00W) and Kosmonavt Pavel Belayev (16.00N 21.00W) in the Atlantic Ocean retransmitted data from the Buran through a Raduga (available were Raduga-11, -22 and -19) link to a receiving station in the Moscow area and further via land lines to the FCC. To maximize redundancy for this very important flight, another flow of data from the Buran was retransmitted through the Kosmos-1897 (ESDRN) satellite to other receiving stations on the territory of the U.S.S.R. All in all, four different relay paths were used to ensure reliable communications.

14. MANNED SPACEFLIGHT COMMUNICATIONS AND DATA LINKS

In manned spaceflight, the Soviets distinguish the following communications and data links [23]:

- Command Radio Link;

  Earth to orbit (space station, spacecraft) control commands
  Earth-station two-way telephone communication
  Station to Earth television and telemetry signals

- Television Communications System;

  Station to Earth television signals

- Telephone Communications System ("Zarya");

  Earth-station two-way telephone communication
  Station-spacecraft two-way telephone communication
  Earth to station teletype

- Radiotelemetry Communications System ("RTS");

  Station to Earth telemetry signals
  Spacecraft to Earth telemetry signals.

A space station carries at least two RTS systems, one for service information and the other for information from the scientific and experimental apparatus.

REFERENCES

1. SIPRI Yearbook 1989, Stockholm International Peace Research Institute, Oxford University Press, p.65.
2. *Spaceflight*, Vol 27, July/August 1985, p.306-309.
3. Salyut, A technical memorandum of the Congressional Office of Technology Assessment, Washington DC, December 1983, p.57-62.
4. R. Hofstätter, Sowjet-Raumfahrt, Birkhäuser Verlag, Basel, 1989, p.150-151.
5. Interavia Space Directory 1989-90, Ed. A. Wilson, p.595.
6. G. Smirnov, Dozorniy Kosmosa, Aviatsiya i Kosmonavtika.
7. Aviation Week, New York, 26 Jan. 1969, p.26.
8. B. Ruzicka and L. Popelinsky, Rakety a Kosmodromy, Nase vojsko, Prague 1986, p.213-221.
9. Interavia Space Directory 1989-90, Ed. A. Wilson, p.253.
10. A.G.Masevich *et al*, Scientific ballooning, Austria-Innsbruck, Oxford Pergamon Press, 1979, p.179-186.
11. N.L. Johnson, The Soviet Year in Space 1988, Teledyne Brown Engineering, January 1989, Colorado Springs, U.S.A., p.19.
12. Salyut, A technical memorandum of the Congressional Office of Technology Assessment, Washington DC, December 1983, p.62-63.
13. The road to the Red Planet, Novosti Press Agency Publ. House, 1988.
14. L.Matveyenko *et al*, JPRS-USP-84-003, 1984, p.72.
15. R.Sagdeyev *et al*, JPRS-J1957394, 1988, p.1-2.
16. Department of Defense, Soviet Military Power 1986, US Government Printing Office, Washington DC, 1986, p.43,45.
17. Jane's Land-based Air Defence 1989-90, Ed. T.Cullen and C.F.Foss, UK 1989, p.19-21.
18. SIPRI Yearbook 1989, Stockholm International Peace Research Institute, Oxford University Press, p.66.
19. D.Goure, Soviet Radars: The Eyes of Soviet Defences, Military Technology, 5/88, p.36-38.
20. T. Brooks, in Jane's Defence Weekly, 31 Mar. 1990, p.578.
21. N.L. Johnson, The Soviet Year in Space 1988, Teledyne Brown Engineering, January 1989, Colorado Springs, U.S.A., p.22.
22. A. Maksimov, in Aviatsiya i Kosmonavtika, January 1989, p.10-11, and March 1989, p.40-42.
23. Salyut, A technical memorandum of the Congressional Office of Technology Assessment, Washington DC, December 1983, p.54.
24. De Grote Times Wereldatlas, Kluwer Algemene Boeken, 1983, Ede, Nederland.

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