SCIENTIFIC INTELLIGENCE REPORT

THE SOVIET SPACE RESEARCH PROGRAM

MONOGRAPH IV
SPACE VEHICLES

26 February 1960

CENTRAL INTELLIGENCE AGENCY

OFFICE OF SCIENTIFIC INTELLIGENCE

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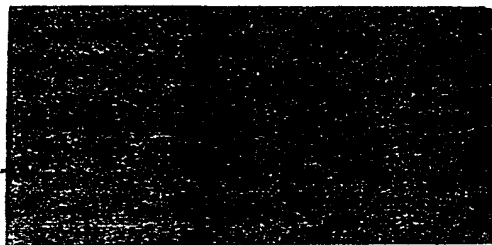
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THE SOVIET SPACE RESEARCH PROGRAM

MONOGRAPH IV
SPACE VEHICLES

SUMMARY AND CONCLUSIONS

1. The Soviets are fully capable of designing and developing significantly advanced space vehicles and will probably solve the materials problem for the re-entry of manned earth satellites during the period mid-1960 to mid-1961. The Soviet Union's achievements in the penetration of interplanetary space include a powerful launching vehicle that has permitted the payload of earth satellite vehicles and space probes to be constructed by conventional aircraft techniques and with readily available materials and instruments. Furthermore, the Soviets can, when necessary, develop miniaturized structures and their nuclear program will probably provide radiation shielding support.

2. The Soviets have developed instrumented unmanned earth satellites and space probes using existing ballistic missiles as launching vehicles. The exceptionally powerful launching vehicle, as demonstrated by the large payload weights of Sputnik III and the Lunik missions, indicates that the vehicle probably consisted of a basic military intercontinental ballistic missile (and most certainly of propulsion, control, and guidance systems developed for military purposes). Similarity of ▮▮▮▮▮▮▮▮▮▮▮▮ on Soviet ICBM's and launching vehicles for the Lunik final-powered-stage indicates that the vehicles probably are identical or very nearly so. The similarity in announced weights of the three Lunik final stage vehicles, and the similarity

of ▮▮▮▮▮▮▮▮ on the launching boosters utilized for these shots also indicate that the three Lunik final-powered-stage vehicles are probably identical or very nearly so, except for the difference in payload weights. Based on the gross weight of the Lunik I final powered stage, the launch weight of the complete vehicle is estimated to be about 500,000 pounds. The launching thrust-to-weight ratio is about 1.5 to 1; thus, the launching thrust of these vehicles is about 750,000 pounds. It is estimated that current Soviet launching vehicles of the Lunik type could fire a 5,000- to 10,000-pound earth satellite into a 100–150 nautical mile orbit.

3. The large payload capability of the launching vehicles has enabled the Soviets to use readily available materials and instruments in space vehicles, but they can develop lightweight, miniaturized structures for complex space missions when necessary. They are capable of solving current problems concerned with materials of construction and fabrication technology for space vehicle launchers, instrumented satellites, and space probes. They can design and develop high-strength, low-weight structural materials, including ablating, refractory, and other types, for solving the aerodynamic heating problem involving re-entry vehicles (recoverable satellites, satellite capsules, and space probes). The exhibited model of the Lunik I final-powered-stage vehicle shows conventional aircraft

structural technique and use of aluminum as the material of construction; this fabrication technology is considered to be typical of current ballistic missiles utilized as launching vehicles for Soviet space vehicles (satellites and lunar probes).

4. Soviet high-altitude research vehicles have yielded a wealth of important scientific data for the design of space vehicles, especially the structure of re-entry capsules. Soviet ballistic missiles fired down range will probably be used as test beds for studying problems of re-entry and recoverable capsules. It is estimated that the Soviets will solve the materials problems for the re-entry of a manned earth satellite in the period mid-1960 to mid-1961.

5. There is no evidence of Soviet research specifically directed towards the radiation shielding problem as it applies to manned space flight. The radiation shielding research that is conducted as part of the Soviet nuclear energy program should contribute to the solution of this problem, but there is no direct intelligence information to confirm such support.

6. Payloads larger than those estimated for current capability will require the development of launching vehicles specifically designed for the Soviet space program, which when available will end the apparent dependence on ballistic missiles except for adaptable propulsion and guidance components. The size of these vehicles will be determined by the mission, payload and propulsion systems available. Nuclear propulsion, which would materially reduce the launching-vehicle size for large payload weights, may be available by the late 1960's.

DISCUSSION

INTRODUCTION

The structure and configuration of space vehicles are coincident with that of the airframe involved — the overall structure that contains the propulsion system, guidance system, and payload. The airframe must be strong, lightweight, and capable of resisting aerodynamic heating. The payload, whether it be a space probe or a satellite, has its own airframe that must have similar airframe properties; moreover, the aerodynamic heating problem is of greater magnitude in missions requiring the re-entry of a recoverable payload into the earth's atmosphere. Therefore, basic research and development are directed toward the production of strong, lightweight, heat resistant materials and refractory,* ablating,** heat sink,*** and transpiration cooling **** materials for special pur-

pose applications on re-entry vehicles. Additional requirements are imposed by the bands of harmful radiation surrounding the earth, solar eruptions, and cosmic rays in space; these conditions present a major shielding problem for most manned satellites or space probe missions.

Test vehicles for investigating these problems and for developing re-entry vehicles may take the form of vertically fired high-altitude rockets, long-range ballistic missiles fired down range, and rocket-powered aerodynamic research vehicles.

In the Soviet space research program, existing military and scientific missiles and equipment have been utilized insofar as possible for launching vehicles, satellites, and space probes. Relatively heavy, unsophisticated space vehicles with large payload capabilities, which have performed well and collected considerable data of various types have resulted. To fulfill increasingly difficult missions, Soviet scientists and engineers are expected to develop more refined and specialized space launching vehicles. The modified military ballistic missiles now used as launching vehicles will have to be replaced with larger pro-

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* Refractory materials are those capable of withstanding high temperatures without loss of their desirable properties.

** Ablating materials absorb heat by vaporizing or by melting and sloughing off the melt.

*** Heat sinks absorb heat in a large mass of material having a high thermal capacity.

**** Transpiration is the dissipation of heat by evaporation of liquids forced to the surface through a porous medium.

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pulsion units designed to meet the needs of interplanetary and manned space missions. Nevertheless, many components of military equipment will continue to be used in the space program.

The development of military missile airframes and their modification for space flight is probably supervised by the Chief Artillery Directorate, the principal ordnance organization of the Ministry of Defense. Scientific aspects of the space vehicle program are supervised and coordinated by the Interagency Committee on Interplanetary Communications under the direction of Professor Dr. L. I. Sedov. Basic research and development related to vehicle structural materials are most likely performed by appropriate institutes of the USSR Academy of Sciences.

The military ballistic missile program and its scientific space portion are large scale efforts which involve thousands of scientists, engineers, and technicians. It is evident that the best Soviet talent is being utilized in connection with these programs. One cannot at this time estimate the number of persons involved but there is no evidence of any quantitative shortage of personnel. In view of accomplishments to date it would appear that these personnel are being effectively utilized.

Ballistic missile research and development is centered in the Kaliningrad area some twenty miles northeast of Moscow with flight testing in the Kazakhstan area. In the Kaliningrad area of some eight square miles are located the Central Artillery Design Bureau, Scientific Research Institute/Plant 88, Scientific Research Institute 4, and static test facilities at Plant 88. The resources of this area have been expanded in the post-war period and further expansion is feasible. It is believed that numerous facilities of the State Committees for Aviation, Shipbuilding, Defense Industry, and, perhaps, others are directed and coordinated from the Kaliningrad area in the creation of both the ballistic launching vehicle for space flights and the space vehicles themselves. Facilities suspected of contributing specifically to the space vehicle airframe development program are Scientific Research

Institute 88, Kaliningrad; Plant 8, Sverdlovsk; Automobile Plant 186, Dnepropetrovsk; All Union Institute of Aviation Materials, Moscow; and Plant 82, Tushino.

SATELLITES AND SPACE PROBES

The immediate problems concerned with the structural design of an instrumented satellite or space probe have been to build a minimum-weight structure that will withstand the aerodynamic heating and acceleration stresses. Soviet satellite and space probe achievements to date attest to the fact that currently available materials were satisfactory. Future materials research and fabrication technology will be directed towards minimizing the structural and component weights of proposed space vehicles. A recoverable satellite or space probe has the additional problem of providing for re-entry of the vehicle, the instrument container, or at least a portion of it such as a photographic film package. The re-entry structure could be a winged space vehicle or a capsule fitted with retrorockets to slow it down with final descent made with the aid of a special slotted parachute designed for opening during rapid descent in a rarefied atmosphere. These same problems would apply to an instrumented space probe designed for exploring the atmospheres of other planets or for a soft landing on them. For a soft landing on those planets without an atmosphere or for a lunar soft landing, the vehicle must include retrorockets to slow the structure down so that the vehicle is not destroyed on impact. The lack of an atmosphere for braking the vehicle's descent makes a soft landing on these non-atmospheric bodies a major design problem.

Additional problems become apparent when one considers the design of a manned satellite or manned space vehicle. The primary consideration here is to provide for the internal environment of the vehicle: composition and pressure of the atmosphere, gravitational forces, deceleration and acceleration effects, temperature, protection from meteorite impacts, radiation shielding, waste disposal and nutritional requirements are the main problems.

Analysis of published Soviet photographs (see figures 1 to 5) and data (summarized in tables 1 and 2) on satellites and space probes has not disclosed any significant discrepancies from the announced dimensions.[1][2] The last propulsion stages (carrier rockets) of Sputnik I and III separated from the satellite after thrust termination and orbited independently of their respective payloads. The final propulsion stage of Sputnik II did not separate from its payload capsule. The payload and final-stage empty weight for the Lunik I were announced as totaling 3,245 pounds and the final propulsion stage reportedly separated from the "artificial planet No. 1." The payload structures are constructed of an aluminum alloy and are rugged in comparison with U.S. satellites; the Soviets have not needed to utilize the many weight-saving innovations characteristic of U. S. satellites and probes. The Soviet payload structures may reflect some technical shortcomings, but it is more likely that in their desire to be first and because of the large payload capability of the launching vehicle, the Soviets used the most expedient materials, technology, and instruments.

LAUNCHING VEHICLES

Launching vehicle requirements are governed by the theoretical velocities necessary for various missions (see table 3) and by the payload. Calculations show that most of the current Soviet satellites and space probes are impractical if not impossible for a one-stage vehicle using conventional propellants. All of the space missions are attainable with multi-stage vehicles; i.e., staging using two or more rockets. In the configuration called tandem staging (stages stacked on top of one another and fired successively) the payload for any one stage represents the gross weight of the subsequent stage(s). The last stage is the smallest and carries the useful payload (satellite or space probe). As the propellant is consumed in each stage, this stage is dropped from the vehicle and the operation of the propulsion system in the next stage commences. Each stage imparts a velocity increment to the space vehicle; the final velocity of the space vehicle is the sum of the velocity increments for each of the stages. The size of the vehicle and the number of stages and their arrange-

TABLE 1

SOVIET SATELLITES

CHARACTERISTIC	SPUTNIK I	SPUTNIK II	SPUTNIK III
Launch date	4 Oct 57	3 Nov 57	15 May 58
Re-entry date	4 Jan 58	14 April 58	(still in orbit)
Life time	3 months	5½ months	est. 1½ years
Payload (pounds)	184	unknown	2,926
Instrumentation weight (pounds)	unknown	1,120 **	2,134 ***
Configuration	spherical	conical	conical
Dimensions (ft.) *	1.9	6.5 x 3.3	11.7 x 5.7
Burn-out velocity (fps.)	26,200	26,950	26,950
Experiments conducted	Internal and external temperatures, meteor impacts, pressure	Internal and external temperatures, internal pressure, cosmic radiation, ultraviolet and X-ray radiation, meteor impacts, biological experiment (dog)	Earth's magnetic field, primary gamma radiation, solar radiation, earth's electrostatic field, heavy primary cosmic radiation, concentration of positive ions, internal and external temperatures, meteor impacts

* Dimensions given are exclusive of any final rocket stage.
** Total weight of instruments, animal, and electric power source.
*** Weight of scientific research equipment, radio equipment, and power supplies.

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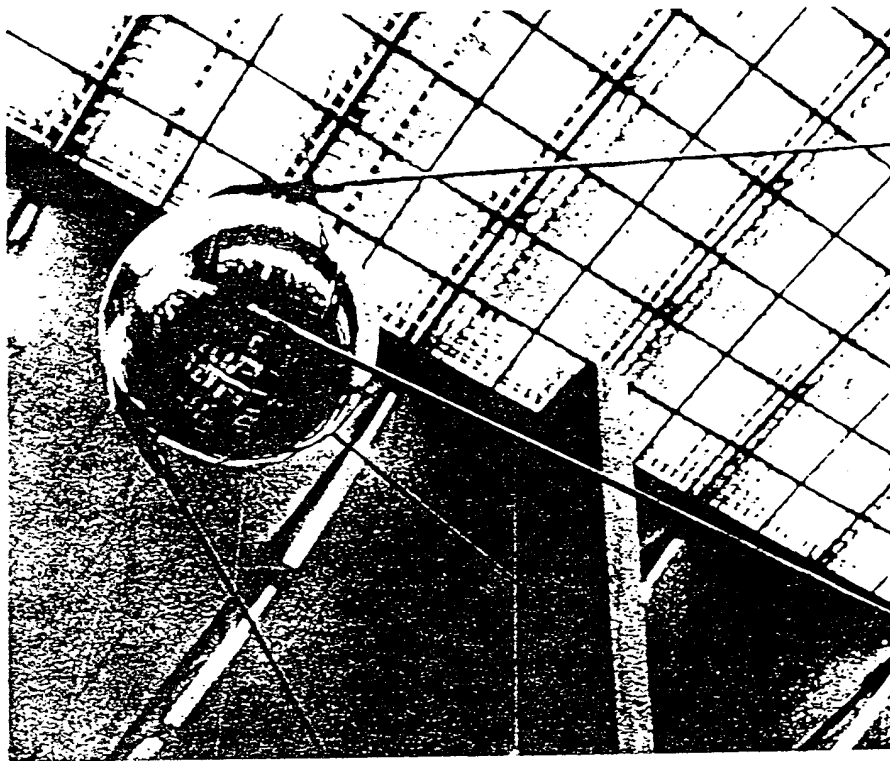
Figure 1. Replica of Sputnik I.
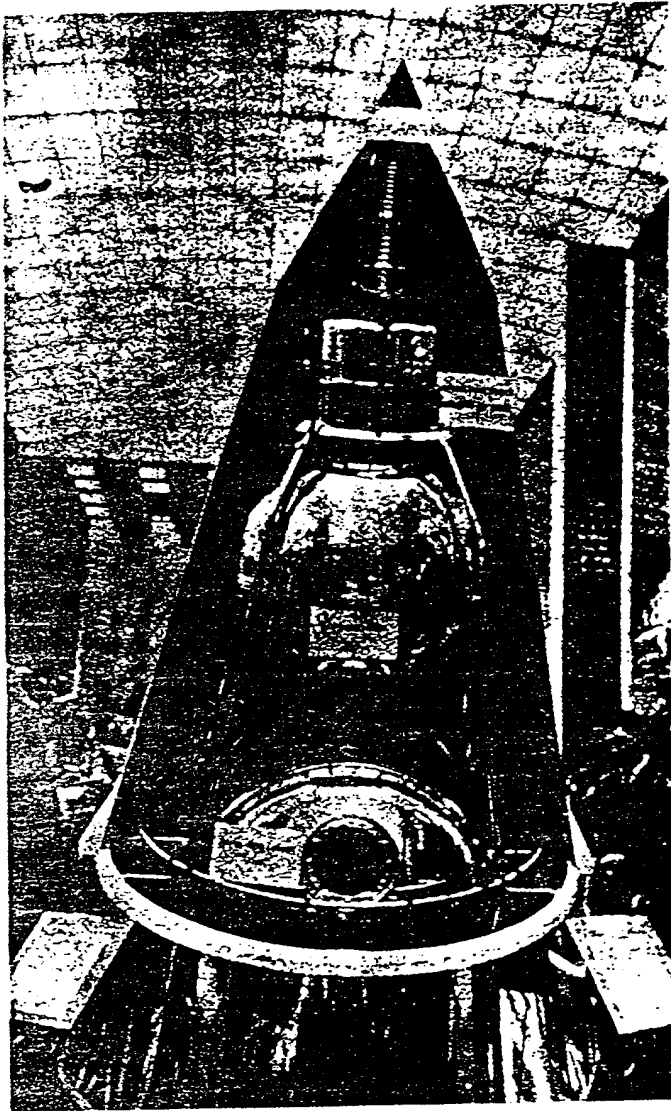
Figure 2. Reproduction of Sputnik II. Airtight cabin near base, sphere containing transmitters and instruments just above, and solar radiation apparatus near top.

Figure 3. Replica of Sputnik III.
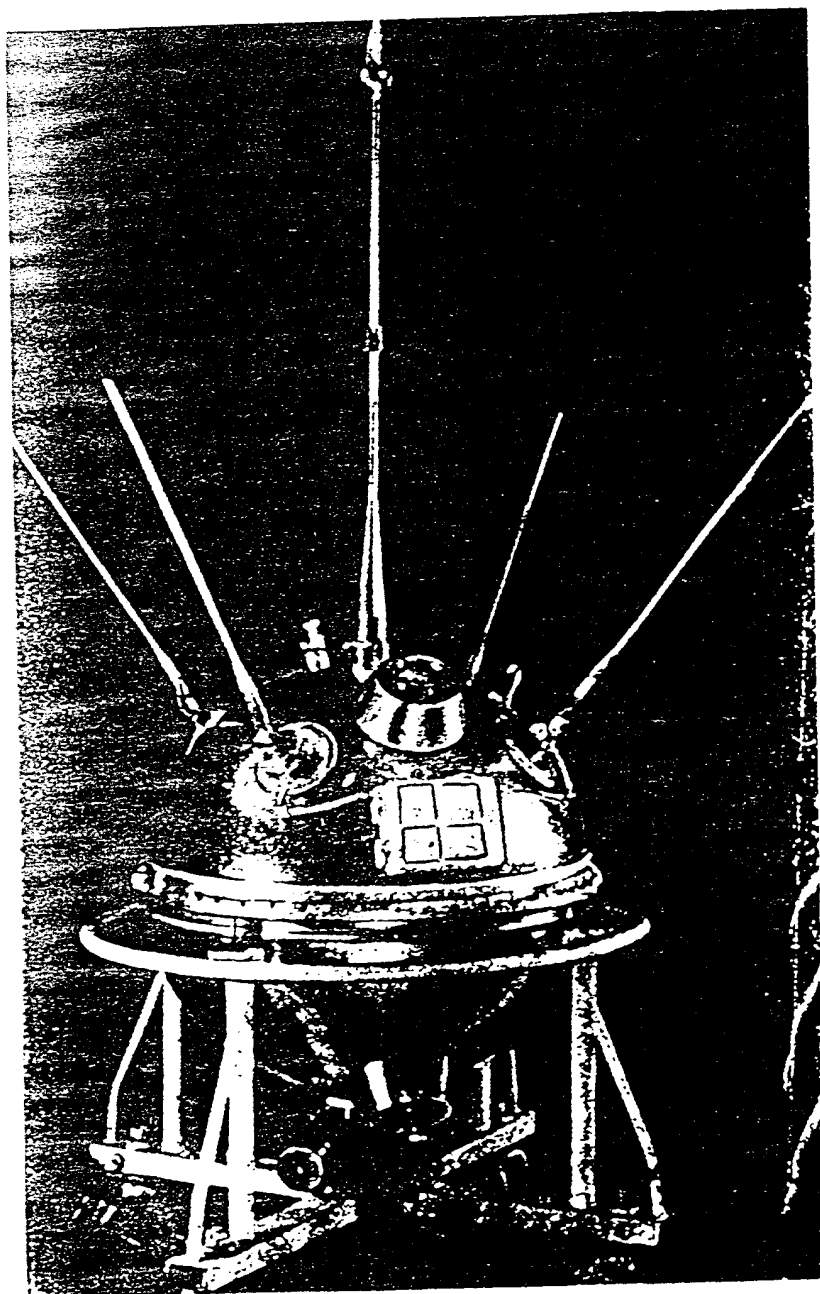
Figure 4. Model of the instrument container taken up by the Soviet rocket, Lunik I, on 2 January 1959, and claimed to have become artificial planet No. 1.

Nose Cone

Second Stage

First Stage

2-Stage Tandem: 2nd stage fires only after 1st stage separates.

Nose Cone

Sustainer Stage

Boosters (engines only)

1½ Stage Partial: All engines fire at launch; booster engines jettisoned prior to sustainer stage burnout.

Nose Cone

Sustainer Stage

Booster Stages (engines, tankage, and structure)

Parallel: All engines fire at launch; booster stages jettisoned prior to sustainer burnout.

Figure 5. Possible configurations for the Soviet ICBM

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TABLE 2

SOVIET SPACE PROBES

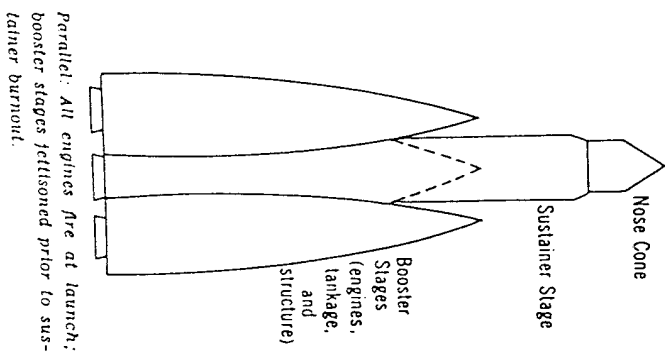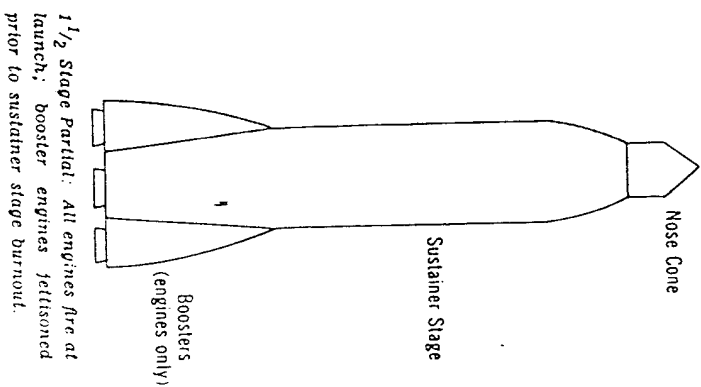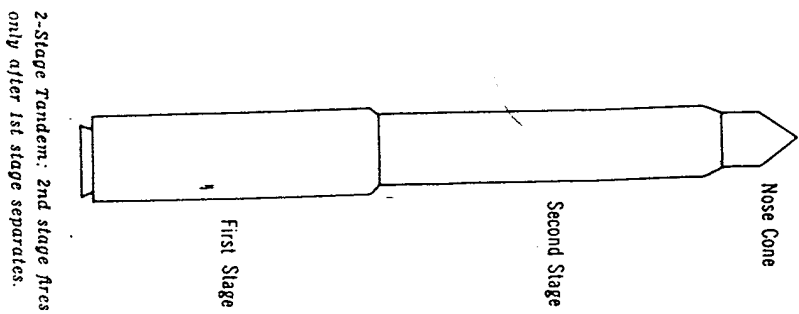| CHARACTERISTIC	LUNIK I (Artificial Planet No. 1)	LUNIK II (Lunar Impact)	LUNIK III (Circumlunar Orbit)
Launch date	2 Jan 59	12 Sep 59	3 Oct 59
Empty weight of final stage (lbs.)	3,245	3,332	3,424
Estimated gross weight of final stage (lbs.)	18,000	unknown	unknown
Length and diameter of last stage (ft.)	17.3 x 8.5	unknown	unknown
Total payload weight (lbs.)	797	860	959
Structure weight minus payload (lbs.)	2,448	2,472	2,465
Gross weight of separating instrumentation probe (lbs.)	397	unknown	613
Estimated instrumentation weight remaining with powered final stage (lbs.)	400	unknown	345
Increase in payload weight over Lunik I (lbs.)	—	53	162
Diameter of instrument capsule (ft.)	2.7	unknown	unknown
Shape of instrument capsule	spherical	spherical	cylindrical
Known experiments conducted	Internal temperatures and pressures, micrometeorites, external temperatures, earth's magnetic field, solar corpuscular radiation, primary cosmic radiation, interplanetary gas components, moon's magnetic field, sodium vapor cloud	Cosmic rays, micrometeorites, earth's magnetic field, interplanetary gas components, moon's magnetic field, sodium vapor cloud, radiation belts, primary cosmic radiation	Photograph of backside of moon

TABLE 3

APPROXIMATE VEHICLE VELOCITIES FOR TYPICAL MISSIONS [3]

MISSION	THEORETICAL VELOCITY, [*] FT/SEC
5500 n. mile ICBM	23,000
Satellite orbit around earth (no return)	26,000 to 35,000
Escape from earth (no return)	36,700
Lunar missions, approx.	35,000
Mars/Venus	37,000

[*] Neglects air resistance, navigational corrections, and gravitational losses (variations in gravitational forces with increasing distance from the earth's surface).

ment is dependent on the mission, payload weight, specific impulse of the propellants, fabrication techniques, materials of construction, and weights of component systems (propulsion, guidance, auxiliary power, and so forth). Different types of staging are illustrated in Figure 5.

A few days after the launch on 4 October 1957 of the earth's first man-made satellite, Sputnik I, Nikita Khrushchev, the First Secretary of the Central Committee of the Communist Party of USSR, stated that the USSR can launch satellites because it has a carrier for them, namely the ballistic missile.[4] Later statements by Khrushchev further implicates the Soviet ICBM as contributing in some way to the launching vehicle for the Sputniks. Academician Leonid I. Sedov, Chairman of the Soviet Interagency Commission for Interplanetary Communications, in October 1957 said that the Soviet satellite program was based upon available military hardware from the start.[5] V. P. Petrov in his book stated that it is only necessary to replace the hydrogen warhead in the nose of a Soviet ICBM with suitable instrumentation to produce an artificial earth satellite.[6] Soviet Defense Minister Rodion Malinovsky stated in a special speech given 3 February 1959 to the 21st Congress of the Soviet Party that the intercontinental

ballistic rocket launched the Mechta space probe (Lunik I).[7] These statements by authoritative Soviets strengthen an already firm conviction that the current Soviet space program is built on the experience gained in their military ballistic rocket program and that the vehicles utilize at least major components of their ICBM hardware.

Photographs of the orbiting carrier rockets for the three Sputniks show that a different launching vehicle was used in each case. (See table 4.) It is believed that the vehicle used to orbit Sputnik III was a Soviet ICBM. The similarity of ICBM and space probe launching vehicle telemetry formats indicates that the ICBM was utilized to launch the final powered stage for Soviet space probes. Telemetry evidence also supports a parallel or partial stage ICBM. Thus, on the premise that Sputnik III was launched by an ICBM, the Soviet ICBM is a parallel or partial staged vehicle approximately 91 feet high and 10 feet in diameter. Calculations based on the Lunik I final stage estimated gross weight of 18,000 pounds show that the Soviet ICBM has a gross launching weight of about 500,-000 pounds.[1] ▓▓▓▓▓▓ evidence shows that the thrust to weight ratio for the Soviet

TABLE 4

PHYSICAL CHARACTERISTICS OF SOVIET SATELLITES AND CARRIER ROCKETS *[8]

AIRFRAME	LENGTH (Ft)	DIAMETER (Ft)	WEIGHT (Lb)
Sputnik I (carrier)	54 ± 5	8 ± 3	——
Sputnik I	spherical	2.3	185 (total weight in orbit)
Sputnik II (carrier)	70 ± 5	8 ± 3	——
Sputnik II	6	3.2	1,120 (instrumented payload)
Sputnik III (carrier)	91 ± 5	10.3 ± 2.0	——
Sputnik III	11.2	5.7	2,925 (total weight in orbit)

* The physical data available come from Soviet announcements (weights) and from photo intelligence.

ICBM is 1.5; therefore, the launching thrust is about 750,000 pounds. Evidence on the materials of construction, airframe and staging technique is totally lacking.

Soviet press releases have revealed a limited amount of information on the Lunik final stage vehicles (reviewed in table 2). In July 1959, the Soviets exhibited a model of the final-stage vehicle (minus rocket engine) and listed the spherical instrument package which separated to become "artificial planet No. 1" as weighing 397 pounds. The final stage was approximately 8.5 feet in diameter and had a height of 17.3 feet. Propellant tankage indicated a liquid propellant system.[9]

A completely reliable source has produced additional information on the Lunik I final stage vehicle, including the diagrams shown in figures 6 to 9 and information on construction details. The internal arrangement of the tankage is such that the rocket engine (not exhibited) is positioned in the hole created by the toroidal tanks. The top tank is made of aluminum, assembled from sections by welding. Its volume is 150 cubic feet. The top tank is fueled through a filler pipe attached to the bottom of the tank. The bottom tank's inside and outside diameters are the same as those of the top tank but it is a true torus with a volume of 93 cubic feet. The bottom tank is fueled through a spring loaded nozzle located on the opposite side of the one for the upper tank.

Figure 9 shows an exploded view of the entire final stage vehicle illustrating the probable manner of assembly. The nose cone tip fits over the forward section of the two conical half sections. At the proper time, the nose cone tip is ejected, the clamps holding the two half sections together are released, and the nose cone breaks away from the vehicle. The spherical instrumentation package is ejected by some undisclosed method at the end of powered flight. The forward reinforced section which supports the nose cone is attached to the curved section of the upper tank. The forward tank and aft body section are joined together to form a continuous cylinder. An aluminum circular heat shield goes around the external surface of the top tank. Thus,

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Figure 6. Diagram of Lunik 1 last stage vehicle

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Scale
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17.25 ft.

8.5 ft.

Figure 7.   Lunik 1 last stage vehicle, side 1

30907 2–60

Scale
.46 inches equals 1 foot

17.25 ft.

8.5 ft.

Figure 8.   Lunik 1 last stage vehicle, side 2

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1. Nose Cone Tip
2. Nose Cone Half Section
3. Lunik Payload
4. Nose Cone Support Structure
5. Heat Shield
6. Lox Tank
7. Main Body Section
8. Fuel Tank
9. Base Plate

Figure 9. Lunik 1 last stage vehicle, exploded view

30909 2-60

the upper tank most likely would contain a cryogenic liquid believed to be liquid oxygen (lox). The bottom tank is attached to the cylindrical body section which is made of heavy gauge aluminum alloy. The volumetric ratio of the two tanks indicates that the propellant system is lox-kerosene and on this basis, the total weight of propellants is approximately 15,000 pounds.

The design and fabrication of the Lunik I final stage vehicle follows conventional aircraft construction practice. The integral lox tank is pressurized to carry body shears, bending moments, and axial loads. The axial force generated by the preceding powered stage is distributed to the skin-stringer structure of the final stage vehicle by eight heavy externally mounted lugs.
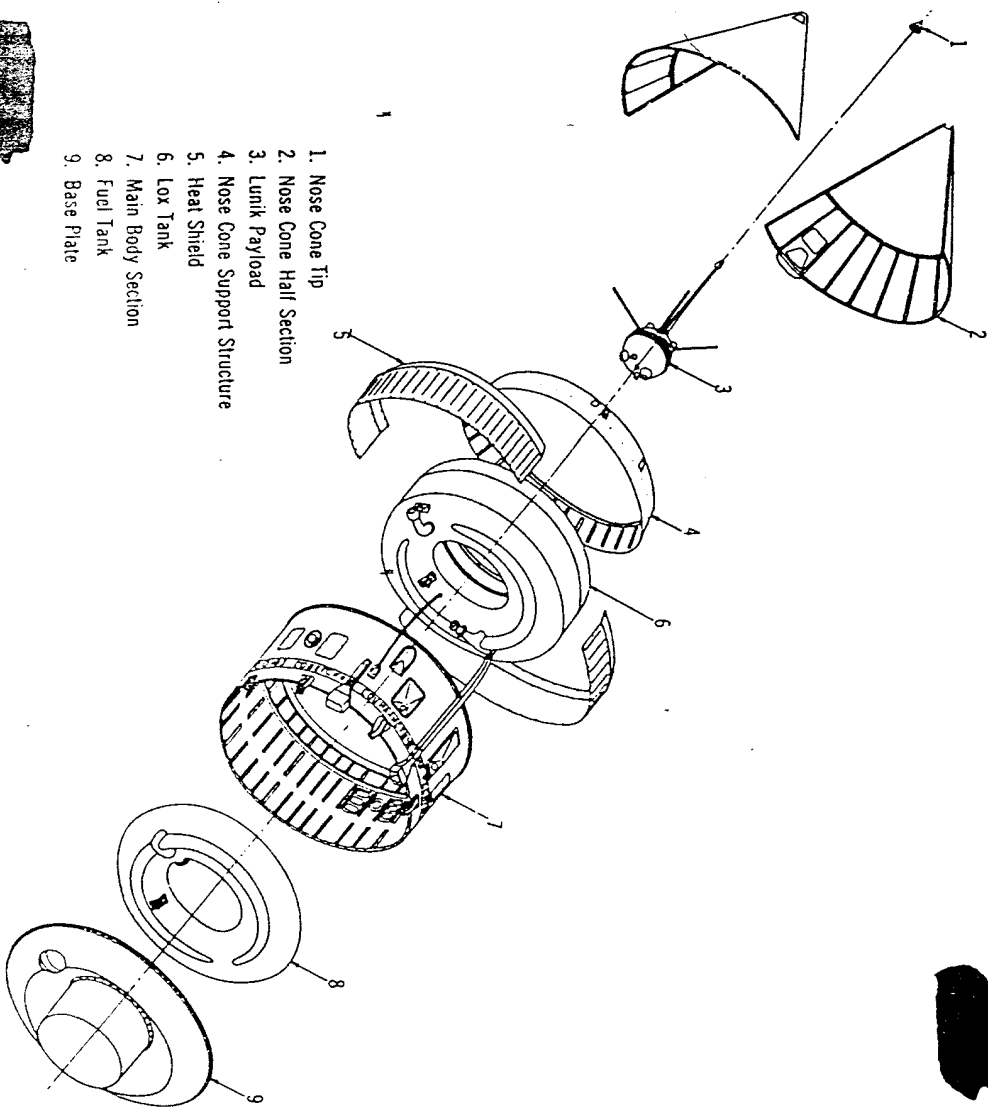
The design of the Lunik final stage vehicle shows that no concerted effort was made to save weight. Reliable intelligence indicates the total structure weight less propulsion system to be 1,760 pounds. Aluminum was the material of construction. The Soviets utilized modern manufacturing techniques, unusually careful workmanship, and extensive automatic machine welding in its construction. Use of heavy forgings and stampings are also in evidence.

The Soviets have ample capability for immediate space missions with their Lunik launching vehicle, which has the capability for a manned satellite mission when the Soviets have solved the re-entry problem. The launching vehicle has estimated payload capabilities for specific missions as shown in table 5. For a 7,500 nautical mile earth satellite, the payload capability is the same as that for any lunar mission except a soft landing.

TABLE 5

APPROXIMATE PAYLOAD CAPABILITY OF LUNIK LAUNCHING VEHICLES

PAYLOAD	ORBIT (Circular)	WEIGHT (Lbs.)
Earth satellite	100–150 n.m.	5,000–10,000
Earth satellite	7,500 n.m.	1,000
24-hour equatorial earth satellite	20,000 n.m.	550

The USSR is not expected to be dependent for long on military developed missiles for the Soviet space program. Soviet development of larger vehicles specifically designed for space missions is most likely well along. The Soviet space program we envision for the period 1959–74 requires the development of these much larger vehicles and of associated propulsion and guidance systems. Estimates show that the Soviets, for every payload pound put into a satellite orbit, required approximately 150 pounds of launch weight and that each payload pound of the Lunik vehicle required about 500 pounds of launch weight. These ratios will naturally become less as the Soviet state-of-the-art improves, but even if the ratios were to halve, the launch weight of future Soviet space vehicles must be estimated at a few million pounds.

The appearance of these future gigantic vehicles is at best only a guess. They will be a few hundred feet high and consist of several powered stages. High-energy propellants will be utilized. In the latter part of the period 1959–74, when nuclear or exotic propulsion systems may be a reality, the number of stages may decrease to two or three and vehicles may be short and thick. During the period of this estimate, Soviet vehicles will probably be developed capable of orbiting large manned space stations, making manned lunar soft landings, and placing instrumented probes into outer space.

MATERIALS OF CONSTRUCTION AND FABRICATION TECHNOLOGY

The construction materials and fabrication technology for space vehicles must produce strong, lightweight, and heat-resistant structures. The need for strength and lightness is merely an extension of aircraft requirements, but recoverable space-vehicle heating problems are of a different magnitude. Steady state heating, as in a propulsion system, must be handled differently from the transient heating of a re-entry vehicle. The extremely high temperatures (caused by aerodynamic heating) estimated to be encountered by a re-entry vehicle for specific planets is summarized in table 6 for various re-entry tra-

jectories.[3] Few of these temperatures are within the performance limits of current materials.

In their efforts to develop structural and other materials for future space vehicles Soviet scientists are undoubtedly investigating many substances, including metals, plastics, ceramics, cermets, and other chemical compounds. There is no evidence to show that the Soviets have materials research and development programs which are directly connected with space flight projects but such projects probably exist and probably are highly classified.

Plastics and Rubbers

The Soviets will probably use plastics in space flight structures primarily as components of major equipment units (rocket engine throats and nozzles), for housings and lightly loaded structures, as insulating materials, and as ablating material for the nose cones of re-entry vehicles.

The Soviets have the capability to use existing, reliable and readily available plastics such as phenolics, acrylates, and polystyrene for space flight applications. The Soviets reportedly are now using plastics fairly extensively in their satellite and space vehicle programs. Smaller and lighter weight components produced from plastics will see greater utilization in future Soviet space vehicles.

Metals and Cermets

There is no evidence of metallurgical research or facilities for such research in the USSR which are directed specifically toward meeting space vehicle materials requirements. However, the USSR is engaged in an extensive metallurgical research and development program which includes studies of high temperature alloys, cermets, and refractory metals of potential importance to space vehicle construction. While much Soviet work is undoubtedly classified, the quality of present known Soviet metallurgical science and technology is uneven and in some areas generally equivalent to that of the West. Published Soviet work on theories of strength and elevated temperature properties of metals and alloys reveals that, whereas a great amount of data and correlations have been produced, the Soviets are now no nearer a satisfactory understanding of these factors than before.

The USSR produces a variety of ferrous and nonferrous metals, including several high-temperature alloys similar to those available in Western countries. Soviet specifications for a nickel alloy similar to Inconel X for use in gas turbines have been found. Inconel X is being used in the construction of a space flight vehicle (X–15) in the United States. The Soviets have made no mention, however, of the heat emissivity characteristics of nickel-based alloys which would provide a more positive indication of interest in employing these alloys in space-vehicle construction. The advantage of Inconel X is its high temperature strength (to about 1600° F); a feature of obvious significance to space vehicle design. Similarly, cobalt-base high-temperature alloys of a composition equivalent to the Western alloy Vitallium are produced in the USSR for aircraft engine applications.

TABLE 6

MAXIMUM EQUILIBRIUM TEMPERATURES REACHED DURING VARIOUS TYPES OF ATMOSPHERIC PENETRATION

PLANET	DIRECT ENTRY AT ESCAPE VELOCITY			DIRECT ENTRY AT ORBITAL VELOCITY			ENTRY BY DECAY FROM SATELLITE ORBIT
	5°*	20°	90°	5°	20°	90°	
Earth	5000	5900	6800	3900	4600	5200	3600
Venus	4700**	5500	6300	3600	4200	4900	3400
Mars	2400	2300	3200	1900	2200	2500	1900

* The re-entry angle.
** Temperatures are given in degrees Rankin (R° = F° + 460).

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Internal structural members and fittings within a space vehicle, although not subject to direct heating, will be subjected to relatively high temperatures and to rapid temperature changes. With suitable design, and possible cooling, the anticipated service temperatures of internal components may be sufficiently below the skin temperature to permit the use of more conventional alloys of construction such as stainless steel or titanium alloys and even certain of the aluminum and magnesium alloys. The USSR produces a variety of stainless steels similar in composition to those produced in the West. Soviet titanium technology is also similar to that of the West and a number of alloys are being produced on a limited scale. Aluminum and magnesium alloys are also produced in the USSR in a variety of compositions. Observations of models of Soviet satellites and the Mechta space probe and its carrier rocket indicates that aluminum is the preferred material of construction. Reports on a Soviet missile production facility, Plant 82, Tushino, claim that duraluminum and stainless steel sheets have been used for missile skins and stainless steel for the nose cones.[10][11]

The refractory metals (primarily tungsten, tantalum, molybdenum and columbium) offer strong possibilities for the solution of extremely high temperature problems encountered in some propulsion systems and in some components upon re-entry. Research investigations on these metals are in progress in the USSR. The biggest barrier to the use of these materials, however, is their low oxidation resistance. Some form of coating must be developed before these metals can be successfully employed in space vehicle components. USSR studies are also being conducted on cermets, silicides, nitrides, borides and carbides; however, there are no indications that these investigations have resulted in significant advances. Related Soviet developmental research in powder metallurgy is comparable in quality to that currently being conducted in the West.

The quality of Soviet metals research is good, but there is no evidence that this native research will provide new or significantly improved materials for use in space vehicles in the near future. It is estimated that, for the next several years at least, the Soviets will continue to follow Western metallurgical research for indications of improved materials or promising research which could be adopted or further developed for use in space vehicles.

Fabrication Technology

Estimates on Soviet fabrication technology for space vehicles are based on USSR exhibits of models of the Sputniks and the Lunik I space probe and its carrier rocket, on the two ballistic missiles exhibited ██████████ ███████████████, and on aircraft structure technology. Soviet space vehicles thus far constructed have utilized conventional aircraft fabrication techniques and are rugged structures; that is, the Soviets have not emphasized weight-saving designs.

For the past 50 years, Soviet workers have been making important contributions to structures technology, especially in the fields of structural mechanics and vibration analyses. World War II developments and subsequent work have been consolidated by the Soviets in a number of good texts and monographs.[12] An examination of Soviet capabilities in structural design indicates that they have the ability to solve the structural problems associated with space vehicles, including re-entry vehicles.

In some aspects of structural theory and analysis that would be directly applicable to the design of a space vehicle, such as design of thin-walled structures, theory of elasticity and possibly creep analysis, Soviet work may be slightly better than that of the West. Although the Soviets are doing good theoretical and applied work in vibrations, the West appears to have taken a slight lead in the associated field of flutter.

Soviet metallurgists have adequate experience in complex metal forming, welding and forging techniques to permit the construction of space flight vehicles using presently known materials of construction. It is believed that as new materials are developed only the minimum time lag will be involved in applying these materials to space vehicle needs.

RADIATION SHIELDING PROBLEM

In 1958, L. I. Sedov acknowledged that radiation shielding poses a major problem for manned space flights.

Of immediate concern for any manned space vehicles are (i) solar flare radiation (which may maintain the radiation levels in the Van Allen bands), (ii) the radiation (Van Allen) bands above the earth's atmosphere (see figure 10), and (iii) cosmic radiation (extremely energetic charged particles such as protons, alpha particles and nuclei of some elements). Any of these types of radiation may increase markedly in amount during solar eruptions, but will not change markedly in character. (See figure 10B); the Van Allen bands will extend somewhat further out during such solar eruptions, and will be more intense by up to several orders of magnitude. When nuclear rockets are developed, possibly in the period 1967-74, it will also be necessary to shield personnel from the nuclear reactor.

Soviet and U.S. satellites and space probes have yielded information on the earth's radiation bands and cosmic radiation. However, from the knowledge gained thus far on this radiation, solutions requiring little or no shielding are possible for periods when there are no solar eruptions. Unfortunately such solar flares are not predictable at present. The earth's radiation bands are toroidal shaped layers above the earth's atmosphere with traces of radiation extending out as far as 30,000 miles, or over 50,000 miles during solar eruptions. The bands are shaped by geomagnetic forces (are latitude dependent) and are not present at polar latitudes. Therefore, one solution would be a trajectory providing for a polar exit and re-entry. An unshielded manned satellite must orbit below 400 miles or above 30,000 miles from the earth in order to avoid the high-intensity harmful radiation bands.[13] For periods of solar quiescence, a possible solution would be to use unshielded manned lunar or space probes and to pass quickly through the radiation bands; there is a possibility that in this manner the dosage received might be less than the maximum permissible dosage. The Soviets have indicated a willingness to do this as a calculated risk.[14][15] Cosmic radiation appears to be a lesser problem than the Van Allen type of radiation.[16]

To shield out the earth radiation bands would require on the order of 10 cm of lead. Part of this shielding is needed for protection from radiation produced by the high-energy electrons striking the vehicle structure. However, if one used this amount of lead in the vehicle, there would be a higher dose contribution from the radiation produced by cosmic rays hitting this shielding. Thus, conventional shielding is not entirely satisfactory for a space vehicle unless cosmic rays can be completely blocked or the radiation produced by them can be completely absorbed.

The basic problem of keeping radiation inside a reactor is much the same as keeping it out of a manned space ship. However, the shielding currently used for nuclear reactors would impose a tremendous weight penalty when used in a space ship. Soviet research is estimated to be underway in a search for lightweight shielding materials which produce a minimum amount of secondary radiation on interaction with primary cosmic radiation. This research is probably conducted at Soviet nuclear energy research installations although there is no evidence of a specific research program. From the small amount of Soviet published material on this subject, it seems apparent that the USSR is now using Western research results and proceeding along parallel lines. Some data indicate that the Soviets are investigating the rare earth gadolinium (Gd) for its neutron-absorbing properties. They also have shown interest in alternate layers of boron-impregnated lead (Pb–B^{10}) and water-boron salt solutions.[17] Both of these studies would be applicable primarily to nuclear reactors and other neutron sources. Other Soviet research includes work on radiation attenuation by the usual types of shielding materials.[18][19] This Soviet work is not currently applicable to the space flight problem, but it will be important for the development of nuclear powered aircraft and space vehicles.
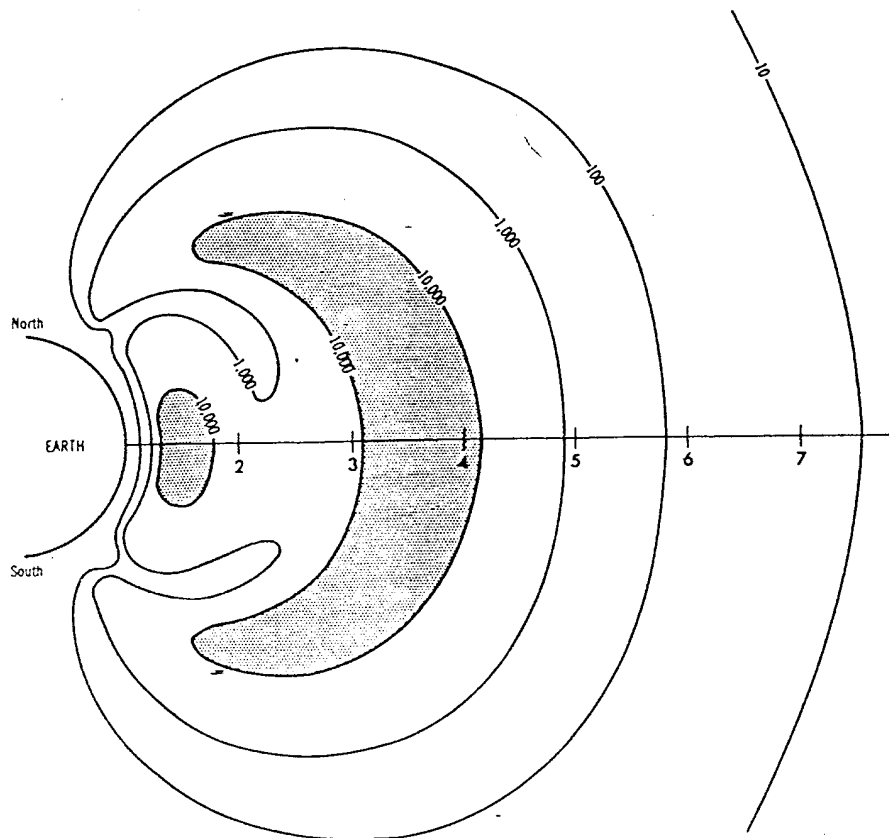
Figure 10a. Cross section of radiation bands surrounding the earth

Cross Section of radiation bands surrounding earth is shown by contours of radiation intensity. Contour numbers give counts per second of charged particles; horizontal scale shows distance in earth radii (about 4,000 miles) from the center of the earth. A relatively radiation-free zone exists over the earth's polar regions. Shaded portion shows the two high-intensity radiation bands which circle the earth. 13/

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Earth and Radiation Belts

Earth
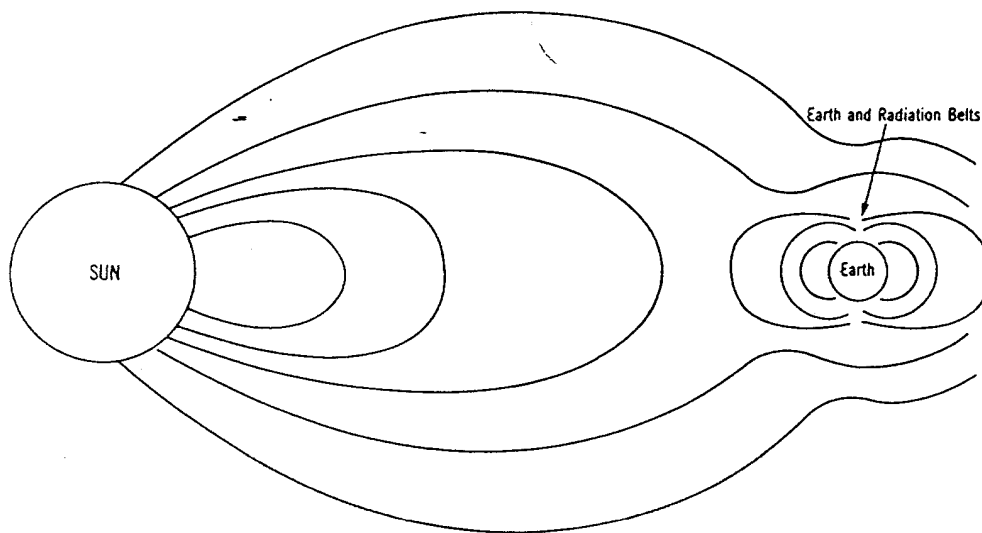
This simplified diagram represents solar flares of charged particles which carry along their own magnetic fields in which the solar charged particles oscillate. When the solar particles and magnetic fields reach the vicinity of the earth they deform and reinforce the Van Allen belts but they also flood the solar system with intense radiation in much the same manner that the Van Allen belts affect the relatively small area around the earth. Such solar activity is quite possibly a mechanism responsible for the maintenance of the Van Allen layers.

Figure 10b. Hypothetical diagram of solar flare activity

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The Soviets will attempt to determine the qualitative composition (protons or electrons) of the radiation bands, either independently or by using U.S. data as it becomes available. A scientific breakthrough could occur which would yield a method of controlling the radiation bands and cosmic particles such that shielding from these would not be necessary, for instance, a new type of electromagnetic field has been proposed as an explanation of gravity and a potential idea for controlling other electromagnetic fields.[27] In lieu of this and during the interim period, the Soviets will probably take this radiation as a calculated risk and make no attempt to shield their first few "astronauts." There seems to be little likelihood that the Soviets (or anyone else) will have made any major advance in shielding within the next ten years.

VERTICALLY FIRED HIGH-ALTITUDE SPACE RESEARCH VEHICLES *

Analyses of Soviet near-vertical firings, in addition to their announced and confirmed successes in space launchings, have provided a significant insight into their space research program. Particularly, these analyses have disclosed important information concerning the vehicles being utilized for this research. This information has a direct application to their military capabilities. The Soviets have made no secret that their space research program is based on military facilities and vehicles; however, they have never specified which missiles were actually being used, except for their ICBM.[20]

The USSR began high-altitude research at least as early as 1949 and has achieved a unique advantage over the West. The Soviets have concentrated on a continuing program of research which to date has permitted them to attain ever-increasing altitudes with their vehicles, carrying heavier and more varied payloads than the West. As a result, they have accrued considerable data of major importance to the Soviet space program.

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* High-altitude space vehicles considered in this report are instrumented ballistic missiles fired vertically for exploring the earth's radiation bands, cosmic radiation, biological conditions in outer space, re-entry phenomena, and especially for the testing of re-entry vehicles.

Since May 1957, the Soviets are known to have fired at least 18 near-vertical high-altitude research vehicles from the Kapustin Yar Missile Test Range (KYMTR); see table 7. There is no doubt that other undetected and unannounced vertical firings have occurred on the KYMTR and elsewhere in the USSR. The 12** with RADINT-confirmed altitudes (16 May 1957 to 10 July 1959) range from about 90 to 255 nautical miles maximum height and probably represent the major firings from the standpoint of altitudes attained and experiments related to vehicle re-entry; for example, vehicle design, construction materials, methods of re-entry, and related scientific and biological factors. Specific Soviet announcements concerning these flights have been limited to the firings on 24 May 1957, 21 February 1958, 27 August 1958, 2 July 1959 and 10 July 1959.[21][22]

These 12 RADINT-confirmed upper-atmosphere and space research firings appear to fall within two distinct groups according to altitude. The lower group of firings attained altitudes of 90–125 nautical miles, whereas the higher group of firings reached altitudes of 240–255 nautical miles. Additionally, the Soviets announced at a TsAGI (Central Aerohydrodynamics Institute) meeting in 1958 that during the period 1949–52, twelve dog-carrying vehicles were launched to altitudes of about 50–60 nautical miles. Similarly, beginning in 1953, about 18 additional test firings with dogs occurred to about the same altitudes. The payload weights have never been published nor has it been possible to confirm the altitudes. On 23 and 25 December 1958, possibly two additional near-vertical firings occurred. ████████████████ ings, but ████████████████ ████████ These pre-1957 firings (over thirty) possibly could represent a third grouping by altitude and probably were accomplished using the Soviet nominal 200 nautical mile ballistic missile.

TABLE 7

SOVIET HIGH-ALTITUDE RESEARCH VEHICLE LAUNCHINGS

CHRONOLOGY	ALTITUDE (Nautical miles)	PAYLOAD (Pounds)	PURPOSE *	SOURCE *
1949–52 .... (12 launchings)	50–60	—	B, S	A
1953–56 .... (18 launchings)	50–60	—	B, S	A
16 May 1957	125	—	—	E, R
24 May 1957	115	4840	B, S	A, E, R
25 Aug 1957	120	—	B	E, R
31 Aug 1957	110	—	—	E, R
9 Sept 1957	120	—	B	E, R
21 Feb 1958	255	3344	G, S	A, R
2 Aug 1958	—	—	G, M	E
13 Aug 1958	120	—	G, M	E, R
27 Aug 1958	243	3726	B, S	A, R
19 Sept 1958	246	—	M	A, ** E,R
31 Oct 1958	246	—	—	E, R
23 Dec 1958	—	—	—	E
25 Dec 1958	—	—	—	E
2 July 1959	90–120	4410	B, S	E, R
10 July 1959	90–120	4840	B, S	E, R
21 July 1959	—	—	—	E
21 July 1959	—	—	—	E
28 July 1959	—	—	—	E

* Key to letters appearing in Columns 4 and 5.

A — Announced   M — Meteorological
B — Biological   R — RADINT
E — ELINT   S — Stabilization, and/or Re-entry, Recovery
G — Geophysical

** Specific date not announced, but this shot inferred from the nature of the experiment conducted. Further details included in text.

At the USSR National Economy Achievement Exhibit, Moscow, February 1959, the Soviets displayed some of the nose cones launched and recovered from vertical firings to altitudes of 60, 115, and 225 nautical miles. The displays also indicated the existence of five basic rocket-launching vehicles identified as A–1, A–2, A–3, A–4, and MR–1. (See table 8.) The latter two were used principally for meteorological investigations. The A–1, A–2, and A–3 (see figures 11 to 13) were used for sending animals to high altitudes.[24] Fragmentary data on the A–1 identifies it as probably the V–2. ▮▮▮▮▮ identifies the A–2 as probably an elongated V–2, possibly the extended-range vehicle (300–350 nautical miles) known as the Korolev missile. Similarly, by ▮▮▮▮▮ the A–3 rocket is identified as the SHYSTER, the ballistic missile exhibited in the ▮▮▮▮▮ (See figure 14.)

Calculations show that the nominal 700-nautical mile ballistic (SHYSTER) missile could achieve the group of firings to 240–255 nautical mile altitude. In addition to the instrumentation, the rocket used in these firings was equipped with a parachute recovery system for returning to earth a capsule containing the two dogs carried by it.[22]

TABLE 8

NOSE CONE WEIGHTS FOR VERTICALLY FIRED ROCKETS

ROCKET VEHICLE	NOSE CONE WEIGHT (Pounds)
A–1	1618
A–2	4840 *
A–3	3344
A–4	825

* Total weight which equals sum of nose cone weight of 3250 pounds and the weights of the two instrument pods (795 pounds each) attached to the center section of the missile.
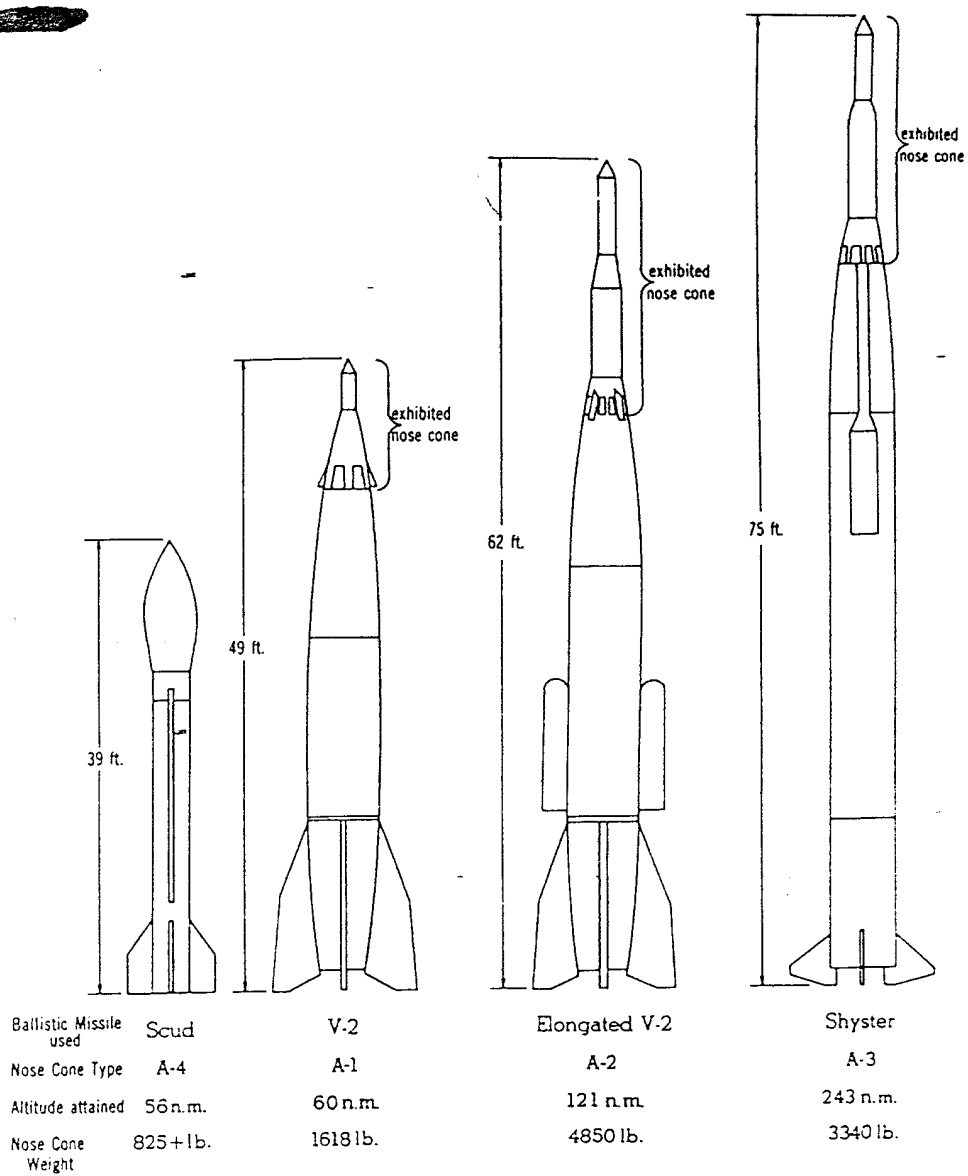
Ballistic Missile used	Scud	V-2	Elongated V-2	Shyster
Nose Cone Type	A-4	A-1	A-2	A-3
Altitude attained	56 n.m.	60 n.m.	121 n.m.	243 n.m.
Nose Cone Weight	825+lb.	1618 lb.	4850 lb.	3340 lb.

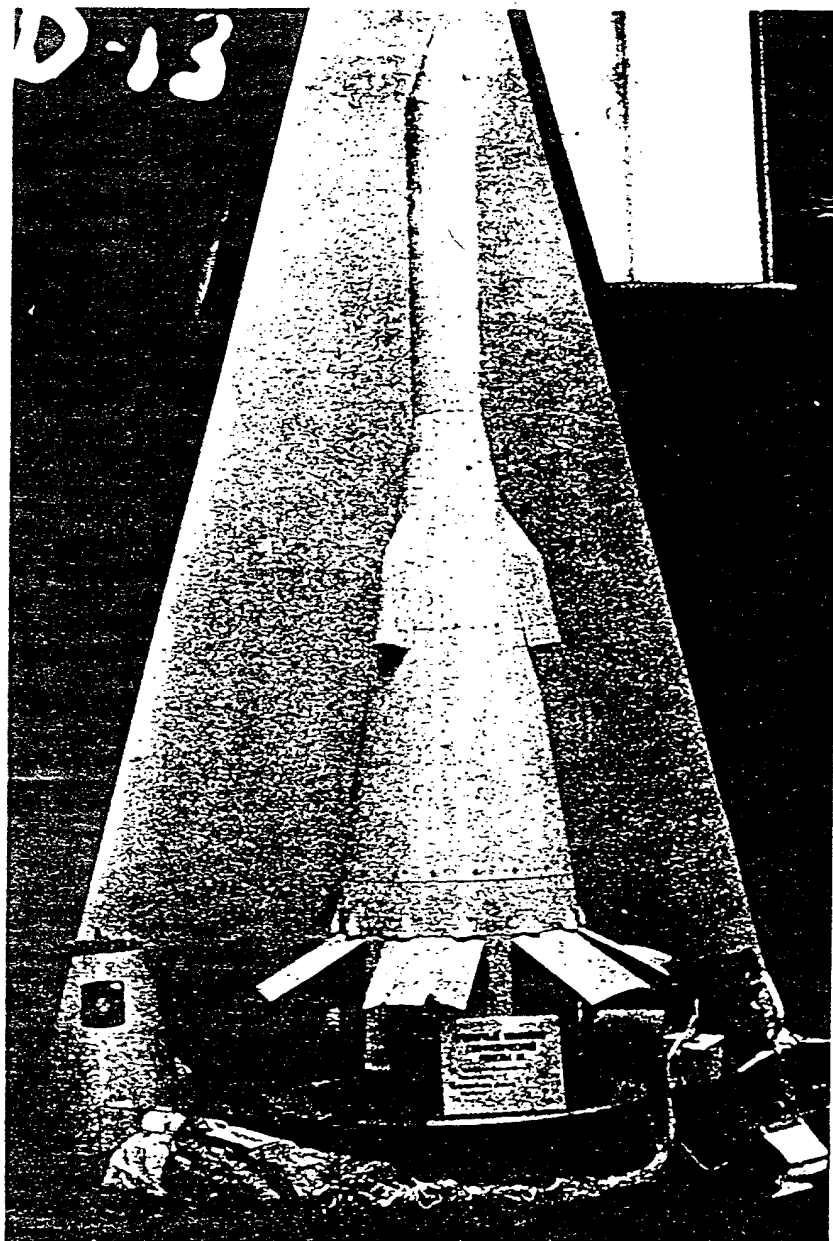Figure 16. Characteristics of Soviet A-1, A-2, A-3 and A-4 rockets

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Figure 11. A-1 nose cone.
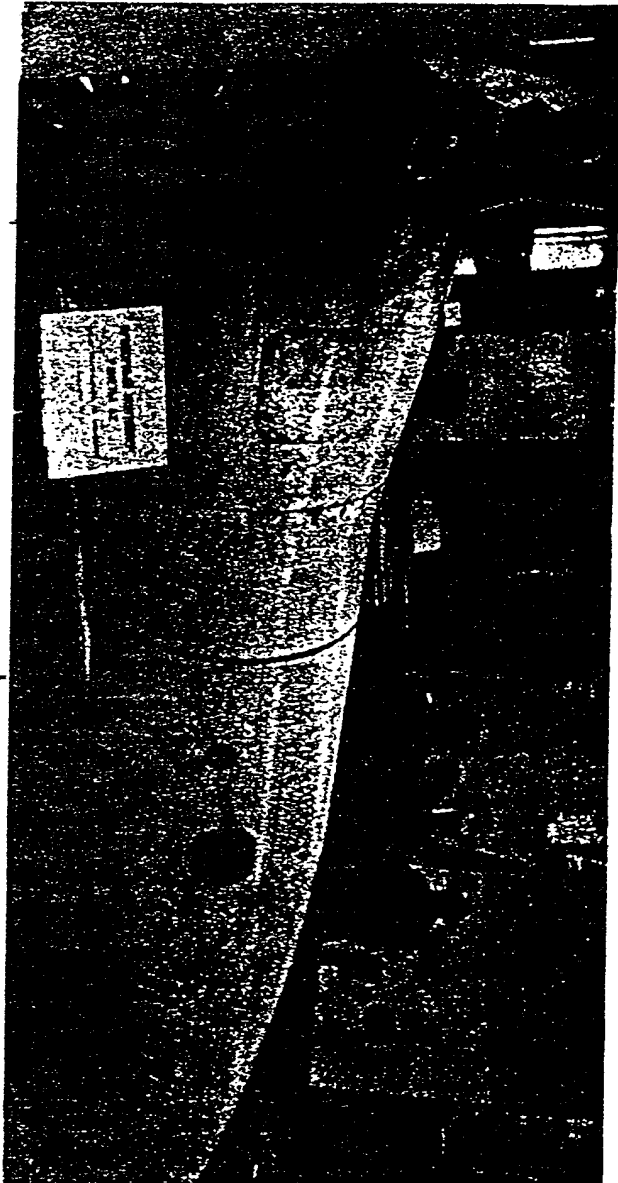
Figure 12. A-2 nose cone.
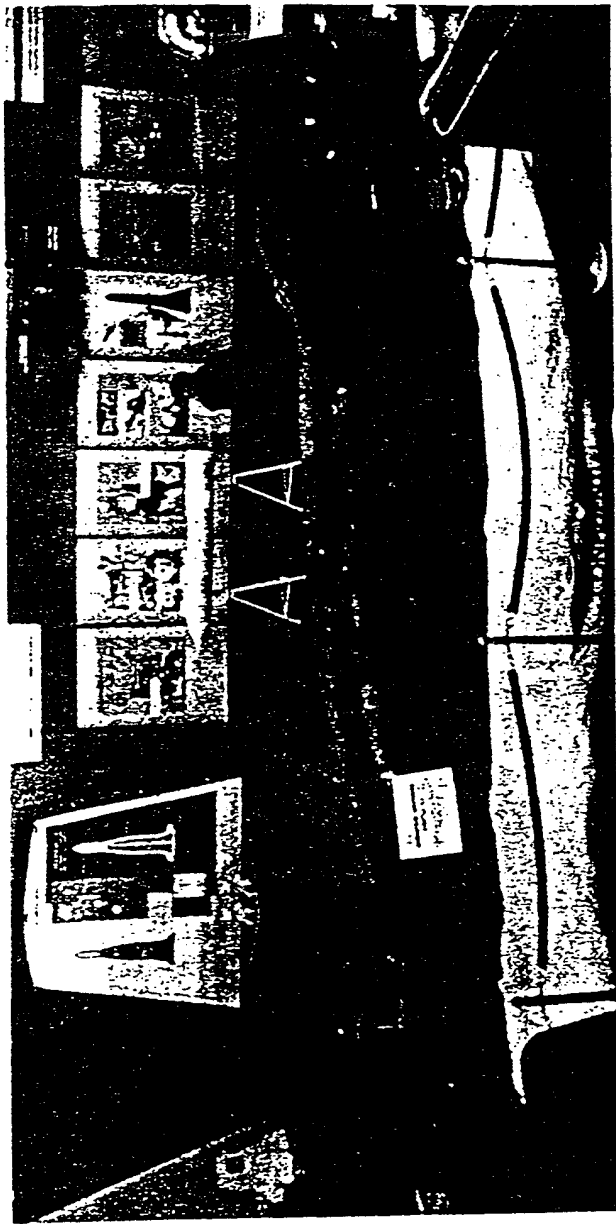
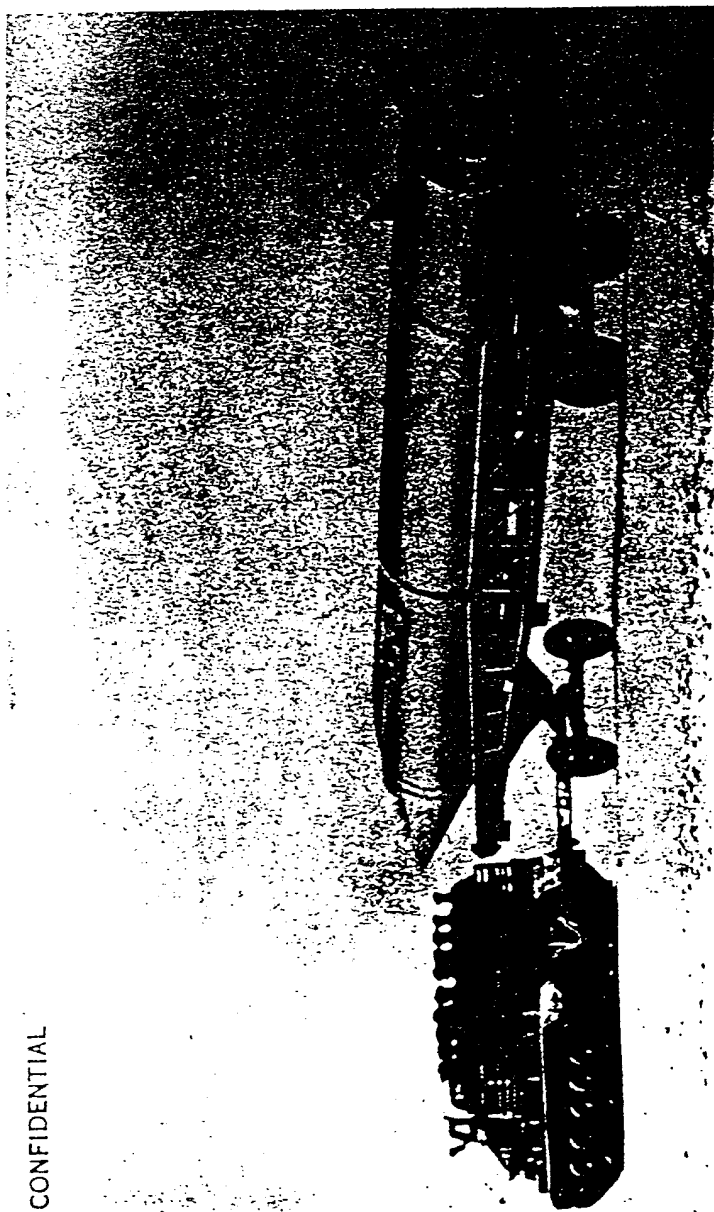Figure 13. A–3 nose cone.

Figure 14. Surface-to-surface missile (Shyster).

The altitude performance (55–60 nautical miles) and a cross-sectional diagram of the A–4 nose cone suggests that the A–4 rocket is the short-range missile called the SCUD (see figure 15), which was also displayed in the [ ] Estimates of the altitude and payload capability of the various Soviet ballistic missiles that are believed to have been used in vertical shots are shown in table 9. Vehicle configurations and heights are shown in figure 16.

From the foregoing it is evident that the USSR has the necessary launching vehicles for conducting a systematic research program at altitudes well beyond the earth's atmosphere. The vertical shot vehicles used to date have carried geophysical, meteorological, and biological experiments as well as furthered studies of the technical and material problems involved in stabilization, re-entry, and recovery of the payload package from vertically fired rockets. Payload weights up to about 5,000 pounds have been used in these studies.[24][25] These experiments and feasibility studies are contributing substantially to the Soviet development of equipment for recoverable animal and manned space flight.

The Soviets have utilized their KYMTR facilities for conducting these high-altitude explorations. This has permitted continuous Soviet monitoring of the performance of the booster vehicle and the instrument package during flight. Moreover, the re-entry and recovery tests of payloads from near-vertical firings occurs at pre-determined points making reliable location and subsequent exploitation possible.

The USSR is expected to continue high-altitude firings, using existing operational ballistic missiles, particularly those of nominal 200, 350 and 700 nautical mile ranges. Additionally, as inventories of the nominal 1100 nautical mile range ballistic missile permit, the Soviets are expected to divert some of these vehicles to the high-altitude and space research program. The propulsion stages of Soviet ballistic missiles supplemented with additional burning stages provide the USSR with the capability of exploring the earth's radiation bands and spatial radiation.

In down range firings, Soviet ballistic missiles have most likely carried instrumentation for investigating the missiles' environmental conditions and re-entry performance characteristics. If the Soviets have not already used some of these down range shots for testing re-entry space vehicles, they are expected to do so soon. All of these missiles give the USSR an early and distinct advantage over other nations in the testing of large re-entry research vehicles.

TABLE 9

ESTIMATED CHARACTERISTICS OF BALLISTIC MISSILES USED IN SOVIET HIGH-ALTITUDE RESEARCH SHOTS

VEHICLE	SCUD	V–2	KOROLEV MISSILE	SHYSTER
Nominal horizontal range (n.m.)	75	200	350	700
Propellants	(Storable)	Lox-Alcohol	Lox-Alcohol	Lox-Alcohol
Specific impulse (seconds)	210	210	220	220
Thrust (pounds	20,000	55,000	75,000	75,000–88,000
Diameter (feet)	2.7	5.4	5.4	5.3
Length (feet)	33	46	—	67
Warhead wt. (lb.) *	1500	2000	2000	3000
Nominal peak altitude (n.m.) **	35	50–75	110–125	240–260

* Warhead weight is as given and defind in NIE 11–5–59 and includes the explosive device and its associated fuzing and firing mechanism. The weight of the nose cone structure, the heat protective material for the nose cone and any adaptation kit are not included.

** The nominal peak altitude of a ballistic missile fired on a near-vertical trajectory is on the order of 40 percent of its horizontal range for the same warhead weight.

RE-ENTRY CAPSULES AND WINGED SPACE VEHICLES

Although there is no direct evidence to support a Soviet manned winged space-vehicle research program, the Soviets have the capability to build a winged space vehicle and put it into orbit. Such a winged space vehicle is one method of recovery of man from a space mission. A manned glide-type winged vehicle using aerodynamic control surfaces can be guided into a shallow glide path descent which is accompanied by a low deceleration rate. It also has the potential capability of selecting its own point of landing. But re-entry (winged or otherwise) raises two major problems: (1) aerodynamic heating and (2) high-speed stability and control of the vehicle. In addition, there are many other problems concerning fabrication techniques, pilot escape provisions and the choice of a launching vehicle if a space vehicle is air launched.

The Soviet investigations on materials of construction could resolve the aerodynamic heating problem for a re-entry capsule and/or winged space vehicle. Solutions to the stability and control problems have already been arrived at theoretically by the Soviets; some have been published in the open literature. However, stability and control will probably be a major problem for the Soviets. Evidence on Soviet fighter aircraft indicates that the Soviets have had difficulty in translating theoretical solutions of stability and control problems in transonic and supersonic flight into operational hardware and apparently are still having difficulties.

A winged space vehicle program is not mandatory for a man-in-space program. The alternative is the use of a re-entry capsule which can be slowed down by drag brakes or retro-rockets, with the final descent made by parachute. The Soviets have utilized drag brakes and parachutes for the recovery of nose cones fired in vertical shots to high altitudes. A Soviet scientist claims that they have found this method to be inadequate for recovering a manned satellite and that a glide type vehicle is necessary.[26]

The various high-altitude vertical nose cones exhibited by the Soviets in Moscow, February 1959, are shown in figures 11 to 13. The nose cone structures appear to be constructed of aluminum. Drag brakes will be noted on the A–1, A–2, and A–3 nose cones.

It is estimated that the Soviets will have solved the manned earth satellite re-entry problem during the period mid-1960 to mid-1961.

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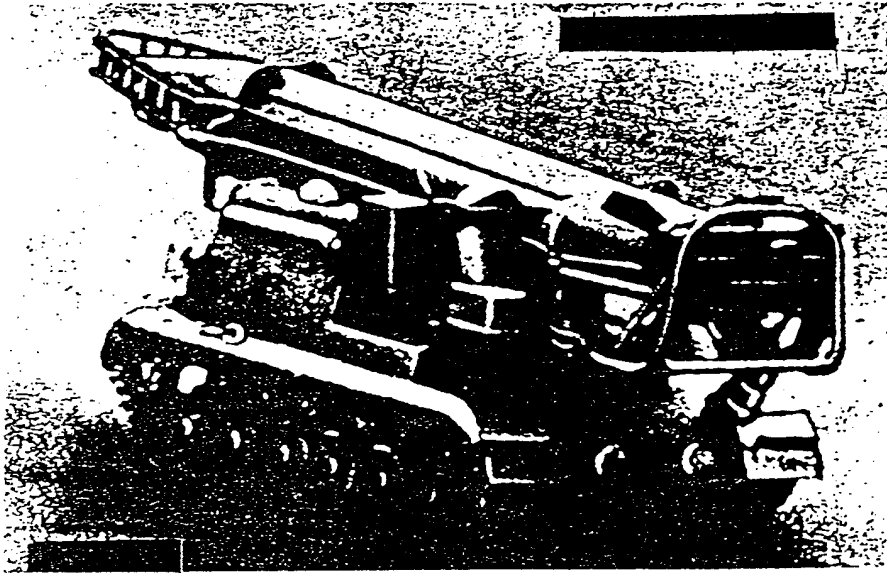ose
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Figure 15. Surface-to-surface missile (Scud).