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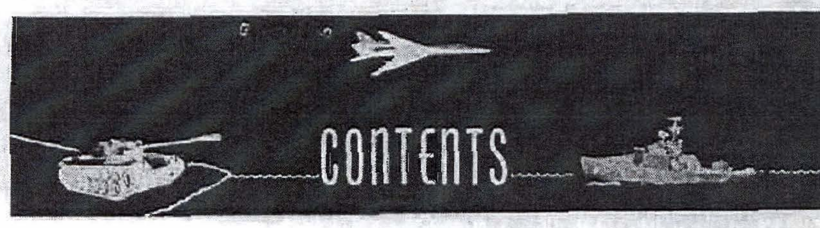

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THE COVER

SOVIET tactical concepts call for fast-moving armor-protected ground forces—in swift movements—to overrun western Europe before NATO forces are able to recover from the envisaged "devastation and disorganization" resulting from Soviet surprise nuclear strikes. Commanders at all levels—division, army, and *front*—now have organic nuclear delivery capability for tactical employment against targets surviving the initial strategic strikes. A high proportion of the better trained Soviet forces are in forward areas, ready for immediate deployment. However, in striving to achieve maximum speed and decisive shock effect, the staying power of both the motorized rifle and tank divisions has been sacrificed. Divisions within the interior, generally, are maintained at a lower state of readiness. For an analysis of some of the problems, see "Readiness of Soviet Ground Forces Varies With Deployment Patterns," page 26. (S)

FOREWORD

MISSION: The mission of the monthly *Defense Intelligence Digest* is to provide all components of the Department of Defense and other United States agencies with timely intelligence of wide professional interest on significant developments and trends in the military capabilities and vulnerabilities of foreign nations. Emphasis is placed primarily on nations and forces within the Communist World.

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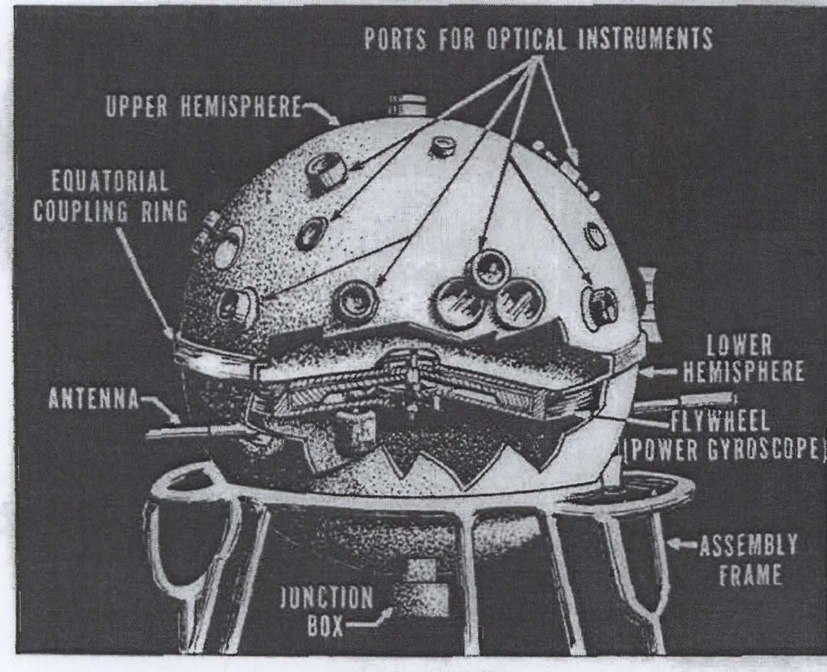
USSR DESIGNS ATTITUDE-CONTROL SYSTEMS TO FIT SPACE PROJECTS

Optical-inertial techniques for space projects evolve according to requirements of the specific mission in the combined program; progress is marked as much by refinement of old methods as by innovations; a recent satellite contained the best features of current sensor/jet development

THE Soviets are pursuing an active attitude-control development program applicable to the variety of probes and vehicles fulfilling the various mission requirements of their space program. Attitude-control methods—observed in the majority of space projects—vary from simple spin-stabilization to the more complex automatic systems. Various optical attitude-error sensors, which include horizon scanners and planet trackers, have been developed and used. A new technique—an ion-flow attitude sensor—may be finding limited use. Stability of the vehicles has been controlled primarily by inertial components. Actuator techniques used to eliminate attitude errors and to correct spacecraft orientation have included flywheels, gas jets, and now, possibly, plasma jets. Indications are that the Soviets will continue to develop and use optical-inertial techniques for spacecraft orientation and stabilization.



HIGH ALTITUDE
geophysical automatic station. (S)

Early development

Developments in vehicle attitude control were first evident in the late 1950's. The Soviets used their vertical rocket program for testing spacecraft orientation and stabilization systems as well as for gathering scientific data in space. Soviet studies of the upper atmosphere during 1957 through 1959 used high-altitude geophysical automatic stations equipped with devices to ensure automatic orientation in space. The primary attitude-control components on board the vertical probe vehicles were optical horizon scanners, body-mounted gyroscopes, and a large flywheel (see figure on left). The optical horizon-scanning system had a field of view of two degrees, with the image focused on a photomultiplier. Three of these optical scanners were mounted to control the attitude of the vehicle axes relative to the local horizon. The flywheel, mounted in the central portion of the payload, acted as a power gyroscope in space and maintained the local vertical of the probe

To change the vehicle orientation, the speed of the flywheel was increased or decreased.

To orient the payload relative to the sun, an optical scanning technique was used. Two photoelectric sensors, which received solar radiation through a large solid angle, were used for rough orientation of the payload. As solar radiation entered a precise orientation sensor, accurate orientation of the payload was accomplished. These sensors were used to determine the position of the sun and the distribution of the solar halo. Orientation of the payload to a given azimuth could be accomplished by using the horizon scanners and the flywheel actuator. To orient the vehicle relative to the sun, the sun sensors were used.

III, launched in May 1958, contained a self-orienting magnetometer with three gimbaled position transmitters that yielded vehicle attitude with respect to the earth's magnetic field. The vertical probes contained and tested an attitude-control system suitable for earth satellite use, but the technology developed during the vertical tests was not used until 1959, during the Soviet lunar probes.

Lunar program

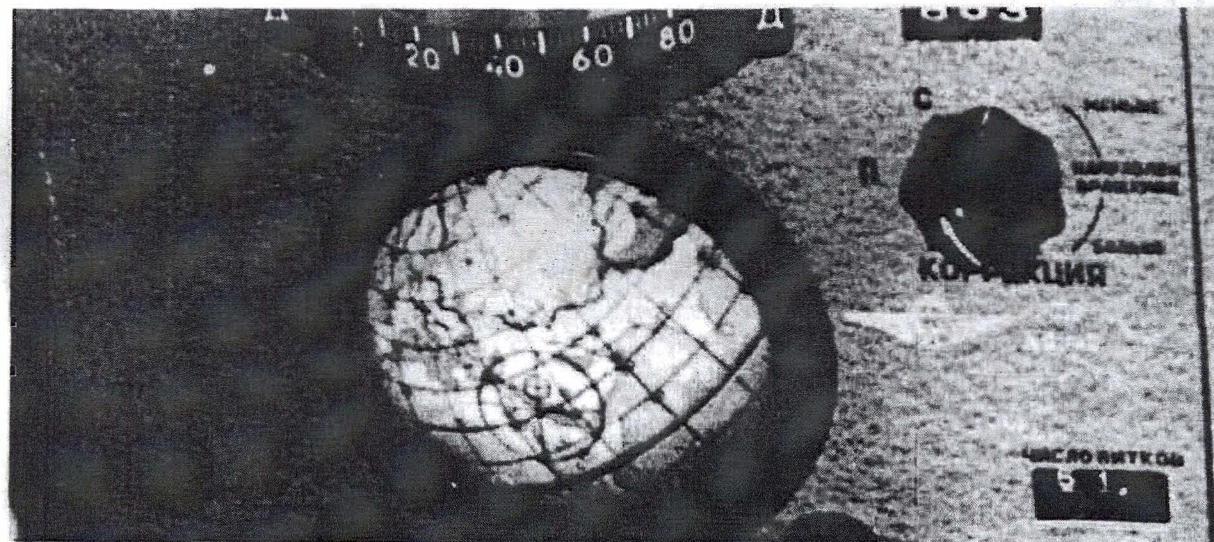
The Lunik III operation contained an active system to orient and stabilize the payload for photographing the back of the moon. An optical orientation system was used to orient one end of the capsule on the sun for a reference and then to orient the other end toward the moon for photographic purposes, using an optical moon-seeker. By using this sun-moon orientation technique in conjunction with gyroscopic-stabilized elements, the payload was in proper position to perform its mission. On completion of the photography, a torque was imparted to spin-stabilize the vehicle. By using a constant angular velocity, favorable temperature conditions within the payload were ensured during the rest of the flight.

Cosmos program

Since 1960 the Soviets have continued to develop and use optical-intertial attitude-control systems, with variations depending upon mission requirements. A variety of launchings using two different launch sites have been made.

The Cosmos vehicles launched from Kapustin Yar are primarily scientific probes using passive spin-stabilization for both attitude and thermal control. Spinup of the vehicle is initiated at termination of powered flight and it is probably internally programed. The torque could be provided by venting fuels remaining in the booster. The spin rate is believed to be about one revolution per minute.

The Cosmos vehicles launched from Tyuratam exhibit continuous automatic attitude control during orbital flight. The attitude-control system probably incorporates three rate-integrating gyroscopes to maintain vehicle reference, with a two-axis sun sensor and a horizon scanner to correct for gyroscopic drift. Gas jets provide torque for the vehicle. An on-board timer and sequence programer commands payload operation, controls attitude modes, and activates correction of the gyroscopes. The attitude system is activated immediately after payload injection into earth orbit, upon entry and exit from darkness, before and after payload operation, and during the preretro period. A recent innovation in orientation observed during a reconnaissance flight

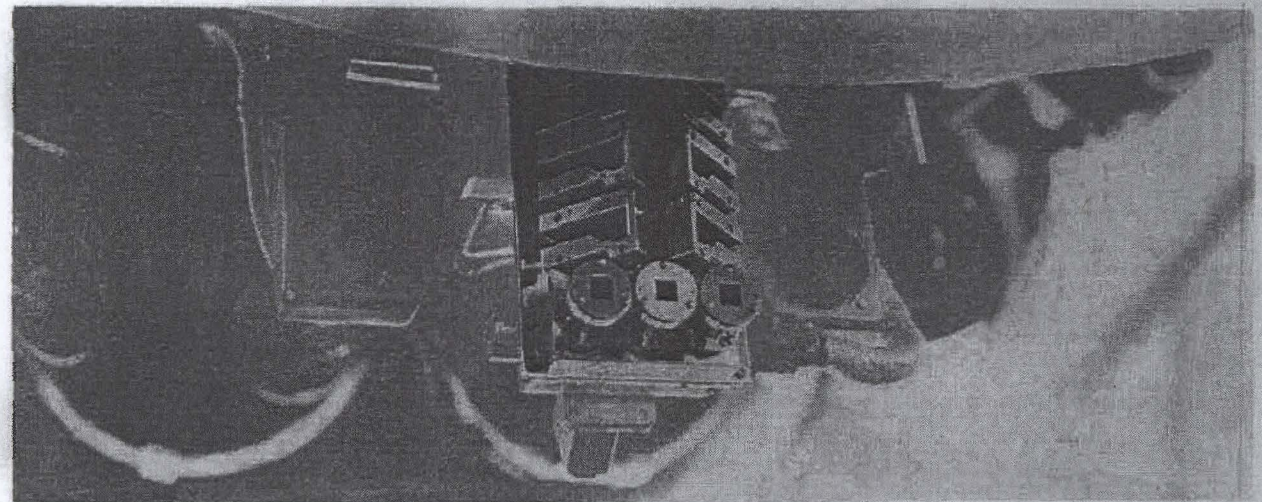


VOSTOK GLOBE DEVICE ~~(S)~~

During normal operation of all the systems, the payload was capable of being oriented within three degrees in the prescribed azimuth, and the payload was capable of maintaining the obtained orientation within half a degree. Development of sun seekers can be seen in the Vostok vehicles, which used a solar sensor for orientation of the retrorocket (see photo page 34).

Earth satellites

Sputniks I and II were injected into orbit with no planned spatial orientation relative to the earth, except perhaps for spin-stabilization. Sputnik



VOSTOK SOLAR SENSOR ~~(S)~~

of this vehicle is the execution of a roll maneuver just before payload operation. The maneuver would facilitate photographing areas normally outside the camera-coverage area during a particular orbit.

The accuracy of the automatic attitude-control system is assessed at 0.30 degree in pitch and roll and 0.03 degree in yaw. The difference in accuracy is that horizon sensors used for determining pitch and roll are less accurate than a point-source solar sensor used for determining errors in yaw.

Manned spacecraft

The Vostok/Voskhod manned vehicles used both manual and automatic orientation systems for spacecraft attitude control. The manual system is basically optical, consisting of a driftmeter-type device used by the cosmonaut to view the earth and determine the heading of the spacecraft. The orientation device is believed to be a rather simple mechanism consisting of two annular reflecting mirrors, a light filter, and a viewing glass marked with lines similar to those on a driftmeter. By viewing the earth's horizon, the cosmonaut can determine the local vertical of the spacecraft, and by looking through the central portion of the viewfinder, he can determine the "run" over the earth's surface. In this manner, spacecraft attitude can be determined. Both the Vostok and the Voskhod vehicles use a gas jet actuating system to change the attitude of the spacecraft, making three-axis orientation possible (see photo, page 35). A control handle is provided to actuate the jets. In conjunction with the orientation device, a mechanical globe is used to denote spacecraft position above the earth. The globe is used continuously during orbital flight. Controls are provided on the globe-device control panel to correct for position and time errors as determined from ground tracking. A dual-drum coordinate indicator, which is apparently mechanically connected to the globe device, gives spacecraft latitude and longitude.

The automatic system, probably a rate-stabilization type, has several modes of operation, including an orbital mode and another mode used for retrofire orientation.

During orbital flight the automatic system does not maintain satellite attitude stabilization, though it maintains the angular rate within the prescribed limits—less than one revolution per minute. The angular rate reference information is probably obtained by caging the attitude gyroscopes during orbital flight. The automatic control system is inertial and is sun oriented for controlling the desired retrofire attitude for ejection from orbit. The method consists of stabilizing the attitude of the vehicle prior to retrofire about two vehicle axes, which are normal to the spacecraft sunline direction. In this mode of operation the attitude gyroscopes are uncaged.

During the Voskhod flights the Soviets took photographs of the earth's horizon to obtain information for use in their horizon definition program. This is a logical program to advance horizon-scanner component development and attitude-control technology. Uncertainties or variations in the geometrical and spectral natures of the earth's disk must be reduced to a minimum. Design of a filter to minimize these errors probably requires a better-than-available knowledge of the statistics of the horizon variations. These variations must be obtained by measurement programs if the full potential of earth-horizon scanners is to be realized.

The Soviets state that they have used a method of spacecraft orientation involving a measurement of the so-called ion wind. The ion wind results from the motion of the spacecraft through the highly rarified particles of the atmosphere.

Historically, the Soviets have equipped their spacecraft with ion traps to detect ionized particles along the vehicle path. A Soviet technical paper indicated that ion traps can be used for determining attitude of a vehicle. Such a device would require two probes or traps symetrically oriented to the velocity vector of the spacecraft. In this case the ion current readings of the probes would be equal; moreover, a difference in the readings could be used to sense the angular error and to generate a correction signal. One pair could be used to determine angle of yaw within two degrees. This attitude sensor technique is not highly accurate, but it is simple and can be used for coarse orientation during space flights, either earth orbital or planetary.

Parking orbit technique

After the Lunik III operation the Soviets began using the parking orbit technique in support of their planetary probes. This technique requires spacecraft attitude control during the earth orbital coast phase and especially during final-stage powered flight. Spacecraft orientation during the earth orbit portion of flight uses inertial (gyroscopic) components. (The presence of a fully gimbaled system, however, cannot be confirmed.) Inertial errors—such as gyroscopic drift—at the end of the orbital coast phase should be tolerable, since the time is less than an orbital period of 90 minutes. The conventional gas jet actuators probably are used during orbital coast to maintain the attitude.

During the Zond I Venus probe, a large amount of vehicle-control activity occurred just before final-stage powered flight. The activity probably resulted from a reduction of the attitude error tolerances for more accurate attitude control. Therefore, probably only coarse stabilization is maintained during the earth orbital phase of flight; later, as the vehicle nears the final-stage ignition point, attitude errors are minimized.

Maneuverable spacecraft

In November 1963 and April 1964 the Soviets launched two space vehicles, which they described as maneuverable. Polyot 2 exhibited an orbital inclination change. The guidance system employed probably is an on-board system, primarily inertial. Because of the short coasting periods, gyroscopic corrections were not required; however, gas jet actuators probably were used to maintain stability during the coasting periods. Attitude-control equipment used by the Soviets during these flights is in keeping with Soviet developments; however, no optical devices were used or required to correct spacecraft attitude. After the maneuvers were completed, the orbiting spacecraft were spin stabilized, with no indication of an active on-board attitude capability.

Planetary program

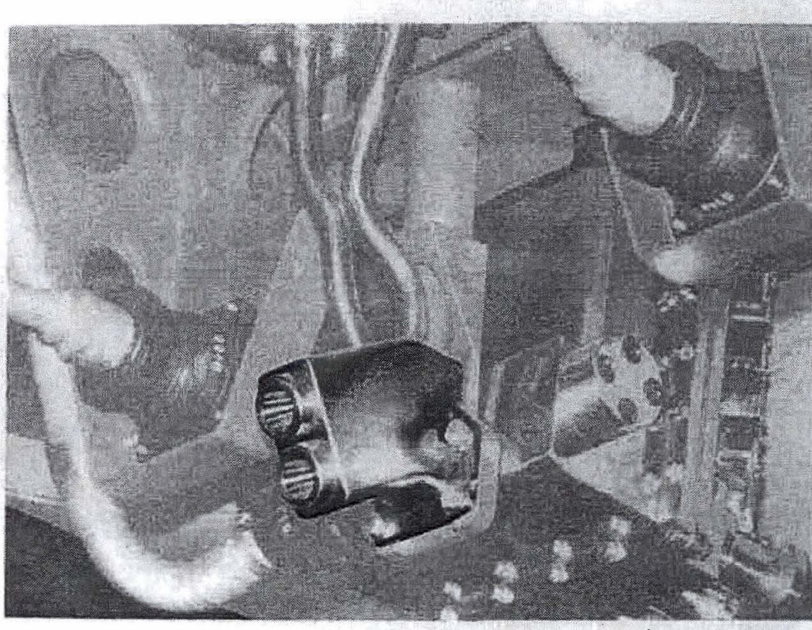
The Soviet Venus and Mars probes have used an active orientation and stabilization system after injection into the planetary trajectory. Early planetary probes used solar panels for generating spacecraft power, and to accomplish this task solar sensors were used to orient the spacecraft and hence the "paddles." Orienting the vehicle on the sun established stabilization about two axes, while the third axis could be established using a second celestial body. Deviations would be detected by the sensors and the error eliminated by an actuator system.

The main actuator technique previously used was gas jets. The Soviets recently announced that they had successfully operated plasma engines on the Zond 2 Mars probe fired on 30 November 1964, to "maintain the spacecraft's position relative to the sun for a long period." They stated that the six plasma engines operated successfully on radio command from the earth. Such a plasma orientation system would be operated only as a fine vernier adjustment, and any rapid or large-scale vehicle-orientation maneuver probably would be accomplished with the conventional gas jet actuators. Consequently the plasma engine attitude-control system probably would be used during the planetary trajectory of the flight to orient and stabilize the vehicle solar cells toward the sun. Power for these engines may be obtained in space directly from solar batteries or from a special power source.

Communication satellite

Recently the Soviets launched a spacecraft called Molniya, which has been described as a communication satellite. The launching techniques were similar to those of the Zond planetary probes and used the parking-orbit technique with inertial-gas jet attitude control. The Molniya 1 was fully stabilized when it reached the final high-altitude, elliptical orbit. The attitude package appears to be in the form of a series of sensors using the sun and earth as references—that is, solar sensors and earth sensors to orient and stabilize the three body axes as well as the antenna axis. To maintain the proper attitude, a system of reaction jets/plasma jets was used.

Soviet space efforts have achieved some spectacular successes. These achievements have resulted from an intensive program that includes study in numerous space realms. Development and research in the techniques of spacecraft attitude control indicate that this field is receiving considerable attention. And while new devices are undergoing research, the optical-inertial techniques appear to be the primary system for orientation and stabilization. [END]



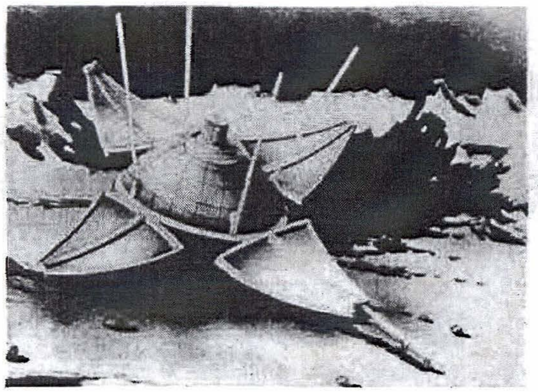
VOSTOK ATTITUDE CONTROL GAS JETS (S)

LUNA-9 SOFT-LANDS ON THE MOON

THE Soviet lunar probe, Luna-9, launched from Tyuratam on 31 January 1966, successfully soft-landed on the moon's surface on 3 February. A number of different pictures were transmitted from the lunar surface by means of photo facsimile. The mission tends to indicate that the moon's surface is hard and capable of supporting man and his required landing equipment. In addition to the facsimile equipment, Luna-9 carried instrumentation to collect scientific data on the lunar environment.

Initially the payload was expected to be operating for at least two weeks. After about four days of operation, however, weakening signals and noisy data indicated that the primary battery power supply was depleted and that no recharging capability existed.

The Soviets state that the payload directed to the moon weighed about 3,300 pounds. Based on this weight and the deceleration thrust required to reduce impact velocity to nearly zero, the weight of the spacecraft as it arrived in the vicinity of the moon probably would amount to 1,200 pounds. The President of the Academy of Sciences, M. Keldysh, stated that the weight of the equipment that soft-landed was only 220 pounds. The instrumentation payload probably was about 50 pounds.



SOVIET conception of Luna-9's moon landing.

The success of Luna-9 marks two significant advances for the Soviets in their manned lunar program. First, the stabilization, attitude control, and retrorocket systems for soft-landing have been successfully tested. Second, invaluable information concerning the surface conditions of the moon has been obtained. The success of Luna-9 is an important step towards placing a Soviet man on the moon. ~~(S)~~

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