NASA TECHNICAL MEMORANDUM

NASA TM-77225

EXPERIMENTS WITH OPTICAL INSTRUMENTS

V. Savinykh

Translation of "Eksperimenty s opticheskimi priborami", Aviatsiya i Kosmonavtika, No. 1, January 1983, pp. 42-43.

(NASA-TM-77225) EXPERIMENTS WITH OPTICAL INSTRUMENTS (National Aeronautics and Space Administration) 8 p HC A02/MF A01 CSCL 20F

N83-31461

Unclas
G3/74 28403

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON D.C. 20546 MAY 1983

ORIGINAL PAGE IS
OF POOR QUALITY

STANDARD TITLE PAGE

1. Report No. NASA TM-77225	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle EXPERIMENTS WITH OPTICAL INSTRUMENTS		5. Report Date May 1983
		6. Performing Organization Code
7. Author(s) V. Savinykh		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address SCITRAN Box 5456 Santa Barbara, CA 93108		11. Contract or Grant No. NASw- 3542
		13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes

Translation of "Eksperimenty s opticheskimi priborami", Aviatsiya i Kosmonavtika, No. 1, January 1983, pp. 42-43.

16. Abstract

Discussion of two experiments performed with optical instruments aboard Salyut 6 and Soyuz T-4.

17. Key Words (Selected by Author(s))	18. Distribution Statement THIS COPYRIGHTED SOVIET WORK IS REPRODUCED AND SOLD BY NTIS UNDER LICENSE FROM VAAP, THE SOVIET COPYRIGHT AGENCY NO FURTHER COPYING IS PERMITTED WITHOUT PERMISSION FROM VAAP.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	8	

EXPERIMENTS WITH OPTICAL INSTRUMENTS

V. Savinykh
Hero of the Soviet Union, Pilot-Cosmonaut of the USSR

After a quarter of a century of the Space Age sophisticated systems have been created for control of satellites, spacecraft and orbiting stations. In both manned and unmanned vehicles all the basic control modes are provided by automatic systems. /12*

But no matter how reliable and sophisticated the automatic systems and computer complexes, the cosmonaut should know how the processes of attitude control of the ship take place. The reliability of any given automatic system is never absolute, and during critical operations involving the safety of the crew, the commander always makes sure of the proper execution of the specified regimes (attitude control of the ship, docking at an orbital station and the descent). Such an operation will continue to be done in the future, regardless of the ever increasing reliability of the automatic systems.

Aboard the Vostok, Yu. Gagarin using the Vzor optical reference controlled the execution of the attitude control prior to descending to Earth. The instrument consisted of two spherical reflector mirrors, light filters and a frosted screen with grid. Rays from the horizon of Earth after leaving the first reflector through the porthole landed on the second reflector and then the frosted screen. When the Vostok is correctly oriented with respect to the Earth, its horizon is projected onto the screen in the form of a closed ring, and the cosmonaut is able to inspect the underlying portion of the

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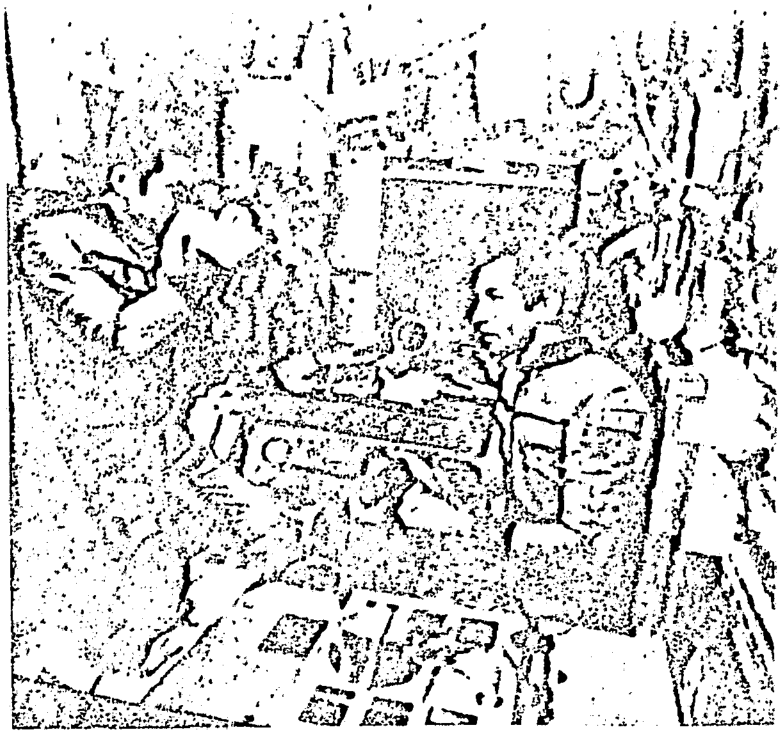
*Numbers in the margin indicate pagination in the foreign text.

Earth's surface through the central part of the attitude control unit. The position of the ship's lengthwise axis with respect to the flight direction was determined by the passage of local reference points in the central field of vision of the unit. Just as on an airplane, the cosmonaut is able to use the passage of local reference points into the field of vision of the unit to determine the direction of the ship in the geographical system of coordinates. The angular velocity of motion of the underlying surface at nadir for a flight at altitude of 350 km is roughly equal to 1½° per second. A similar pattern could be observed from the airplane Tu-154 at an altitude of 10 km.



USSR Pilot-Cosmonauts V.Kovalenok and A. Ivanchenkov.

The Vzor instrument was only able to check the attitude control of the ship, and only in a single so-called zero-indication mode. The complicated flight programs necessitated creation of a new optical attitude control unit installed aboard the Soyuz.

This allows a checking not only of the attitude control in a broad range of angles of misalignment, but also the docking.

The docking unit of the Soyuz is situated on the crew residence compartment. Therefore, to check the docking the crew in the descent module requires a periscopic instrument. Its hair-line can change its direction in space by turning the main prism. The attitude control unit has two fields of vision: peripheral and central. The former allows a checking of the attitude of the ship in terms of a local vertical, the other in terms of the course. Through the central field of vision (with an angle of 15°) the cosmonaut may also observe the orbital station as it is approached. In this case the hair-line is moved to a direction parallel with the lengthwise axis of the ship by turning the prism.

The sight underwent repeated testing aboard the Soyuz and earned a good reputation. Vladimir Kovalenok and myself were entrusted with the concluding phase of the experiments, using photography to document known defects of the instrument that had to be corrected. Before the flight preparations it was necessary for me to study similar sighting devices and explore their strong and weak points. Naturally, we wanted to compare the data of ground experiments with that of actual flight. We also intended to investigate the constraints on checking the attitude control in the region of the terminator, involving glare on the components of the structure and on the porthole. This is especially important when the ship is in "solar orbit".

Working in such orbit is a serious trial for the cosmonauts. The Sun does not pass below the horizon of Earth but illuminates it with oblique rays at low angles. We traveled above certain regions of Earth at the same time when there was either morning or evening and when haze and long shadows were observed. And under these conditions we photographed the screen of the attitude control unit. The photograph revealed glare in the central field of vision. This was caused by the fact that the field of vision of the peripheral and central systems used the same porthole. The Sun was in one of the peripheral windows of the attitude control unit. A light filter was installed in the peripheral window for observation of the Sun and horizon of Earth. Analysis of the reasons for the Glare will enable a correction and enlargement of thc zone of reliable monitoring of the attitude control.

One of the interesting methods of enhancing the contrast of an underlying surface is using the capacity of the atmosphere to polarize sunbeams. By choosing a certain position of a polaroid the scattered light of the atmosphere can be substantially reduced and the observational precision of the passage of local reference points enhanced. The data obtained during flight of Soyuz T confirmed that the checking of the attitude control by means of polaroids enables a further 500 km advance into the zone of shadow.

To increase the precision in checking the course attitude control we use an accessory that introduces an additional magnification in the sighting device, thereby determining more accurately the agreement between the actual course angle of the spacecraft and the given. It was shown that in the case of an ordinary, rather monotonic underlying surface the precision can be raised by 1.5-2 times.

In the process of flight, statistical data were obtained for checking the attitude control above a monotonic surface (wasteland, cloudless sky, continuous cloud cover). Such situations are especially difficult when it is necessary to check the attitude during this time, e.g. prior to descent. /13
Sometimes the passage of reference points disappears for several dozen seconds, as observed by almost all the crews.

The attitude control unit can be used to check the orbital orientation with respect to the vertical and during the night segment of flight a lens screen can be used for the emission glow of the atmosphere at an altitude of about 100 km. However a course orientation by the passage of local reference points is very difficult during moonless nights or in the absence of lights on Earth when flying above monotonous surfaces. In these cases the cosmonaut can check the proper attitude by the motion of the stars across the side portholes of the ship. The constellations of Auriga, Perseus and Andromeda can be recognized without difficulty. And the bright stars Antares, α and β Centaur, Canopus can be seen through another porthole.

During the docking of the ship Soyuz T-4 with an orbital station the crew watched the approach by means of the onboard display, television camera and sighting device. From a distance of about 5 km the station could be seen as a bright dot in the sighting device. This gradually increased in size, and at a range of 500 m the structural elements were quite visible. After approaching the station at a distance of 200 m, the ship hovered. We continued to check its angular position relative to the station in terms of its configuration and the target. We docked in shadow. We continue to check the target, which was lit by the headlight mounted on Soyuz T-4. The sighting device enabled a clear observation of the approach by the crew and provided complete certainty as to the transpiring events.

With no special difficulty we checked the pre-descent attitude, even though unexpected impurities appeared in the sighting device toward the end of flight.

It was important not only to evaluate the proper working of the automatic attitude control system, but also establish the maximum practical precision of the attitude control under such conditions. Leonid Popov and Valeriy Ryumin checked the limit of precision in the solar orientation using the manual control system and servomotors of the station, allowing for the nonrigid structure. Together with the visiting crew that arrived aboard Soyuz-40, we performed the concluding phase of experiments on precision of attitude control under these conditions. Using an instrument with focal distance of 60 m on a screen secured to the ceiling we obtained an image of the Sun more than 0.5 m in size. We then determined the actual errors in attitude control of the station with a precision of 10 angular seconds. During a lengthy time using only manual attitude control we held the image of the Sun on the screen with an error less than 20 angular seconds. The entire process of maintaining the attitude was recorded on movie film, enabling specialists to analyze the peculiarities of such regimes of attitude control and allow for them in future experiments aboard the Salyut station.

In this article we have discussed only two experiments out of several dozen performed with optical instruments onboard the station Salyut-6 and the transporter Soyuz T-4 during our 75-day flight.