uous surface, and the final information falls into a framework which man's sense and experience will recognize and identify.

This photogrammetric equipment and these modern techniques of analysis that I have described are the scientific tools most capable of guiding exploration and assuring success in space. After we have reached the Moon and have established a site, the exploration of outer space—Mars, Venus, and possibly the satellite of another star within our galaxy will be the next goal.

At this homelike luncheon such ideas seem sheer fantasy, but man's experience over the ages has shown that fantasy has, more frequently than not, been proved in the light of subsequent scientific accomplishments to have been too conservative. Who knows now, for instance, what science will develop that will make our trip to another stellar system fact rather than fancy—a trip that may be in the future as routine, as commonly accepted, as our airplane flights are today?

Such trips throughout our solar system will, no doubt, be too far in the future for you or me to personally experience; but, on second thought, maybe not! Maybe some of our younger photogrammetrists will find themselves stationed on the Moon, developing strange photogrammetric equipment—not strange to them, but strange to us—and trying out still more advanced mathematical techniques.

Neither you nor I can really know when or where, but we do know that man is heading in the direction of outer-space exploration. I, for one, have faith that he will get there. And, while our younger photogrammetrists are making their plans for this exploration, since the future belongs more to them than to me, I think I'll sit down and enjoy a second cup of coffee.

*Practical Systems for Preservation of Optical Performance in Airborne Vehicle**

REVERE G. SANDERS,
Vice Pres., Aeroflex Laboratories, Inc.‡

THE problem to be discussed is an old one. It is created by the law of human nature which states that the more man has, the more he wants. The effect of this law is a thing called "Progress."

The subject for discussion concerns the information content of photo recordings made from vehicles in the sensible atmosphere as well as in outer space. Information content can be many things such as:

a. Identifiable ground-control points.
b. Culture detail.
c. Differentiation between soil types, outcrops, timber types.
d. Military Intelligence data.
e. Missile trajectory.
f. Solar spectra and other astronomic data.

For lack of a better method, the quantitative value for the information content of an aerial photograph is considered to be proportional to the system resolution defined in lines per millimeter.

In response to the ever-increasing demand for higher information content in aerial photographs, the optical industry has met the challenge with higher performance optical systems. To complicate matters, there is always the requirement that the photographic system be carried in an airborne or space vehicle of unstable or unusual characteristics.

The difficulty, cost and time of the research and engineering necessary to produce today's exotic optical systems are breath-taking. The results being achieved are worthy of the effort. Furthermore, this is a continuing situation with further progress in store for next year.

* Presented at Semi-Annual Meeting, Oct. 5, 1961 in New York City.
‡ 4825 36th St., Long Island City 1, N. Y.

Of necessity, the test data for an optical system are determined in a laboratory on the ground. Try though we do to simulate atmospheric or space environments, the laboratory bench resolution or distortion tests are the only ones controlled with sufficient accuracy to permit evaluation and differentiation between competing optical systems.

Today's optical systems for non-earthbound photographs are of two types:

a. For aircraft use in the sensible atmosphere.

b. For space vehicle use.

Both of these vehicles present conditions of operation which degrade the resolution potential of the optical system. Of the many factors involved in the degradation process, large and significant contributors to degradation are the various components of vehicle motion.

There are many governmental agencies and commercial organizations participating in the aerial photographic efforts of the United States. Each agency and each company to a large extent specializes in some particular aspect. Aeroflex Laboratories has over the years addressed itself to the task of preserving the resolution of optical systems in mobile environments.

Most of those present at this Semi-Annual Meeting are quite aware of the necessity for stabilizing the optical systems in the airborne environment. Stabilization has amply proved itself and is resorted to whenever maximum information content photography is involved. However, few realize what is involved in advancing the state of the art in stabilization systems. Just as increase in the resolution of an optical system is achieved through the perfection of the design and of the component parts, so it is with the perfection of a stabilizing platform.

A scientific break-through is a glamorous thing. Unfortunately, the advancement of the state of the art in stabilization has proceeded without benefit of any such dramatic occurrences. The tremendous excitement during the 1961 baseball season with regard to the home run record is worthy, of thought. In the years since the Babe Ruth record, many capable men have trained worked, studied, and strained to improve the state of the art of home run hitting. The effect of this persistent hard driving effort has resulted in its improvement by one home run over 34 years—1.65%.

In like manner, the state of the art in stabilization for high-performance optical systems has been advanced by Aeroflex through persistent effort and large expenditures. Fortunately the percent improvement has been considerably greater than in the baseball analogy and has occurred on a steady year-to-year basis.

System performance has resulted from the part-by-part perfection of the component elements of today's sophisticated stabilized high-performance systems. The details of this pattern of improvement follow:

DESIGN

The heavy and seemingly rigid gimbals which surround the optical unit in the old A-28 Platform and its successors have proved to be inadequate to the task of protecting the potential performance of advanced optical systems. The tubular gimbals have insufficient rigidity under high-frequency vibration conditions. Thus, resort was had to a new design approach. The spherical segment gimbal represents a major forward step. It provides far greater rigidity at less weight. Furthermore, instead of a single-track azimuth gimbal, a widely separated preloaded double-azimuth bearing is now possible with further gains in steadiness and strength.

VERTICAL REFERENCE UNIT

The vertical gyro remains the mainstay for use in non-orbiting vehicles. The steadiness aspect of the nulling type gyro is still unsurpassed and is mandatory. Gyros of the synchro pick-off type are inadequate where high-resolution performance is required. The verticality of the gyro reference remains in the order of $\pm 15'$ to $\pm 30'$ depending on whether integrating erection amplifiers are used. Equal steadiness and verticality improved by a magnitude has been achieved by the completion of the Type LS-19 Inertial Vertical Reference. This Schuller tuned system has an RMS vertical accuracy of $\pm 1\frac{1}{2}$ minutes. This LS-19 photogrammetric vertical represents a major forward step both in reconnaissance and in mapping with high-performance optical systems.

The next major step forward in verticality for photogrammetry and reconnaissance will probably result from the integration of the Type LS-19 inertial vertical with a Doppler Radar. This Doppler-Inertial system has been intensively studied. Error analyses show that vertical accuracies of the order of ± 30 seconds of arc can be achieved. As a result of the cost of such a system being very high the equipment has not been developed. Accordingly, no test data exist to verify the attainability of this very interesting order of vertical accuracy.

TORQUER

No stabilizing system utilizing gear drives can be tolerated in a high-performance sys-

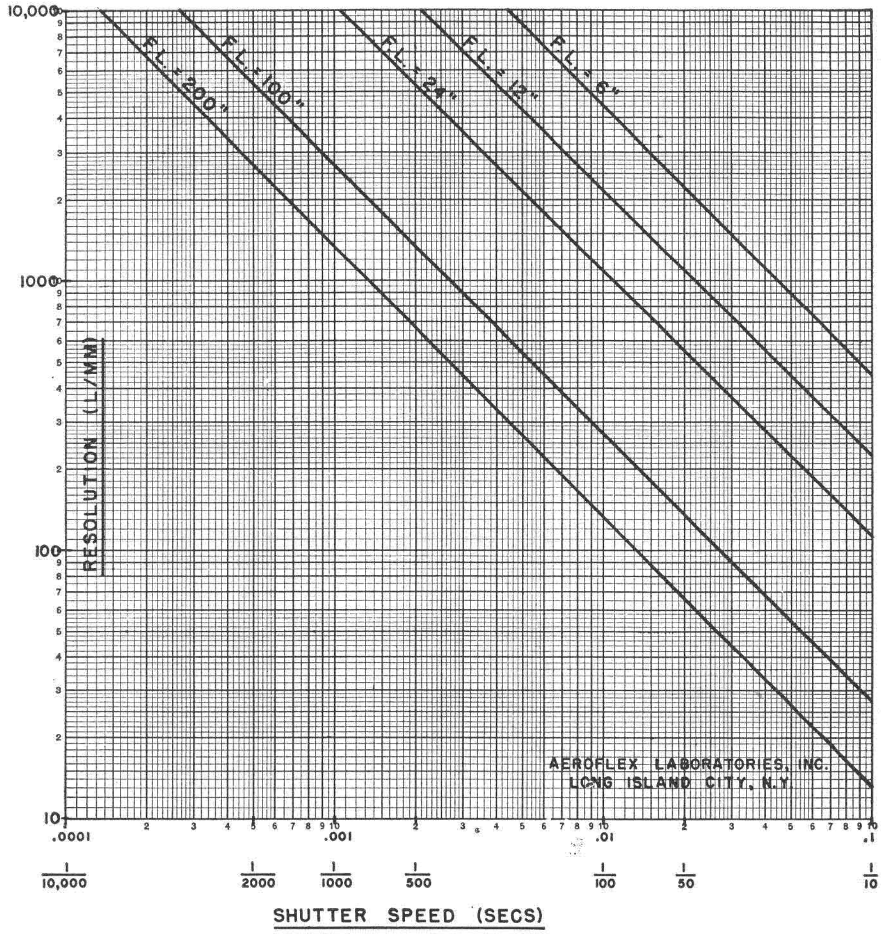

FIG. 1. Resolution versus Shutter Speed for 30 sec/sec Mount Motion.

tem. If the gear trains are sufficiently accurate and are closely enough meshed, they will transmit the resolution-destroying angular components of vibration. The conventionally designed torque motors provide freedom from vibration transmission. However, these conventional torque motors are designed to have a characteristic known as slot lock. The result of this limitation is a step-type of motion which, for high-resolution systems, degrades the performance to the extent of 10 or 15%. The Aeroflex contribution to the advancement of the state of the art in this field is the perfection of the Infinite Resolution Torquer; this eliminates this source of degradation.

DATA BRIDGE

Any high-resolution optical system must be critically balanced to prevent angular motion from creeping in with the attendant degradation of resolution. Any electrical cables which are attached directly to the optical assembly create a dangerous hazard to high-performance which degrades resolution by a factor of at least 10%. The Data Bridge has been perfected to provide a reliable, continuous, and non-coercive transmission of power and control signals to the optical system. This invention has materially increased the resolution performance of the stabilizing platform by completely eliminating this source of error.

WEIGHT SHIFTER

Center of gravity balancing of an optical system is of utmost importance to high-resolution performance both in aircraft and in orbiting vehicles. The automatic sensing of an imbalance to a high degree of accuracy is an attribute of the Infinite Resolution Torquer. However, the conventional method of rebalancing the system is inadequate to maximum performance systems. The conventional system consists of a weight driven by the turning of a lead screw. This system has been replaced by a liquid weight shifter. This consists of two recepticals connected by a tube. One tank is filled with a particular fluid of high specific gravity. A pump in the closed system moves the liquid to counterbalance any static or low-frequency dynamic imbalances. This system has the unique ability to provide energy absorption. The improvement to resolution is in the order of 5%.

ISOLATORS

An advancement which approaches the "break-thru" status lies in the invention of the Cable Isolator. This revolutionary approach to the attenuation of the high frequency vibrations in aircraft provides features not heretofore attainable in a practical form, to wit:

- Low amplification at resonance
- Long shelf life
- Long operational life
- High damping
- Independence from high or low temperature effects
- Independence from corrosion
- Freedom from "bottom-out" effect under shock or acceleration.
- Tunable for final trimming of system to avoid unwanted resonances
- Advantageous packaging capability.

While vibration is not a problem in vehicles in orbit, the optical system is subject to severe shock and to vibration during the launching stage. Protection of the optical system during this critical stage is mandatory if the full operational performance of the optical system is to be obtained during the orbiting phase of the surveillance operation.

BEARINGS

Low friction bearings have been constantly improved by Aeroflex and by other organizations to the point where very little further improvement can be expected from the conventional design. Aeroflex is presently working on an air bearing which is uniquely adapted to the requirements of high-resolution performance of exotic optical systems. By this effort, Aeroflex expects to achieve a minimum increase to resolution of 10%. Additional information will be made available as this in-house program progresses.

INTERTIAL REACTOR

In orbiting vehicles and in balloon gondolas where the mass of the optical system is large in comparison to the mass of the vehicle, any corrective motion imparted to the optical system will most likely result in the optical system remaining stationary and the vehicle itself moving in response to the impressed force. There are two methods to overcome this. One is a system which meters a jet discharge of the proper force and direction thereby holding the vehicle stationary, while the optical system is forced to move in the desired manner. Another system, better in some respects, is the use of an inertia wheel of carefully calculated inertia. The desired motions of the optical system react against the inertia of the wheel, and are therefore independent of the vehicle.

CONCLUSION

The result of the foregoing is the availability of a degree of steadiness on a production basis of 30 seconds of arc per second of time. The effect on system resolution of this steadiness is shown in Figure 1. Steadiness values of less than 30 seconds of arc per second of time are being achieved on engineering prototype equipment.

TO THE MEMBERS AND SUBSCRIBERS!!

"Whenever a new membership, a subscription, or a change of address is sent to us we process it as quickly as possible. However, as with all publications and the administration of mailing list services, the members or subscribers might find a lapse of at least six weeks before receiving the regular issues. By the time the membership or subscription lists are correlated with the mailing date of the magazine, there is by necessity a seemingly long waiting period. Your patience and consideration will be greatly appreciated by the staff at national headquarters."

C. E. PALMER
Secretary-Treasurer