tion before then because he made a six-gimballed system to eliminate gimbal-lock. Of course, as in so many elaborate systems with six gimbals, he did not eliminate gimbal-lock.

The first instance of instrument stabilization was in 1537; a shipboard compass was pendulously erected in gimbals. It was even proposed that on shipboard the man reading a sextant sit in a stabilized bucket. I have no record that this system was actually tested.

The first stabilized aerial photography was done in 1858 by T. T. Tournicot, a French balloonist. The results are not known by me.

The U. S. Geological Survey attempted stabilization in 1918 and the Army Air Corps in 1921. These systems were given up primarily because of lack of good components. They were brute force gyro approaches, and there was not enough then known about gyros to do a good job. The British developed a brute force, gyro-stabilized camera mount in 1945. That one came much closer to doing a job. Their report is interesting in showing that they had the same problems we have had in the last few years. We presently feel we know more about these problems and some of the answers.

Dr. Baker flew a single point suspension mount in 1946 in some work at Harvard. The results from his tests were highly improved resolutions. The first U. S. Air Force production stabilized mount was the A-28 mount. It was a dressed-up, completely Americanized production version of the Steinheil mount developed originally in Germany for the U.S.A.F.

The principles we have been developing and will be discussing today, are those that have existed and were under process of development many, many years ago.

Talking about aerial camera stabilization makes evident that there are really two categories of stabilization. We started out looking for good verticality. The Steinheil mount and the A-28 mount were designed primarily from the standpoint of verticality. There are limits to what mounts can do in improving verticality. While verticality was the reason for getting into the stabilization business, our investigations showed that there was a lot more to be gained by stabilization. The steadiness of the camera while the shutter is open results in improved photography, higher resolution, and the ability to get more information out of the photograph. Earlier today vibration in helicopters was discussed; this type of steadying could well apply in the helicopter field.

There are many related problems and some will now be explained. We will start with Mr. Levick.

Some Problems Involved in Military Reconnaissance Requirements and the Application of Stabilization to Their Solution

MR. TOM LEVICK,
Boeing Airplane Company

IN AERIAL reconnaissance it is more important to locate and identify targets than to maintain camera verticality; therefore camera steadiness is the prime interest in stabilization.

Stabilization of the long focal length cameras which are needed to record detail from a high altitude, results in pictures of much higher quality than could be obtained if the cameras were mounted in conventional fixed mounts. This is especially true during night photography; the combination of long film exposure and aircraft motion would result in excessive image movement on the film.

Boeing recently completed a series of high altitude, night photo tests using a stabilized camera. Exposure time was approximately one tenth of a second; image movement due to forward motion of the airplane was compensated by moving the film during the exposure. The resolution of the photographs thus obtained averaged sixteen lines per millimeter with some measuring as high as twenty-two lines per millimeter. Under identical conditions but without stabilization, pictures obtained during these tests averaged six lines per millimeter.

Reconnaissance devices, other than cameras, are still subject to many of the same environmental conditions which cause loss of quality in photographs. These devices will require stabilization if the effect of airplane motion is to be eliminated and their resolution maintained at a high level.

In high speed airplanes it is necessary to automatically accomplish as many functions as possible. This eliminates human error and frees the crew members to perform other operations. Automatic azimuth positioning of the stabilized camera would eliminate the last minute corrections which now have to be calculated and manually set in a very short period of time.

Design Problems on a Twin Camera Mount Using Brute Force Stabilization

MR. WILTON STEWART,
Hycon Mfg. Company

IN TRYING to achieve high resolution, or long exposure times, one cannot bolt a camera directly to an aircraft. Because an aircraft is not a stable platform, it is necessary to isolate the camera from the aircraft rotational motion. This is usually done by a gimbal mounting, either a three-axis gimbal mounting, or two, depending on whether or not the motion about one axis can be neglected. Mounting a camera on a gimbal introduces a number of other factors, namely, that it is very easily disturbed by small forces.

In designing a stabilized camera mount, the designer would like to eliminate these forces. Since this is not actually practical, he tries to minimize them.

The other approach is to oppose the disturbing forces with counteracting forces, and a combination of minimizing the disturbances and counteracting them is usually used. One of the disturbances entering into a mount is unbalance. If a camera is suspended in such a manner that its point of suspension is not coincident with the center of gravity, an unbalance exists which tends to upset the camera. Mounting the camera pendulously is not a complete solution and sometimes is not a solution at all because of the side forces introduced in aircraft flight. Other forces coming into play are those due to electrical cabling, i.e., the spring forces of the cables, internal torques generated within the cameras, and friction torques generated by the methods of mounting. Slaving a camera to a specific position, relative to dynamic vertical, is not as severe a problem as stabilization. Several servo techniques today are capable of handling this without too great a complexity.