ever, the Air Force has not forgotten the requirement for vertical stability and is continuing its quest for a satisfactory solution.

Every photogrammetrist dreams of some day having truly vertical photographs. In learning to be a photogrammetrist, Chapter 1 of the photogrammetry test gives to a student instruction on vertical photographs, and their similar triangles and simple ratios. He thinks that photogrammetry is a cinch. But then he turns to Chapter 2 which starts out "Since we never have truly vertical photographs we must learn to deal with tilted ones. To learn how, study the rest of this book, plus Volumes 2, 3 and 4."

The original tilt requirement from the Corps of Engineers was for tilts not exceeding $3\frac{1}{2}$ minutes about each axis, making a resultant tilt of about 5 minutes. Five minutes is so near one-tenth of a degree that someone started using one-tenth of a degree, or six minutes, as a criterion. Later this drifted to six minutes about each axis, or a resultant of $8\frac{1}{2}$ minutes. Maybe after this is achieved the original requirement will be reviewed.

The original tilt requirements earlier mentioned would have been useful in setting up the multiplex in areas where control is sparse. However, with modern plotting instruments, like the Kelsh plotter and some foreign instruments, and with higher altitude photography, three minutes of tilt is excessive. Tests to determine how much tilt can be tolerated have not been completed but it seems to be more in the order of one minute. Even with one-minute tilts, there probably would be residuals in our parallaxes which could be recognized and which we would want to remove. Since we wouldn't know which projector to tilt, we might make matters worse instead of better.

I do not want to leave the impression that photos stabilized to $3\frac{1}{2}$ minutes or even five minutes would not be extremely valuable in photogrammetric work. One very important use for such photography is in locating the nadir point of shoran controlled photography. The position of the aircraft can be accurately determined from shoran measurements, but a large error may arise in locating the point on the ground directly beneath the aircraft, especially in uncontrolled areas.

Another very obvious and useful application of stabilized photography is for controlled or semi-controlled mosaics. For such mosaics we now analyze each photo and rectify those having excessive tilts. With tilts under five minutes, we could eliminate this time-consuming and expensive operation. Accuracies of slotted templet assemblies also could be improved with photography having low tilts. There are many applications, other than map compilation, for which low-tilt photographs are superior to those having up to, say, three degrees tilt, which much unstabilized photography has.

Efforts to improve the verticality of the stabilized mounts are being made by the Air Force and Aeroflex Laboratories. Flight tests show that improvements are being accomplished although the problems become more acute as the vertical is approached.

Questions and General Discussion

MR. LEWIS (Pacific Air Industries): In his talk Mr. Beck didn't say whether in his opinion there is much difference in the installation of a camera mount in the jet aircraft as opposed to the conventional type. I don't believe any commercial photogrammetrist today has jet aircraft in the air. However, Mr. Alter covered the question so thoroughly he has me greatly disturbed.

MR. ALTER: Yesterday I questioned one of the lecturers on the advantages he got out of speed. He said that he really didn't need the speed but instead he was looking at the altitude he got out of a jet aircraft. I don't believe speed is of any advantage. In fact, it is a distinct disadvantage. Altitude reduces the cost of photography tremendously, but I think that the problems you run into with a jet aircraft just to get altitude would be many times the problems you have at the present moment.

MR. BECK: From what we have been able to learn in discussion with our vibration and flutter men, we anticipate much less trouble from airplane vibrations on the stabilized mount and expect a lot better resolution of the camera on jet installations.

MR. LEWIS: In what particular types of jet aircraft have mounts actually been installed?

MR. BECK: At present the only one we have is an A3D airplane.

MR. STEWART: I wish to add something more on stabilization, not in the camera mount itself but in the aircraft. Make the aircraft more aerodynamically stable and you have a better platform to work from. Along with the stabilization of the aircraft is increasing the shutter speeds so that the camera can tolerate higher rates of oscillation and still provide high resolution pictures. It generally is a severe problem to increase shutter speeds because the aperture of the lens must be increased to get the same amount of light on the film. Increasing lens aperture compounds the problems of shutter design.

MR. PALLME: The point you have made is well taken. Improving resolution is not the job of only the mount manufacturer; actually it in part is the responsibility of each of those involved in the end photography—the airframe manufacturer, the camera manufacturer and so on.

MR. HARMAN (U. S. Geological Survey): I investigated the single point center of gravity suspension that Dr. Baker worked on several years ago. It seemed to me to have a wide application and afford some means of improving general stabilization especially in photogrammetry.

MR. PALLME: Making use of single point suspension appears promising. Certainly Dr. Baker's work so indicated. His results were exceptionally good for very little equipment, but you cannot use it on a single camera of today's design. The point of suspension must be at the center of gravity and that is somewhere down inside of the camera and probably right in the light path, Dr. Baker's work was on a twin camera mount and the two cameras were so mounted that the center of gravity was at a point where no structure existed and he could put in a single point suspension. Right now this does not appear to be a universal solution to the problem but it certainly does look like a good solution for the multiple camera arrays where the center of gravity will be where the camera structure does not exist.

MR. STEWART: On the new twinplex photography, single point suspension is a real possibility. It might improve the photographs. I haven't had much experience in looking at photogrammetric pictures but I believe you use speeds which are quite high—1/200 of a second or so. I doubt if you will get much improvement in resolution under those conditions, with a stabilized mount or a single point suspension mount. The lenses are not high resolution lenses; probably in the fixed installations that you have, with high shutter speed and short focal length, I am inclined to believe you secure about as high resolution as you can get out of the lens.

MR. PALLME: No matter what we do in mounting the equipment it is certainly true that you cannot get resolutions better than that which the camera can give in a bench test back in the lab.

MR. LEWIS: I again return to the application of jets to commercial photogrammetry. Can any of the panelists give an idea of the first type of jet that might be released for commercial photogrammetrists, and what possible type of mount might be installed in it most economically?

MR. PALLME: Any answer to that would be only a guess and we don't have anyone here from the military who would be able to make such a guess.

MR. DOYLE: The Lockheed F-80 was used as a photographic airplane and possibly there might be some available soon. The McDonnell F2H might also be considered.

MR. LEWIS: In other words, all of that production is controlled by the military.

MR. PALLME: I think that is a pretty fair statement. We all would like to be doing a fair amount of commercial work. Instead we are all doing military work.

CAPTAIN READING (U. S. Coast & Geodetic Survey): Can anyone provide information, unclassified, about the progress of present day gyros? Could you get a gyro which would progress at a very low but more or less constant rate, watch the stars and make observations?

MR. PALLME: All we can say here is that star trackers exist and some are very good. Gyros today are better than they used to be so the question is whether you can

afford to carry a star tracker. In all of the work we have been discussing, a relatively simple gyro is being used. We know we can get a very good vertical, but generally, this requires a B-29, as a minimum size aircraft, to carry the necessary equipment. So the idea certainly is correct; you can be very accurate with star trackers. A question of economics is involved.

MR. DON RADER (North American Aviation): In connection with the problems of designing camera mounts, particularly any in vibration-isolating elements, has anyone come across a material which is really outstanding as compared to existing isolators, and that can be obtained on the market? In the latest program I was in we tried to use a metal device that was sort of a mesh affair in which the resistance of the various wires of mesh represent damping elements. The results were not much better than with ordinary rubber. We have tried all the way from nothing to good soft rubber and come up with about the same answer.

MR. ALTER: If you are talking about deterioration of rubber mounts, I think there has been some trouble due to both heat and ageing. Of course, silicon rubbers have done something to eliminate this. I don't know whether we are talking of the same metallic vibration isolator, but I recently came across one that appeared to be made out of steel wool with a wire screen in it. The testing lab indicates that it is a good substitution for some of the rubber type mounts that have been used. It seemed to be ordinary steel wool wound inside of an ordinary helical spring; it gave excellent results, whereas the rubber type of mount deteriorated during the test they were then running.

MR. STEWART: I understand that Mr. Rader has in mind a camera installation. On such an installation you are generally interested in rotational vibration and are usually completely uninterested in translatory vibration. If you are flying about 10,000 feet, for example, under fairly long exposures and not too high resolution, you can tolerate three inches of translation during exposure and it won't affect your picture at all. Only the forward speed of the aircraft will give translations of this magnitude. What you really want to isolate is rotation and you should probably bolt your camera directly to the aircraft.

MR. RADER: We were successful in the RP-45 bolted directly to the aircraft by solid aluminum blocks. Could softer mounts be substituted? In another smaller jet fighter type they tried everything, and actually they were all about the same. The soft rubber was advocated by the Air Force. They had never heard of this metal type. They found the rubber was as good as any.

MR. PALLME: When any vibration isolators are used it is extremely important to know where you are to place them. This translatory motion can exist in large magnitude. It is often converted into rotational motion by the so-called isolator. Instead of being an isolator the device becomes an angular motion generator in many cases. This is a real problem that one must fully solve and then the vibration isolator can do some good. I think almost any one of the isolators will do some good if it is properly used, at least that has been our finding. Some have better damping characteristics than others and some have much better life characteristics. The important thing is to mount them in the right place to begin with so they don't make the problem worse rather than better.

CAPTAIN READING: Probably one of the best mounts I ever heard of consisted of three pieces of clothes line on a couple of pieces of plywood. Canada has thick-skinned aircraft and wanted to get a wide-angle lens down to the skin so they wouldn't have to cut too big a hole. They hooked it to the camera mount; the azimuth and the clothes line had just the right curve and got the lens down close to the hole.

MR. PALLME: That mount actually had an advantage in that it could have translatory motion but it didn't put in much rotational motion.

MR. HARMAN: It wouldn't handle 32 G in flight.

MR. PALLME: No, and it would be rather difficult for Aeroflex to sell to the Air Force.

This panel must be closed. We have brought forth questions that could get some people started in thinking seriously.