Discussion on Missile Photography

Chairman and Moderator

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Participants

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J. E. Durrenberger, White Sands Proving Ground, N.M.

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A. G. Petrasek, Radio Corp. of America, Harrison, N.J.

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Mr. Lipton: This is the first panel discussion on Missile Photography held before a Convention of the Society. It has been evident for many years that the photography associated with the testing of missiles and similar targets in space is becoming increasingly specialized. The field includes research leading to development of instruments varying in size from tiny cameras to huge missile-tracking telescope installations. The new instruments require infrared devices and electronic accessories, including television equipment, in addition to the familiar components of lenses, cameras and mounts. The complex relationships existing in the atmospheric path from the object to the recording instrument must be thoroughly investigated. Proper photographic emulsions and methods of controlling development are of great importance, and must be carefully chosen. Throughout all this endeavor lies one basic condition of operation: the final result can be achieved by only one attempt — no retakes are possible. It is hoped that this meeting will be followed by many others in which the complete range of problems in this field will be explored, discussed and evaluated.

Mr. Endelman: The effect of atmospheric disturbance on long-range focal-length lenses has not been brought forth with any concrete examples of corrective measures. Can the panel in general tell what is being done in the way of some type of filtering effects or in the actual design of lenses to overcome these atmospheric problems?

Mr. Martz: Several things can be done and have been tried with varying degrees of success. For example, if you elevate a camera station above the layer of heat radiation from the ground, you get improved resolution. This is a standard practice for surveyors who get ten feet above the ground, or higher, on towers if they can.

If you use a shorter exposure time, such as 0.001 sec, or even 0.0001 sec or less, you freeze the small-scale irregular refraction or image blurring that causes the trouble and you get a much sharper image. You may get a very peculiar looking object: a straight line may appear as if broken up into sections because different parts of it are refracted differently, but with exposures of the order of 0.001 sec or less you do get better resolution and less image dilution; therefore you get more range because of increased contrast in the film plane.

Also, you can use long wavelengths, those in the far infrared, since the long wavelength light is less refracted than ultraviolet or blue light. You will, at least theoretically, get less atmospheric blurring effect with long wavelengths, of about 10,000 to 15,000 A, in the optical photographic region.

Mr. Schepler: It should be pointed out that with infrared it is necessary to use much better optical systems to get comparable results on account of the loss of resolution in using the longer wavelengths. Whether you gain or not in going in this direction depends upon the problem at hand.

Mr. Waddell: For the past couple of years at the University of Michigan, studies have been made of sunrise at various times of the year, with a view to selecting sites for astronomical observatories. The studies of the turbulence of the sun, for example, are the most weird and wonderful things that you've ever seen; even at the picture-taking rate of 3000 frames/sec the turbulence is very noticeable on the sun's surface, and it's possible, for example, to get a comparison between turbulence and temperature on the surface of the sun and the surface of the earth.

Mr. Fay: After hearing the comments relative to the effect of increasing lens diameters, can someone tell us the actual fraction of the area of the 200-in. telescope mirror which is usable?

Mr. Martz: The entire surface gives satisfactory results for the purpose for which it was intended, which was as a light gatherer for spectrographic work and for taking photographs of faint stars and faint nebulae. The question of fine detail definition is something else again. There the atmospheric refraction limits quality and, as I mentioned earlier, you might do best with a 20 to 24-in. diameter with an eccentric diaphragm over it, and let the rest of the mirror remain unused. The 200-in. mirror is quite satisfactory for its original purpose of light-gatherer, and not as a fine detail rendition instrument.

Mr. Carrion: We now have an instrument with a 30-in. diameter mirror, 100-in. focal length with which we have gotten very good detail, photographing horizontally at 5 miles. We can even distinguish the branches on trees. We haven't had time to measure this; in fact only this week we showed it to Dr. Schendel.

Mr. Lipton: The point was made earlier this afternoon that the diameter you can use depends somewhat on the geographical location in which you are situated. If you are situated over water or the line of sight is over water, as Mr. Carrion pointed out, you may have less turbulence and less refraction of the air waves to deal with. If you are over ground or hilly country, the result might be entirely different.

I would like to propose a few additional questions for discussion.

Since television equipment is of primary interest to many in our audience, it would be very pertinent to find out what part television can play in these optical instruments.

Then, with regard to photography in satellite tracking, everybody today is interested in the satellite. How about the instruments for photographing or visually observing it?

Next, do we need film emulsions different from those already available, in order to get the best results considering the infrared portion of the spectrum or any other portion of the spectrum?

Will infrared techniques be used more intensively in the future?

And finally, what about aircraft for the use of long focal-length tracking equipment? Can we extend the range of usefulness of optical equipment when there are clouds, for example?

This discussion was held on May 3, 1957, during the Society's Convention at Washington, D.C.

Mr. Carrion: At the Ballistic Research Laboratory our only use of television to date has been in using closed-circuit TV as a guiding scope. The closed-circuit TV has been placed on the tracking telescope in a guiding-scope position, whereby we are enabled to get back a mile or two and track the instrument. This enables the trackers to be out of the impact areas.

Mr. Van Dyke: We, also, have been conducting some experiments, with the assistance of the Denver Research Laboratory, in the use of television as a means for tracking. Our emphasis, however, was slightly different. We were anxious to extend our ability to see a great distance, not necessarily to allow tracking from a remote point.

Unfortunately we found that we were unable to push back the horizon of human vision beyond a given point; that is, assuming a certain optical system was used both as a telescope through which an operator could look and also that a duplicate of that telescope was used with either an image orthicon or a smaller tube and the picked-up information shown on a screen. We were unable to extend a person's vision at the present time, and we decided to await further developments in television tubes. This was in spite of the fact that, regardless of how small the object got, the television screen always was able to produce a finite sized image.

Mr. Petrasek: What orthicon did you use in that experiment?

Mr. Van Dyke: I don't recall the name of the orthicon. We also used two different vidicons with which we were able to get fairly well down into the infrared region.

Mr. Petrasek: Did you try the wide-spaced, low light-level orthicon (RCA, Type 6849), under adverse conditions, such as at night? This instrument was developed about 1½ years ago.

Mr. Van Dyke: No, we could not have, because these experiments were completed about that time. We are hoping that the state of the art is going to catch up on this and that we will be able to go further with it. I understand White Sands is continuing this type of experiment; but at Mugu we've had to drop it temporarily.

Mr. Petrasek: At our Lancaster plant we have improved the low-light-level capability of orthicons and quite recently we have developed an orthicon with a trialkali photosurface, which may enable you to accomplish more in the direction you are going.

Mr. Lipton: Mr. Martz, can you tell us about plans for photographing the satellite?

Mr. Martz: There is an article in the January 1957 *Sky and Telescope;* and in the April 1957 *Journal of the Optical Society of America* there is an article on optical problems of the satellite by Tousey of the Naval Research Laboratories. He gives further references and goes into the tracking problems briefly. But I think I would like to refer this to Mr. Durrenberger who is on the Visual Tracking Committee.

Mr. Durrenberger: There are a number of methods in the mill regarding the actual photographing of the satellite, but once again I think we're going to learn a lot before we're through with the project. The first thing, of course, will be to get the satellite up where it is going or where it is supposed to go. After that is accomplished, the first basic tracking method on which they are depending is, of course, the Navy Research Laboratory's Minitrack system. This is, in essence, a beacon-type unit in which a phase relationship measurement is taken in varying degrees of fineness down on the ground. The angular aiming of the Minitrack antenna system itself is to be calibrated in conjunction with the narrow-angle ballistic camera which has a focal length of approximately 40 in. A flashing light system on an aircraft is to pass through the approximate region in which the Minitrack is expected to operate. The Minitrack stations are favorably deployed for the particular problem.

In order to get as close to real-time data as they can, the flashing light on the aircraft is actually going to be coded in conjunction with WWV time signals in such a way that you will read sidereal time directly and come up with final data in terms of right ascension and declination from the individual stations. This is getting away from the actual photography of the satellite itself.

The information from the Minitrack stations and other sources will be gathered and sent to the Electronic Computer Center at the Smithsonian Astrophysical Institution in Cambridge, Mass. This information is to end up in a rather rough orbit calculation which, in turn, will be relayed to the various IBM Computer Centers or Nunn-Baker Schmidt-type camera stations. These contain a Nunn-Baker Schmidt-type instrument which again is being distributed in locations favorably deployed around the expected orbit. Fortunately, one of these stations is going to be right in our backyard at White Sands. There was a complete write-up on the Nunn-Baker Schmidt in *Sky and Telescope.*

The people who are going to operate this unit tell us that they expect to cooperate very closely with us who are in the amateur visual observers' groups also scattered through the world. As a backup, and quite frequently backup instrumentation turns out to be prime, we are setting up, on a completely volunteer basis, groups of visual observers with comparatively wide-field, low-magnification telescopes, comparable to a rich field telescope, aimed along the meridian so that observers will actually have overlapping fields. We intend to cover an area from about 45° of declination from our Zenith in both directions. The expected magnitude of the satellite, if it is in the predicted orbit, has been variously mentioned as 5.6, 6.2, 6.3 and out to beyond 9th magnitude, which we cannot expect to get by the limited light-gathering capability of the so-called Moonwatch scopes. These are essentially nothing more than a telescope which will give a 12° circular field with a 5½-power magnification, arranged so that in the 12° field you can circumscribe an 8° square in such a manner that the successive observers have a ½° overlap in their respective fields.

Should we detect a satellite, which of course would be going at a very rapid angular rate, there will have to be a minimum time delay in order to alert the crews, since the Nunn-Baker camera from the Smithsonian will be only about 15 airline miles east of us.

However, we expect to be able to transmit information by radio, giving the approximate declination and right ascension of the satellite as we spot it. We, of course, are rigidly oriented along the meridian. The Nunn-Baker's are in equatorial mounts so that they will have tracking capability. Since the expected approximate angular velocity is known, if we give them an indication of what the declination will be, they will then start with their very wide-angle unit. Radio will be the quickest way we will be able to alert the local group. Any hope of detecting it by any of the normal satellite-detection means, such as Prof. Tombaugh has perfected in his work for the Office of Ordnance Research, is unlikely because of the very high angular rates and the fact that the satellite is only going to be visible from the earth during periods of twilight — before sunrise and after sunset. This means that there is a good chance that there will be considerable skylight background during the period of transit, which will make photography extremely difficult on a random search basis.

Mr. Lipton: What does the panel think about the need for different kinds of emulsions on film compared with what now exist?

Mr. Clemente: The tremendous increase in film speeds that has occurred in the past five years, both in black-and-white and color emulsions, has certainly alleviated a lot of our difficulties. We've been very gratified to see these increases.

Mr. Hunter: There is a new material just being readied for release in long lengths for theodolite use. It's known as Super-Anscochrome and has a nominal speed of 100. Apparently installations like NOTS are using regular Anscochrome in their theodolites at a speed of 125, which badly aggravates grain, does not help out definition, etc. This new material gives results quite comparable at 100 to regular material at 32. This will help, but we're quite confident that users like NOTS will be using a speed of around 400, so we will be right back where we were. I believe that these speeds of 400 will allow them to use either smaller lens diameters or shorter exposure times; either one or both should help this definition problem.

Mr. Durrenberger: Optically and mechanically, we are very rapidly approaching the ultimate for our optical capabilities with reference to ballistic cameras.

I doubt, however, that we have yet reached the ultimate for emulsions, which are what we are actually measuring in getting our final data. Quite frequently, as we go to higher speed emulsions, not only do we get a coarser grain, but in order to cover the spectral sensitivity that we desire together with high speed, we end up with thicker and thicker emulsions.

Within a very short time we are going to have available comparators which will consistently be able to read out to a micron and which will have automatic digitizing devices capable of transmitting information or recordings good to $\pm 2\ \mu$. Now in order to make full use of the capabilities of the tools we are getting, I believe we are going to need thinner and thinner emulsions which should, in turn, be subject to less randon emulsion shift. Right now, random emulsion shift actually does not match the precision which the other components have achieved.

Mr. Clemente: Greater speed also is a help in the area which was discussed earlier. We have found that in the Bowen cameras, where we use a mechanical rotating drum shutter, the blurring of the image due to refractive disturbances in the atmosphere seems to disappear very rapidly as you get below 100 μsec exposure. We can very definitely notice the difference in the blurring of the image of a fixed object such as a telephone pole. There is considerable difference between a 20-μsec exposure and a 100-μsec exposure, which indicates that the heat waves or shimmer produce complex waves which include frequencies that run up in the neighborhood of 5 kc or higher.

Mr. Van Dyke: I'd like to return to what I spoke about earlier — in the hope that there are others interested in the availability of high-speed tracking equipment at this time. At Point Mugu we have four tracking mounts which we call Motu's (mobile optical tracking units). Each is capable of angular velocities of about 60°/sec and angular accelerations of about 60°/sec squared. These mounts also are capable of carrying a camera load of about 300 lb. At the present time we have a 70mm Mitchell and a 35mm Mitchell on the mounts and the 70mm is equipped with a 300-cm focal-length lens, and the 35mms are equipped with 60-cm focal-length lenses. There's space available, if necessary, for another camera to be mounted. These instruments photograph azimuth and elevation scales with about the same general range of accuracy that the Askanias have, and have just been turned over to operational service.

Five more of these instruments, but this time without the actual scales, are planned, three to go to Patrick and two to NOTS annex in Pasadena.

Mr. Endelman: What do you suggest when the tracking rate can be extremely slow but the error should be only one to two seconds of arc?

Mr. Van Dyke: Accuracy to within 1 sec of arc, which is 1 ft at 40 miles, is more than we can hope for at present.

W. J. R. Brown: With respect to the film sensitivity problem which was discussed a few moments ago, we are completing a fairly extensive study of atmospheric optics at the AFMTC range. An experimental film has been obtained for this use from Eastman Kodak Co., labeled Special Order No. 1166, but, of course, available to anyone. This may represent the prototype of an aerial film called Kodak Plus X Aerecon Film (Eastman Kodak Co. states that this film is now available). In our laboratory and field tests this film has been found to be roughly comparable in graininess and resolution to the present Kodak Linagraph Shellburst Film which represents some sort of standard in the field of aerial missile photography. The new film has perhaps a little lower gamma, but it has the advantage of some four times the speed. Although in many cases this speed is of no particular advantage since the optical systems are perfectly capable of operating satisfactorily with what is available, in other cases this film would perhaps represent a real advantage. In our extensive laboratory and field tests it has been found acceptable in all ways, if the slight loss in gamma, in the neighborhood of 20%, can be tolerated.

Mr. Clemente: In some of our work we are using black-and-white film in the 25 to 75 times underexposure region where we find that the normal film-speed ratings, which are made for the more linear portion of the H&D curve, don't have much meaning for us. Actually we are more interested in the shape of the toe of the curve than anything else in this particular area, and this is something that we find is not generally known. We find it very difficult to get any information about films unless we can actually take them out and use them.

W. J. R. Brown: These speed evaluations were made on that basis, not on the basis of the conventional ASA speed index which, as you say, has virtually no meaning in this particular case. This particular film performs very nicely indeed in the underexposed region.

Mr. Lipton: Will infrared techniques be used more intensively in the future in the type of work which we have been discussing today?

Mr. Schepler: Using infrared may not help as much as would sometimes be expected. In our use of infrared, for example, we have made a coordinate cell for measuring tracking offset, or what is sometimes erroneously called tracking error, using lead sulfide on a glass plate. This plate is put in the camera in place of the film. We are using it on a Contraves cinetheodolite. The system provides an angular position of the target with respect to the camera to ± 0.1 mil.

In land and airborne tests of this device, we have obtained some improvement in range over our photographic method. Tests that have been made on other ranges and by some commercial organizations have shown equal or better results in the yellow and red regions of the visible spectrum than in the infrared.

At the Air Force Armament Center we are constructing an infrared target range for measuring airborne infrared detectors. Either heating coils or hot water pipes in a strip of blacktop pavement, 450 ft long and 150 ft wide, will make it possible to turn heat on and off to get various widths of hot strips and adjacent cold strips, thereby providing a resolution chart for infrared testing. By flying over this strip with an infrared detector we will be able to measure the resolution, the sensitivity and the detectability of the infrared detector.

Mr. Kinder: We have found, working with various types of detectors for tracking error or offset, that the main difficulty is with signal-to-noise ratio rather than angular resolution as no beacon is permitted on the missile. It is necessary to determine automatically which is the target in respect to the noise background. This requires a better signal-to-noise ratio than if there were a human operator there to decide. We are working with various methods of space filtering, frequency or wavelength filtering, tuned amplifiers, and television methods of improving contrast, each of which improves the signal-to-noise ratio.

Mr. Petrasek: Depending on the ways you are using the infrared detectors, it may be of interest to note that there are available some gold-doped germanium infrared detectors which will probably go out into the far infrared, to about 10 μ.

Mr. Schepler: That is of great interest. Even though we are doing no development in this field, we are interested in the infrared detectors available and being developed commercially. At present, we are planning a program at Patrick AFB with a type of detector system for tracking missiles similar to the one I previously described. There is really a fine, hot infrared source in the tail end of a missile, which is ideal for tracking. This appears to have good possibilities for achieving good range, which we have not been able to achieve with the coordinate-cell system. This was partly because we had to put a pulse infrared source on our target, and it turns out that a large aircraft is needed to carry a source large enough to get any appreciable range. This is a definite limitation. We expect to get considerably more range when we run these tests on missiles at Patrick.

Earle B. Brown: Could Mr. Schepler advise us what is the color temperature of the infrared sources that he has been using?

Mr. Schepler: We have been using a pulsed source developed at MIT, but I cannot tell you offhand the color temperature of this source. We are investigating missile rocket plumes from this standpoint and we expect to determine the spectral distribution of the energy and to locate hot spots in the plume. If you cannot locate a hot spot, the resolution will be considerably less. If we can detect hot spots in the plume it will mean that we can position the missile much more accurately.

Mr. Lipton: What is the feasibility of using aircraft as a mount for optical tracking equipment of moderate or long-focal-length lenses?

Mr. Van Dyke: We have been successful at Point Mugu in taking stationary camera pictures, in an airborne situation, with lenses as long as 40-in. focal length.

W. J. R. Brown: In the Physical Research Labs at Boston University, we have considered the problems of airborne surveillance for targetry. Our particular field of interest is not that of theodolite angular measurement, but simply of surveillance photography. With our ground measurements, using equipment at Patrick, we found that with an $f/10$ 20-ft focal-length system we were obtaining resolution from the ground of airborne targets at roughly between 10° and 30° elevation, running from 8½ microradians down to approximately 50 microradians, largely as a function of the differential refraction or heat shimmer which was apparent at the time.

In the course of the study it became quite apparent that if things are to be seen at a considerable distance, you need considerably better than 50 microradians. Consequently we embarked on a feasibility program, at least in terms of what can be done with an airborne camera station. We feel that, based on experience with long-focal-length optics stabilized in gyromounts, etc., such a system could very well be described which would attain somewhat better than 8 microradians at all times with focal length up to 20 ft.

Letter to the Editor:

Magnetic/Optical Stereophonic Sound

These comments are in reference to the Discussion published on p. 763 of the December 1957 *Journal*, at the close of the paper "Further Data on Infrared Transparency of Magnetic Tracks," by George Lewin, which was presented at the Society's Philadelphia Convention with a demonstration of stereophonic sound from a magnetic/optical film. In relation to the information set forth by Dr. Frayne and Col. Ranger in the discussion of Mr. Lewin's paper, these comments are submitted on the basis of the technical work done at Telefilm, Inc., facilities to produce the stereophonic demonstration film, when it was my privilege to work closely with Col. Ranger in the technical production of this film.

When these experiments were started, we realized, as Dr. Frayne pointed out, that magnetic and optical are two radically different methods of recording. This in itself does not, of course, mean that the two systems cannot be aurally matched. Disk recording and tape recording are quite different, yet with equipment developed in the last few years, we can now produce a disk recording virtually indistinguishable from its original tape, even when compared under the most critical conditions.

Similarly, we in the 16mm film industry now have available to us new recording galvanometers, new emulsions, and automatic controls over processing and printing, so that we are now making tracks on 16mm release prints that would have been considered adequate for 35mm only a few years ago. Projection equipment is constantly being improved to take advantage of these better tracks.

At the present stage of the art we have little difficulty supplying a 16mm release print track with essentially flat response from 75 to 7000 cycles, and a number of experiments have been conducted demonstrating the possibility of extending the range even further. (I believe Mr. John Maurer has been quite active in these experiments.) Intermodulation and harmonic distortion are still with us, but with modern quality control methods in developing and printing, along with the new recording galvanometers, we are getting quite good results in our attempts to get lower distortion readings. I won't say they are as good as we would like to have them, but, for instance, we can hold single sine wave distortion in the mid-frequencies to about 5%. This certainly leaves room for improvement, and yet, unless you play the track on a very good speaker and in a dead room, you don't hear the distortion at all. Cross-modulation distortion is not a serious problem. With good processing and printing control the cross-modulation distortion on variable-area recordings can be kept well below audibility. I believe most people in the industry are getting about a −38 to −40 db, using the standard test procedures, which is quite adequate.

With magnetic sound primarily in mind, there is no practical reason why the magnetic frequency response cannot be limited to match whatever is available on the optical; and for that matter, we could deliberately introduce a little noise and distortion into the magnetic in order to better match the optical. So I think if we proceed from the standpoint of getting the best possible optical and then matching the magnetic track to it, there is no reason why we cannot get a very acceptable match between the two. I might add parenthetically at this point that since the two tracks are normally played at a lower level when used together than if either was used monaurally, the inherently higher noise level of the optical track is quite a bit less apparent.

An additional advantage of the optical magnetic combination over a system using two magnetic tracks lies in its compatibility. The fact that this is only a two-channel system makes it feasible to use only one track if necessary, in the same way that one can listen to only one side of a two-channel radio broadcast and still hear an acceptable program. Compatibility is going to be a big issue if 16mm stereo is to become accepted production technique. The use of an optical track covered with a halftrack magnetic stripe would allow the print to be played on any 16mm sound equipment presently in use, while machines equipped with lead sulfide cells could play the additional optical track under the magnetic, with corresponding improvement in output and signal-to-noise ratio.

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From John A. Maurer

In response to the request to review the comments:

I agree in general with what Mr. Guy has said, but it should be pointed out that he has understated the case as to the quality that can be obtained with 16mm optical sound. During the past few months, I have made a large number of tests by rerecording from ¼-in. magnetic tape records to 16mm release prints using the linearity-compensated variable-density system which I described at the Philadelphia convention, with a frequency response flat to 11,000 cycles. The results have been pleasing even when played in direct comparison with the original tapes.

When properly designed, wide range recording equipment is used, the only really noticeable difference between magnetic and photographic records is the higher background noise of the latter. As film is generally processed in the industry, this difference is of the order of 15 db. Most of the noise of the photographic track, however, is due to suspended matter picked up by the film from the processing solutions, the wash water, and the air used for drying. Photocell hiss and the noise due to the