PHOTOGRAPHY IN THE ROCKET-TEST PROGRAM*

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SUMMARY

The vast bulk of information gained during a rocket or guided-missile test firing at Inyokern is obtained photographically. This type of detailed recording requires a large number of specialized photographic instruments of various types. They include cinetheodolites, ribbon-frame cameras, high-speed motion picture cameras, and others. The importance of color in this program is described, together with some of the difficult problems that are encountered when combining color film with the high shutter speeds necessary to stop the motion of fast-moving test objects. Some solutions to these problems of underexposure are mentioned.

THE primary function of the United States Naval Ordnance Test Station is the development and testing of weapons, particularly those in the fields of rockets and guided missiles. Located west of Death Valley in California's Mohave Desert, the 800-square-mile expanse of desert and mountains that

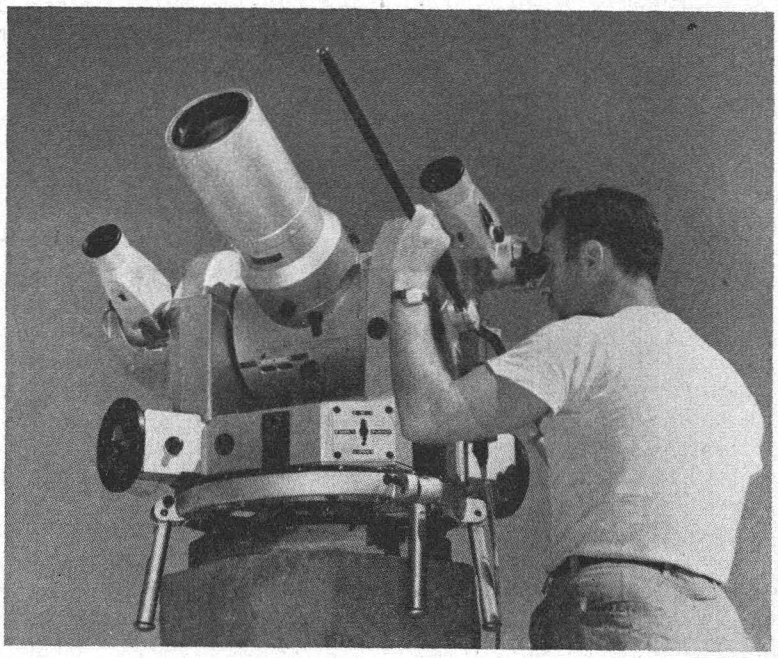

FIG. 1. Askania Cinetheodolite used for guided missile instrumentation at Naval Ordnance Test Station. These instruments have been modified as shown to permit one-man tracking of high-speed missiles.

contains the principal test ranges was selected not only for its isolation but also for its excellent seeing conditions, for the vast bulk of information obtained from these test firings is photographic in nature.

While many of our photographic problems remain unsolved, we feel that we have come a long way since those hectic wartime days when scientists and

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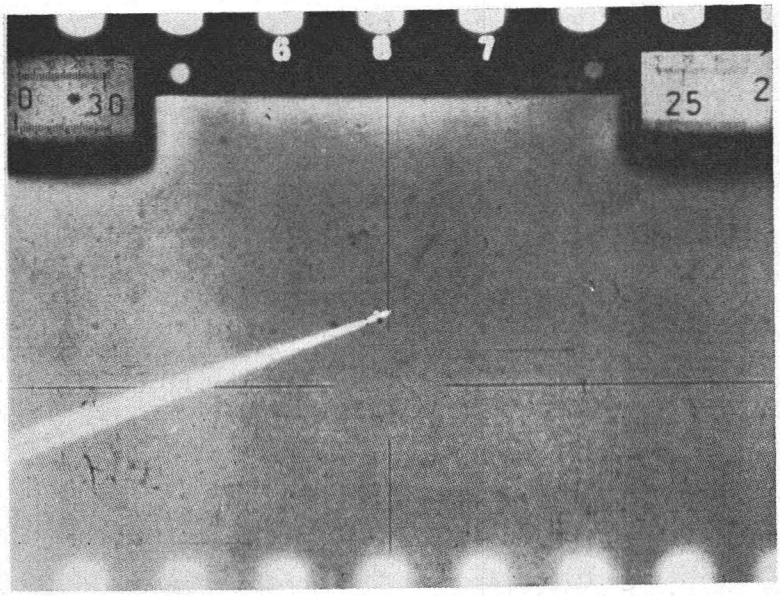

FIG. 2. Typical sample of record obtained by Askania Cinetheodolites. At the top of the frame are, from left to right, azimuth scale, frame number, and elevation scale.

technicians from the California Institute of Technology first pitched camp on the desert sands and commenced firing rockets from crude launchers. Those pioneers came armed with only a few well-worn Eyemo and Bell and Howell Superspeed cameras as their means of securing information on the test firings, but they developed many of the basic principles of ballistics photography as it is practiced today on our numerous, well-instrumented testing ranges. That early type of photographic coverage served only as a more permanent record of the same information obtained visually by the observers; now an amazing variety of specialized instruments furnish precise numbers denoting velocity, ac-

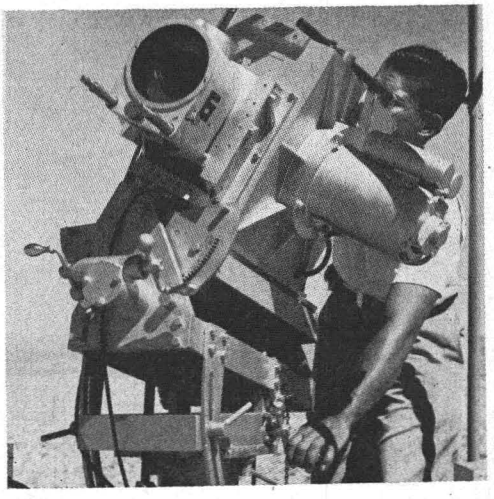

FIG. 3. The Bowen Ribbon Frame Camera can be accurately aligned to photograph an expected rocket or missile trajectory. The camera operates at from 30 to 180 frames per second, recording on $5\frac{1}{2}$-in. aerial roll film.

celeration, range, altitude, spin rate, and other data that are the basis of any scientific evaluation and improvement program.

One of the most valuable of these specialized instruments is the cinetheodolite, recording missile position against time in a network that permits the computation of accurate trajectories of flight. At Inyokern, the basic cinethodolite is the German Askania Kth 41, as modified. This instrument operates at 2 or 4 frames per second, producing double-frame 35-mm. pictures on Ansco Color motion picture film. Color film has been found to be the most suitable means of obtaining easily assessable contrast between painted rockets and the blue-sky background. The Askania theodolite has been improved at Inyokern to permit

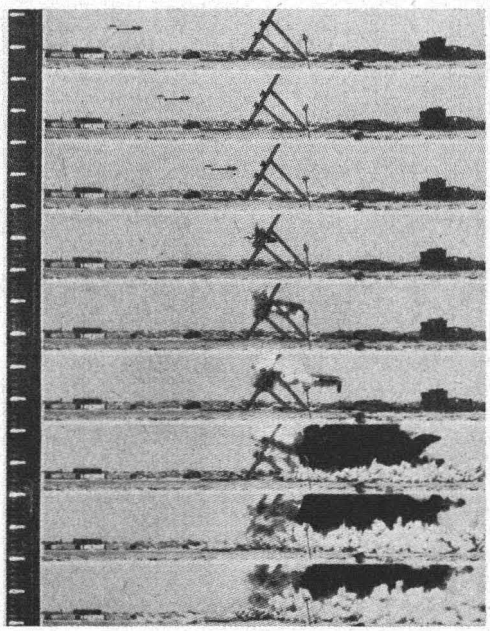

FIG. 4. Typical sample of record obtained by Bowen Ribbon Frame Cameras. This record shows an 11.75-in. aircraft rocket striking and penetrating an armor plate target with resultant high order detonation.

free-wheeling single-operator tracking in place of two-man geared tracking to permit fast-moving test objects to be followed. Since high-tracking rates resulted in blurred images of the azimuth and elevation dials, the shutters exposing these dials have been removed and replaced by gaseous-discharge lamps, which effectively "freeze" the dial motion. Work has also been done to achieve more effective synchronism of the several instruments in use than was possible with the original equipment.

The Bowen Ribbon-Frame Camera, described in detail by Green and Obst,† is a precision nontracking camera capable of providing extremely accurate metric data on 5½-inch aerial roll film at rates of from 30 to 180 frames per second. It is a valuable supplement to the Askania theodolite, especially during the early portions of flights through burning time.

Thirty-five-millimeter Mitchell cameras are operated at speeds up to 120 frames per second to provide information on roll, pitch, yaw, separation of booster from missile, and off-range deflection. The addition of a second lens and

† In a separate publication of the Naval Ordnance Test Station.

shutter into the side of the camera case has converted these cameras into so-called "chronographs," This auxiliary camera system photographs the image of a stop watch on the corner of each frame of film, permitting the assessment of the action photographed to the nearest 1/100 second. Forty-inch lenses are most commonly used with these cameras, which are operated from conventional tripods or from powered tracking mounts. As in the case of the Askania theodolites, Ansco Color film is used in this camera on most firings.

To obtain detailed slow-motion studies of launchings, separations, static firings, or detonations, extensive use is made of 16- and 35-mm. high-speed

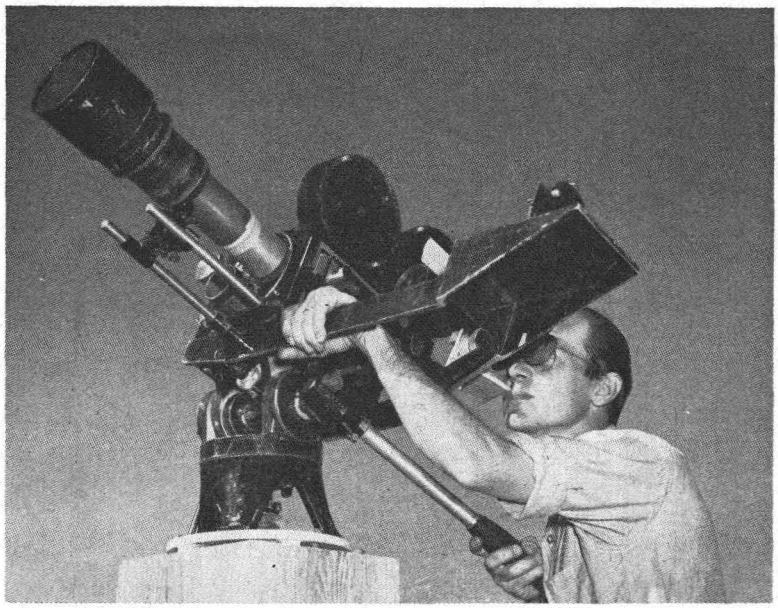

FIG. 5. Mitchell Chronograph 35-mm. Tracking Camera with 18-in. lens used at Naval Ordnance Test Station to determine missile attitude, roll, and separation information.

motion picture cameras operating at speeds up to 4,000 frames per second. Some success has been achieved at Inyokern using color film at speeds up to 500 frames per second, because of the brightness level usually encountered on the test ranges which are located on alkaline dry-lake beds.

These and other optical methods of obtaining direct photographic data of test firings are no more important, however, than the indirect photographic records obtained electronically. Recording cameras photograph oscilloscope tubes, record magnetic pickup traces, and, as oscillographs, receive vital telemetering data from the test objects themselves. Their operation adds to the thousands of feet of motion picture film, wide film, and wide paper which is expended to obtain detailed recordings of a single flight that might last only a few seconds.

Less quantitative but no less valuable information is secured by "newsreel" photographers who obtain 16-mm. Kodachrome records of the assembly and checkout of missiles, their placement on the launchers, their flights, and the state of their remains, when found. This coverage is supplemented by remotely controlled 4-×5-inch still cameras which obtain Ektachrome photographs of missiles as they just clear the launchers during firing.

The Naval Ordnance Test Station conducts extensive work in the field of

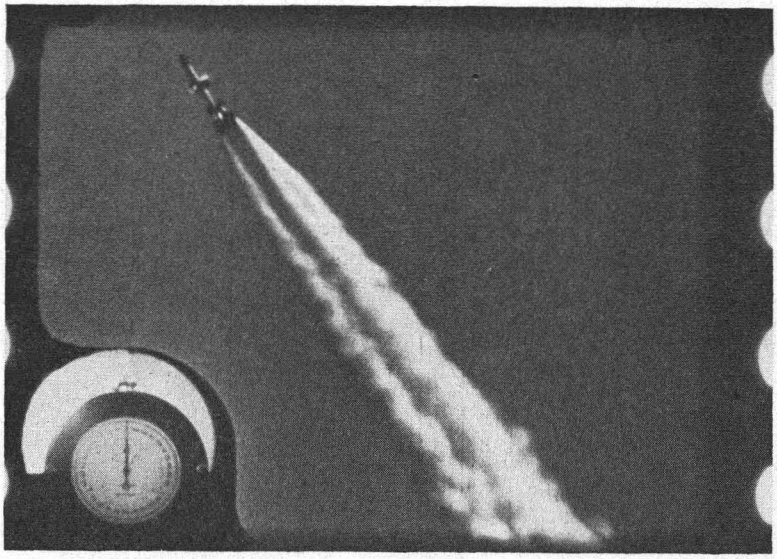

FIG. 6. Typical sample of film obtained by 35-mm. Mitchell Chronograph camera. Stop watch image is recorded in corner of each frame.

airborne rocket firings and underwater ordnance studies which supplement the firings performed on the ground ballistics ranges. At Inyokern many interesting adaptations of camera equipment have been made to obtain data on firings made from planes in flight against ground targets, while the Underwater Ordnance technicians in Pasadena are busy developing totally new techniques of high-speed underwater illumination and photography.

The photographic operations on the ranges and in the research laboratories funnel into the Photographic Laboratory Section, which operates an 8,000-square-foot production laboratory in one wing of the huge new Michelson Laboratory. While the amount of footage involved is not large by commercial

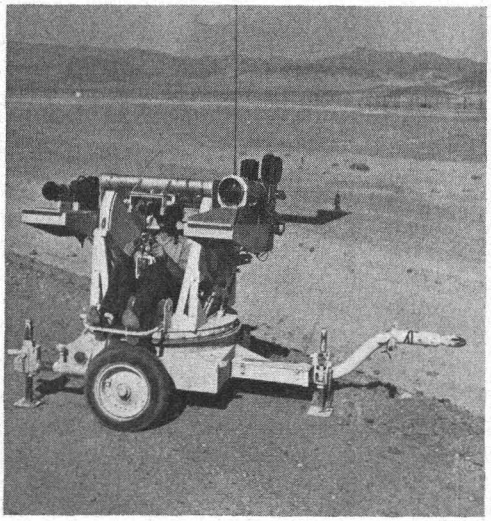

FIG. 7. This MK 45 powered tracking mount carries a 16-mm. Eastman High Speed Camera with 20-in. lens and a 35-mm. Mitchell Chronograph Camera with 40-in. lens.

laboratory standards, the lengths of film handled are just as valuable as those shot on a big production scene in an epic Hollywood film. This film is strictly a one-take affair—there are no retakes. An atmosphere of urgency is ever present in the processing laboratories; frequently the test conductor is standing by to see the first round's records before proceeding with the day's firing schedule. Yet the film must be handled with the extreme care required to produce records that can be minutely assessed under powerful magnification to deliver metric data.

The use of color film in the rocket instrumentation program presents several difficulties. Long focal-length lenses are usually required to photograph distant

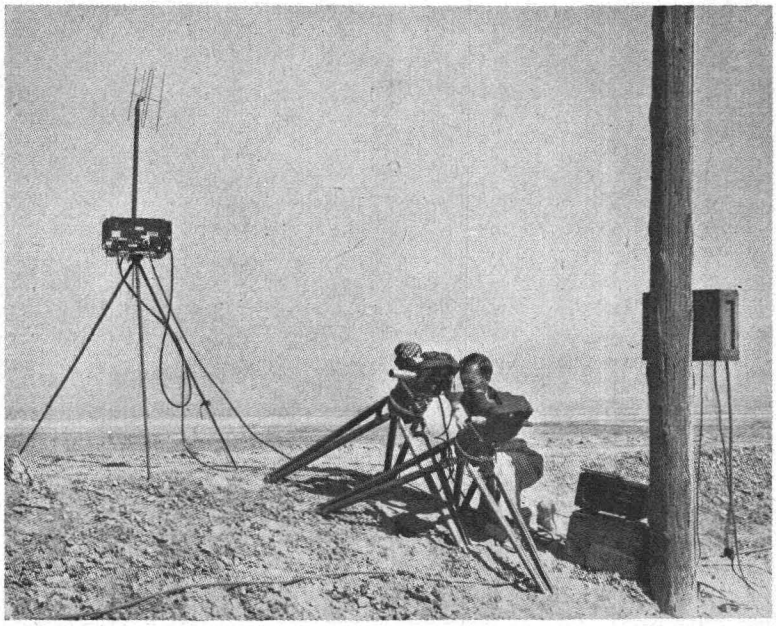

FIG. 8. Two 16-mm. Eastman High Speed Cameras are aligned to cover the launching of a guided missile. The radio receiver at left receives a broadcast 1,000-cycle note and transmits it to timing lamps in the cameras.

objects in space or to photograph objects on the ground from safe distances. Such lenses are usually rather slow, and high shutter speeds must be used to freeze the motion of supersonic missiles. This combination of factors usually means severe underexposure when a film with an American Standards Association rating of 10 is used. Therefore, the Photographic Laboratory has devoted considerable study to methods of effectively raising the emulsion speed of material such as Ansco Color Type 235 motion picture film and Etkachrome cut film. Efforts to date have been confined to a juggling of recommended developing times, although it is realized that several other methods are available for investigation. At present, we obtain normal Ektachrome transparencies exposed at $f/2.5$, $^1/_{800}$ second, by increasing the first developer time from 15 to 20 minutes. Much of the Mitchell Chronograph Ansco Color motion picture film is exposed at $f/8.0$, $^1/_{384}$ second. We have increased Ansco Color first developer time to as much as 33 min. and have also juggled color development times. These deviations in processing times do not appear to have caused marked changes in color balance, although color fidelity is not of great concern in our case.

Rocket photography at Inyokern has indeed come a long way since those pioneering days of the California Institute of Technology. Yet, we feel that we are only beginning to learn the science of ballistics photography. As missiles become faster and go farther, instrumentation difficulties multiply, and it becomes evident that much remains unknown and untried. As workers in the program of our nation's defense, we appreciate the valuable assistance and advice given us by the Society of Motion Picture Engineers as we attempt to add to the sum of knowledge in our still infant field of specialized photographic endeavor.

AUTOFOCUSING DESK PROJECTOR

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Review

For many years a small, portable projector to facilitate transfer of detail from photographs to maps has been needed. Several engineers and surveyors in the field or in small offices not equipped with the large Saltzman-type projector have constructed workable but more or less crude devices to do the necessary scale changing and projection. Some were little more than a lens, mirror, and light; others were more elaborate. None, however, were auto-focusing, and none were precision instruments.

The projector described by Mr. Samburoff should fill a very real need in schools and in small engineering and field offices where more elaborate and more costly larger projectors are not available. If performance and adaptability of this projector are as satisfactory as its appearance, it will be a valuable contribution to the photogrammetric equipment field.

C. S. Maltby

A COMPACT, portable, reflecting desk projector featuring autofocusing throughout its range of 0.33X to 1.5X, has been designed and developed by Reed Research, Inc., Washington, D.C. under the sponsorship of the U.S. Geological Survey. This instrument fills a need for a small unit capable of projecting relatively larger copy for compilation of new, or revision of existing maps. Designed for field use the projector measures $16\frac{1}{2}'' \times 20'' \times 34\frac{5}{8}''$ and, when ready for packing, weighs 56 pounds. It will project any $7'' \times 7''$ area of opaque copy in sharp focus throughout its range on a horizontal work table. Copy up to $18'' \times 24''$ can be handled. Figure 1 shows the three quarter view of the projector in use. Figure 2 is the left side view showing mechanical detail.

The base and column assembly, the lens carriage, the lamphouse, and the autofocusing linkage and mechanism comprise the four major components of the instrument. The $15\frac{3}{4}'' \times 20''$ base serves as a work surface and supports the column assembly consisting of a base casting and two chrome plated, tubular steel columns. The lens carriage and the lamphouse are guided on the main column by ball bearing rollers and are prevented from rotation about the main column by ball bearing rollers acting against the secondary column. Aluminum alloy castings are used throughout.

The lamphouse contains the pressure plate, copy holder and a first surface diagonal mirror. Two 150 watt lamps with $1\frac{1}{4}''$ radius spherical reflectors provide the illumination. Internal light baffles eliminate reflection of the light source through the lens. The lamphouse is of aluminum alloy sheet construction. The lid snaps on and is quickly and easily removable to provide access to the inside of the lamphouse for bulb replacement and cleaning of mirror and pressure plate. Forced ventilation was found to be unnecessary. The cooling air enters