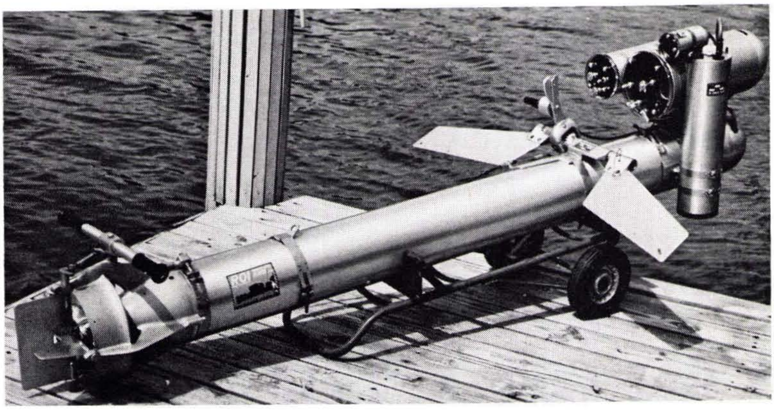

FRONTISPIECE. The latest *Pegasus* 70 mm. underwater photogrammetric system.

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History of Underwater Photography

The near future already surpasses the wildest dreams of last year.

IT HAS FINALLY become clear that underwater photography has been neglected too long as the major tool of underwater exploration. Only underwater photography with its millions of information bits per picture can provide a bridge between the diver, normally a younger man short on knowledge and experience, and the senior non-diving scientist, engineer, or poet. Even if the latter are divers, they cannot hope to observe everything in the few minutes of bottom stay while busy with cold, pressure, weightlessness, leaks in the mask or breathing system, getting lost, unfriendly marine life, and other problems. This compares with the pilot busy with flying the airplane right-side up, avoiding weather, traffic or flak, watching the engine; or the astronomer numbed by cold, boredom, old age, and inefficient eye sensitivity.

In all cases, the photographic camera supplements the eye and brain by catching a fleeting instant and preserving it with all its details. Then the explorer, investigator, engineer, or scientist has a full opportunity to study in a quiet and comfortable office or projection room all the important (though small) features that may not have been apparent at the time of direct observation: geology, plant and animal life, human presence, remote stars

DIMITRI REBIKOFF

* Presented at the Annual Convention of the American Society of Photogrammetry in Washington, D. C., March 1965 under the title "The Evolution and History of Underwater Photography" as one of several papers on underwater photography, all contained in this issue.

and nebulae, unknown bacteria, etc. These are gradually revealed by careful and insistent systematic examination called photo-interpretation. A most interesting area also is remote photography, including TV, capable of depth and duration performance far beyond any human capability.

THIS IS A SHORT, and by no means complete, history of underwater photography.

First of all Louis Boutan, French zoologist and marine engineer, began in 1893 to design a practical housing around a 9×12-cm. glass plate "detective" box camera. Plates could be switched from outside, and water pressure equalization between outside and inside was provided by a rubber bladder. He soon concluded that no commercially available camera could be satisfactory for underwater use, a finding still true today.

He then experimented with a *reverse* camera, entirely flooded, and with an air lens. The photographic emulsion proved just as sensitive in contact with salt water as dry. Developing, fixing and washing were, of course, no problem. Optical problems led then to a large (18×24-cm.) pressure-resistant camera with an automatic plate magazine. This camera was so heavy it had to be suspended from an empty wine barrel as a float and set up on four adjustable feet (Figure 1). It featured a pneumatic remote-control system from the surface, and a long and effective sunshade designed "to avoid illuminating the suspended particles near the lens." We have a beautiful print of a kneeling, helmeted diver holding a phototray with the inscription *photographie sous-marine* made in 1894 with this camera. (Figures 2 and 3).

Louis Boutan realized soon the essential requirement for artificial light, as daylight underwater converts every intevening suspended particle into a completely unwanted secondary light source located closer to the camera than the subject. Dark places like the deep sea, caves, and wrecks provide the best photographs; dusk or night being perfect for shallow water.

IN 1894 ENGINEER MARTIN CHAUFOUR rigged the world's first flashbulb, a short magnesium ribbon electrically ignited within an oxygen-filled glass jar. This had the major inconvenience (still existing today) of a single exposure.

He then rigged and used successfully, despite a few minor explosions, a wonderfully seaworthy, if bulky, undersea Rube Goldberg system featuring a glass clock cover atop a large oxygen-filled barrel containing a small lighted alcohol lamp (Figure 4). A curved tube ending above the lamp's flame was connected to a rubber ball filled with magnesium powder via a long rubber tube. All the diver had to do was to squeeze the ball to obtain a reliable repeating flash—unless the clock cover became completely opaque by the second shot. Some beautiful marine life documents were thus obtained.

Later, in 1899, Louis Boutan enclosed two powerful electric arc lamps within massive, cast iron, cylindrical and spherical housings. These arc lamps were mounted in the most modern way, 45 degrees sideways and forward of the camera so as not to illuminate all the suspended particles between subject and camera.

Again, *Photographie sous-marine* was written on a stretched canvas target, and the whole system lowered to 50 meters (depth limited by the electric cable).

The test photo was excellent, but Louis Boutan writes, "too heavy at sea aboard a rolling and heaving boat. It is too dangerous;

ABSTRACT: *Like aviation, underwater photography has been developed in the United States and France since the turn of the century by the same breed of curious experimenters and scientific explorers. This story of the pioneers is traced from 1893, when Louis Boutan produced the first underwater photographs with his 5×7-inch plate camera, to the recent development of underwater photogrammetric survey and charting by the author. Some of the important developments include artificial lighting, the strobe flash, the silver-zinc battery, super-wide angle and corrected lenses, SCUBA diving gear, automatic air pressure regulator, a navigable underwater camera vehicle, sonar remote control systems, research submarines, stereo movie photography, TV, etc.*

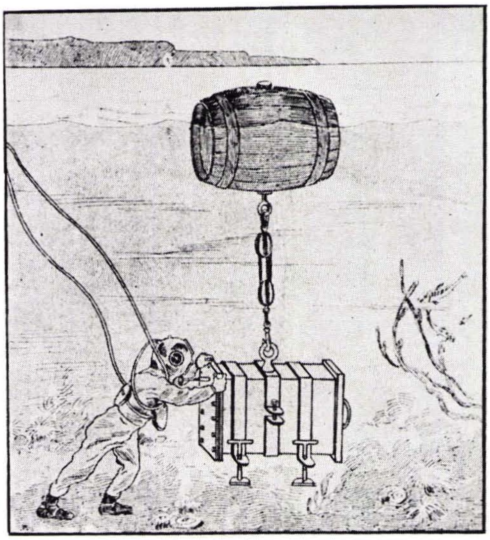

FIG. 1. Louis Boutan pushing his 8×10-inch underwater plate camera into position about 1894.

never again!" This is still valid today, for all the excessively heavy oceanographic cable-hung equipment experimented with again and again by some landlubber newcomers who prefer to ignore their predecessors' experiences. He also found the electric cable hung from the boat too heavy and cumbersome. This, too, is still valid today.

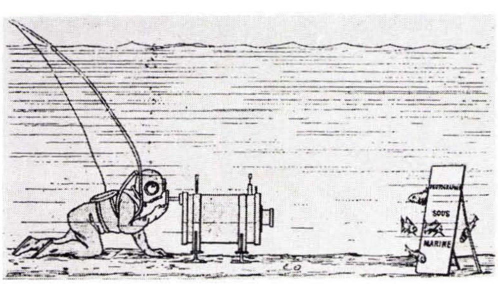

FIG. 2. How the world's first underwater snapshot was taken (1898).

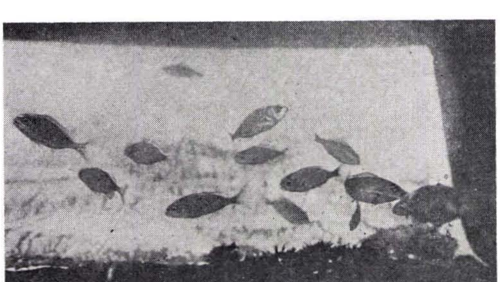

FIG. 3. The snapshot that resulted from the apparatus shown in Figure 2.

FOR A LONG PERIOD of time underwater photography was forgotten while the airplane and the automobile were being created.

Then, about 1913, an American press photographer and cartoonist, John "Ernie" Williamson, created the world's largest camera housing, a six-foot spherical chamber large enough for not only both motion picture and still cameras but also the photographer himself, "oft accompanied by wife and baby. . . ."

The chamber was safely connected to a permanently moored barge through a large reinforced flexible hose, big enough for a ladder. The observation porthole was as large as the chamber itself, and the whole assembly was limited to a shallow depth in the Bahamas' coral reefs, perhaps 15 to 20 feet.

J. E. Williamson made many good, authentic commercial 35-mm. motion pictures, including the first and best *20,000 Leagues Under the Sea* by Jules Verne in 1915. He created a beautifully frightening rubber octopus operated by a diver hidden inside, which appeared in many subsequent Hollywood "underwater" films produced mostly (like some of the latest TV shows) in the studio swimming pool. This movie star octopus was finally lost overboard a few years ago and must now be a real puzzler to passing live octopi. J. E. Williamson must also be credited

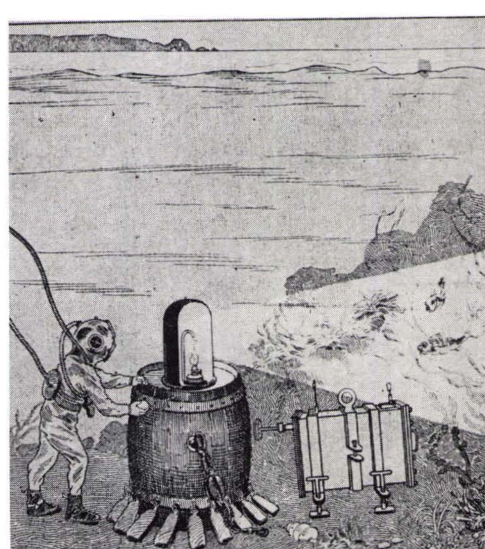

FIG. 4. The Louis Boutan repeater magnesium flash system (1895).

with the first underwater color motion picture in 1924, *The Uninvited Guest.*

THE NEXT SIGNIFICANT achievement in 1925 was color photography by Charles Martin assisted by Drs. Langley and M. Valentine. Working on shallow Bahamas' coral reefs, the camera was loaded with the Lumiere autochrome additive color plate. Light was provided from the surface by exploding a one-pound load of magnesium powder carried by a small raft, a rather crude arrangement after the Louis Boutan devices.

In 1931 Mr. A. Dratz, an optical research engineer who was working for the French Navy in the Toulon Arsenal, was apparently the first to recognize the necessity of a water-refraction correcting lens system between the water outside and the air inside the housing. Unfortunately, his correcting lens depended on a very expensive and difficult-to-make hemispherical dome glass. This shape had to be ground and polished one at a time for many hours. Full correction of all aberrations were not achieved, but modern versions of this original dome design are often proposed or tested again to this day, most often lacking the essential properly computed second correcting lens member.

WHAT REALLY STARTED the development of underwater photography was the new ease and mobility afforded to divers by the SCUBA (Self-Contained Underwater Breathing Apparatus) gear, invented in 1926 by Commander Yves LePrieur. It was made essentially of a small high-pressure air tank on the back, an automatic air regulator matching the breathing air pressure to the surrounding water pressure, and a face mask for clear vision. It was the original forerunner, with its 1863 Rouquayrol-Denayrouze demand-regulator, of all today's highly reliable SCUBA apparatus.

Commander Y. LePrieur's research in undersea photography resulted, among other developments, in the first underwater, stereo, motion picture camera, made up of two synchronized 16-mm. cameras mounted side by side at the proper interocular distance.

A young Austrian biologist, Dr. Hans Hass, was probably the first to produce both still and 16-mm. motion picture photography while swimming around sharks, beginning around 1937 in Curaçao and Bonaire in the warm and clear Caribbean. He achieved world fame with brilliant shallow-water photography of coral reefs, beautiful coral fishes, and larger sharks; and designed well-

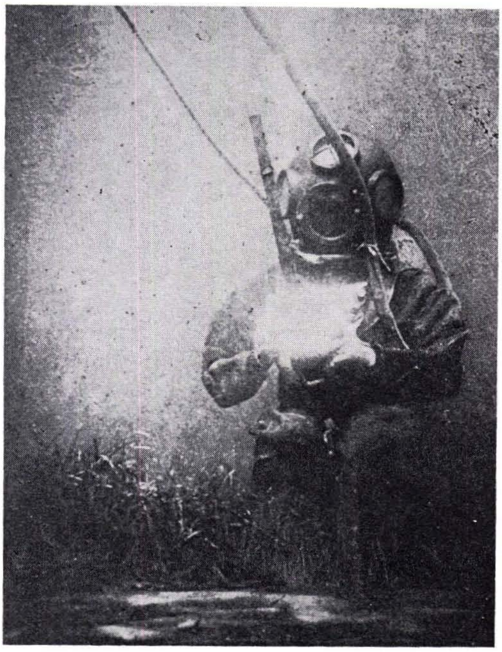

FIG. 5. Reproduction of the world's first remote-controlled snapshot underwater after diver David had set the camera and kneeled in its field.

engineered and successful housings for high-quality cameras, especially for the Leica and the Rolleiflex (Rolleimarin). Dr. Hass and Dr. Hoffman were the first to use cast aluminum, a first step to reduce the excessive weight in water of the early bronze and iron housings that could not be carried in mid-water by weightless swimming divers. Good mid-water attitude and depth control, using the lungs as a swim bladder, and fish-like swimming with the rubber fins invented by Capt. DeCorlieu (France), were proven essential to high-quality underwater photography by Dr. H. Hass. A most important point is that the bottom of the ocean is always covered with a silt layer that muddies the water thoroughly as soon as an old style "hard-hat" diver tramples the bottom with his lead-soled boots, or tries to set up a camera tripod.

AT ABOUT THE SAME TIME, Fenimore Johnson of Philadelphia contributed many outstanding developments to the art of underwater photography. Among other items were very well-designed aluminum camera housings, and an underwater still camera. He contributed, too, the ingenious clear-water cone installed in front of the camera lens that made possible for the first time clear photography and vision of a limited area even in the murkiest harbor waters.

Soon after Dr. Hans Hass (and advised by Cdr. LePrieur), Capt. Jacques Yves Cousteau achieved early fame by showing an excellent black-and-white 35 mm. motion picture film, *Epaves* (wrecks) skillfully shot and produced by Capt. Philippe Taillez, the pioneer and first commander of the French Navy *GERS*, or submarine research group in Toulon. The camera was enclosed in a simple cylindrical housing by Taillez and his team.

In 1943, J. Y. Cousteau and Engineer Emile Gagnan improved on the LePrieur and Commeinhes SCUBA lungs, adapting from wartime city-gas automobiles an efficient and sensitive automatic pressure regulator. Patterned after the 1863 Rouquayrol Denayrouze diving gear, this regulator was to become the early aqualung (SCUBA)—the favorite tool of the modern underwater photographer with the DeCorlieu fins and the LePrieur-Forjot diving mask.

Between 1947 and 1949 we were engaged in adapting our Eclatron portable strobe flash to different scientific and industrial applications. One of these was the study of propeller cavitation in water tunnels first, and later on ships' hulls in the open ocean. This required underwater high-speed strobe, synchronized both with the propeller and with a stereoscopic pair of automatic, underwater, 35 mm. pulse cameras.

In 1949 Henri Broussard, the founder of the Submarine Alpine Club in Cannes, wrote us stating that "daylight was insufficient for photography around 40 meters (130 feet)."

Despite my protesting (I could not swim very well), I found myself soon equipped with SCUBA, fins, and a too-heavy lead belt. The result was that I went to the bottom like a stone—20 feet the first day, 80 feet the second, 150 the third—and then I started to learn to swim with fins.

The first essential problem was powerful lighting, especially as the early Kodachrome had a sensitivity limited to about 8 ASA.

Our 1949 high-voltage battery strobe light was a startling success. It was housed in a long plexiglas tube filled with clear transformer oil, installed at maximum distance forward of the camera lens to avoid lighting up the particles in suspension between subject and lens (according to the oft ignored principle described by Prof. Auguste Piccard in his bathyscaphe design). Not only every frame had good contrast and definition in the center, but the brilliant colors of the fixed marine life, such as sponges and coral, just defied description. This work, the equipment and subsequent discoveries, were published in *Science et Industrie Photographique*, Paris (and also in *This Week* magazine) in August 1952.

It must be said here that the first deep-sea, one-shot, remote underwater photographs were recorded in 1939 by Drs. Maurice Ewing and Allyn Vine, of Lamont Geological Laboratory, using an open camera and a single magnesium flashbulb triggered by a bottom-contact weight.

The amazingly colorful undersea world revealed by our strobe system led to the development of self-contained high-power floodlights for color motion pictures. After trying and discarding xenon arc tubes and others because of excessive weight and complexity, we finally developed in 1950 a simple pressure-resistant, water-cooled, low-voltage incandescent lamp with the same reflector and physical arrangement as the strobe. Many 16-mm. color motion picture films were then produced of all our following explorations in several oceans. This lamp has the same non-spill deep reflector as our strobe lamp.

In 1955 Professors A. Ivanoff, Y. LeGrand and Cuvier of the Paris Museum of Natural History, after studying thoroughly the eyes of fishes, came to the conclusion that it was impossible to obtain any satisfactory photographic vision through a flat glass or plastic porthole because of the plane diopter effect that makes such a porthole the equivalent of a 3.4-dipoter magnifier lens. Such a lens introduced into the optical path not only increases the focal length of the camera lens by 34 per cent, restricting the field of vision by 34 per cent in angle and about half in area, but also re-introduces all the optical aberrations, such as chromatism, sphericity, astigmatism, etc., that were so painstakingly removed from the expensive modern camera lenses.*

Professor Ivanoff, along with the rest of us, founded the Submarine Research Institute in Cannes to join forces and find a practical way to solve the problem by entering the water and start seeing, thinking, and living like fish. The Ivanoff-Rebikoff lens is a typical result of this multidisciplinary team effort. It is a reverse Galileo Telescope computed out of two new types of optical glass to correct fully all aberrations along with the focal-length increase for the first time. It has

* See accompanying article by Mr. Wakimoto—*Editor*.

proven since to be the ultimate improvement in underwater optics, applicable to all cameras, all optical instruments, and the human eye.

At last, we could have clear photographic vision of large areas of the ocean bottom instead of the old narrow-angle shots showing only divers without head or legs, small parts of wrecks, or underwater houses or oil rigs, a type of photography still prevalent today as long as old flat-windowed cameras continue to be used by operators unaware of basic optics.

A number of advanced underwater lenses have been designed and made, each a single type for a specific frame size. Examples are the new 80-degree Dr. Robert Hopkins underwater lens for use behind a conventional flat porthole, the Leitz-Canada 43 mm., and the Nikon 28 mm. "wet" lenses with their first element in contact with the water.

AN IMPORTANT BOON to underwater motion picture photography and photogrammetry was provided from 1950 to this day by the outstanding silver-zinc battery invented by Professor André in Paris, and produced by Yardney Co., and other battery companies. The special value of the silver zinc battery lies not only in its tiny size and weight (about one-sixth of both lead-acid and alkaline batteries), but above all for its practically constant voltage during discharge. This makes possible a constant light intensity and color temperature with efficient low-voltage incandescent lamps. Let us note here that: (1) both arc and xenon arc lamps have proven impractical so far because of their complex, heavy, and inefficient ignition and ballast systems; and (2) power cables surface-fed by generators are not only a negation of the modern air-hoseless SCUBA diving methods, but are also much more *expensive* than the silver-zinc batteries for the same amount of illumination.

WE FOUND QUICKLY that the complete system of battery power supply, floodlight camera, and controls introduced so much hydrodynamic drag even in the smallest size with neutral buoyancy that a vehicle system proved to be essential. In 1951, we developed the "torpedo" and "scooter" towing units (Figure 6), nothing more than a $\frac{1}{3}$ horsepower electric motor turning a three-bladed shrouded propeller through a reduction gear.

We found soon (in 1952) that the power had to be increased to $1\frac{1}{3}$ horsepower to achieve a minimum speed of over 3 knots, which is a minimum speed to travel any distance within the time limits of the SCUBA system, and also to overtake and photograph reliably other swimming divers and most fishes. This amount of power could not be controlled directly any more; this made necessary the design and successful experimentation of the *Pegasus* photographic vehicle (Frontispiece and Figures 7 and 8).

Pegasus is a long, thin, torpedo-shaped, aluminum marine machine, the final result of many years of evolution in undersea engineering. It is "flown" just like an airplane by stick and rudder precisely controlling pitch, roll, and yaw. The underwater pilot-diver has a complete instrument panel with artificial horizon, gyro compass, depth meter, and propeller revolution log, all made necessary

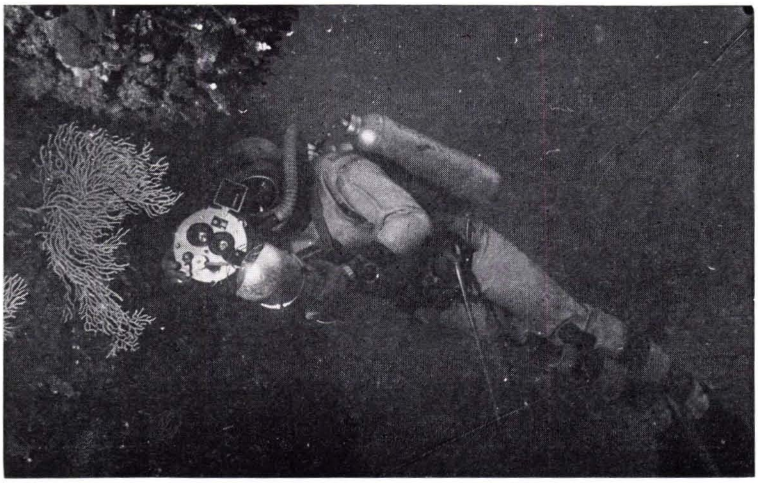

FIG. 6. Dimitri Rebikoff's first photogrammetric camera with double correcting lens and strobe "torpedo" in 1952. Depth–110 feet. Photo by G. Barnier.

FIG. 7. Dimitri Rebikoff with his first underwater stereo "pressure cooker" camera with "torpedo strobe" oil-filled lighting system in 1950.

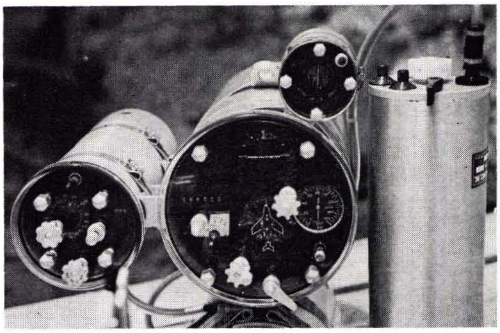

FIG. 8. The Pegasus instrument panels. Left–intervalometer; center–the navigation and altitude gyro panel.

by the fact that visibility, even in the clearest water, is limited to a few hundred feet at most.

Pegasus is thus a stable and precisely controlled platform for all photographic operations, from all 16 mm. TV program photography without a disturbing swimmer "rock and roll," to the most sophisticated industrial and military 70 mm. area mosaic, stereophotogrammetry with an automatic pulse camera controlled by an intervalometer system. It also provides utmost safety and comfort to the underwater photographer by doing away with exhausting and dangerous pushing of heavy camera and lighting equipment, by supplying effective and swift transportation from boat or shore to location, by supplying air tanks, suit heating, unlimited lighting, sonar communications and ranging and safety devices, such as life raft and shielded hull. We can now safely carry two 400-foot 16mm. Rebikoff-Milliken, corrected wide-angle, high-precision motion picture cameras, or two 35 mm. or 70 mm. Rebikoff Flight Research 92 degrees plus cameras.

A VERY IMPORTANT AREA of underwater photography is TV, where the film emulsion is merely replaced by a vidicon or image orthicon tube behind exactly the same lens system. Mr. Emmanuel Wexler of Paris patented some of the first underwater remote controlled systems from about 1945 on. We remember experimenting in Cannes with the very early iconoscopes inside a well-designed spherical aluminum photo housing with quartz windows (developed by Dr. Paul Hoffman in Munich for the German Navy during World War II). Dr. Udo von Schulz, well known for his sonar mosaic camera demonstration, was also an early pioneer of underwater television. The latter has become a major tool of underwater work and construction, especially in the hands of pioneer "hookah" construction diver André Galerne from Paris, now in New York.

About 1954, Dr. Harold Edgerton* of MIT developed a very well built and rugged deepsea version of the 1949 Rebikoff torpedo-shaped electronic strobe flash and added a very simple and reliable 35 mm. remote-controlled pulse still camera, specifically designed to be operated from a dangling oceanographic wire. The system was completed by an ingenious sonar trigger actuating the camera and strobe at just the right distance from the bottom.

(Note: The same action is simply obtained in the Lamont camera system by a trigger weight hanging down the predetermined range. This weight was later to be mistaken shortly for the *Thresher*'s conning tower, for want of a modern wide-angle corrected lens.)

This Edgerton system has become a standard item aboard most oceanographic ships, and also on many research submarines beginning with Dr. Jacques Piccard's *Trieste*, gathering endless and fascinating evidence in many spots of the world's oceans. Among other applications, it recorded marine life, including fishes, seven miles down with *Trieste*, and the wreckage of the *Thresher*, also with the *Trieste*, the latter along a random curved track shown in a weird and fascinating tapeworm mosaic.

THE MOST SIGNIFICANT development of recent times appears to be in processing and film material. The visibility in water is deter-

* See accompanying article.—*Editor*.

mined by the contrast separation threshold between the brightest details of the subject and the brightest secondary light sources between subject and lens represented by illuminated particles.

Any increase in the contrast gamma will increase visibility. Systematic application research has become overdue with the Log Etronic process (now used by Woods Hole), high contrast development and printing, high contrast film material such as Aerocon Ektachrome, and more sophisticated lighting systems—with a big question mark on highly touted laser systems.

In the field of optics, the old Dratz hemispheric glass, or plexiglas dome, has found new youth with the extreme wide angle "Fisheye" and Kinoptik lenses. They have extreme distortion, however, limiting their use to original artistic effects and some types of one-shot surveys.

Most interesting is the corrected panoramic camera invented by Gomer McNeil. A lateral angle of 120°, without loss of definition, is achieved but, typical of a panoramic cylindrical projection, the scale change over the 120° is considerable. An advanced version of this camera will be experimented with as a mosaic photogrammetric system with 120° angular coverage along the track. The U. S. Navy Oceanographic Office is planning to install this downward-pointing camera on their Rebikoff Pegasus, which is fully equipped with an aircraft-type gyro-instrument panel. This may become one of the most advanced and unique underwater photogrammetric systems so far.

AT THE BOTTOM END of underwater photography technology, we have recently discovered that our lowly amateur Instamatic camera system has completely eliminated the eternal bugaboo of underexposed downward shots and overexposed upward shots, thanks to the simplest form of automatic aperture control in which a cadmium sulfide photocell directly drives the aperture leaves. We must now install, and soon, the same system on all our advanced motion picture and still cameras.

THE NEAR FUTURE OF underwater photography already surpasses the wildest dreams of last year. Not only do we have to chart the continental shelf prior to the deep sea in a continuous area mosaic, stereo-photogrammetric chart, but we must also record photographically every activity of man-in-sea, be it commercial or scientific. Just as in outer space, man is too busy just surviving or performing the simplest tasks to do any effective observation. This observation is today (just as in astronomy or microscopy) best performed by a camera faithfully recording every detail. Later these observations can be studied leisurely and repeatedly by the world's best experts, who do not usually have the time or opportunity to go observing on location.

To conclude, the artistic value of the sheer beauty of the discovered ocean bottom landscapes and marine life should not be neglected in a modern world where the wonders of nature are too often destroyed by the activities of man.

See announcement of 1968 Congress in Switzerland on page 940.