Our chore was a pretty big one, and I went back to New York and told the management of the company that I knew exactly what we had to do, but it was so secret I could not let them know. They should merely give me the authority, and I would go ahead and do it. They were quite impressed, and they did it. That was about eleven o'clock in the morning. At three o'clock in the afternoon when the papers came out, there was far more there than I had ever known, and so goes the security.

Much has been published since then on the Bikini experiment, but few people have been fortunate enough to hear the interesting details firsthand. We are to be so favored today by a paper to be delivered by Colonel Paul T. Cullen. Colonel Cullen has been in Army Air Forces photography in various capacities since about 1930. During the war he set up a shuttle photographic service between the American and the British forces on one side and those of the Russians on the other side of the enemy. The idea was to take off, fly across enemy lines, take pictures, drop down in Russian territory, gas up, and come back for another photographic sweep, and so back and forth. Colonel Cullen made the first flight to prove the system and took photographs of the Ploesti oil fields on the way. You have all heard of that. However, like all military men—and this goes for the Navy, too—they get trigger happy at one time or another, so Colonel Cullen takes great pride in the fact that he finished the war as the commanding officer of the Second Bomber Group in Europe.

Last year Colonel Cullen was appointed Chief of the Army Air Forces photographic efforts in connection with the operation of the Joint Army-Navy Task Force 1, which conducted the Bikini experiment. I present to you this afternoon Colonel Paul T. Cullen.

COL. PAUL T. CULLEN: Ladies and Gentlemen: It is a privilege to appear before you again and to present a report that touches on *the* great event of our age —the burst of an atomic bomb. All of you were electrified on August 5 and 6 of 1945 by the news that the Air Force had dropped one atomic bomb at Hiroshima, Japan. The awesomeness of this new weapon of warfare still bewilders and confuses much of the world. We have accepted the explosive power of TNT and petroleum as a commonplace feature of modern life. But what about the fission of an atom?

The development of the atomic bomb was one of the best kept secrets of the past war. For this reason, and also because of scientific uncertainty regarding the lethal range of the bomb, very little photographic coverage attended the first public unveiling of this weapon. This situation was unchanged when the third *A* bomb was dropped over Nagasaki three days later. Then our scientific and military minds awoke to the realization that despite the detonation of three bombs, our knowledge of the effects of atomic fission was still largely theoretical because accurate data on many of the fission phenomena had not been obtained.

It was just after Nagasaki had been bombed that I overheard Mr. Higgins, the naval shipbuilder who was visiting the Marianas base of one of the B-29 wings, remark "The atomic bomb has put me out of business as I can't see much use of a fleet against such a weapon." The same thought appeared editorially in our press during the following months.

Influenced then by the lack of accurate information on the behavior of the bomb and curious as to the value of a fleet in atomic warfare, the Joint Chiefs of Staff approved the Navy Department's proposal to stake out an eighty-ship "guinea pig" fleet against which atomic combs would be detonated

The site selected was Bikini Lagoon in the Marshall Islands, Central Pacific, and the target date was 15 May 1946, which was later postponed until

July 1. Operation "Crossroads" was the code name given the mission and much publicity was attendant upon the various Task Units of Task Force One, which was charged with the accomplishment of the tests.

Because the Air Force has all the airplanes, B-29's, and the crews who were trained in atomic bomb delivery, it was requested to join in the tests. The Air Force readily agreed. It, too, was curious. What about the bomb? its ballistics? its lethal range? effect of the shock wave on aircraft and persistence of radioactive agents? There was little question as to the *A* bomb's effectiveness. The two hundred thousand casualties in Japan spoke silently but eloquently of the destructive quality of two bombs. The Air Force also agreed to provide the aerial portion of the photographic record required by the atomic scientists.

The Navy Department provided the ground and ship photographic record and also certain aerial photography desired for publicity and for purely naval purposes such as water wave studies, etc.

It was just a year ago that I was pulled out of the annual meeting of this society to be informed that I was responsible for the AAF portion of Crossroads photography. Let me warn you here that whereas this report will attempt to remain impartial—'tis inevitable that it will be mostly concerned with Air Force participation.

The problem was first stated in the following words: "Put a Fastax camera in two B-29's and follow the bomb carrier into the target because we want pictures of the first two seconds of the burst." Please note that we were not given an accurate statement of the problem, instead we were given a partial solution. Actually, it took us weeks to determine exactly what the scientists, the Air Force, and the Navy wanted. Normally, problems if clearly stated, can be analyzed, the possible solutions laid out and the most practical selected. However, because of the lack of knowledge about atomic phenomena, and failure of our people to make an analysis of the end desired, our operational planning was kept in turmoil. We actually received a *new* photographic requirement just three days before Able Day!

Let us look more closely at the problem which confronted us. We were to photograph the following:

1. The Air Burst.
2. The Fireball.
3. The Wilson cloud chamber condensation effect.
4. The shock wave both in the air and on the water.
5. The water wave.
6. Establish the position of the target fleet and of each vessel fixed with reference to the rest of the fleet and to the bomb burst.
7. Determine the height of the burst.
8. Determine the position of the burst with reference to the aiming point.
9. Determine the rate and quantity of the cloud growth.
10. Determine the striation and dissipation of the cloud with reference to time and place.
11. Record oil streaks in surrounding water from sunken ships to show set and rate of current.
12. Record the damage to vessels, especially those sinking before the boarding parties could examine them.

Factors influencing the solutions adopted were:

1. Forecast of weather unfavorable to high altitude photography of surface objects.

2. The overcautiousness of the staff surgeon which imposed the handicap

of a many mile separation from the burst. At one time he insisted that the photographic aircraft be twenty miles away. He was persuaded to relax his fifteen mile dictum only ten days before the test. Then he permitted us to venture within 12 miles which was the closest distance from which aerial photographs of the air burst were made, although aerial cameras were used from towers erected by the Navy on the islands of Bikini lagoon, 3 to 9 miles from the fleet.

3. Our superspeed cameras had only 2 to 4 seconds of operating time, thus if the scientists were to have photographs of the first two seconds after detonation, a nice problem in precise timing had to be solved.

4. Although we had the utmost confidence in the ability of the bombardier to hit the aiming point, we also recognized that this type of bomb was new and photo coverage must be secured no matter when or where the bomb detonated.

The final solution had most of the photographic airplanes circling the aiming point on the twelve mile circle for thirty minutes prior to the approach of the bomb carrier. Cameras were trained on the target fleet at all times.

The photogrammetrists devoted many hours to painstaking measurements and calculations and were successful in deducing from the photographs the information needed to fulfil these requirements. We now know that if we had had a simple statement of the requirements in January or early February, we could have planned our photography in such a way that the required information would have been secured much more rapidly and more simply. By the time we reached the conclusion that what we needed was P-80 airplane, flying directly over the target fleet at the exact time of detonation, it was too late to obtain airplanes and crews, and work them into the precise over-all pattern. Photogrammetrists were called upon to plot the track of the bomb carrier and indicate the point of release because of the question as to the bomb's accuracy. This was not in the original requirement: however, our camera installation had been so thoroughly worked out that it covered even this unforeseen requirement.

Before showing you a chart of the air operations, I would like to say a word about those who made up the Air Force Photo Unit. When I walked out of this society meeting a year ago, the Air Force was being stretched thin on the rack of demobilization. There was no Photo organization available for this job. It was recognized that this special task required new applications of existing techniques. By ones, twos, and threes, the cameramen, laboratory workers, pilots, mechanics, navigators and radar men were assembled at Roswell, New Mexico for rehearsals and drill prior to going to the Marshalls for the last two months of precision rehearsal. For airplanes we used B-29's, the Boeing superfortress; C-54's, the Douglas Skymaster transport; and B-17's, the Boeing Flying Fortress. Each of the B-29's (the photo version is called an F-13), and the C-54's carried 25 to 27 cameras. The F-13's required a crew of 17 while the C-54's carried 26. The B-17's were used as drones and carried no human crew.

The Photo Unit was made up of over 500 men, many were civilians drawn from the Motion Picture industry, others came from the Air Materiel Command, while the balance came from all parts of the army.

The pilots were all combat veterans, but for the majority of the air crews, this was their first overseas operational mission. Our wartime experience in crew training paid dividends in whipping our mixed civilian and Air Force technicians into smoothly operating teams. Each man performed his share of the job faultlessly.

Most of our cameras were installed abeam, thus the left side of each photo airplane was perforated with many ports for cameras, large and small, still and movie. The F-13's (that's the B-29 remember), had four remotely controlled

machine gun turrets and a tail turret. The machine guns were removed and 35 MM movie cameras (The Jerome) installed. There were eleven cameras in the turrets of each airplane which were aimed and tripped by two operators using gunsights.

The Mitchell 35 MM motion picture cameras, both standard and high speed models, were used from the F-13 and C-54 airplanes. These precision studio cameras secured beautiful film in both black and white and technicolor monopak. Very little of this has been seen by the public. Bell and Howell 16 and 35 MM and Eastman 16 MM cameras exposed much of the film which you will see later.

The most numerous of the still cameras installed were the 24″ Fairchild K-18's. This camera was mounted obliquely with the 18″ side vertical. Fairchild K-19's were used with a special hookup of the photo electric cell to secure precise staggering of camera shutters. Advantage was taken of the high cycling rate of the Eastman K-24 20″ focal length cameras to get a good sequence of the cloud build-up.

A complicated pattern of filters, shutter speeds and film bases was evolved which would insure coverage of all phases of phenomena even if some airplanes were blocked out of the picture by clouds or mechanical difficulties. Actually, our entire force of airplanes functioned perfectly for both Able and the Baker Day detonations.

For film we used Eastman Super X, Super XX, Infra Red, Topographic Base, Kodacolor, Kodachrome, and Monopak. Installations included normal vertical camera, trimetrogon and Sonne cameras, and all types of obliques. In addition, we constructed what we called a "Blur" camera which was a standard Fairchild K-18, modified to permit the 490 feet of film to pass through the magazine at the rate of 400 inches per second. No shutter was used when this film was exposed at the time of the Able detonation to give us a linear record of the rate and amount of growth of the fireball. A time base was put on the film by means of a pulse amplifier, salvaged from some other gear so that we came up with a time record that permitted us to make a linear measure of time in terms of 250 microseconds. A high speed photometer was built and used, which moved film at the rate of 1000 inches per second. We also used motion picture cameras, both vertically and in all the oblique positions. These included the Western Electric Fastax 16 and 35 MM models, capable of 4000 frames per second and the Eastman high speed camera, capable of 3600 frames per second. One or two of these cameras were used at top speed, the balance at 1000 frames per second, and 750 frames per second. The Mitchell high speed turned up at 96 frames per second and the B&H 16 MM at 128 frames per second.

The night before Able Day, that is the night of June 30, it rained. We started loading our cameras into the airplanes at midnight. By four in the morning, everything was set with the exception of some of the photometric equipment. Dr. Frye of Boston University completed this installation en route to the target. Takeoff was started into an overcast, formidable looking sky. Most photographers are artists so I know that you would have enjoyed that pre-sunrise flight from Kwajalein to Bikini. As we bounced through the lower undercast, we could see the light of the morning from below the horizon. Above were clouds in all directions. On each side of us, high piled cumulous clouds lined our course. One by one, the additional F-13's of the formation broke through the clouds. About this time, the sun peeked above the horizon to paint the cascaded cumulous clouds with silver and gold. The range of colors was exquisite. Pastel shades, the brilliant white of the limned cumulous clouds showed the proverbial

silver lining. But it was a very discouraging outlook as I led the F-13 formation over the target area an hour before bomb drop. Clouds obscured the fleet on both of our vertical runs. In addition to that, there were upper clouds cutting down the light. Photographic F-13's were at 26,000 feet, the C-54's took up their orbit at 12,500. The C-54's had even greater cloud blockage than we had at the higher altitude. However, the weather continued to improve until as Dave's Dream, the bomb carrier started its bomb run, there was hardly a cloud in the immediate target vicinity. As a result, we had far more photography than we actually needed—far more than we had any reason to expect. The precautions taken to insure adequate coverage, no matter where the bomb exploded, paid off.

As you recall, it did not explode as close to the aiming point as we had expected: despite this, many of our cameras were on the initial instant of burst and stayed with the developing atomic cloud throughout its growth.

On Baker Day, somewhat similar conditions prevailed, and we took off into a rainy sky, which gave way to continually improving weather as the morning grew, until at 8:30, we had very fair weather conditions. Actually, there were a few more clouds than on Able Day, but still far less than there had been on any of the rehearsal days. Once again, every airplane, every camera, every man was in position, a beautifully timed operation, functioning exactly as planned.

The high speed color photographs that were made of the Able and Baker bursts illustrate in a very remarkable fashion the relativity of time and a highly dramatic event which took place in a split second is stretched over minutes before the eyes of the scientists. The movement of the shock wave, the forming of the clouds before their eyes, the changing colors of the fireball, all are slowly unfolded in unbelievable fashion for one who actually witnessed the spectacle.

It has been my fortune to see thousands of bombs explode, mostly in anger. So it was with that background that I witnessed the flash and rapid expansion of the air burst. Many of the observers who witnessed the Bikini test did not get a true impression of the fearsome might that was unleashed because their imaginations and the fairy tales of junior scientists had created in many of them an expectation that they would see the whole world go up in smoke and flame. But had they the background of witnessing the puny effords of hundreds of ordinary high explosive bombings, I believe a truer picture of the Able Day demonstration would have been drawn in the press and radio.

Six minutes after the bomb dropped, the cloud was on the level of my airplane at 26,000 feet and was still growing. As we wheeled our airplane toward the base, we could look back a hundred miles and see this characteristic atomic cloud reach 60,000 feet. The impression of terrific unused force being expended in the upward surge of the cloud will always stay with me. The Able Day cloud had a beautiful, ethereal, though awesome, aspect. In contrast with this the Baker Day explosion presented a dirty, brutish upheaval. It looked like a steaming caldron. The impression of strength was still there; the beauty of form and color was gone.

The nature of the phenomena and the locale in which it took place caused a very high value to be placed upon color photography. Only in color film do we capture the delicate shading which gives impression of a seething, irresistible force emanating from the cloud.

Photography and photogrammetry in the Air Forces have not kept pace with other development in a supersonic age. It seems that the plea that I made last year is appropriate this year. There must be faster methods of producing the results of photography, whether it be in the forms of maps, of photographic

prints, or transparencies. We must have all-weather photography and be able to secure photography from guided missiles, from extreme heights, and from tremendous distances. This, I think is your problem, and one which the society and its members are well qualified to meet.

In this brief résumé of the use of the fourth and fifth atomic bombs, I have not attempted to bring before you the results obtained. Most of these results are and will remain classified. Some of the studies are continuing while others are temporarily suspended for want of personnel and funds. However, the record is there on the film, 87,000 still exposures, 93,000 feet of motion picture film, and will be available for study in the years to come. You may be sure that not many atomic bombs will be detonated in the immediate future. I think you realize that the photogrammetrist has played, and will continue to play, an important part in the analysis of the atomic phenomena. The spectroscopic and photo density studies are of direct interest to the photogrammetric industry. It is obvious that we are living in an age of transition. The American people are more concerned about their position in the world of the future than at any other time in our history. By retaining the atomic bomb in our possession, we know that the peace of the world is secure, at least for the time being. The folly of repeating the disarmament of 1923 is apparent to most of us.

PRESIDENT SANDERS: Thank you, Colonel Cullen. There is a very friendly rivalry, and many of us who smile a little bit when we see the Army and the Navy get together are the very ones who realize that they do work together beautifully when the time comes for a showdown. One illustration of that is the fact that a Navy picture is now to be used to illustrate more completely the talk which Colonel Cullen has just delivered.

The motion picture "Operation Crossroads" emanates from the Joint Army-Navy Task Force One as part of the record of that operation. In order that we may have a proper perspective to start out with, a few words of introduction of the film are to be given by Mr. A. C. Lundahl, of the Photo Interpretation Center of the U. S. Navy. Mr. Lundahl.

MR. A. C. LUNDAHL: Mr. President, Ladies and Gentlemen: I am caught in a cross fire of Army and Navy relations, but it is not going to prevent me from telling you some of the reactions which have occurred in our plant in the handling of the photogrammetric data relating to Operation Crossroads. First, before I tell you something about that, I want to give you a thumbnail sketch of what our organization is, inasmuch as it is the youngest photogrammetric organization in Washington at the present time.

Although we trained many hundreds of Navy photo interpreters during the war, we were converted to a civilian status about March 1, 1946, and following that conversion the first objective which was handed to us was the treatment of the photos of Operation Crossroads.

The Naval Photographic Interpretation Center is divided into five units. We have a Terrain Model Section, which makes rubber models that handle various spot assignments where model making is required. We have a Photo Interpretation Unit, which is currently engaged in keeping abreast not only of all the information that we acquired during the war but of new information on enemy airfields, on enemy flak analysis, and various radar planning devices, and all the other aspects of photo interpretation with which you are already familiar. We have an Interpretation Training Unit, which is currently training about thirty-five USN officers in the principles of photo interpretation. Upon completion of the fifteen-week course, they are assigned to duty with the fleet. We also have a photogrammetry course which lasts fifteen weeks, and we have