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[full name of interviewee]

about Space Photography - film, equipment, processing.
[main focus of interview]

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Biographical - [date/place of birth; family background] _____

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Education - _____

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Career Path - Army Map Service
Defense Intelligence Agency, Dept of Defense;
1965 - MSC, Photogrammetry

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Topics - MSC photogrammetry problems; lunar surface mapping; 500 photos Gemini 4; earth photo identification; terrain & meterological studies; photography success of Gemini 5; dirty window on Gemini 7; photographs of faulty nose cone wiring; clearer windows w/ less silicone sealer; Collins lost camera in space; Dunkelman low-light experiment; high precision mapping; Contract for mapping services; micron photography; precision photography & precision reproduction; Special film & supplies; working w/ experimenters; photography for Simulators; Swiss cameras & Kodak Versomats; aerial color mapping; multi-spectral cameras; Apollo Applications Program; photography on unmanned flights; advances - new film, old cameras; geoscientific detection work;

(over)

Man-operated Cameras Give Best Photography;
Kodak System; ~~color negative~~ film processing;
~~State~~-of-the art equipment & film
Classified status; fine spot scanner;
enlarger; Contact printer;

Interview with Richard W. Underwood
5/27/68

I came from the Defense Intelligence Agency of the Department of Defense. Actually I was loaned to NASA in 1963 on the Echo 2 project. NASA wanted to find out why the balloon was failing. The yield point and the rupture point were very close. NASA people came to Army Map Service where I worked and presented the problem and we analyzed it. The problem was in trying to photograph a very highly reflective surface, map the surface, and find out where the shear was. We said we could do it. Three of us were detailed to GSFC--myself, and two of my assistants. We worked in a big hangar at Lakehurst, N. J. We took aerial mapping cameras, recalibrated them for finite focal distance, and erected them on great stands 90' above the floor. We photographed this balloon (which was the world's largest) as it was inflated, noting the pressure changes. We couldn't read the surface of the balloon because it was so highly reflective, but we analyzed the parallax of the random dots on the surface from one camera to the other and ran the data through a computer and then drew contour maps. Together with radar data (radar signals were also being bounced off it), we could work the information together and determine what the trouble was with the balloon. The contractor, the Scheldahl Co. manufactured 3 more balloons at Northfield, Minn which incorporated the recommended changes and the thing then worked.

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MSC hired me as a photogrammetist, as a consultant, just before Gemini 3, in January 1965. The Center had started to run up against a lot of photogrammetric problems and didn't have a way to solve them. ASTD at the time really wanted me but didn't have a space so I was put in Photography since photography and photogrammetry are closely allied;

actually photogrammetry is scientific precision photography and its utilization. At the time I was not considered to be part of the Gemini team. We then had the rudementary beginning of the earth resources program; an airplane was available, and the Center wanted to instrument it and put cameras in it.

We began with a few good ideas, some old World War II surplus cameras and that plane--a post-World War II Convair. Also we began supporting the lunar surface mapping group under John Dornbach and Jim Sasser. They were getting into the mapping program to select these landing sites on the moon for the Apollo program.

During the flight of Gemini 3, a few pictures were taken--I think 24. There wasn't too much to them. On some you could see the earth and the rest of them were clouds. It was a busy 3 orbits and people weren't really interested in photography. In Gemini 4 photography was to be a big thing what with the walk in space, etc. Some rather spectacular photography resulted and everybody from the President on down liked it. We got back about 500 pictures. Those released to the press consisted of White's walk in space. We had 19 of them and there were another 400 of earth views. Nobody knew what was in them, and it was about 8 days after the stuff came back that I got a chance to see it. Mr. Brinkmann asked me to look at one particular roll, and as I looked at one picture, I commented "Oh boy, a beautiful shot of the Nile Delta." Another one was a splendid shot of the Bahama Islands, and another was Florida and so on down the line. Brinkmann, who was amazed asked "you mean you know what's in those pictures?" I said sure. I had worked in photo reconnaisance for years and I could tell where they all were taken. He called Dr. Gilruth and told him that the Center finally had someone around here who knew what the devil we were taking pictures of. Dr. Gilruth came over and I pinpointed the geographic

location of about 25 of them on a quick run through the roll. Dr. Gilruth looked at me and said "well, fine - from now on this is one of your duties - to identify these pictures." I've been doing it ever since. I systematically went through them, got the flight charts to determine what altitude the astronauts were at by where they were vs how they fell together in the sequence, what revolution they were on, and then summarized everything in a little publication. We have given away several thousand copies of it to interested people. That was the beginning--from the Gemini standpoint.

Then the experimenters started to get in the act. We got the S-5 experiment--Dr. Lohman with his terrain study photography and Ken Nagler with his S-6 meteoroligical study. By Gemini 5, we began to program this material as part of the flight and Gemini 5 was to stay up 8 days - plenty of time for picture taking. We loaded up 4 magazines of film, and trained the crew in the use of the camera. They went up there with instructions as to what we would like them to take pictures of. They did take some pictures, but failed to take a number of others because they were in a tumbling mode so long and other problems that developed in the spacecraft. Nevertheless, we got some sensational pictures out of the flight and I would say if we evaluated the comprehensiveness of Gemini 5, we probably got a wider variety of usable scientific photographs from it, than any of the other missions. A lot of them had specific photos of great value, but they didn't cover like Gemini 5 - Cooper and Conrad did a great job. We got underwater information, surface currents, coastal currents, KSC, the deserts of the world, they monitored a big typhoon for a number of days and photographed it; small storms, development of weather over vast areas on successive orbits; the variety of information that came out of

of the flight was excellent. Later on these guys were busy with their rendezvous and docking and the time alloted to photography was cut down. There was a timeline developed after that, I guess. Photography was possible between 33 hours and 12 min and 33 hours and 18 min or something like that and they clicked away so as to get a portion of the earth. They then forgot about it for a day or two. They all used up their film except Gemini 8- they didn't get a shot at it. A lot of film was used up in rendezvous - a couple of hundred pictures of the 6-7 rendezvous. I guess it was rev 14 or rev 15 that Stafford got some tremendous pictures of Africa.

Gemini 7 which lasted 14 days, the crew got a lot of real good stuff. It probably would have been better than 5 but there was a very dirty window and if the sunlight was on the window it degraded the pictures so that they weren't as useful. There was a lot of good data, but not as good as we would have liked. Then they carried a role of infra-red Ekto Chrome on Gemini 7 which is the only time that has been used in space to date. Gemini 8 they photographed the rendezvous, and then had the trouble that required them to come home, even though they brought back empty magazines. The Gemini 9 crew encountered the problem of the ATDA they couldn't dock to, but they photographed it real well--took a couple of hundred pictures--very spectacular photography. They also photographed why the nose cone did not deployebecause they got within inches of where the wires were hooked up and they took photographic evidence that it was wired wrong. Although these photos were taken 185 miles above the earth at a speed of 5 miles/sec, they were used to document the situation and the contractor was docked for his substandard performance--which is a rather unique way to do it. I don't remember whether it was Lockheed or McDonnell, but it seems

there was some jurisdictional conflict at the Cape. I don't know whether it was a union squabble or squabble between contractors as to who had rights on the pad at that time. In the resulting confusion something didn't get done, and when the signal was given to deploy, the clamshell springs reacted but the charge was not set off, because the electrical circuit was wrong. It just hung on. They also took some unique photographs, as a bonus of the ablation effects on the nosecone of a rocket going out into space, which is something they couldn't have done if it had deployed.

Gemini 10 was such a busy mission what with rendezvous with 2 Agenas and a couple or three EVA's, that the photography wasn't the greatest. The crew was too busy and a few things were going against them. I remember Life Magazine or another publication saying that John Young wasn't the greatest photographer in the world because his rendezvous pictures weren't as good as those of Gemini 8 or 9, or the 7-6 rendezvous. I thought that was a rather unfair criticism, as the flight dynamics were such that he was required to rendezvous into the sun. In other words the Agena was between him and the sun, and evan a kid photographer knows that he should put the sun over his shoulder when he takes a picture. However, they didn't have this choice. They photographed it anyway to document it for our engineers, and as far as the engineers were concerned it was great photography. Life Magazine griped that it wouldn't make the prettiest cover in the world, but I notice that they did put it on the cover of their magazine anyway.

During this flight the crew photographed the windows and from that we learned what caused the problem of poor visibility, and it gave us enough time to get the windows on Gemini 12 reworked. Liquid silicone is used between the panes to seal them. McDonnell would put this gooey stuff in there and put enough in to be sure of doing an effective job of sealing. But when the rocket staged, it would fly through its own fireball and this would cause intense heat on the windows and these silicones would gas out and redeposit on the exterior surface of the window. This made the window a bit more opaque and hurt photography. The windows of Gemini 12 had not yet been sealed, and when the silicones were added, McDonnell was careful that their workmen didn't squirt too much in there. It sealed as it was supposed to but the excess was not sufficiently great that it could vaporize and as a result, we had very clean windows.

Apparently from the standpoint of engineering photography, Gemini 10 was probably the best as far as the aerospace engineer was concerned. Collins lost a camera on the flight. We sent him a bill for it, but he said he wouldn't pay it because he knew right where it was - it went right over Houston every afternoon about 5:00 until it reentered and burned up which was about 14 months later, I guess. When Dr. Haselbad came down here, he wanted to meet Mike and when they shook hands, Mike apologized for loosing his camera. Haselblad told him to not be concerned, as it was the best piece of publicity he had ever gotten--having one of our cameras in orbit for over a year. (Haselblad even posted a $10,000 reward for anybody who would go up and get it. There wasn't much of a chance for that sort of thing).

Gemini 11, of course was the high flight - 851 miles from earth. We had a hotshot crew there - Gordon and Pete Conrad. They were really tremendous people to work with on the training. They went up to get great photography and they got it. In one training session at the University of N. Carolina, Larry Dunkleman from Goddard had an experiment he wanted to fly on the mission. It wasn't approved for flight at the time. We were training the crew in Moorhead Planetarium at the University of N. Carolina, (it was used throughout the whole program). I had talked to Larry the night before in the motel, and Larry said - "I came down despite the fact that my experiment is not yet approved and if I get a minute or two I am going to try to talk with Conrad and tell him what I would like to do in this experiment." He was hoping that Pete would give him a few minutes of his time the next day. He went over to the planetarium about 7:00 the next morning and Pete and Dick were sitting there with their backup crew - Bill Andres and Neil Armstrong (?). Pete came over and shook hands with Larry and he said - I know your experiment isn't onboard, but let's go over it this morning like it was the most important part of the whole program. That's the kind of crew we had on that flight from the photographic standpoint. Larry was delighted. Nobody does a better job than Pete Conrad. It was a low light level experiment involving air-glow or dim light. Larry has always been known in the trade as Dim Light Dunkleman, because with less than one foot-lamba of light around, he's happy. The rest of us go blind about that stage of the game.

On Gemini 11 we got pictures up to 800 miles in altitude, and they are rather spectacular. We are still getting a lot of mileage out of them.

On Gemini 12 with Aldrin and Lovell there was a lot of photography to do and they got a lot of really good stuff. We asked Buz Aldrin to take two pictures of a view instead of one. Because he would be moving so fast, it came out in stereo, and scientists would be able to get more out of say 100 stereo pairs than 200 singles. Buz did that and we got a lot of valuable data from the photogrammetric and the stereo point of view. It was tremendous photography.

I began in the Photo Division as the only person assigned as a scientific consultant and then things started to grow. It became obvious that I couldn't handle it alone. The lunar surface mapping people wanted mapping products, and it was obvious that the general laboratory at MSC could not provide them service for several reasons. A general laboratory has to crank out as many products as it can as cheaply and rapidly as possible to meet the needs of the Center and the PAO. But for high precision photography such as the lunar surface people need to make their maps, volume production is of no value. Two glass plates may serve their photogrammetrist for a month's work. They don't need a million items of merchandise, but what they get must be of high precision and must be of absolute reliability. Thus the objectives of a general lab and the needs of the selenographist are not compatible. The type of service we needed exists primarily in a very few agencies of the government where work is conducted in high precision mapping. I came out of a high precision mapping group and when I wanted some help I went to the Army Map Service and borrowed Rudy Davalos for 6 months. I had

worked with Rudy a number of years earlier when he was employed by a civilian contractor in San Antonio. I was then the government technical monitor of the contract. It was obvious to me that without Rudy the company would have really been in trouble. He has unusual technical capabilities and enthusiasm. In 1962 or 1963 the company went bankrupt and a number of really good technically qualified people were dumped on the streets of San Antonio. I was then in Washington trying to put together an organization so I went to San Antonio and hired a number of people I knew were very competent, and Rudy was the first. Thus when I came to MSC, I asked him to MSC on a 6 months detail which in reality gave us time to work out the paperwork and pick him up as a NASA employee. Army Map thought it was a dirty trick because they lost a real good man, which I guess it was. As our outfit grew and it became obvious that with the earth resources program becoming larger and flying more flights with a second airplane, we were going to need more help. I went back to Army Map Service and asked Johnny Salinas if he wanted to come back to Texas (he was a native of San Antonio). He thought this was a great idea. With Johnny added we had the nucleus of competent group. But as requirements grew we knew we had to have more people, and my idea was to go back and pirate them from Army Map Service. NASA had different ideas. I was instructed to go to a contract concept. We worked out a contract with Data Corporation of Dayton, Ohio, to furnish us about 5-6 people the first year of the contract. They furnished us with a very competent group of personnel.

In the meanwhile I had built a high precision lab in the front of the building where our offices used to be. Mr. Brinkmann, John Holland, Edmon ds, and I gave up our real plush offices for the photo lab and we

moved up in the back corner of Building 8. We needed this precision lab to service the earth resources program and the lunar mapping program. With earth resources program money, we bought several pieces of expensive equipment. Although earth resources money was used, and the equipment might get some utilization in earth resources program, it for sure was needed by the lunar sciences people. We were trying to build a precision lab and we didn't give a damn where the money came from as long as we got one that was complete and designed to handle airborne photography. We assigned Data Dorp to do the earth resources work, because earth resources was picking up the tab. Johnny and Rudy did most of the work for the lunar surface people.

Precision photography is usually is usually micron photography--where microns, not fractions of an inch are the basis for measurement. This photography is radioed back and has to be reconstituted into a photograph. They are long narrow 35-mm strips fitted together to make a picture. We put it on glass plates 9x18", 1/4" thick and weighing about 6 pounds apiece. They are flat to 2/100,000", which is pretty flat. In fact, it is so flat, if you touch these plates together, you don't get them apart again unless the surfaces have an emulsion buffer. Otherwise the surfaces are stuck together, and can't even be slid apart. We put this image on these glass plates very precisely so they could use them in their plotters. I understand they have been well satisfied with our work once we learned what they wanted and they learned what we could do for them. We had a little trouble at first because in transmission one strip might be emulsion up and the next one might be emulsion down. Sometimes

they were positive views, whereas a negative view was needed. We ironed our problems out and developed a special form and language so we always knew what we were talking about whether over the phone or on paper and things have gone great from then on. With the two contractors involved (Autometrics and Lockheed) and one of our own and all different contractors and different directorates, it was enough to create problems. Really to support them correctly, we are still not doing things right. The whole philosophy is wrong. In any of the agencies doing high precision mapping, the people in the photo lab are an integral part of the overall mapping effort - they have the same line of supervision and the materials never leave the environment. Here they are made in Bldg 8 and are used in Bldg 226. When you take glass outside, humidity and temperature change precision products. From that standpoint we are not able to give the quality of work that we would like to. Then we have administrative problems. We are in the Administrative Directorate and the lunar surface mapping element is in the S&AD.

Precision photography and precision reproduction of the material is required. If the maps of where astronauts expect to touch down on the moon aren't reliable, it will be because we won't be getting the ultimate out of the materials we have to work with. Most of us have worked in the mapping business before, and we know these problems.

As we go more and more into this area of work we expect requirements to grow. Eventually we will have lunar orbiting cameras, we will bring the film home, and no doubt will make more precise maps of the moon--maps for traverses across the moon by manned vehicles. We will have
347 to have the proper precision accurate mapping equipment here to make the
379-1 maps and to be able to deliver them the product that is compatible with the equipment they have. There is no point in them having a machine good to 1/10 of a micron of accuracy if we give them a photo product that's only good to 10 microns. That's a waste of money and effort. The end results are no better than the weakest link in the whole problem, which right now is the way we do business.

The earth resources program badly needed the second airplane, the Electra. It's well instrumented. We're still flying the Convair. I won't fly in it myself because I don't think it's safe. I've had
379 2400 plane rides in my life and it's the only airplane I think is unsafe. It's obsolete and too heavy to fly; there is too much gear on it. If it ever loses an engine it will be in serious trouble. We want to replace that airplane. The division has photographers on it, which are our only people onboard. As soon as these films come back we get them to the site to process and duplicate for the user scientist as quickly as possible.
380 In the early stage of the game we had a lot of problems. The contractor came onboard, then there was a money shortage last year. They decided to cut down on procurement. Procurement cycles on these special films tend to be extremely long. I guess someone figured we would not be able to spend as much money if we lengthened our procurement cycles. We ran out of material, and it takes months to get special emulsions from

the manufacturer. We had a helluva big backlog of work as a result. All of our experimenters were a little mad at us and mad at the program. It looked for a while like it might fail for that reason, but we got it straightened out. We promised we would turn this stuff around in about 14 days, and put it in the hands of the experimenter. He would have exact high precision duplicates of color films and infra-red color films, the radar data and all the other information he needs. If scientific photography can be done from an airplane perhaps it can be done in space and if we can do it in space, we want to know how good the results are going to be. If we need 10' of accuracy when the spacecraft will only give you 100' of accuracy you might as well forget about flying something in space for it isn't going to give you the answer you want. We now have reduced the turn around time to less than a week on most of our work and we have a very happy crew of scientists now in the program. All the bugs have been worked out and everything is going well, but it's growing. This year when we went back to contract with Data Corp., we asked for 10 people instead of 6, and we will probably need more in the future.

In the meanwhile, other people in the Center learned that precision photography had come to MSC and they also became interested. Most of these people were in the S&AD. This was something of a problem, for we had two organizations in S&AD who paid for our equipment, and picked up the tab for our operations, and they both want their work like yesterday. We're trying to get the work through in an orderly fashion and they are both giving us hell because we aren't doing their work first. Now that the Earth Resources Office has been reorganized, I think this problem will iron itself out. The Lunar Receiving Lab people wanted high precision

photographic analysis of their electron microscopy and other work beyond the capabilities of ordinary photography such as electronic dodging of photography. There we take a small portion of the gray scale and enlarge it to the point where we can read a great deal of data which can't be seen in an ordinary photograph because the eye won't sense that many shades of gray. For example some of these tests they run on sterile mice blood cells, have been enlarged 20,000 times. We have enlarged them even more and dodged them to the point where we can see portions of these cells and nothing else. Also in other cases they want high precision enlargements for precision measurements. With the advent of the lunar landings, I am sure that's going to have a tremendous importance as far as scientific photography is concerned.

Other people who have required precision photographic work have been in the flight crew support area, and involve the use of the lunar and earth simulators. Link built these complex and expensive simulators. They use film as a means of simulating terrain for the astronauts. We duplicate these films for them, and give them the exact color and fidelity of the original. If the original film breaks or is torn up, the astronaut will be able to use the duplicate, and he'll see the same hues and colors and brightness levels that he would have had in the original film. Our work for them entails special handling, it goes on special film with special sprocket holes, etc. It complicates the work but it keeps it interesting.

The equipment we have been able to secure has all been first class - the aerial cameras we put onboard the aircraft are all made in

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Switzerland. We had to get exceptions to the Buy America Act to get them, as high quality cameras seem to be either German or Swiss for mapping. We have a SEB-V Zeiss Rectifier which is as precise as any made in the world today for photogrammetric rectifications. It has a built-in computer that computes the isoshift as we tilt these photographs and continually centers the image in order to give the correct perspective. For processing of films we went to Eastman Kodak and bought two Versomats. The DOD was then the only organization using this equipment. There was a real fight to get it, but we felt we needed it if we were going to do quality color work.

When I worked for the DOD I used to push color pretty hard, and I was reprimanded for my efforts and told to stick with black and white. When I came to MSC I was allowed to start color work from the air. We have done much of the pioneering in aerial color mapping photography even though theoretically that isn't our primary role. We have done enough of it and have done a good enough job with it that the entire scientific community comes to us for advice. In many cases they plea with us to process color films for them because we have a good system here. Not only do we have very precise density controls, we are attempting to buy electronic equipment to do tone control. The color machine controls the temperature to a very small fraction of a degree, and it replenishes the chemistry very precisely. Instead of having the whole system at a given temperature, we can control each tank at the best chemical temp, which of course is a big advantage. The film is neatly handled and beautifully processed and all the work that has come through has been of exceptional quality.

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When we started, scientists weren't too interested in color because they were just like everybody else, they'd only worked with black and white and a few of them said they were only interested in interpreting black and white. We flew color anyway. I guess then we had 20 experimenters in the program, and now we have a couple of hundred. If we went out to fly some black and white tomorrow they'd murder us. They've all been converted to color. They are used to working with it, and they are getting far more information out of their studies than they would have with black and white. The reason is simple - a good eyeball can distinguish 200 shades of black and white--it can distinguish about 20,000 shades of color. We were able to pioneer this work thanks to the earth resources people getting us the money for the equipment, cameras, etc. It's starting now to spread throughout the country as a valuable tool in earth sensing. If Eastman Kodak's volume of sale of color film were known, I'll bet it would be a logorithmic curve going steadily up, and soon their work will be all color, I am sure, because the data is there and in so much more detail.

We've done a lot of pioneering work with our multi-spectral cameras here. We had the first one built. Itek built us a 9 lens camera where we could look at 9 portions of the electromagnetic spectrum simultaneously. We built our own Haselblad space cameras and mounted them in pods and have fired them simultaneously. We can even improve on the Itek system. The use of multi-spectral photography is really growing due

to what NASA-MSC has done for the scientists. Two years ago everybody thought multi-spectral photography was great, but no one had any application for it. We are now breaking up the electromagnetics spectrum into discrete portions. Some of these cameras will only see the near ultra violet or the ultra violet and others will see other portions of the spectrum, the reds perhaps, greens, and yellows. It is possible to build with filtration so that it can be cut off at any point desired. The University of Arizona is doing some work through earth resources on square wave response - where the cutoff and cuton are almost square functions. There is not a curve going up to a given point and coming down - they are straight up over and straight down. This is really what we want instead of a gradual curve which takes several hundred angstroms to rise to a given peak and work through the earth resources program.

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We also are doing some work on coating films so they are only sensitive in certain band widths.

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For the past three years we have pushed the earth resources program pretty hard, but couldn't get anyone to listen. All we had initially was a handheld Haselblad on a Gemini flight. Now it seems like every company wants to get in the earth resources business. I guess they realize that if Apollo Applications goes, its main value is in earth resources. It's the return that taxpayers will buy, and the returns are just fantastic. For several years I have predicted that there will be a complete rennaissance in remote sensing over the next 5 years. I hope it's the MSC school that accomplishes this advance.

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We would like to have the program controlled from here. I guess if someone else ran it it would probably be essentially the same idea, but we think it can be done best from manned vehicles--from space stations, and space platforms--and yield very valuable data on geology, geography, oceanography, agriculture, crop disease, and hydrology. Practically every geoscientist I've met, even biologists are quite interested in what they can learn from this type of photography. A biologist looks through a microscope; you put him 200 miles above the earth, give him a picture, and you wouldn't think he would get much out of it, but such is not the case. It is simply amazing what is starting to come out in literature on what can be done with the use of the cheap $500-600 camera compared to data that has come out of our more sophisticated systems. This is the wave of the future and I hope we are going to be here to ride it.

We've built a Class A Laboratory here but it is designed around the requirements of an aircraft program and not around AAP so now we are looking ahead to AAP. We have many ideas on how we can best serve NASA in that program. If some day we are told to start a new lab to meet these requirements, we will have already begun work on the plans. I hope we'll be able to lay out a fairly comprehensive plan within a matter of a few days.

In the meanwhile the money is coming out of Apollo and that is keeping us alive. About a year ago, our mail was very heavy from people wanting information on space photography. We decided to augment our staff

by one geologist. I know it must seem strange that the photo lab which is under the Administrative Director, would be the right place to find a geologist, but Herb Tiedemann is here. He was Paul Lohman's assistant at Goddard and he wanted to come to Houston to live. We knew he was competent in space photography. He had also worked with the astronauts assisting Lohman as an experimenter and he had worked with me when I was the technical monitor on the photographic experiments flown on Gemini. Herb came around May 1967, and he handles a lot of our correspondence with people from all over the world - research scientists and academic people who want to look at this photography. Since all this information has been released, we put it on a light table and they can peruse it as long as they wish. We hope they will use it to do some research which is constructive and incorporate it into the literature, so we will have more to back up the values of space photography.

For the Apollo program's two unmanned flights we put a camera on-board after much weeping and gnashing of teeth--we would have had no luck at all until we got Paul Haney in the act. Paul justified it as a public affairs function. So we flew it for pretty pictures. But it went out 12,000 miles and got some spectacular views of the earth from that altitude which was something that hadn't been done before. When the 502 mission came along, we had the same camera and again we had no interface with the spacecraft other than the nuts and bolts that held it, and the Apollo Spacecraft Program Office didn't want anything to do with us because they had enough problems of their own. We interrogated the computer to find out what the spacecraft was going to do, and how to

mount a camera on it to get decent pictures, and on the basis of that information we got two stereo photographs looking straight down at the earth for nearly 2 complete revolutions--a tremendous piece of information. We used a new film that we had been trying to get from Eastman for a long time. Under the program as planned we expected to get between 3/4 and 6/7ths of a revolution. In other words the camera would look down at the earth from New Orleans to Guymas. We were satisfied with this arrangement, but we were surprised by being handed a bonus. The spacecraft fouled up and didn't roll up at Guymas like it was supposed to, and we got pictures of a complete pass around the world, across the US from ocean to ocean and back out into the Atlantic again. The geoscientists who have seen this photography with this new film are elated at the results. Its a big improvement in technology. Again it is the same camera that flew in Mercury--not a very sophisticated camera--but the new film yielded information never believed possible.

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We expect to support Apollo right on up to the lunar landing with the new and better Haselblads. We are trying to improve the film technology and handling technology, giving advice on photogrammetry in an attempt to get more precise information out of our photographs of the lunar surface and the rendezvous and dockings of the Apollo.

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The earth resources program is really our test bed for AAP using airplanes. I expect a rather large AAP program will develop here at MSC--at least we hope it will be here. If we go into the earth resources of AAP you have to start somewhere, and the best place is with an airplane or several airplanes so you can fly various altitudes and work from there. Many of the sensors are photographic but many of them are not and we don't have too much to do with those that are not. We have mapping cameras using

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conventional Ektachrome film, we also use a color infra-red film which is sensitive into the infra-red range of the light spectrum and gives a false color picture. The film was developed for camouflage detection, but we found that its application in geoscientific detection was equally good if not better than detecting camouflage, because nature is probably as sophisticated a piece of camouflage as has ever been devised. The multispectral cameras are used for gathering data in the narrow bands of the spectrum. The color film is the widest band. It sees the total band width and these others look at smaller portions of it. A picture taken at 4500 Angstroms has certain signature and a simultaneous photograph on another film taken at 7200 Angstroms has an entirely different signature. The relation of signatures in these 9 lenses in different emulsions tells you something geologically or from an agricultural standpoint. It can detect disease in crops, beatle or insect infestation in crops, and improper irrigation (both over and under and when irrigation water is carrying some deterrent to crop vigor). It can detect illegal cutting of timber, and overgrazing. It can detect when people in New York City were sneaking out at night to water their lawns during a water shortage, because their lawns came out a brilliant red on these infra-red photographs, whereas everybody else who didn't water their lawn the night before showed a dirty brown on the photos. Big brother is really watching from up there! There are a number of radars and other sensors on the vehicle--thermal infra-red sensors which can detect temperature changes in ocean currents and hot spots on the earth--thermal anomalies in different types of rock, depending upon calibration. The radars can see through the clouds that cover the earth, get right down to bedrock and give a lot of good data. These sensors gather data simultaneously. The

information comes in here right from the airplane and we process it out, duplicate it and get it on out to the users rapidly as possible. The airplane right now is out in California. We have a number of Brazilians and Mexicans out there with it who are guests of MSC and the earth resources program, as part of our effort to build international cooperation.
On the ground are other scientists who gather ground truth. Some of them are taking samples of salinity in the Sulton Sea and in the irrigation ditches, moisture content in fields, etc., in the Imperial Valley. Others are analyzing the reflectivity of rock and surface, soils, and trees; others are measuring radiation effects. They are doing all kinds of things depending on what the pet project of the investigator is.
If we are in the area and have the plane overhead we might be getting data for 10 different scientists on the same run. From the ground truth-generated information vs the flight-generated information we can develop data useful in a spacecraft or a manned orbiting laboratory. We know that if we get these sequenced signals in California we will also get them in Africa, South America, or Asia when similar conditions exist. That's the basis of the program, and that's why the aircraft program exists. It's a training ground for a spacecraft program, and enables us to determine whether it's feasible to invest our money in a given system.

During Gemini 5, we told the crew to take some pictures of the earth, and asked them to use up 4 magazines of film. We gave Conrad and Cooper a little rundown on what we wanted in general. They brought back information of really great scientific value. There were a couple of pictures of the

Bahama Banks and several of some unique sand dunes in Africa, and perhaps several more of patterns of coastal currents in the Gulf of Mexico and so on. They were putting that gray matter between their ears to work. They were very selective in the choice of subject matter and they brought back about 300 pictures. Of that number 95% were of exceptional value. A machine can't do that. A machine usually also/can't repair itself whenever a problem develops. I guess one could be built that would recognize when not to take a picture because the area is cloud covered, but what if those clouds are unique? The weather bureau might get a lot of data out of pictures of those clouds if they were of a specific type of clouds. The weather bureau is quite interested in vortices and in particular how they develop. The ultimate of a vortex is a typhoon, a tornado, or a hurricane. Conrad, Cooper and other astronauts have photographed the birth of a vortex. Perhaps a machine could be developed that after orbiting the earth 84 times would bring back a few pictures of that nature --would point the camera at the right time at the right place, have the right setting for the light, etc., and bring it back as a beautiful picture. The astronauts did so on a number of occasions. A man who is a scientist and perhaps a geoscientist knows the needs of a geoscientist and is able to satisfy these needs. He can change the magazine, change the film from one type to another, change the setting to get the best effect, he can look out that window toward the horizon and pick up something of value and photograph it when it goes by him obliquely or under him. On space stations he can probably process these films and even analyze them in the spacecraft when necessary in the interest of time. For example, hardly anyone wants to know what yesterday's sea state was. But a ship would find information on today's

sea state or the immediate sea state every useful and a shipowner can save a lot of money if he knows it. We might even be able to build a spacecraft that will analyze such information and dump it as electronic data. Certain operations can be automatic. The only difficulty with photography is that we have never gotten exceptional photography out of unmanned systems. When a man is in the loop one can expect better jobs. It would have been great to run unmanned U-2's over the USSR and avoid the complex political problems. But the U-2 would have been a fairly useless tool without anyone onboard to select what information he was going to get. I think man is in the loop to stay. He's just too good a machine to waste.

We call our area the precision lab because the work we turn out is tailored to very stringent requirements in terms of chemistry, temperature, cycling, etc., and we have gone beyond the normal in color reproduction and are going now beyond the normal in tone control. We analyze all this material very closely, buy it in large batches, freeze it, so it won't change in sensitivity and monitor it the whole time it's out on a job so we can get the best results.

Today in photosciences you just don't buy a bunch of equipment and put it together and have it work. You buy a system. We selected a Kodak system because it did the best job as a system. The film that flies in the airplane is Kodak Ecktachrome. The film then is put through a color processor which was built by Eastman Kodak, and cycled for their film. The chemistry is made by Eastman Kodak because it is very unique in the way it works. The machine technique was developed by Eastman Kodak. The processor runs at about 4 fee/tmin, so with a 200' roll of color film it is out of there in about 50 minutes. In the old days with the old

rewind system, it took 8 manhours to process a roll of color film, and it was no where near as good. Now in 8 manhours about 8 rolls of film can be produced, so the machine pays for itself pretty quick. These film are up to 10" wide and up to 1000' long, all in color, and there is no change from the beginning to the end of the roll because the chemistry is replenished as rapidly as it's used, the temperature is held constant, and so on down the line. We have a black and white machine that does the same thing though it isn't as sophisticated since it doesn't have to be. The color machine has 14 tanks of chemistry; the black and white machine has 3.

We are now attempting to improve the color negative processing because our users are interested in their product and not what we put in the camera. We can do the job much cheaper for MSC by doing color negative material instead of positive. To reproduce it we use a Niagara which is a machine developed for intelligence photography to give very high resolution. It was classified for a number of years, but finally downgraded so we could get one. It goes beyond our capabilities somewhat but it gives us the highest possible resolution and the gentlest handling of films. We are getting a lot of utilization out of this machine. It will resolve 500 lines per millimeter, which is pretty near the state-of-the art. Our biggest handicap is the equipment we use. We use this equipment in an unclassified mode and the information is releasable. We can't use state-of-the-art equipment because it is reserved for classified precision reconaissance work. So we have to wait for it to be declassified. The same is true of film. We have to wait until the better films are declassified and this hurts us a bit, but is a situation we have to live with.

Other equipment we have in our lab includes a continuous printer for the long rolls of aerial film. It has a fine spot scanner that can look through the moving negative, draw stock to duplicate it, and adjust the velocity of a raster beam on a cathode ray tube and therefore "dodge" - take out the shadows so you barely even seem them. You see information in the shadows which in the normal picture was so jet black that the human eye wouldn't detect anything. We have an enlarger that does the same thing. Many people believe these things are nearly human. They do what was once an art. Some people were exceptionally good at it and others were no good at all. Sometimes dodging techniques were highly lethal because cyanide was used and a number of oldtime photographers were killed in the process. When the thing overdarkened, they would use cyanide to bleach it out and if they ingested enough of that they were in trouble.

The contact printer we have uses a TV tube as a light source. It is set up to project a certain amount of light and certain scales of densities. It isn't quite as smart as a human being because if you lay a 50¢ piece on it, the machine attempts to get so much light through it and if it takes a million years it tries to do it. It doesn't have the capability of turning itself off when it has an impossible condition to cope with. These machines were developed mainly to locate minefields (to pinpoint the location of mines). They've also been used a great deal in archeological exploration. (It can detect by amplifying the gray scale changes in albedo that the human eye could never work with). A gray scale density in this machine if enlarged 20 times will give 20 densities. We can take a checkerboard and put it on there and set it so it prints out a continuous gray scale and things of that nature.

Other devices we have to support the program in the chemical field and film and emulsion research sensitometry, etc. But it's still rather small. We have 1/2 million invested in our equipment.