*Photogrammetry is the Key to Exploration of Space. Keynote Speech**

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YOU are here because work in photogrammetry or an allied field is your primary concern and the knowledge you obtain from examining the exhibits, from hearing the papers, and from talking to your cohorts will assist you in your work.

This purpose is basic with all of you; but there is a large group among you who have a stronger reason. This is the group who are part of—or closely associated with—man's rapidly approaching greatest adventure of all time—the exploration of space.

Many of the papers read yesterday afternoon and this morning were concerned with systems oriented in space; or with providing simulated space environments on earth under which these systems could be tested. One paper discussed the requirements of a mount which would provide laboratory-type performance of systems while functioning on a space platform. There was a paper on digital storage of stereo data—data which when operated on by electronic computers would answer the questions of analytical photogrammetry—of what object is where.

If you add to this technical interest in space equipment and analytical methods, the daily front-page stories of the space probes, both ours and Russia's, and the large volume of other related technical material being turned out, you cannot doubt that the exploration of space is the frontier of twentieth-century man.

Nor can doubt exist in the mind of any knowledgeable engineer that this frontier will be levelled only through the intelligent and significant use of photogrammetric equipment and techniques. All of you, in your own minds, will undoubtedly accept this statement without question; however, in order to understand truly this idea, let us take a few minutes to do three things:

(1) Examine the state of the science of photogrammetry in the world today
(2) Review the reasons for space exploration
(3) Summarize the past exploratory accomplishment of photogrammetry

First, the status of photogrammetry today. Unquestionably, using Lord Kelvin's balance, it weighs in as a scientific enterprise. It was he who said many generations ago,

> When you can measure what you are speaking about and can express it in numbers, you know something about it; but when you cannot measure it, cannot express it in numbers, you have scarcely, in your thoughts, advanced to the state of a science.

By these standards, photogrammetry is certainly a science. It is basically an extension of the very old science of geometry in the sense that it investigates certain qualitites of objects such as size, shape, distance, proportions and equality. In order to do this, it customarily records the information by means of photography which, again using Lord Kelvin's criterion, is most worthy of being called a science.

There seems no basis at this point to limit the sensors to the visible portion of the spectrum. Radar and infrared detector systems obey the same geometric principles

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referred to above. Consequently, their methods of application and analysis closely parallel those of photogrammetry. For these reasons, let us consider during the time of this speech that the proper role of photogrammetry in space exploration is acquiring information about heavenly bodies by means of all electromagnetic sensors.

Secondly, what are the significant reasons for exploring space? The trip to the Moon, for instance, since it is our nearest neighbor, will represent man's first step into space. Everyone knows of Jules Verne's Trip to the Moon a century ago. That book was the basis of many a jest. But our modern, extremely detailed scientific plans are no jest. The question still stands: Why does man want to go to the Moon?

There are many scientific reasons such as the low escape velocity of 7,000 miles/hour instead of Earth's 25,000, which will assist materially deeper space exploration, and the clear visibility with telescopes which astronomers have needed for centuries. But heading the list undoubtedly is the same psychological imperative that Hillary cited when he climbed Mt. Everest. He climbed it, he said, "because it was there." In effect, because no man had previously attained its summit. He, as man's representative, wanted to prove that mankind could meet the challenge.

And so it will be with space exploration. From the time of Columbus and the founding of the Colonies, the pioneering spirit has driven American exploration. In the beginning the explorer equipped himself with weapons of defense for self protection, with whatever information concerning the unknown land could be obtained from the natives, and with faith in his project. Spanish Conquistadors captured the Inca treasures and destroyed that civilization, but they planted their flag on the Pacific Shores. Wagon trains crossed the North Atlantic continent and their guides drew crude maps for those who followed.

Exploration continued through the centuries but exploration methods changed. Today, we investigate accessible areas with highly precise photogrammetry, and with slightly less precision, inaccessible areas where no ground-control is possible. Photogrammetrically maps have been made of the jungles of Africa and the Amazon river bed. Detailed information of the Alaskan territory has been compiled photogrammetrically to build the DEW Line. Also, areas of the north and south polar caps, on which no man has set foot, have been mapped in detail.

In Africa, the Amazon, Alaska, the polar caps—only photogrammetry was capable of doing the job, or producing reliable maps and of obtaining detailed information of these forbidding areas. Such accomplishments show that photogrammetry will be a capable space probe.

Before man, or men, will land on the Moon, there will have been obtained, through photogrammetry, enough information about conditions there to assure the safety of our astronauts. We will have learned the details of the Moon's topography, and have analyzed its surface composition. We will have determined whether all or only part of the material needed to support human life must be carried from the earth.

The first phase in this exploration has long since been begun. From the Earth, the Moon has been observed, photographed, and measured by means of telescopes. Maps have been drawn labelling the dry lunar seas and the mountains. Approximate heights and depths of these features are known. Astronomers all over the world have named and have located thousands of topographic features and they have also recorded the great range of temperatures, experienced by our natural satellite.

The second phase in Moon exploration is now supplementing the first. Man and scientific instruments have been lifted high above the atmosphere, have been orbited around the Earth and safely landed. These experiments which have been done with all of the rigor of modern science have proved that both men and equipment can survive in space when adequate provisions have been made. We know too, that communications with our astronauts can be maintained during flight.

Also at this time, better photography for more accurate mapping of the Moon is

under serious consideration. Maps which will facilitate the next exploration phase will soon be available.

The third step of exploration lies just ahead. First instruments alone, then men and instruments together, will orbit the Moon itself in an observing vehicle. The fundamental objectives, using all information-gathering sensors as referred to above, will be to collect data and to carry out experiments that will extend man's scientific knowledge for the impending landings on the lunar surface. Photography, with visible light and with the new high acuity camera systems, will provide the highest information content and the most accurate measurements possible; infrared will supplement this information and fill in certain gaps in our knowledge of the lunar surface; and radar, with "radargrammetry" techniques, will analyze other aspects of the area to be explored.

The fourth and final phase of the lunar exploration will be the establishment of bases for the operations on the Moon, and for continuing thrusts out into space. The investigations required by such activities will be similar to those carried out on the earth. Surface investigations, selenophysical studies and atmospheric analysis will lead to the establishment of communications and transportation networks and environmental facilities. All of these physical needs, however, will require the securing of a class of information, not previously necessary. And this too, can best be done photogrammetrically.

At the present status of our world knowledge, the many details needed to know about our satellite are only surely available when the latest refinements and the most advanced photogrammetric techniques are employed. The activity must be supported with mapping cameras of greater sophistication than our present, hardworking KC-1. Perhaps cameras having two cones, back to back, as suggested by Pryor in the paper he presented last year at the national convention, should be used.

We shall undoubtedly need complete automation of the photographic camera, and precise control (or knowledge), of the photographic station. Panoramic cameras which orbit the Moon will have line-scan systems generating photographic records that will depart from the classical central perspective concepts. Systems other than photographic emulsions for recording data will most certainly be developed and we can expect new media for storage and transmission of these observations which in turn may introduce new parameters into the photographic processes.

The electronic computer will play a major role in analytical photogrammetry in the reduction of the recorded data. Using all the sophisticated computational methods developed in the last ten years for electronic computer and using correlative statistical techniques, it will be possible to reconstruct observations from data for trajectory, calibration, astro, and similar.

Automatic image correlation, automatic identification, and digital photo storage will undoubtedly be available in the near future. Ultimately the photogrammetric reconstruction of visual observations may become a purely analytical chain with minimal human control. Our plotting devices will become viewing devices, integrally connected to large capacity, real time digital computers and the optical spacial model will be formed in the computer where all the dynamic parameters can be fully utilized with few, if any, analog approximations.

As photogrammetrists you must recognize that the quantities observed by the lunar probes will probably be continuous quantities; however, owing to the anticipated techniques of recording, communicating and storing, the data will become available from the space platform in non-continuous form. Restoring the photographic data to continuous form by tieing all elements together is essentially an analytical problem. Since the geometric relationships between images must be reconstructed from the mathematical relationships between object and image space, this must be as precise as possible so that the lunar surface may be viewed as a contin-

uous surface, and the final information falls into a framework which man's sense and experience will recognize and identify.

This photogrammetric equipment and these modern techniques of analysis that I have described are the scientific tools most capable of guiding exploration and assuring success in space. After we have reached the Moon and have established a site, the exploration of outer space—Mars, Venus, and possibly the satellite of another star within our galaxy will be the next goal.

At this homelike luncheon such ideas seem sheer fantasy, but man's experience over the ages has shown that fantasy has, more frequently than not, been proved in the light of subsequent scientific accomplishments to have been too conservative. Who knows now, for instance, what science will develop that will make our trip to another stellar system fact rather than fancy—a trip that may be in the future as routine, as commonly accepted, as our airplane flights are today?

Such trips throughout our solar system will, no doubt, be too far in the future for you or me to personally experience; but, on second thought, maybe not! Maybe some of our younger photogrammetrists will find themselves stationed on the Moon, developing strange photogrammetric equipment—not strange to them, but strange to us—and trying out still more advanced mathematical techniques.

Neither you nor I can really know when or where, but we do know that man is heading in the direction of outer-space exploration. I, for one, have faith that he will get there. And, while our younger photogrammetrists are making their plans for this exploration, since the future belongs more to them than to me, I think I'll sit down and enjoy a second cup of coffee.

*Practical Systems for Preservation of Optical Performance in Airborne Vehicle**

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THE problem to be discussed is an old one. It is created by the law of human nature which states that the more man has, the more he wants. The effect of this law is a thing called "Progress."

The subject for discussion concerns the information content of photo recordings made from vehicles in the sensible atmosphere as well as in outer space. Information content can be many things such as:

a. Identifiable ground-control points.
b. Culture detail.
c. Differentiation between soil types, outcrops, timber types.
d. Military Intelligence data.
e. Missile trajectory.
f. Solar spectra and other astronomic data.

For lack of a better method, the quantitative value for the information content of an aerial photograph is considered to be proportional to the system resolution defined in lines per millimeter.

In response to the ever-increasing demand for higher information content in aerial photographs, the optical industry has met the challenge with higher performance optical systems. To complicate matters, there is always the requirement that the photographic system be carried in an airborne or space vehicle of unstable or unusual characteristics.

The difficulty, cost and time of the research and engineering necessary to produce today's exotic optical systems are breath-taking. The results being achieved are worthy of the effort. Furthermore, this is a continuing situation with further progress in store for next year.

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