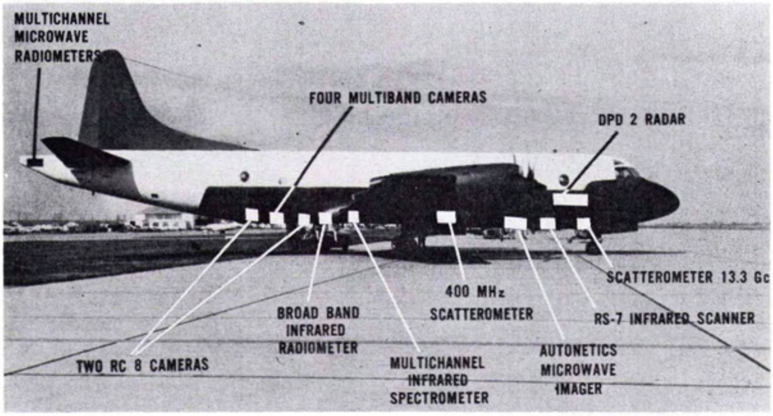

FIG. 1. NASA earth resources survey aircraft Electra P3A showing instrument locations.

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NASA Earth-Sensing Space Flight Experiments

Man may have a powerful new tool to apply in his struggle to cope with his environment.

(*Abstract on page 164*)

REVIEW AND STATUS OF EARTH RESOURCES PROGRAM

ONE YEAR AGO Dr. Peter C. Badgley, at this forum, outlined a new NASA activity referred to as the Natural Resources Program. During the past year this Program has moved ahead in an evolutionary manner. It is now referred as to the "Earth Resources Survey Program," which better describes its scope. The Program is primarily concerned with determining the feasibility of monitoring the Earth's natural and cultural resources by remote sensing from space. This is now considered one of the Space Agency's most promising fields of endeavor relative to Space Applications.

The Manned Spacecraft Center at Houston has been designated as the lead Center with respect to this Program. One of their tasks as lead Center is to carry out aerial data gathering operations. A Lockheed-Electra aircraft (P3A) of 40,000-foot altitude capability has recently been acquired and is currently being fitted with complex remote sensors (Figure 1). The P3A will supplement the Program's existing aircraft, a Convair 240, and will enable higher altitude and more complex multispectral sensing over selected test sites throughout the country. The aircraft program provides user agencies with a variety of remote sensor data and is aimed at the definition of the most suitable instruments and systems for space flight.

The Earth Resources Program has tentatively defined a sizable group of instruments for space flight, and Figure 2 indicates the

* Presented at the Annual Convention of the American Society of Photogrammetry, Washington, D. C., March 1967.

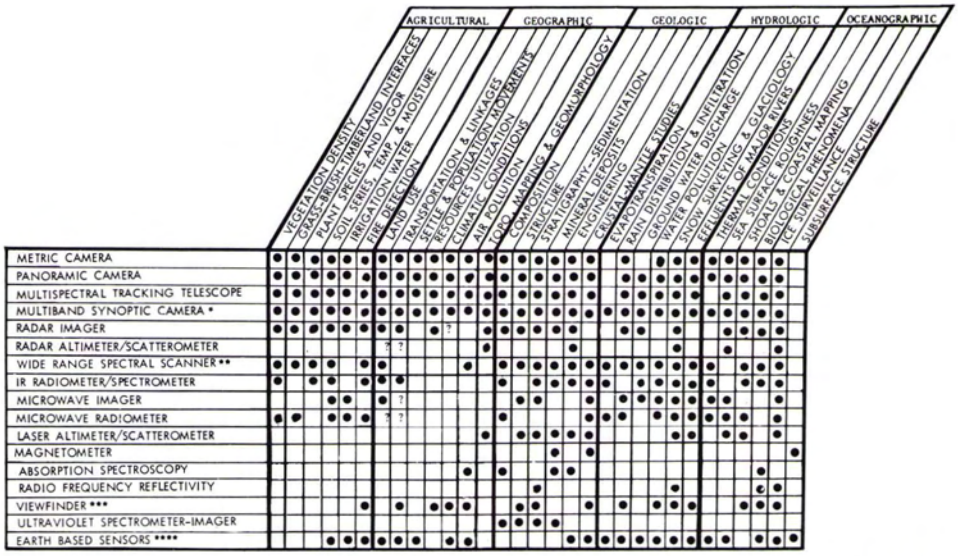


FIG. 2. Potential applications of earth resources data-gathering systems. (*) Defined for both film return and telemetry modes. (**) 0.32 to 14.0 microns. (***) This instrument augments an astronaut's vision with optical power and directional data. The astronaut can utilize the viewfinder by itself or in conjunction with other directional type sensors. (****) These earth-based sensors may include a number of fixed and mobile instruments, such as buoys, seismographs, stream gauges, etc., placed on or near the earth's surface for detecting, recording, and transmitting a variety of earth resources phenomena of interest to a large number of users. (This table has been summarized from more detailed tables for each dicipline and, therefore, does not include all the anticipated applications which have been identified to date.)

latest thinking on their potential applications. This chart includes the input from cooperating governmental agencies as well as scientific and academic organizations. Putting all these instruments into space is a complex job which will require careful planning to achieve optimum results.

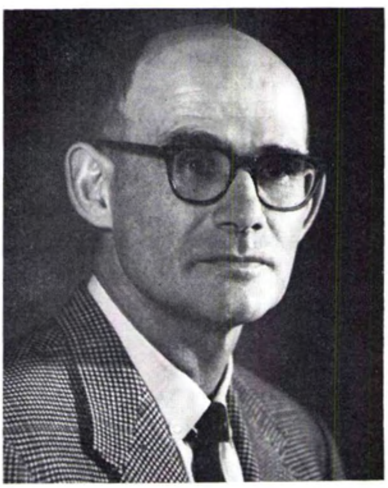
However, two flight experiments have been defined using the multiband camera approach. These two experiments may be viewed as the precursors to more complex systems where the potential applications of multispectral remote sensing can be more fully determined. The Program is not committed to any particular mode of flight. Two experiments are being scheduled for manned Apollo or Apollo Application flights, but NASA is also studying a small automated Earth Resources Survey (ERS) satellite which will probably involve telemetry rather than film cameras. The main purpose of this paper is to cover the two photographic experiments which do involve manned flights and film return.

EXPERIMENTS SO65 AND SO42

NASA has designated its first multiband space experiment as SO65. This utilizes four Hasselblad cameras which may fly this year on Apollo flights. SO42 involves six fixed cameras which can photograph sizable sections of the Earth's surface. This latter experiment is designated for the Apollo Applications Program and probably will not fly before 1969. Details relative to the two experiments are as follows:

I. SO65—MULTIBAND TERRAIN PHOTOGRAPHY (HANDHELD)

The objective of this experiment is to



ALDEN P. COLVOCORESSES

compare multiband with conventional techniques and to provide data essential to the definition of experiment SO42, which will be described subsequently. The photographic equipment consists of a nest of four handheld (or bracket-mounted) Hasselblad cameras which are commonly bore-sighted. The cameras are shuttered simultaneously and may look through the standard Apollo window or possibly have direct exposure in the space environment. Initially, 80-mm-focal-length lenses will be used which are the same as were generally employed on Gemini missions. This is actually a modification to SOO5, which is the experiment that produced the beautiful and meaningful space photos with which we are now all familiar.

As for SOO5, Dr. Paul Lowman of Goddard Space Flight Center is the Principal Investigator, and areas throughout the world have been selected for this experiment. Governmental agencies as well as individual scientists have contributed to this area selection. The definition of film and filters, of course, is the key to this experiment. Table 1 indicates the preliminary selection and associated bandwidth that has been defined for the first flight. Current aircraft tests might well indicate some changes to this table. It is hoped that conventional color photographs may also be taken of the same scenes to provide additional comparative data.

The second flight experiment will involve changes in film, filters, and focal length as dictated by the first flight. It is envisaged that these tests will continue as long as they achieve significant results.

ABSTRACT: *During the 1967–1969 time period NASA is planning two Earth-orbital photographic experiments as a supplement to the MERCURY and GEMINI-type efforts. The simpler experiment calls for tying four Hasselblad cameras together and simultaneously obtaining multiband coverage of the same Earth scene. The second experiment involves metric cameras of 6-inch focal length which again in multiband mode can photograph relatively large areas of Earth. In both cases film will be returned.*

TABLE 1. PRELIMINARY BAND SELECTIONS (SO65)
(In Order of Priority)

Film	*Filter*	*Bandwidth (Microns)*
1. Infrared (B&W)	89B	0.7 to 0.9
2. Panchromatic (B&W)	25A	0.6 to 0.7
3. Panchromatic (B&W)	58	0.48 to 0.6
4. Color Infrared	15	0.5 to 0.9

2. SO42—MULTIBAND SYNOPTIC PHOTOGRAPHY

From its title this experiment may seem to be a duplication to the one just described, but actually it is quite different. It involves a bank of six fixed cameras, five of which each have the capability of covering a sizable portion of the Earth's land surface. As Figure 3 indicates, all but one of the cameras will be space-proved versions of conventional mapping cameras of 6-inch focal length. Such cameras have wide fields of view, and when shuttered simultaneously, they combine synoptic and multispectral (multiband) characteristics—thus the experiment name.

The sixth camera is of smaller size, has a quartz lens, and will operate in near-ultraviolet wavelengths. The object of this experiment is to determine the extent to which multiband synoptic imagery can actually be applied to the survey of resources. Again, the selection of film and filters will be the key, and while they have not been finalized, Table 2 indicates the bandwidths that would probably be chosen if a decision had to be made today. Note that five narrow bands (including the near ultraviolet) and one broad band, which probably would be on color or color infrared film, are included. Table 3 indicates the basic camera characteristics, and Table 4 shows some of the coverage logistics.

The area specified for primary coverage is the conterminous United States, which is in effect a test area. Coverage of any portion of the 48 states could be applied to this experiment by various user groups, but there are priorities within this area which have been indicated by such agencies as the Departments of Agriculture and Interior. Figure 4 indicates these priority areas. It is interesting to note that 1969 and 1970 are years of *truth*

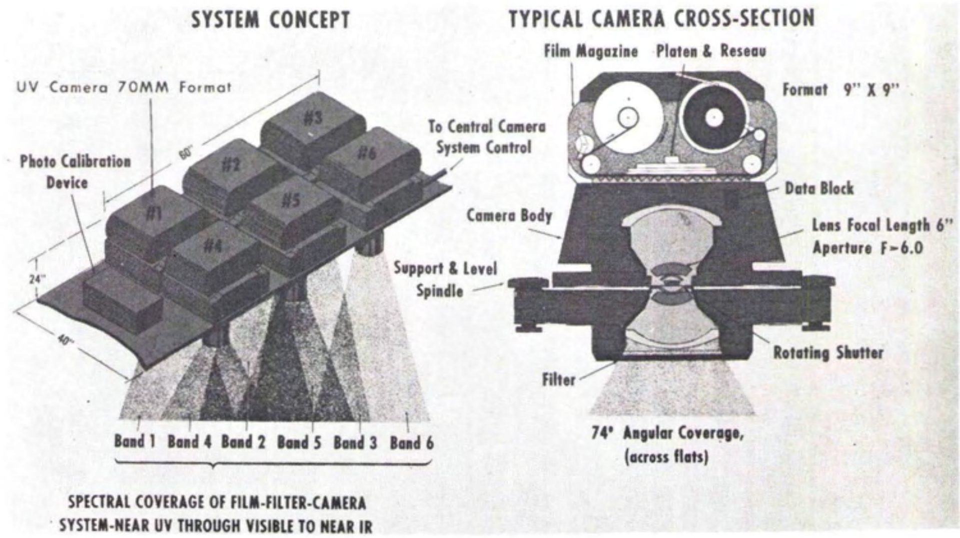


FIG. 3. Multiband synoptic camera system.

insofar as the United States is concerned. Agricultural, population, and housing statistics will be acquired during these years, and the first comprehensive *National Atlas of the United States*, which is being published by the Department of Interior, is also scheduled for completion during 1969. Space photography of this same time period can realistically be evaluated in terms of numerous resource applications.

TABLE 2. PRELIMINARY BAND SELECTIONS (SO42)

Camera No.	*Bandwidth (Microns)*
1.	0.3 to 0.40
2.	0.4 to 0.48
3.	0.50 to 0.57
4.	0.62 to 0.67
5.	0.77 to 0.92
6. (Broadband)	0.40 to 0.90

TABLE 3. CAMERA CHARACTERISTICS (SO42)

	Five Metric Cameras	*One UV Camera*
1. Format	9″×9″	$2\frac{1}{4}$″×$2\frac{1}{4}$″
2. Focal length	6″	3″–6″
3. Angular coverage	74°	42°–21°
4. F-number	<6	≃3.3
5. Spectral range	4000Å to 11000Å	2000Å to 4000Å
6. Shutter synchronization	±1 millisec	±1 millisec
7. Ground resolution (from 125 n. m.)	∼35 meters	∼60–120 meters

TABLE 4. SO42 PHOTOGRAPHIC COVERAGE
(Based on orbital altitude of 125 n. m.)

	Five Metric Cameras	*UV Camera*
Total weight of film (assumed)	200 lbs	3.1 lbs
Total length of thin base film (0.022 lb/ft²)	11,000 ft	605 ft
Film length per camera	2,200 ft	605 ft
Number of frames per camera	2,640	2,640
Ground coverage per frame	188×188 n. m.	46.8×46.8 n. m.
Photo scale	1/1,500,00	1/1,500,00
Stereomodel size (60% overlap)	112.8×188 n. m.	
Gross area coverage	37,200,000 sq n. m.	

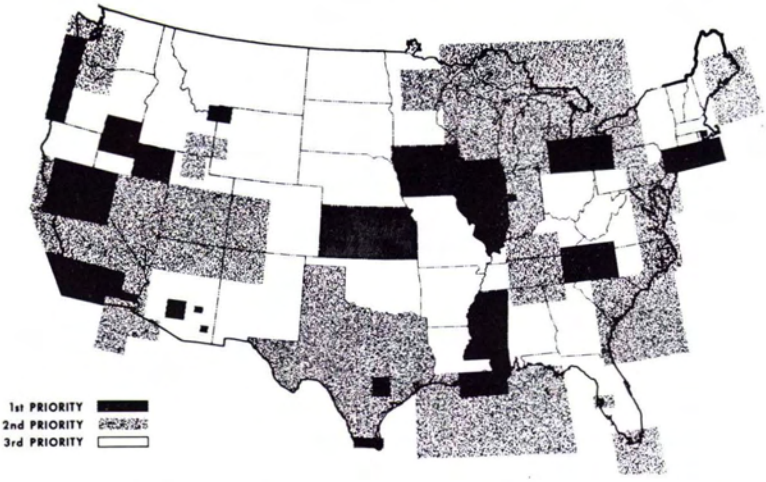


FIG. 4. Space flight test area priorities, Conterminous United States. Priority of areas of interest is based on requirements of the principal user agencies (Departments of Interior, Agriculture, and others) as indicated to NASA relative to synoptic photography from space (broadband and/or multiband).

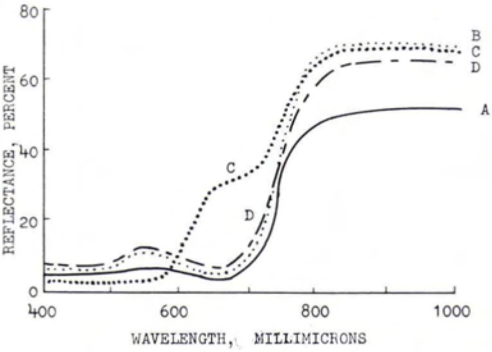


FIG. 5. Vegetation light reflectance curves are potential parameters for mapping vegetation types by multispectral measurements. Correlations between light reflectance curves of four Coast Range vegetation types and the tone of these types as imaged on various film-filter combinations are evident and provide a basis for identification. *A*—Monterey pine. *B*—California bay. *C*—poison oak. *D*—Coyote brush.

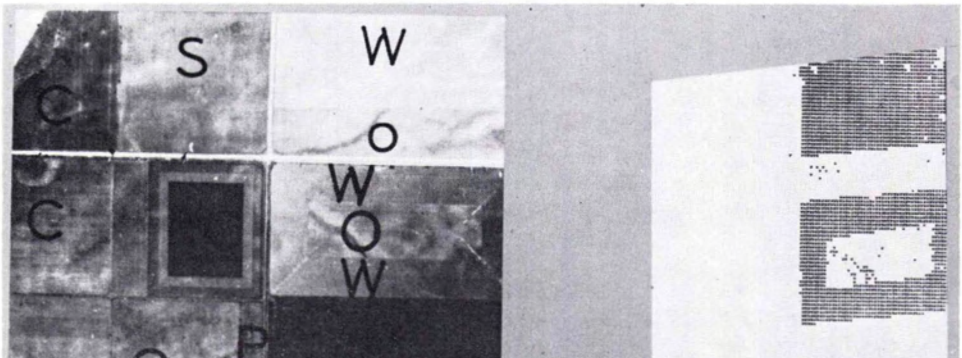


FIG. 6. Wheat field sensing and mapping by automated multispectral data analysis. *Left*—Aerial photo of wheat, oats, corn, soybeans, etc., in test area. *Right*—Computer printout of wheat achieved over 90 percent probability of correct identification by comparing responses in four spectral bands. (By Purdue University, prepared in cooperation with the U.S. Dept. of Agriculture.)

Expected Results

What type of product is expected from these experiments? We know that reflection from various objects on the Earth's surface varies with wavelength (hence the objects' color). Figure 5 illustrates this phenomenon with respect to four natural vegetation types. Color film records these differences to some extent, but recording the spectral bands separately has some real advantages. This has been illustrated in numerous instances.* It is believed that the multiband mode would provide a far greater wealth of data. But what about operational systems? Photographic images are difficult and time consuming to convert into a form suitable for automated analyses. For phenomena which are time variant and which must be analyzed in a matter of hours, days, or even weeks, the photographic mode leaves much to be desired. However, NASA's principal role in this field is research, and the photographic camera is one of the most effective research tools in existence.

Perhaps as a result of such experiments as SO65 and SO42, operational systems will develop of the type illustrated by Figure 6. Here the camera is replaced by a multichannel scanning imager and the photographic image replaced by a computer readout. In this instance four spectral bands, in or near the visible spectrum, have been analytically combined to differentiate wheat from other crops. Although such a system is still in its early stages, it is not difficult to visualize the extent and status of the world's wheat crops, ocean currents, or soil moisture content being monitored from space and statistics thereon being made available on a timely basis. When such systems are put into effect and combined with the other forms of knowledge that space technology can and does provide, then man will have added a powerful new dimension to be applied to his struggle to cope with his environment, the outcome of which depends to a large extent on his ability to utilize and manage the resources of this world.

* Color illustrations furnished by the author are not reproduced here because of technical and budgetary reasons.—*Editor.*

Articles for Next Month

Frederick J. Doyle, Mapping from satellite photographs.
J. M. Eggleston, et al, Lunar 'Rolling Stones.'
William J. Schneider, Color photographs for water resources studies.
Melvin J. Umbach, Color for metric photogrammetry.
R. Gene Barry and *Thomas P. Courtney,* Selenodetic control from Ranger photos.
Ralph H. Wight, A panoramic rectifier for tactical field use.
J. E. Colcord, A survey of training aids.