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7. UNMANNED SPACECRAFT FOR SURVEYING EARTH'S RESOURCES

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I will try to give you a synoptic view of the earth resources satellite program at NASA going back into history a little bit, the current status of the program, and a word or two of how we visualize in the programmatic sense it will continue into the future.

We recognized at NASA several years ago that an effective earth resources satellite could be designed and developed within the existing state of the art, but we faced a rather difficult problem. That was to decide exactly what form such a satellite should take. Obviously we had several alternatives. The first model of the satellite could be a simple, small device launched by a Scout vehicle containing just one Hasselblad camera that would go into orbit and obtain some imagery. Then the film could be returned from orbit, recovered and the data analyzed. Or else we could go to the other extreme and develop an enormous spacecraft fully equipped with all kinds of different sensors -- infrared, microwave, radar, radar scatterometer, high resolution TV camera, etc.

There were a few people back in those days -- 1964-65 -- who felt that we should proceed immediately with the development of an earth resources satellite. Then there was a more conservative group who felt that we should look at the problem and study it carefully and try to optimize in some form the first project that we would engage in. It was the conservative group that eventually prevailed, largely because the "gung-ho" group couldn't decide exactly what they wanted. There was considerable uncertainty as to what form the satellite should take. There was considerable uncertainty as to how we could process the data, analyze it and extract the information that we needed. So from early 1967 when we initiated the ERTS program, we laid out a rather carefully controlled plan for the development of this satellite. We first went through a Phase A conceptual study at the Goddard Space Flight Center. The study, which was completed in October 1967, was conducted at a time when the entire national space budget was in a declining curve, and cost was an important factor in the recommendations which were made. One of the recommendations, reflecting the desire to launch the first satellite as early as possible, was that we would take an existing satellite design which had already proven itself in some previous function and try to modify it to accommodate the earth resources objectives. As a result of that approach, we used the Phase A conceptual study for the preparation of a spacecraft specification document, and this document in turn constituted the basis for the issuance of a request for proposals to industry which came out in May 1969. Since that time, we have received five rather massive proposals from industry for the Phase B-C -- which covers definition and preliminary design of the first

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two ERTS satellites designated A and B. The proposals are still in the process of being evaluated by NASA; however, this process is expected to be completed very shortly. At that time the Administrator will make the selection of the contractors for this job. When the Phase B-C studies are completed five months after award of the contracts, we will receive from each of the contractors engaged in this effort a proposal for Phase D, hardware development, and we will hopefully be able to launch our first satellite somewhere around the first half of 1972. From the time we completed our Phase A study to the time of the issuance of the request for proposals, we were not exactly standing still. For one thing, there was considerable study going on inhouse at NASA as to the type of spacecraft we should aim for and the objectives we should try to accomplish. One important objective was development of data analysis capability, and this was being achieved largely through the use of data acquired from the aircraft program, which Dr. Dornbach described for you; and also we were in the process of going through design and development of the sensors which would go on board the first ERTS satellite.

Figure 7.1 shows the basic objectives of our first two ERTS

- SENSOR TECHNOLOGY
- ENVIRONMENTAL PARAMETERS
- SIGNATURE INTERPRETATION
- DATA HANDLING
- OPERATING EFFICIENCY

Figure 7.1. ERTS Technical Objectives

satellites. This program is to determine the feasibility of obtaining useful data from space and the ability to analyze and interpret this data to extract the information needed for the different disciplines, i.e., agriculture, hydrology, geology, oceanography, etc. It is also desirable to show that the spacecraft and data analysis system provides an efficient methodology that could be developed further into an operational system in the future.

The key features of the first two ERTS satellites would be to cover the United States and the ocean areas immediately adjacent as shown in Figure 7.2. We would have some recording capacity on board the satellite

- o PRIMARY EMPHASIS ON COVERAGE OF U. S. AND ADJACENT OCEAN AREAS
- o EXPECTED LIFE TIME - ONE YEAR
- o 496 N.M. HIGH INCLINATION, SUN-SYNCHRONOUS ORBIT, 10-12 AM SUN ANGLE
- o 17 DAY RESPECTIVE GROUND COVERAGE CYCLE

Figure 7.2. Key Features of ERTS

so that we could obtain some oceanographic information from distant regions of the Pacific and the Indian Oceans and perhaps even the polar regions. The orbit finally selected for ERTS would be a sun-synchronous, circular orbit high inclination actually almost polar at 496 nautical miles altitude. This orbit will give us about a 17 day repetitive ground coverage.

Figure 7.3 shows the payload of the ERTS satellite -- and the

- o 2" RETURN BEAM VIDICON - 3 CAMERA SYSTEM
- o (SPECTRAL BANDS: 0.47 - 0.57, 0.58 - 0.68, 0.69 - 0.83)
- o FOUR CHANNEL MULTI-SPECTRAL POINT SCANNER
  (SPECTRAL BANDS: 0.5 - 0.6, 0.6 - 0.7, 0.7 - 0.8, 0.8 - 1.2)
- o DATA COLLECTION SYSTEM
- o WIDE BAND VIDEO TAPE RECORDER

Figure 7.3 ERTS Payload

sensors were described to you in considerable detail today by representatives of industrial concerns that are developing them, and I'll refer again to them to give you a view of how Headquarters visualizes the performance of these instruments. They consist of the high resolution TV system under development at RCA, the multi-spectral scanner, and a data collection system which I will dwell on in just a moment in more detail. We are also considering the tape recorder as part of the payload.

In Figure 7.4 the sensors are described in a little bit more

	SPECTRAL BANDS (MILLIMICRONS)	DESIGN GOAL RESOLUTION* (FEET PER LINE-PAIR)
3 CAMERA RETURN BEAM VIDICON TELEVISION SYSTEM	475 - 575	340
	580 - 680	340
	690 - 830	460
MULTISPECTRAL POINT SCANNER	500 - 600	460
	600 - 700	460
	700 - 800	460
	800 -1100	460

Both TV and scanner will record a swath 100 NM wide from 500 NM altitude with 10% overlap to assure contiguous coverage.

*Under most favorable lighting and scene contrast conditions. The smallest object which may be identifiable in the data will vary depending upon the specific conditions of lighting, scene contrast, and atmospheric clarity.

Figure 7.4. Candidate Sensors for ERTS - A to Provide Contiguous, Repetitive Multispectral Observations of Earth Resources Phenomena

detail, the return beam vidicon cameras with their spectral bands and our ground resolution. The same applies to the multi-spectral scanner, and as Mrs. Norwood indicated there might be an additional channel on the scanner to cover the further out infrared region.

Figure 7.5 gives in still more detail how we visualize the RBV system will perform. The important thing about this chart is that it shows how the performance of the vidicon drops off appreciably as we move into the near infrared region with camera 3. This affects the ground resolution.

IMAGE FORMAT	3 Simultaneously Exposed Frames Viewing A Surface Area 100 N.M. Square from 500 N.M. Altitude. Repetition of Exposures over a Period of 17 Days Provides Complete Coverage with 10% Overlap.

PERFORMANCE CHARACTERISTICS	CAMERA 1	CAMERA 2	CAMERA 3
RESOLUTION (AT 10:1 SCENE CONTRAST)	3500 TVL*	3500 TVL	2600 TVL
SPECTRAL BANDS (MILLIMICRONS)	475-575	580-680	690-830
VIDEO BANDWIDTH (MHZ)	4	4	4
IMAGE DISTORTION (MAX)	1%	1%	1%
READ OUT TIME (SECONDS)	5	5	5
TIME BETWEEN PICTURE SETS (SECONDS)	25	25	25

SYSTEM CHARACTERISTICS (ESTIMATED)

WEIGHT	145 POUNDS (3 CAMERAS, 3 CAMERA ELECTRONICS, 1 CONTROLLER)
POWER	143 WATTS PEAK, 140 WATTS AVERAGE
VOLUME	2.0 CUBIC FEET

*Television lines. The smallest discernable object in images will depend upon the spectral band, actual scene contrast, lighting, and atmospheric clarity and is expected to be from about 300 to 600 feet for many earth resource phenomena.

Figure 7.5. 3-Camera Return Beam Vidicon Television System

Figure 7.6 is a chart that indicates in summary form the multispectral scanner described to you earlier. The only comment I would make about the two types of sensors is that the spectral bands covered are quite

THE OBJECT PLANE SCANNER PROVIDES CROSS TRACK SCANNING BY USE OF A FLAT "ROCKING MIRROR" LOCATED IN FRONT OF THE TELESCOPE COLLECTOR, THE IMAGE PRODUCED AT THE PRIMARY IMAGE PLANE OF THE TELESCOPE IS RELAYED BY USE OF FIBER OPTIC BUNDLES TO THE DETECTORS. SIX DETECTORS ARE USED IN EACH SPECTRAL BAND TO PERMIT A SLOWER SCANNING ACTION OF THE "ROCKING MIRROR" AND THEREBY INCREASE THE SENSITIVITY OF THE SENSOR. THE SCANNER IS TO VIEW A SWATH 100 NM WIDE FROM AN ALTITUDE OF 500 NM.

DESIGN GOAL PERFORMANCE CHARACTERISTICS

SPECTRAL BANDS	500 - 600 MILLIMICRONS
	600 - 700
	700 - 800
	800 -1100
INSTANTANEOUS FIELD OF VIEW	230 FEET SQUARE
TOTAL VIDEO BANDWIDTH	4 - 6 MHz

SYSTEM CHARACTERISTICS

WEIGHT	83 POUNDS
VOLUME	1 CU. FT.
POWER	45 WATTS AVERAGE

Figure 7.6. Four Band Multispectral Object Plane Point Scanner

similar. This is very desirable as far as we are concerned since we will be able to compare the results which perhaps will give us a better handle as to which one is most valuable for the different disciplines. It is almost certain that the scanner will be more useful for some disciplines and the TV systems for others. Exactly how it will divide up is a matter of uncertainty, and the fact that we have similar spectral band coverage in both instruments will help us resolve that question.

Figure 7.7 presents features of the video-tape recorder. This recorder has not been developed previously. We hope the performance of the instrument will be as indicated on this chart. Tape recorders traditionally have been fairly difficult to design. We have had many problems with them. They have a tendency to fail, sometimes well ahead of the expectations. But if everything works out right, the design life-time of this recorder can be expected to be somewhere around 1000 hours of operation. The other important feature is the recording time of 30 minutes. We will be lucky if we achieve that capability, but if we do and we are able to develop it in time for the ERTS A launch that means that we will be able to cover some of the distant ocean regions of the world which is very desirable for our oceanographic community.

TOTAL WEIGHT - 45 LBS. POWER CONSUMPTION -70 WATTS

TAPE LENGTH - 2000 FT. TAPE WIDTH - 2 IN.

TOTAL RECORDING TIME - 30 MIN.

DESIGN LIFE TIME - 1,000 HR. OF OPERATION

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MAXIMUM DATA ACQUISITION TIME FOR ORBIT - 45 MIN.

PLANNED ACQUISITION:

(1) DIRECT READOUT OF DATA OVER U.S.

(2) DATA RECORDED OVER OTHER AREAS AND TRANSMITTED TO U.S. GROUND STATIONS

Figure 7.7. Features of Video Tape Recorder for Additional Coverage

Figure 7.8 shows ground station considerations. At the present

* U.S. SUPPORTING GROUND STATIONS:
  - o ROSMAN, NORTH CAROLINA
  - o FAIRBANKS, ALASKA
  - o MOJAVE, CALIFORNIA
* GROUND STATION REQUIREMENTS:
  - o 40 - 85 FT. PARABOLIC ANTENNA FOR WIDE BAND RECEPTION
  - o DATA AQUISITION EQUIPMENT
  - o DATA RECORDING AND REPRODUCTION FACILITY

Figure 7.8. Ground Station Considerations

time we are planning to equip three ground stations with the necessary instruments to receive signals from the ERTS A and B satellites. The three ground stations are at Rosman, N.C.; Fairbanks, Alaska; and Mojave, California.

Figure 7.9 will show you what kind of real time coverage can be

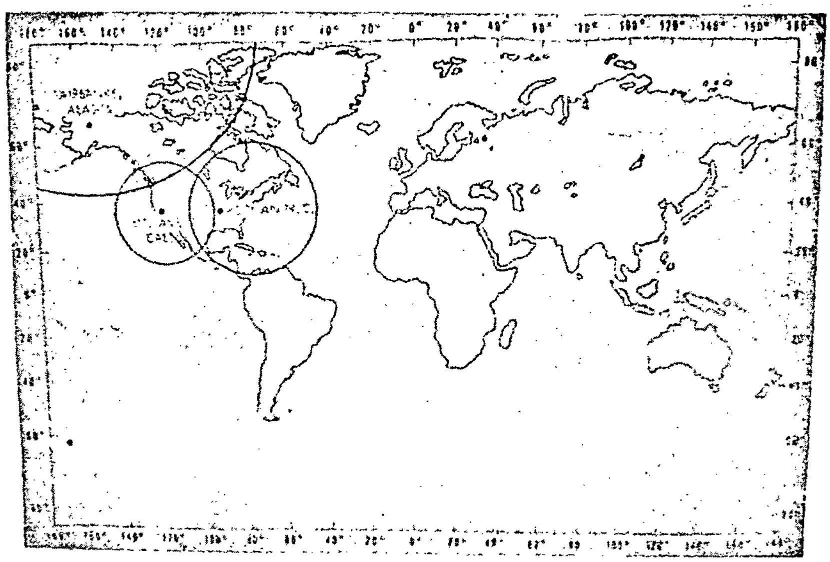

Figure 7.9. ERTS Ground Station Visibility Map (496 N.M. Orbit)

achieved with these three stations. If the recorder should fail early in the game, we would still be able to receive data from our satellite covering the three circled regions indicated in this map. This means that the entire continental US would be covered, all of Alaska, and most of Canada excepting the small region shown up in the North-east.

Now finally let me move on to what kind of a schedule we presently visualize for the ERTS A and B. Hopefully, ERTS A will be launched in the first half of 1972. It has a lifetime expectancy of one year which means that it will be in operation for four complete seasons -- and this is very important for a number of disciplines like agriculture that would like to observe crops and their evolution during a complete cycle. Finally the ERTS B will be launched just about when the ERTS A is expected to start causing technical problems. It also would be then in operation also for one year. We have projected a first operational satellite being launched sometime after that. In other words, if ERTS A and B are complete successes -- and most people in the R&D business know this is not very likely -- it is possible that someone could make a decision to proceed with exactly the same type of a vehicle with the same type of sensors for an operational system.

So far I have covered a thumbnail sketch of the history of our ERTS program and where we stand right now. The next point I'd like to raise will be where we might possibly proceed in the future. It would be very desirable if we could fly a photo-recovery mission simultaneously while ERTS A and/or B were still operational. This would give us also a hard film type of camera output for the different disciplinary areas. So if we had the necessary support and funding and approval that would be necessary for such an additional project, I think it would be very desirable to fly an additional small satellite sometime during the period from 1972 through 1973 to obtain some hard film imagery simultaneously with the output of the ERTS A and B. That is one item we can look for in the future. Another objective would be to continue with the ERTS program development. Everyone will recognize that ERTS A and B will not be the end of the R&D phase for Earth resources in space and that we would probably like to continue with a program to obtain data of interest to certain specialized disciplines. For example, in the design of the ERTS A and B, we have tried to optimize the spectral band selection and the sensor selection to satisfy various specialized disciplines. For example, in the design of the ERTS A and B, we have tried to optimize the spectral band selection and the sensor selection to satisfy as many potential users as possible. This results in certain other disciplines not being covered in sufficient depth. Disciplines like oceanography could very well use certain other types of sensors, perhaps radar scatterometers to observe the sea state conditions, or a sensor that would give them tonal variations of the sea, or surface temperature of the oceans which might be very useful to the fishing industry for example. A follow-on ERTS program to cover some of the other disciplines in more depth and with greater attention perhaps could be looked forward to. Finally, let me go back to what Dr. Barringer mentioned earlier today. In the future perhaps we would like to include an experiment that could monitor the air pollution and our evaluation of the development of the sensors and the data analysis from the sensors indicates to me that a flight approved model of such an instrument could possibly be developed within the next three or four years.

Questions and Answers

Q. On the question of sun angle. The Apollo 6 photos were extremely remarkable from the geologists point of view with a low sun angle. Would it be possible to consider at some stage an ERTS that could give us low sun angle coverage?

A. That would certainly be a factor to consider for one of our future ERTS missions.

Q. I see the clock time has changed from the original 9 AM something to 10 or 12. Why has this happened? Secondly, you used the term -- tape recorder. Does this mean there will only be one aboard?

A. To answer the first question, we can really reserve the final opinion as to the best sun angle until the Phase B-C studies are complete. There may be some factors that will be brought out during the definition and preliminary design phases of our program. As far as the tape recorder is concerned, we plan to carry two recorders aboard. We plan to have that much redundancy.

Q. Several times you rather carefully said that the recorder would give capability to obtain imagery over distant oceans. There is no technical reason why you couldn't obtain imagery over distant land or ocean areas, is there?

A. Only if you have a suitable ground station in line of sight of the spacecraft that would receive the image. Regarding your comment, there is no particular reason we just happen to be more interested in the oceanographic data than in covering foreign countries with this experimental vehicle.

Q. Will you be able to transmit simultaneously live coverage and recorder coverage?

A. Yes.

Q. Do you have definite plans now for soliciting more information from the oceanographic community regarding official plans?

A. We intend to issue an opportunity's document for ERTS A and B which means that the entire scientific and technical community of the US or of the world for that matter will be informed as to the ERTS A and B program and the sensors we plan to carry aboard these satellites. Any scientist or group of scientists can submit proposals to us for the use or the analysis of the data we expect to obtain. So oceanographic experiments could be proposed to NASA or to any of the user agencies like the Department of Interior or Navy Department suggesting a particular form of utilization of the data we expect to acquire.

Q. What about your own inhouse planning for future development beyond A and B? You mentioned at the end of your talk that oceanography was one area where more expansion was planned.

A. That's right. At the moment, we are considering a possible follow-up program for ERTS that might include two additional satellites with emphasis on oceanography. We would then look to the oceanographic community for advice as to the type of sensors they would like to see on board those satellites.

Q. You said you were going to elaborate on the data-collection systems.

A. Yes, I forgot about that. We intend to include in the payload of ERTS A and B a data collection system. This would be a relatively simple experiment. It would consist of a receiver-recorder-transmitter package that would be capable of picking up measurements from the ground, transmitted to the satellite by small transmitters associated with the sensor. We would take existing sensor designs, like sensors to measure the temperature of water or the depth of snow or any other variables on the earth's surface and associate it with a transmitter. The transmitter would then broadcast the data to the satellite which would pick up this information as it was passing over the site being measured or surveyed, would record the data, and then during a subsequent orbit transmit all this information to one of our ground stations. By this experiment we will show that such a system would be useful for a potential operational satellite to cover large areas of the earth not in direct sight from a ground station.

Q. Why do you need a separate small satellite to take film type pictures in the 1973 time slot when you are going to have the Apollo applications vehicle up there?

A. If an Apollo application vehicle is up there taking these measurements, I think it would probably satisfy our requirements. It is just that there might be some incompatability of scheduling. Both the ERTS A launch and the AAP launch could be affected by lots of factors, and we would not like to delay, say the ERTS A launch to be compatible with, say, a slippage of six or eight months of the AAP which could very easily occur for technical reasons that we can't predict at the present time.

Q. Wouldn't a six-month delay be worthwhile as opposed to developing another whole satellite?

A. There is also the factor of automation. We are still looking toward a relatively cheap way of acquiring data versus the more expensive way that the manned vehicle represents as an operational tool.

Q. What is the AAP latitude coverage?

A. Presumably the AAP mission could go up to 50°, so consequently we would have adequate inclination for some of the test sites we want to cover in the ERTS.

Q. In the beginning of your talk, you mentioned ERTS A, B, C, D. On your schedule you only showed B and C, and just a moment ago you indicated that C and D were not sure things. Is this correct?

A. So far we have only ERTS A and B approved. Everything beyond that is conjecture and planning, and has not been approved.

Q. I understand that NASA chairs an interdepartmental committee in Washington. Have you addressed the problem, the characteristics of an operational system?

A. No, we have not addressed the questions of an operational system yet, and this would be premature until we can evaluate the results of ERTS A and B. As soon as that is accomplished, we will give full attention to an operational system.