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Environmental Monitoring Series

# OVERHEAD ENVIRONMENTAL MONITORING WITH LIGHT UTILITY AIRCRAFT: Demonstration and Evaluation of the System

Environmental Monitoring and Support Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Las Vegas, Nevada 89114

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# OVERHEAD ENVIRONMENTAL MONITORING WITH LIGHT UTILITY AIRCRAFT: Demonstration and Evaluation of the System

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## FOREWORD

Protection of the environment requires effective regulatory actions which are based on sound technical and scientific information. This information must include the quantitative description and linking of pollutant sources, transport mechanisms, interactions, and resulting effects on man and his environment. Because of the complexities involved, assessment of specific pollutants in the environment requires a total systems approach which transcends the media of air, water, and land. The Environmental Monitoring and Support Laboratory-Las Vegas contributes to the formation and enhancement of a sound integrated monitoring data base through multidisciplinary, multimedia programs designed to:

- develop and optimize systems and strategies for monitoring pollutants and their impact on the environment

- demonstrate new monitoring systems and technologies by applying them to fulfill special monitoring needs of the Agency's operating programs

This report addresses the development and feasibility demonstration of a self-contained sensor module called the Enviro-Pod (Pod). This device, which in its initial configuration houses two panoramic cameras, is intended to place an aerial photographic data acquisition capability into Regional and other field offices of the U.S. Environmental Protection Agency. The Pod is capable of satisfying some of the many special-purpose monitoring tasks facing the Agency, including monitoring for enforcement and compliance and during environmental episodes and emergencies. Future developmental efforts will provide other sensor configurations of the Pod.

George B. Morgan
Director
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Las Vegas, Nevada

# ABSTRACT

The U.S. Environmental Protection Agency (EPA) is seeking to provide its 10 Regional Offices with a low-cost remote-sensing capability through development of a self-contained sensor module called the Enviro-Pod (Pod). Its key attributes are economy, compactness, portability, and simplicity. It has been certified by the Federal Aviation Administration for use on commonly available light aircraft.

The design, development and manufacture of the prototype was accomplished by the U.S. Air Force Avionics Laboratory through an interagency agreement with the EPA. As presently configured, the Pod module contains two identical KA-85A panoramic cameras. One is mounted in the conventional vertical position and the second in an oblique position looking 45 degrees forward of the aircraft. The Pod has been successfully demonstrated in Washington, D.C., Boston, Atlanta, Philadelphia, and New York for EPA staff officials and personnel from eight other Federal agencies. Use of the Pod is foreseen in enforcement, compliance, episodic, and emergency monitoring activities.

This document summarizes results of feasibility demonstrations and recommends a program for the production and suitability testing of the Pod module. Possible future sensor configurations for the Pod are also presented.

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## ACKNOWLEDGEMENTS

Demonstration flights to assess the usefulness of the Enviro-Pod for monitoring environmental problems were conducted in EPA Regions I, II, III, and IV during the periods of May 31 to September 1, 1977. The efforts of the following individuals in planning, scheduling and coordinating the flights at each location are sincerely appreciated.

Region I - Boston, Massachusetts
Mr. Richard Keppler, Office of Research and Development
Mr. Edgar Bernard, Management Division

Region II - Edison, New Jersey
Dr. Robert Mason, Surveillance and Analysis Division

Region III - Philadelphia, Pennsylvania
Mr. William Cook, Chesapeake Bay Program

Region IV - Atlanta, Georgia
Dr. David Hill, Surveillance and Analysis Division

# INTRODUCTION AND BACKGROUND

As part of its regulatory responsibility, the U.S. Environmental Protection Agency (EPA) has the task of monitoring the environment of this Nation to ensure the validity of its environmental standards and to assure legal compliance. The territory to be monitored is vast. Consequently, aerial photography as well as other rapid, cost-effective remote-sensing systems have gained increased use in EPA's operational monitoring programs.

The Agency's Office of Research and Development has, since its inception, supported monitoring technology development programs. The Enviro-Pod (Pod) with its potential for several different sensor configurations is one recent product of these programs.

The U.S. Air Force Avionics Laboratory, Wright-Patterson AFB, Ohio, designed and fabricated the prototype Pod under and interagency agreement with the EPA. On January 19, 1977, formal approval for flight operation of the Pod was granted by the Federal Aviation Administration (FAA) with issuance of a Supplemental Type Certificate. Familiarization and checkout procedures for support personnel began in March 1977, and during the period April through August, feasibility tests were conducted.

This report describes the initial flight tests and Regional demonstrations. The tests were intended to simulate, as closely as possible, actual operational conditions.

## CONCLUSIONS

The results of the feasibility tests and demonstrations indicate that the camera-configured Pod is capable of cost-effectively acquiring high quality, high resolution imagery over small areas and single targets. Demonstrations also disclosed a keen interest in the Pod by potential users in EPA Regional Offices and in other Federal organizations.

Several minor problems encountered during the demonstrations will necessitate limited design modifications and/or adherence to specified operational procedures. A redesign of the control box is required to add an individual intervalometer and frame counter for each camera. The given weight maximums of the aircraft must be strictly adhered to and in most cases will allow only one observer to fly along when the Pod is attached. While the KA-85A panoramic camera is a rugged, relatively simple device, it should be loaded and maintained by experienced personnel to prevent damage to the shutter curtains.

The Pod was designed primarily as a reconnaissance system and as such is not suitable for coverage of large geographic areas. Essentially, it is ideal for routine and emergency monitoring of point targets, stream segments, and small areas of generally less than 25 square miles. If program requirements dictate the use of the image data for mensuration, mosaicking, or transfer of detailed information to a controlled base, the use of metric cameras will be necessary.

The Pod in its current configuration provides high resolution panoramic imagery in both the vertical and oblique camera positions. At a typical flight altitude of 3000 feet, the resolution of panchromatic film at nadir is 18 centimeters (0.6 ft.). This type of imagery is well suited to analyzing details of, for example, industrial facilities, utilities, and outfalls.

Because of its overall higher cost, color film should only be used where the color information of the subject is vital for analysis of the environmental problem.

## RECOMMENDATIONS

Based on the experience gained during the demonstrations and comments from participants, the following recommendations are made concerning the Pod.

- Modify the engineering by redesigning:
  - the operation control box and wiring harness to provide individual camera interval and count circuits for frame counting.
  - charging circuitry to provide external battery charge circuits.
- Review Pod assembly details, adjusting as required to minimize manufacturing costs.
- Develop a Standard Operating Procedures manual for Pod users. This manual should address consideration of such factors as:
  - availability of adequate existing photographic coverage.
  - utility of panoramic imagery in providing desired data.
  - film type used to assess the environmental problem.
  - secondary targets of interest in the area to be covered.
  - cost effectiveness for the specific mission.
- Conduct additional demonstrations for other EPA Regional Offices.
- Produce a sufficient number of Pods to provide one to each requesting EPA Regional Office.
- Transfer the FAA Supplemental Type Certificate from the U.S. Air Force to the EPA to facilitate the production of the Pod.

- Amend the FAA Supplemental Type Certificate to include all applicable aircraft of the Cessna 172 series, e.g., 172K, 172N.
- Redesign or modify the equipment to permit FAA certification for the higher performance Cessna 182 series.
- Establish a program to provide support to Agency users of the Pod, to include:
  - training in the operation, maintenance, and applications of the Pod.
  - training in the use of remote sensing imagery in environmental quality assessment.
  - establishing a system for supporting the Pod program to include camera maintenance, film processing, and photographic interpretation.
- Establish a program to identify, determine applicability, produce, test, and gain certification for additional sensor systems for the Pod, e.g., television cameras and infrared sensors.

# SYSTEM CONCEPT AND DESIGN

The design criteria initially established for the Pod were:

- fit a commonly available aircraft.
- be easily installed.
- be transportable as checked luggage aboard commercial airlines.
- require no modifications to aircraft.
- be fully FAA certified for the aircraft.
- be adaptable to more than one sensor.
- provide data that could be analyzed by the environmental scientist as well as the photo interpreter.

Under the interagency agreement with EPA, the U.S. Air Force Avionics Laboratory's Reconnaissance Division determined that it should indeed be possible to develop a compact, low-cost device meeting these criteria. The group also showed that the aircraft most suitable, in terms of availability, performance, and payload, was the Cessna 172 series (see Figure 1).

The KA-85A camera system (specifications listed in Appendix B) was identified as the initial sensor for the system. Its primary features included compactness and high resolution. Forty of these cameras in operating condition were located and subsequently transferred to the EPA.

Figure 2 is a contact print of imagery from the vertical-looking camera along with a 40X enlargement of one section. Figure 3 is an example of imagery from the forward- and vertical-looking cameras and illustrates the monitoring capabilities of the sensor system.


Figure 1. The Pod installed on a Cessna 172.

Figure 2. Contact print of Pod imagery (below) and a 40X enlargement of one segment.

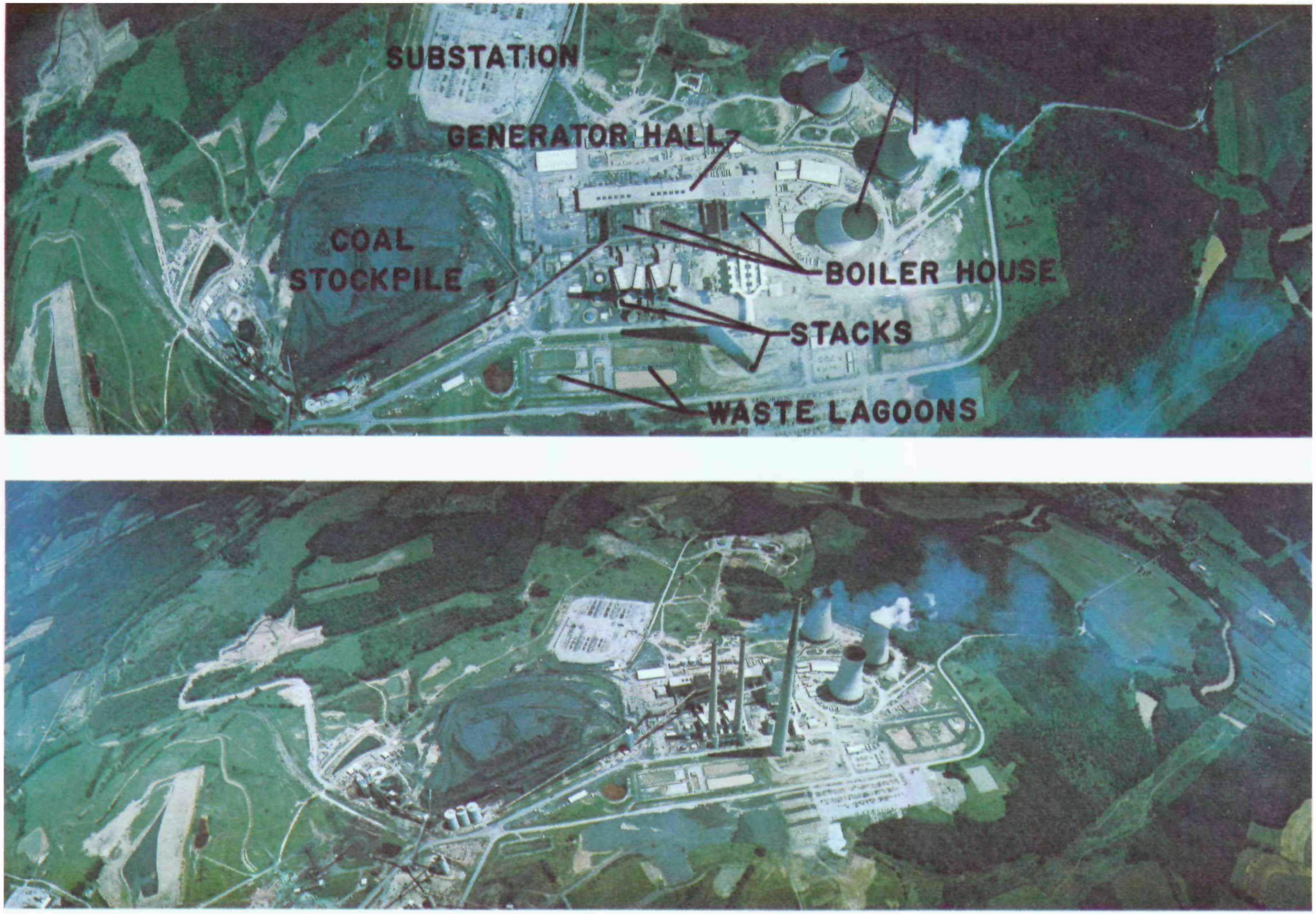


Figure 3. Examples of Pod imagery from the vertical-(above) and forward-looking cameras.

The pod consists of two mated sections carried as an integral unit (specifications listed in Appendix B). The two sections designated A and B (see Figure 4) each contain a camera bay mounting one of the KA-85A cameras connected to a power source consisting of two 12-volt Gel/Cell® batteries. The camera in the forward section (Section A) is oriented to photograph at nadir (vertical), while the one in the aft section (Section B), is oriented 45 degrees forward of nadir. The two compartments each have a viewing window of 6.4-mm thick select plate glass set into a removable frame. A metal plate covers the window and protects the glass during shipment.

The Pod sections are constructed of sheet aluminum riveted to a framework of aluminum bulkheads and bracing and are mated together with a set of four hinges locked in place with pip pins. The dimension of the completely assembled unit is about 122 centimeters by 41 centimeters by 33 centimeters and its weight is about 66 kilograms. Each section, fitted with a removable cover and handles, can be transported as a piece of luggage on commercial airlines.

The top rim of the Pod, designed to fit the Cessna 172 fuselage, is fitted with a pliable weather seal to mold it to the fuselage contour and to protect the aircraft finish.

The assembled Pod is attached to the aircraft with four stainless steel straps anchored to the seat rails with a clamp mechanism. The straps are fitted with turnbuckles which attach to heavy brackets bolted to the Pod. The flexible straps are contoured to fit over the door sill so that interference with door closure is negligible. Also, the underside of each strap is lined to prevent scratching of the aircraft.

A camera control box located in the aircraft cabin is wired into the Pod electrical system through a four-strand ribbon wire located in the aircraft cockpit. The control box allows the operation of the cameras either separately or simultaneously. Cycling can be accomplished by manual control or at five pre-set intervals of 1-, 2-, 4-, 8-, or 16-seconds. A frame counter, ready light, cycling light, and individual camera on/off switches are also included. A small solid-state battery charger permits recharging of the batteries between flights.

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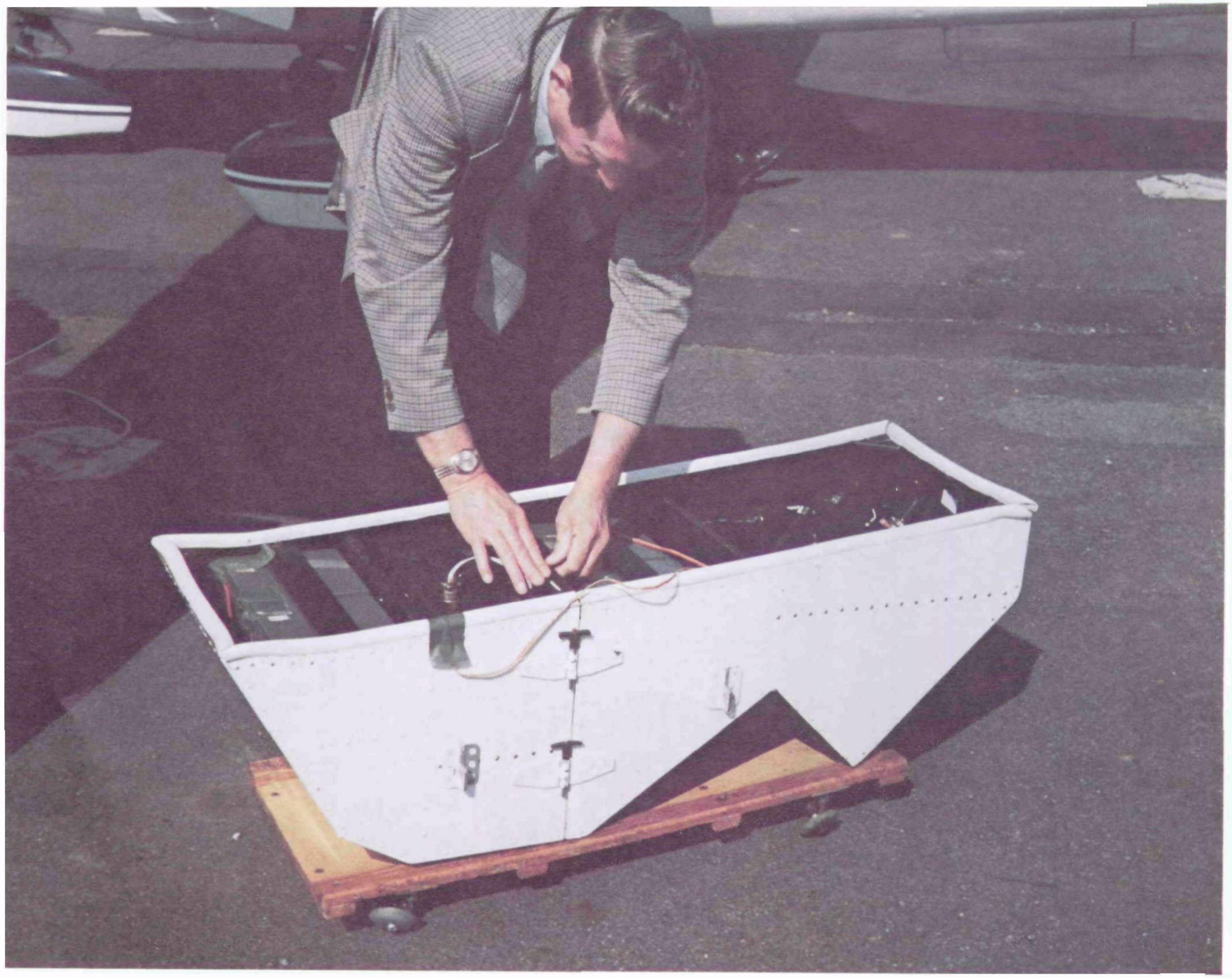

Figure 4. Preparing the Pod for installation on the Cessna.

## DEMONSTRATIONS

The first series of demonstration flights was conducted by the EPA Environmental Monitoring and Support Laboratory, Environmental Photographic Interpretation Complex (EPIC) in the Washington, D.C., area during April 1977. These were conducted to acquaint EPA headquarters personnel and representatives of other Federal agencies with the Pod.

Demonstrations were also held in four EPA Regions during the period May through August of 1977 to evaluate the utility of imagery data from the Pod and its application to practical monitoring problems. The tests were designed to (1) ascertain the technical attributes and problems involved in the operation of the Pod; (2) determine the utility of the camera-configured Pod as a monitoring tool for the Regional Offices; and (3) identify specific environmental problem situtations during which Pod photography would be applicable. The demonstrations were conducted in a manner which would duplicate the operational employment of the Pod. Aircraft charter or leasing companies near the base of operations were contracted for these missions.

The Pod has also been evaluated during actual operational field programs. At the request of EPA Region IV a segment of the South Fork of the Forked Deer and Obion Rivers in Tennessee were photographed using the Pod system, and questionable dredging activities were documented. The Emergency Response Branch in Region III requested Pod coverage of an area along the Delaware River in Philadelphia. Of interest was a site where electrical transformers were dismantled allowing the PCB-laden oil to seep into the ground and eventually enter the river. The imagery obtained showed definite traces of oil bleeding from the shore area near the site.

Finally, following the Johnstown, Pennsylvania, flood of July 20, 1977, EPA's Oil and Special Materials Control Division requested photographic coverage of the flood area using both the Pod and conventional techniques. The imagery was acquired on July 22 and sent, after processing and analysis, to the Regional Response Team at Somerset, Pennsylvania, where it was immediately used for the direction of clean-up activities and to brief the Federal Disaster Assistance Agency Coordinator. More detail was apparent in the imagery from the KA-85A cameras in the Pod even though the scale was about a third of the conventionally acquired 9-inch format metric data (Figure 5 and 6). It was also noted

Figure 5. Contractor-acquired photograph of the Johnstown, Pennsylvania, flood.

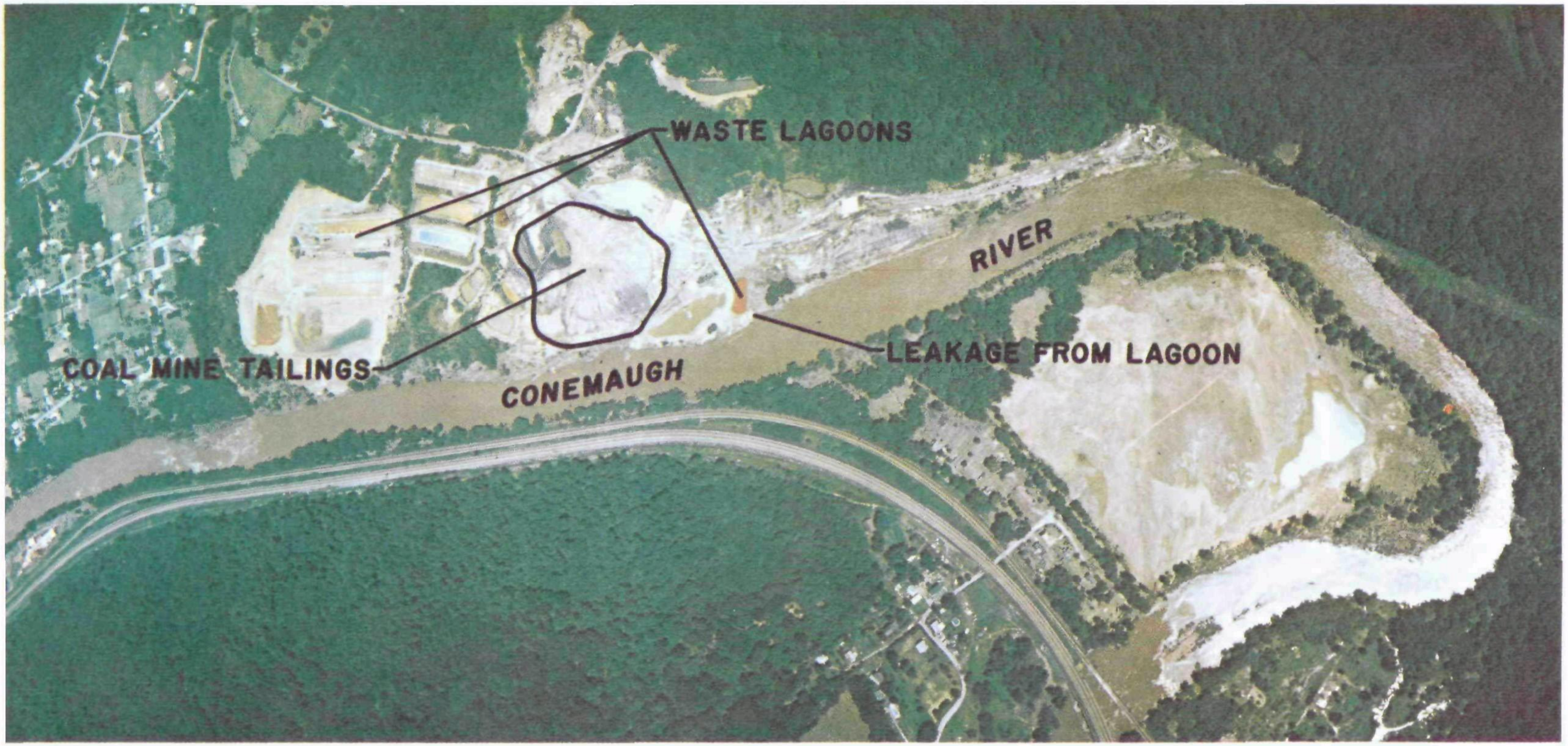


Figure 6. Pod-acquired photograph of the Johnstown, Pennsylvania, flood (same scale as Figure 5).

that the imagery from the 45 degrees forward oblique camera provided a more familiar perspective than the vertical.

Additional potential applications of Pod imagery include:

- Emissions identification and documentation.
- Compliance monitoring.
- Discovery and location of non-filers.
- Discovery and documentation of dredge and fill violations.
- Oil and hazardous materials spill detection, reconnaissance and storage, and containment surveillance.
- Water supply reservoir surveillance and preferred intake locations documentation.
- Monitoring station siting.
- Determination of extent and area coverage of nuisance weed and/or algae growths.
- Location of leachate around landfills and surveillance of landfill operations.
- Documentation of existing land use and prediction of environmental impacts.
- Provide imagery for inclusion in Environmental Impact Statements.

It is anticipated that as Regional remote sensing programs mature, many other uses for Pod imagery will become apparent. With the future development of other sensor configurations (thermal scanner, television systems, forward-looking infrared systems, and other camera systems) the Pod would become even more versatile in its monitoring role.

Experience with the Pod during the trial phases firmly established its cost effectiveness when used to rapidly acquire imagery over a small geographical area. Table 1 summarizes the cost data derived from the Pod demonstration flights for a typical low level mission for which the Pod is best suited. The cost figures are based on the maximum color film load which can be carried by the Pod. The typical mission was assumed to take place at a 2500-foot altitude at an operational camera-on range of about 43 miles. The travel radius from the base airport was assumed to be 150 miles.

Alternative imagery acquisition methods, i.e., use of Agency or contractor photo-reconnaissance aircraft for the type of mission described which are clearly within the capabilities of the Pod system, are less cost-effective. The primary difference results from the higher overhead and operational costs for the class of aircraft used and the conventional (mapping) systems on board. These latter systems are essential, however, when detailed mensuration and/or mosaicking are required. Typically, imagery acquired from the Pod system also demands less interpretation and analysis because of the strike nature of the missions on which it would most frequently be used. Hourly rates for the use of generally higher performance photo-reconnaissance aircraft systems range upwards from a minimum of $150 per hour. Crew and per diem costs may be added to that base depending on the operator. For the mission described, therefore, the total cost using the conventional techniques would range from about $500 to nearly $800.

TABLE 1. TYPICAL PHOTOGRAPHIC MISSION COSTS FOR ENVIRO-POD

| | |
|---|---|
| CAMERA DATA | |
| Format size | 5.7 cm x 18.3 cm (2.25 in x 7.2 in) |
| Total frames required | 300 |
| Total area covered | 85.2 sq miles |
| AIRCRAFT COSTS | |
| Lease/Rent | $37-$43/hour |
| Total this mission | $116-$131 |
| LABORATORY PROCESSING | |
| Original color and one duplicate copy (total materials) | $164 |
| TOTAL ACQUISITION AND PROCESSING | $280-$295 |
| TOTAL/SQUARE MILE | $3.29-$3.46 |

An important aspect of the demonstrations was to determine what problems might be encountered in an operational mode and what system modifications are recommended. Several minor problems related to the cameras, the Pod itself, or the aircraft were corrected during the tests.

In addition one problem was noted with the design of the control box. When attempting to fly a mission at a prescribed altitude and ground speed, the fixed intervals available on the intervalometer (1, 2, 4, 8, and 16 seconds) did not permit adequate flexibility. This resulted in film being used at a faster than necessary rate (to ensure stereo coverage) or to cycle at a slower rate and not acquire stereo coverage. Also, as both cameras are cycled from the same intervalometer and the coverage of the forward-looking camera far exceeds that of the vertical, considerable excess film was used by the forward-looking camera. During the demonstrations the cameras were normally operated manually to conserve the film supply. A redesign of the control box and the incorporation of separate, infinitely variable intervalometers and separate counters would correct this deficiency.

Problems with the cameras were totally related to loading. It was found to be very easy to damage the shutter curtain during loading, causing the camera to malfunction.

Aircraft-related problems were dependent on the aircraft used. The most serious problem encountered was oil from the engine getting on the camera ports giving resultant imagery a fuzzy or out-of-focus effect. This was a problem only on a few aircraft, and in an operational mode this problem could be minimized by checking the aircraft for oil deposits on the underside prior to installing the Pod. A second solution would be to design a spoiler which would direct the oil away from the camera ports.

It is anticipated that through the experience gained from the demonstrations many of the problems encountered can be eliminated or minimized in production versions.

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2. Aircraft Owners and Pilots Association, AOPA's Airports USA 1976. Washington, D.C. 1976. 528 pp.

## APPENDIX A. FEDERAL AGENCY PARTICIPANTS

Eight government agencies attended Enviro-Pod demonstrations in the Washington, D.C., area.

U.S. Department of Agriculture:

Agricultural Stabilization & Conservation Service
Soil Conservation Service
Forest Service
Foreign Agricultural Service

U.S. Department of the Interior:

U.S. Geological Survey
Land Information Analysis

U.S. Department of Commerce:

National Oceanic & Atmospheric Adminstration

U.S. Treasury Department

U.S. State Department

U.S. Army Engineer Topographic Laboratory

U.S. General Services Administration:

Federal Preparedness Agency

U.S. Department of Energy

# APPENDIX B. CAMERA AND POD SPECIFICATIONS

## POD DESCRIPTION

The Pod is designed in two sections which are mated together with hinges and pip pins and installed as a unit on the aircraft. As presently configured, each section has a camera bay and space for mounting two 12-volt Gel/Cell® batteries. The camera in the forward section (Section A) is oriented to photograph the nadir; the camera in the aft section (Section B) is oriented to photograph 45 degrees forward of the nadir.

The weight and dimensions of the Pod ready for shipping (with batteries and without cameras) are:

| Section | Length | Width | Height | Weight |
|---|---|---|---|---|
| A | 50.8 cm | 40.6 cm | 33 cm | 18.1 kg |
| B | 71.1 cm | 40.6 cm | 33 cm | 25.9 kg |

The assembled unit dimensions are 121.9 by 40.6 by 33 centimeters.

## CAMERA SPECIFICATIONS - KA-85A

| | |
|---|---|
| Camera type: | Panoramic |
| View angle: | $39^{\circ}$ 18' in line of flight; $130^{\circ}$ perpendicular to line of flight |
| Lens: | 80 mm, adjustable iris, f/2.8 to f/22 |
| Shutter type: | Focal plane, two fixed slits |
| Shutter speed: | 1/1000 sec, optional 1/250, 1/500, 1/2000 |
| Cycle interval: Interval mode | 1, 2, 4, 8, 16, and 32 secs |
| Autocycle mode | 0.6 sec |

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| | |
|---|---|
| Forward motion compensation: | |
| Rate | 0,500 or 700 milliradians changeable cams, cosine corrected for scan angles |
| Type | Moving lens |
| Format size: | 57 x 183 mm |
| Lens filter: | Wratten 21 (Orange) |
| Film load: | 70 mm x 61 m (standard base), 300 frames; 70 mm x 122 m (thin base), 600 frames |
| Scanning time: | 0.18 secs per frame |
| Thermal control: | External heaters and thermostats |
| Heater temperature: | $22.2^\circ \pm 2.8^\circ$ C |
| Power requirements (average): | 24 to 28.5 Vdc, 3 amps with heaters off, 6 amps with heaters on. Surge current, 35 amps for 100 milliseconds |
| Camera weight (with film): | 10 kg |
| Dimensions: | |
| Width | 30.8 cm |
| Height | 31.1 cm |
| Length | 16.5 cm |

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

The U.S. Environmental Protection Agency (EPA) is seeking to provide its 10 Regional Offices with a low-cost remote-sensing capability through development of a self-contained sensor module called the Enviro-Pod (Pod). Its key attributes are economy, compactness, portability, and simplicity. It has been certified by the Federal Aviation Administration for use on commonly available light aircraft.

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17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
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