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R. B. Gerding

G. F. Johnson

D. K. Weidner

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**MANNED EARTH OBSERVATORY:
POSSIBLE CONTRIBUTIONS TOWARDS
ENHANCED UNDERSTANDING OF THE MARINE ENVIRONMENT**

R. B. GERDING*
G. F. JOHNSON*
D. K. WEIDNER**

ABSTRACT

The Manned Earth Observatory (MEO) study being conducted by TRW under the management of NASA/MSFC will establish the conceptual design of and the mission requirements for an Earth Observation Laboratory that will be flown on Shuttle missions beginning in 1980. MEO offers a variety of unique inroads to improving our understanding of the marine environment. The Shuttle-MEO is a valuable addition to a multi-level multi-disciplinary remote sensing program. The unique attributes of MEO are its experimental flexibility due to man-instrument interaction, its complimentary orbit (intermediate between non-orbital and high-orbital platforms), its high weight and volume capacity and short duration missions.

Among the most promising applications of MEO are:

- Regional and Local Water Pollution
- Plankton Dynamics
- Polar Processes
- Circulation Dynamics
- Air-Sea Interactive Processes
- Surveillance of Marine Resources.

- Develop reference missions for the earth observation facility.
- Establish mission requirements for the earth observation facility.
- Develop conceptual designs for the required experiment instrumentation and major supporting equipment.
- Develop conceptual layouts for the Manned Earth Observation facility and perform systems and operations analysis.
- Develop cost, schedule, and Supporting Research and Technology (SRT) requirements.

The manner in which the first objective was satisfied affords an introduction to the discussion in this paper.

The earth observation disciplines that were addressed in the study included:

- Agriculture, forestry and rangelands
- Geology
- Hydrology
- Meteorology
- Oceanography.

In addition, special consideration was given to multi-disciplinary problem areas related to:

- Environmental impact of natural and man-induced modifications to earth resources.
- Experiments concerned with archeology, mapping of urban areas, developing countries, etc.

Candidate earth observation experiments for manned spacecraft implementation were identified for each of the earth observation disciplines mentioned above. The scientific

MANNED EARTH OBSERVATORY

TRW is currently under contract with NASA/MSFC for a Mission Requirements Study for a Manned Earth Observatory. The purpose of this study is to establish mission requirements and develop a conceptual design of a Manned Earth Observatory facility to be used with the Space Shuttle. The specific objectives of the study, are to:

- Define candidate earth observation experiments that are compatible with the early Space Shuttle missions.
- Identify required experiment instrumentation, supporting equipment and subsystems.

* TRW Systems Group, Redondo Beach, Ca.
** NASA/Marshall Space Flight Center, Huntsville, Ala.

community was consulted for suggestions on operational and technological needs and on experimental approaches. This was accomplished through TRW's continuing interaction with various sections of the community and through Earth Satellite Corporation, the study subcontractor, and their consultants. A total of 60 candidate experiments were identified.

Three specific selection criteria filters were developed and defined in order to permit the selection and justification of those candidate experiments that could best be performed with a manned spacecraft/low-altitude orbit mission (see Figure 1).

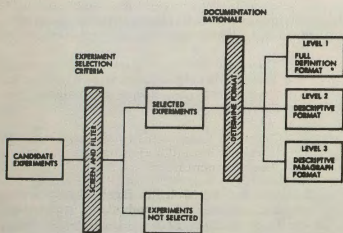


Figure 1. A Step-Wise Analysis is Used in the Experiment Selection, Definition and Documentation Process

The three filters were:

Experiment Characteristics - Advantages of Shuttle Sortie earth observation missions reside primarily in orbit, mission, and operational flexibility and in mission frequency. Candidate experiments were screened on the basis of Shuttle-unique suitability by comparing the hypothetical utility of the Shuttle platform with that of automatic (unmanned, fixed performance) orbital platforms and with that of aircraft.

Importance - The value of an experiment can be assessed by considering: 1) whether it meets the desires of a large cross-section of the user community, 2) the extent to which it may be of value in solving problems of national importance not readily solvable by other means, 3) Whether it will be useful in developing needed operational systems, and 4) Whether it is complementary

with experiments being performed on other programs. If the answer to at least one of these questions is positive, the experiment passes this filter.

Technology - This filter asks the basic question: Can the experiment be sufficiently developed to meet the early Shuttle Sortie time-line? Consideration was given to: 1) Hardware development, 2) Analysis techniques, and 3) Shuttle constraints. If the answer to this question was Yes, the experiment passed this filter.

The selected experiments (i.e., those experiments which passed all three filters) were documented according to several formats which reflected the applicability of the experiments to early Shuttle Sortie reference missions and, particularly, their applicability to the derivation of mission requirements (see Figure 1). The formats correspond to three levels of experiment description and definition:

Level 1 - A detailed experiment description and definition format which includes:

- a) Experiment objective, background, technical approach, relevancy, role of man, etc., and
- b) Measurement/observation requirements.

These experiments were considered for reference missions.

Level 2 - A descriptive format which includes the experiment objective, background, proposed technical approach, etc. This format was used to document those experiments that are still considered applicable to early Shuttle Sortie missions, but for one or both of the following reasons did not receive the attention accorded to those experiments that will be making up the sample reference missions:

- a) Full definition of measurement/observation requirements not yet determined at this time, and
- b) Lower over-all potential importance compared to other experiments.

Level 3 - A descriptive paragraph or two giving a synopsis of the experimental concept. This documentation was reserved for:

- a) Experiments for which many important elements remain to be defined, thus making the experiment difficult to evaluate for Shuttle Sortie missions, or
- b) Experiments, which in the judgment of the Study Team ranked lowest when compared to other experiments on the basis of their potential importance.

The Level 1 experiments were used to construct conceptual reference missions which could be analyzed to derive the mission requirements of a Manned Earth Observatory. The instrumentation and supporting equipment associated with these experiments were characterized through specification of physical/performance characteristics, with drawings, and by delineating structural/mechanical/electrical interfaces, and were used to develop preliminary configuration for the Manned Earth Observatory facility.

WHAT WILL SHUTTLE SORTIE MISSIONS DO FOR EARTH OBSERVATIONS?

The Space Shuttle Sortie offers a cadre of concepts and options to earth observation which cannot be totally realized on any other remote sensing data platform. These concepts and options can be divided into two categories: 1) Those that would benefit a variety of experiment areas including earth observations, and 2) Those that are particularly advantageous to earth observations. In this section, a number of options in each category that are significant in terms of earth observations will be discussed.

Shuttle Sortie seven-day missions with a payload capacity of up to 27,250 Kg in a bay 18.2 meters long and 4.5 meters in diameter offer numerous options to a variety of experiment areas including astronomy, material sciences, communication/navigation, and earth observations.

The Shuttle Sortie program provides an expanded flexibility in planning and phasing of missions. Seven-day missions may be flown at intervals as short as several weeks. When the Western Test Range (WTR) becomes operational as a launch site (by 1982), a wide choice of orbits will be available (an altitude range of 100 to 600 n. mi. and an inclination range of 28.5 to 100 degrees). The payload capacity of the Shuttle will allow multiple experiment area payload missions (e.g., material science experiments can be performed concurrently with earth observations

experiments because they will not have conflicting earth coverage requirements).

Large volume, heavy instruments can be flown on Shuttle missions. For example, multi-frequency, broadband, multi-resolution radar systems with 9 meter antennas, weighing up to 950 Kg can be accommodated on the Shuttle. In addition, a wide variety of instruments can be flown on a single mission.

Shuttle Sortie missions utilizing a manned laboratory or pressurized module offer the possibility of using non-space-hardened equipment. This would reduce costs by avoiding the expensive reliability and redundancy built into space-hardened equipment.

As a test bed for techniques, concepts and instruments, the Shuttle will provide an early opportunity to test sensors slated for future unmanned spacecraft. Man's utility in space can be explored in a variety of applications areas. The near-zero gravity environment offers new vistas for laboratory experimentation.

As part of a multi-level, multi-national earth resources data acquisition and evaluation system, Shuttle Sortie missions are of particular value. The Shuttle will supplement low resolution unmanned spacecraft and high resolution aircraft by providing intermediate resolution. A significant quantity of remote sensing instruments can be flown on the same payload and operated simultaneously, offering a new quality of multi-dimensional data

Broadscale, highly dynamic phenomena can be monitored in low inclination orbits (28.5 to 35 degrees, based on the Shuttle's presently projected capability) on a frequent basis. Depending on the size and distribution of phenomena of interest, observations can be taken up to three times a day. Highly dynamic phenomena which occur during specific yearly time intervals can be monitored on a short duration Shuttle Sortie mission, obviating a long-duration unmanned spacecraft.

Data in hard form requiring little additional processing can be readily obtained. High resolution (approaching 5 meters) multi-spectral data would be of considerable value to a variety of earth observation disciplines. For example, high resolution survey data comparable to U2 systems, but on a worldwide basis, would be of particular value in metropolitan area studies. Photography is an easy means of obtaining this data at a low cost. Unlike unmanned spacecraft, the Shuttle Sortie will allow retrieval of film data.

SYNOPSIS OF PROPOSED
MEO OCEANOGRAPHIC EXPERIMENTS

Capitalizing on the advantages of Shuttle Sortie missions, the Manned Earth Observatory could conduct a wide variety of earth observation experiments. The balance of this paper will focus on the candidate experiments developed within the discipline of oceanography and identified in the MEO study.

LEVEL 1 EXPERIMENTS

I. REGIONAL WATER POLLUTION MONITORING

Objective: Provide a basis for global and regional monitoring of water pollution from space by:

- Determination of the effects of wastewaters on the receiving waters
- Measurement of the effectiveness of wastewater management programs.

Relevancy and Background: Many localized areas with pollution problems exist throughout the world, especially where rivers empty into coastal areas. Requisite frequency of coverage and synoptic overview for monitoring all areas of interest effectively and economically may be provided only by orbital platforms. As water quality and discharge monitoring programs grow in various areas, emphasis will be placed on use of in situ, aircraft, and spacecraft platforms in a coordinated effort to maximize effectiveness of coverage.

This experiment is a precursor to a fully developed operational system that can be employed in coordinated multi-level multi-national programs to effectively police various water bodies. The experiment is designed to test the ability of a sophisticated monitoring program to classify pollutants by type, distribution, and source. In an operational system these data will be used to estimate the success of ongoing programs attempting to alleviate various forms of pollution or construct an effective means of treatment (e. g., dispersion), and test the ability of a sophisticated monitoring system to gather useful information on the circulation as a precursor for an operational system.

Technical Approach:

- A multi-spectral complement of sensors would be trained on a variety of localized areas with pollution problems to gather data on surface materials, transparency, sea surface temperature currents, tidal flushing, sea state, water color, and phytoplankton.

- in situ and aircraft data acquisition programs would be coordinated via real-time communication link. Data from non-MEO platforms would be processed in real time and transmitted to MEO for onboard analysis. The experiment would be directed by the MEO crew.

Resolution/Accuracy Requirements:

Parameters of Interest	Spatial Resolution (Meters)	Spectral Resolution (Micro-meters)	Accuracy		Amplitude
			Spatial (Meters)	Spectral (Micrometers)	
Floatables (e. g. oil slicks)	30	0.01	50	TBD	0.002 NEAP
Transparency (turbidity)	30	0.01	50	TBD	0.002 NEAP
Temperature (sea surface)	30	-	50	-	0.5 deg. C
Sea State	30	-	50	-	0.5 deg. C
Phytoplankton (chlorophyll) and water color	30	0.015	50	.0025	0.002 NEAP
Salinity	30	-	100	-	1 - 2 ‰/‰

Key: TBD - to be delivered
NEAP - noise equivalent change in reflectivity

Table 1. Resolution and Accuracy Requirements for the Parameters of Interest.

Sensors and Equipment:

- a) Primary Instruments
 - Multispectral Camera System
24 x 24 cm. (9 x 9 in.) film
Six cameras (four B&W, color, and false color)
 - High Resolution Multispectral Camera System (70 mm film)
Six cameras (four B&W, color, and false color)
 - Wideband Synthetic Aperture Radar (WBSAR) (Medium Coverage, High Resolution Mode)
 - Laser Altimeter/Scatterometer
 - Visible Imaging Spectrometer
 - IR Multispectral Mechanical Scanner (Ocean Surface Temperature Measurement)
 - High Resolution Visible Imaging Spectrometer
 - High Resolution IR Multispectral Mechanical Scanner (Ocean Surface Temperature Measurement).
- b) Correlative Support
 - Pointable Identification Camera
 - Data Collection System.

c) Support Equipment

- Wide Angle Viewer/Hydrogen Alpha Line Viewer
- Tracking Telescope
- CRT Display (e.g., oscilloscopes)
- Tape Recorders
- On-board Data Processing Equipment.

- Wide Angle Framing Camera
24 x 48 cm. (9 x 18 in.) film
- Wideband Synthetic Aperture Radar (WBSAR) (Wide Coverage, Low Resolution Mode)
- Laser Altimeter/Scatterometer
- IR Multispectral Mechanical Scanner (Ocean Surface Temperature Measurement)
- Visible Radiation Polarimeter (VRP)
- Passive Multichannel Microwave Radiometer (PMMR)
- Microwave Radiometer/Scatterometer

II. SEA ICE MAPPING

Objectives:

- To measure the horizontal and to some extent the vertical dimensions of sea and glacial ice fields and to determine their distribution
- To determine ice type.

Relevancy and Background: Mapping and monitoring the extent of the polar ice can be used to estimate their heat sink capacity and their effect on global temperature changes, thus providing a basis for long-range weather forecasting. This information would also be useful in predicting ice boundaries for shipping in the high North and South latitudes, and would provide data that will enhance understanding of sea ice dynamic processes.

Technical Approach:

- A near-polar low (approx. 150 n. mi.) orbit would be used to provide complete coverage of polar regions every five days with a ground swath width of 100 n. mi.
- An automated suite of sensors would be used for continuous mapping
- High resolution instruments would be slaved to a tracking telescope for study of specific areas of interest
- Complementary data would be acquired simultaneously with imagery on boundaries, texture, and albedo of snow and ice fields, surface roughness (water and ice), and thermal properties.

Resolution/Accuracy Requirements:

Resolution: 50 - 100 meters
Accuracy: 1 km

Sensors and Equipment:

- a) Primary Instruments
- Panoramic Camera, 12 cm (5 in.) film

b) Correlative Support

- Pointable Identification Camera
- Data Collection System

c) Support Equipment

- Wide Angle Viewer/Hydrogen Alpha Line Viewer
- Tracking Telescope
- CRT Display
- Tape Recorders
- Onboard Data Processing Equipment.

III. PLANKTON PROFILING AND SHALLOW-WATER BATHYMETRY

Objective:

- To demonstrate the utility of a space-borne system in acquiring data on horizontal (and to some extent, vertical) distribution of phytoplankton in the global ocean
- To obtain coastal bathymetric measurements using multi-band photography.

Relevancy and Background: Large-scale synoptic surveillance is the key to understanding the dynamics of ocean surface circulation. In the open ocean, a valuable means for remote discrimination of boundaries separating differing water masses exists in the contrasts of backscattered light due to differing concentrations of phytoplankton pigments.

Maps of shallow ocean areas must be continually updated for purposes of navigation and coastal engineering. Early Gemini and Apollo photography demonstrated the value of orbital platforms in this application.

Technical Approach: For plankton profiling, measurements of spectral radiance will be made over pre-selected areas by means of a scanning spectrometer operating in the spectral range from 400 to 800 nanometers. In addition, measurements will be made of the vertical plankton profile at specific points within the above areas by means of a new sensor to be developed. This sensor will consist of a very high power, pulsed laser, and a gated, filtered photomultiplier which will receive reflected laser radiation from various depths beneath the ocean surface. Operation of the sensors will be closely coordinated in time and space with a ground truth program which would document the actual distribution of phytoplankton.

Imagery of shallow ocean bottom will be backed up by real-time in situ data on water clarity, bottom reflectivity, and tidal height (water depth).

Resolution/Accuracy Requirements:

"Instantaneous Field of View" approx. 20 meters for laser profiles.

Spatial resolution approx. 30 m for bathymetry.

Sensors and Equipment:

a) Primary Instruments

- Multispectral Camera System
24 x 24 cm (9 x 9 in.) film
Six cameras (four B&W, color, and false color)
- Laser Altimeter/Scatterometer
- Visible Imaging Spectrometer

b) Correlative Support

- Pointable Identification Camera

c) Support Equipment

- Wide Angle Viewer/Hydrogen Alpha Line Viewer
- Tracking Telescope
- CRT Display
- Tape Recorders.

IV. MAPPING OF UPWELLING AREAS

Objectives:

- Test a method for detecting and monitoring the upwelling areas of the world

- Map the spatial extent of upwelling areas on a global basis and study their short-term dynamics.

Relevancy and Background: Upwelling is a dynamic ocean circulation process whereby deep water is conveyed upward to replace horizontally-transported surface waters responding to wind stress and Coriolis force. The cold upwelled water is nutrient-rich and supports high levels of phytoplankton productivity.

The best fishing grounds are frequently located near areas of upwelling where the higher trophic levels feed directly or indirectly on phytoplankton. Most upwelling areas throughout the world are mapped fairly well for specific times of the year (because of their regular seasonal occurrence), but global maps created from these discrete localized maps are very crude. What is needed is a better documentation of the dynamics of these seasonal upwellings as well as those that have not been investigated (i. e., when do they start, how long do they persist, what is their intensity, etc.).

Technical Approach:

- Observations to be made in the visible portion of the spectrum will include cloud patterns, ocean color (phytoplankton concentration), and surface roughness (sun glitter).
- Infrared measurements will provide backup data on location of masses of cool upwelled water and provide an indication of advective transport of the upwelled water.
- Ground truth will be provided by in-situ programs already gathering data on an operational basis as well as by special programs set up specifically for the Shuttle mission (e.g., off the coast of Peru).
- The scientist/astronaut's main function would be to evaluate CRT displays of temperature and chlorophyll isopleths and conduct precise off-nadir pointing at regions of interest with a set of high resolution instruments slaved to a tracking telescope. Another set of instruments of moderate resolution would map the upwelling areas on a regular basis.

Resolution/Accuracy Requirements:

	<u>Mapping System</u>	<u>Tracking System</u>
Spatial Resolution	2 Km	100 m
Spatial Accuracy	1 Km	100 m

Sensors and Equipment:

a) Primary Instruments

Mapping Instruments -

- Visible Imaging Spectrometer
- IR Multi-spectral Mechanical Scanner (Ocean Surface Temperature Measurement)
- High Resolution Visible Imaging Spectrometer
- High Resolution IR Multi-spectral Mechanical Scanner (Ocean Surface Temperature Measurement)

b) Correlative Support

- Pointable Identification Camera

c) Support Equipment

- Wide Angle Viewer/Hydrogen Alpha Line Viewer
- Tracking Telescope
- CRT Displays
- Tape Recorders.

V. OCEAN WIND AND WAVE MEASUREMENTS

Objective:

- Test a multi-sensor method of remotely measuring sea state, and surface wind speed and direction
- Analyze surface wind fields around islands and off coasts.

Relevancy and Background: Comprehensive ocean surface wind and wave information is a pre-requisite both to effective long-range weather prediction and to short-range prediction of conditions hazardous to maritime transportation. Interpretation of cloud patterns in high-resolution imagery from meteorological satellites has provided valuable information on surface wind conditions and an indication of the future potential of orbital platforms in this application. MEO will demonstrate the utility of other advanced sensors in the analysis of ocean-atmosphere coupling via wind stress.

Technical Approach:

- As a precursor to an operational system, MEO will obtain high resolution data on sea surface conditions. Through observations of associated cloud systems, with the aid of advanced optical systems, cloud pattern-sea state relationships will be examined.
- A multi-sensor subsystem in the Shuttle at low earth altitudes (150 - 250 n. mi.) will monitor the appropriate data over a variety of areas at a high spatial resolution. The orbit will have a low inclination and will be phased to maximize coverage of coastlines and islands of interest. To monitor the short-term dynamics of the surface wind conditions, areas of interest would be observed from one to three times per day.

Resolution/Accuracy Requirements:

	<u>Spatial Resolution</u>	<u>Accuracy</u>
Glitter measurement	350 m	350 m
Wave height measurement	25 m	5 cm
Photographic recording	25 m	50 m
Radar imagery	30 m	30 m
Microwave radiometry and scatterometry	1500 m	1500 m

Sensors and Equipment: The sensor subsystem for this experiment in the Shuttle, like that of Skylab, includes a telescope and a microwave radiometer/scatterometer system. In addition, however, it includes a glitter camera, a high resolution camera system, a laser altimeter and a synthetic aperture radar. The entire subsystem, except for the calibrated synthetic aperture radar, will be automatically pointed to the surface area viewed through the telescope, so that correlated data will be obtained from targets of interest.

a) Primary Instruments

- Panoramic Camera
12 cm, (5 in.) film
- Wide Angle Framing Camera
24 x 48 cm, (9 x 18 in.) film
- Wideband Synthetic Aperture Radar (WBSAR) (Medium Coverage, High Resolution Mode)

- Laser Altimeter/Scatterometer
- Glitter Framing Camera
- Microwave Radiometer/Scatterometer.

b) Correlative Support

- Pointable Identification Camera
- Temperature and Humidity Profiles — Will provide data relating to pertinent meteorological conditions in the atmosphere.

c) Support Equipment

- Wide Angle Viewer/Hydrogen Alpha Line Viewer
- Tracking Telescope
- CRT Displays
- Tape Recorders.

LEVEL 2 EXPERIMENTS

I. REMOTE CENSUS OF FISH SCHOOLS

The objective of this experiment is to examine the feasibility of measuring the abundance, distribution, and size of near-surface fish schools in selected ocean areas. A large photographic telescope, fitted with contrast-enhancing light filters (polaroid and spectral), would be used as the primary sensor. The operator would direct aircraft to areas of interest for "ground truth" data on school density, size, and identification.

II. EUTROPHICATION STUDY

Coastal areas will be selected which receive heavy inputs of organic waste materials and which consequently support a high level of primary production. Some of these areas will be instrumented for supporting data on inorganic micronutrients, oxygen content, coliform bacteria, phytoplankton concentration and productivity, transparency, and water temperature. The Shuttle-borne instruments will obtain data on chlorophyll content, sea surface temperature, and ocean color.

LEVEL 3 EXPERIMENTS

I. STUDY OF CURRENT DYNAMICS

This Shuttle experiment would be designed to test the feasibility of using a multi-spectral sensor subsystem to map the location, areal extent, and vector of surface currents. These currents will be

mapped at several opportune times during the year by obtaining data on sea surface temperature, displacement of surface objects, and ocean color.

ADDITIONAL EXPERIMENTS UNDER CONSIDERATION

(LEVEL UNDETERMINED AS YET)

- LIGHT IN THE SEA
- OIL SPILL IDENTIFICATION
- LASER-INDUCED BIOLUMINESCENCE.

LEVEL 1 EXPERIMENT INSTRUMENTATION

The Level 1 oceanography experiments utilize sensors from eight different instrument classes: Telescopes, Viewers; Cameras; Multi-Spectral Scanners; Spectrometers; Radiometers, Radars, Lasers and Polarimeters. By employing a variety of spatial and spectral resolutions, these sensors can be used to investigate many aspects of the marine environment as shown in Figure 2 and Table 2. The number of experiments requiring a given sensor depended upon its application flexibility. For example, the telescope and wide angle viewer can be used to monitor a wide variety of phenomena and are, therefore, required by all the Level 1 experiments. Other sensors, such as the glitter framing camera, are selective in their application and can only be used to observe a few phenomena.

CONCLUSIONS

The Shuttle/Sortie missions represent a unique new tool to environmental remote sensing and to the field of oceanography. While the Shuttle/Sortie missions will share with other orbital platforms the advantages of providing a synoptic overview of dynamic near-surface oceanographic phenomena at frequent observation intervals, they will not be nearly as constrained in ground resolution, spectral resolution, and accuracy of measurement capabilities as has been the case with other remote data acquisition platforms. The man-in-the-loop flexibility of the system, which will permit addressing of phenomena-of-opportunity on an ad hoc basis, imparts a unique empirical value to the Shuttle Sortie missions from the standpoint of oceanographic data acquisition. It is anticipated that experimentation with the versatile sensing systems aboard the Shuttle/Sortie missions will resolve the most direct R&D pathways leading to highly sophisticated operational oceanographic remote sensing systems of the future.

Table 2. Experiment Functions of the Level 1 Instruments

Instrument	Applicable Level 1 Experiments	Experiment Function
Tracking Telescope	I, II, III, IV, V	<ul style="list-style-type: none"> ● High resolution view of target area. ● Provide pointing information to other instruments
Pointable Identification Camera	I, II, III, IV, V	Photograph of target area for identification of observables.
Panoramic Camera	II, V	High resolution or stereo panoramic photography.
Wide Angle Framing Camera	II, V	Planimetric and topographic surveys of target areas
Multispectral Camera System	I, III	<ol style="list-style-type: none"> a. Multi-spectral photography, wide coverage, high resolution. b. B/W and color photography, wide coverage, high resolution.
High Resolution Multi-spectral Camera System	I	High resolution multi-spectral photography of selected target areas.
Wideband Synthetic Aperture Radar	I, II, V	<ul style="list-style-type: none"> ● (Wide Cov., Low Res.) Map ice fields by contrast with sea water scattering. ● (Wide Cov., Low Res.) Images of ocean surface backscattering for determination of pollution and wind patterns.
Laser Altimeter/ Scatterometer	I, II, III, V	<ul style="list-style-type: none"> ● Determine wind/wave statistics on ocean surface. ● Determine surface texture of ice and snow fields. ● Profile chlorophyll depth below ocean surface.
Visible Imaging Spectrometer	I, III, IV	Spectrometry and imaging of ocean surface color to identify organic matter, sedimentation and pollution.
IR Multi-spectral Mechanical Scanner	I, II, IV	Thermal mapping of ocean surface.
High Resolution Visible Imaging Spectrometer	I, IV	Spectrometry and imaging of ocean surface color to identify organic matter, sedimentation, and pollution.
High Resolution IR Multi-spectral Mechanical Scanner	I, IV	Thermal mapping of sea surface.
Glitter Framing Camera	V	Obtain images of solar and lunar glitter pattern to reduce average sea state and locate areas of reduced state.
Visible Radiation Polarimeter	II	Measure intensity and polarization of sunlit atmosphere and terrain in several spectral bands.
Passive Microwave Radiometer	II	Precipitation survey, establish sea surface roughness and wind, and measure sea surface temp.
Microwave Radiometer/ Scatterometer	II, V	Measurement of sea surface roughness and altimetry.
Wide Angle Viewer	I, II, III, IV, V	Obtain a wide angle, low resolution view of the area of interest.

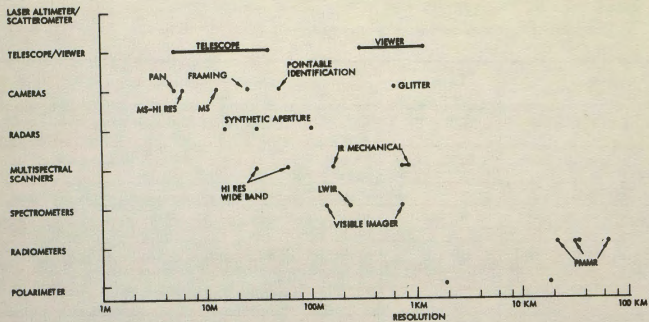


Figure 2. Horizontal Resolution Provided by Oceanography Sensors
(Altitude: 200 n. mi.)

Reference: NASA Contract NAS8-28013 to TRW Systems Group
Mission Requirements for a Manned Earth Observatory
Final Report, Volumes I, II, III, and IV (To Be Issued)