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REPORT

on

A NIMBUS G PRE-LAUNCH FIELD EXPERIMENT IN THE GULF OF MEXICO, OCTOBER 1977

by

H. van der Piepen
OPTICAL SCIENCES DIVISION

PRETORIA
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1. INTRODUCTION

This report deals with a large scale field experiment, which was arranged in support of the Nimbus G - Coastal Zone Color Scanner (CZCS) project. The purpose of this experiment was to provide three air- and two shipborne platforms simultaneously to members of the Nimbus G Experiment Team (NET) and to other scientists in order to collect data from common test sites. Besides establishing fundamental relations between the light in the sea and the biochemical properties of water, these data will be used mainly for the development of algorithms during the pre-launch phase of Nimbus G.

2. REMOTE SENSING OF WATER COLOUR

2.1 The water colour problem

(1) The colour of water as seen by a remote observer is one of the most obvious parameters of our lakes and oceans, and therefore numerous attempts to measure the upwelling radiation with the aid of spectral radiometers and multispectral scanners from low and high altitude platforms have been reported in the past.

While some of these water colour sensors were successful in recognizing and mapping very distinct features, e.g. acid dumps, oil slicks, bottom reflections, and high sediment and silt loads near river discharges, much research is still needed in order to relate such parameters as pigment, yellow-stuff and sediment concentrations in different types of water in a more quantitative way to the radiation as detected from multispectral sensors on future spacecraft.

(ii) Any colour sensor operates on the principle that the upwelling spectral radiance from the water is modified by absorbing and scattering substances in the water, and that by selecting the proper spectral channels, subtle changes in the spectra can be used to determine the presence and the concentration of these substances.

(iii) In reality the contribution of the water subsurface signal occupies only a small fraction of the total upwelling radiation. More than 80 % of the total irradiance at the receiver is due to sky luminance resulting from Rayleigh and Mie scattering within the FOV. Furthermore, the radiation, which falls onto the water is not constant due to atmospheric effects and due to changing incident sun angles.

The sea signal comprises the remaining 20 % of the irradiance. This component originates from the interactions of the downwelling light field with the ocean surface, the water itself and the ocean floor.

Variations and interactions among these three components are extensive and difficult to predict, depending on the sea state, water clarity, water depth, etc.

2.2 The Nimbus G/CZCS

(i) The CZCS is the first spaceborne multispectral scanner operating in the visible and in the infrared spectral region, which has been specifically designed for the remote sensing of water. The six spectral channels are listed in Table 1.

Channel	Centre Wavelength	Half Width	Observation
1	443 nm	20 nm	Chlorophyll Absorption
2	520 nm	20 nm	Chlorophyll Correlation
3	550 nm	20 nm	Yellow Stuff
4	670 nm	20 nm	Chlorophyll Absorption
5	750 nm	100 nm	Surface Vegetation
6	11,5 [illegible]	2 μ	Surface Temperature

TABLE 1 : CZCS SPECTRAL CHANNELS

Channels 1-4 will have selectable gain settings to allow for sun angle variations during the year. Channel 5 has only one gain setting as it is for use over land. (This gain will be comparable to that of MSS channel 6 on Landsat, but adjusted for the high noon ascending node orbit of Nimbus G.) Channel 6 uses the best atmospheric window for day and night ocean surface temperature mapping.

The IFOV of the scanner is 0,05 degrees, which equates a sea level square of 825 meters on a side from the nominal orbital altitude of 955 km. The active portion of the scan is 78,7 degrees, which produces a cross track swath of 1566 km. The scan rate and IFOV size are such that each swath overlaps the preceding one by about 25 per cent.

The scanner mirror is capable of being tilted forward and backwards by plus or minus 20 degrees line of sight about the spacecraft pitch axis in 2 degrees increments. This movement is commandable and is used to avoid sun glint.

(ii) The most important orbital parameters of Nimbus G are listed in Table 2.

Expected launch date	:	31 August 1978
Orbit	:	sunsynchronous, polar
Inclination	:	99,3° (to west)
Height	:	955 km
Period	:	104 min
Orbits/Day	:	13,8
Precession/Orbit	:	26° (westwards)
Precession/Day	:	4,55° (westwards)
Repeat cycle	:	79 orbits, 5,7 days
Ascending Node Time	:	12 noon
S/C Forward Motion	:	6,4 km/s

TABLE 2 : NIMBUS G ORBITAL PARAMETERS

3. GULF OF MEXICO

The Gulf of Mexico is an extremely well-studied area. The entire basin forms a semiclosed system with oceanic input through the Jucatan Channel and outflow through the Straits of Florida. Run-off from about two-thirds of the area of the USA and more than half the area of Mexico empties into the Gulf. This large amount of run-off is mixed into the surface water of the Western Gulf and makes the chemistry of parts of this system quite different from open ocean areas.

Surface current patterns and deep-water spreading are largely determined by topography. Water enters from the Caribbean over the 1800 m sill of the Jucatan Channel and leaves through the Straits of Florida with a sill depth of 600 m. This current has a velocity of 50-200 cm/s and transports about 30 x 10^6 m^3/s. Generally, a spring intrusion of water intensifies through the summer into a pronounced loop extending northwestward into the Gulf. In late summer this loop sometimes becomes a separate eddy detaching from the main current and drifting westwards.

For summer conditions (due to larger evaporation), the distribution of surface salinity is usually different from that during winter months. In the Eastern Gulf the salinity distribution is modified by the seasonally dependent loop current. In the North-West Gulf the salinity gradient is determined by the amount of run-off, which varies all the time.

4. TEST SITES AND CRUISE PLAN

4.1 Platforms

The following platforms were available during this field experiment.

Aircraft

(i) U-2, flying at high altitude (19,8 km);

(ii) Lear Jet, flying at medium altitude (approx. 4 km);

(iii) Cessna, flying at low altitude (300 m).

Ships

(i) "Gyre", belonging to the Texas A and M University. Chief scientist on board was Prof Dr S.Z. El-Sayed.

(ii) "Researcher", belonging to NOAA. Chief scientist on board was Dr C. Maul.

4.2 Criteria for Test Site Selection

The test sites were selected with regard to the following criteria:

(i) They should include different types of water with emphasis on areas with outstanding features, like e.g., dump sites, river discharges, upwellings, etc.

(ii) Whenever possible they should be within the operation range of the aircraft used, i.e. relatively close to the U.S. coast.

(iii) They should include at least the boundary of a warm, anticyclonic gyre, mentioned in section 3 of this report.

(iv) They should permit joint operation of the "Gyre" and the "Researcher" in some areas.

(v) Any schedule should be flexible enough to allow for bad weather conditions but also for mobility in case any unusual features should be discovered during flight operation. (The latter requirement was made possible due to a good communications system not only between the two ships but especially between the ships and the different air bases from where the aircraft were operated.)

4.3 Cruise Plan

The cruise pattern (Fig. 1) was planned in consideration of the remarks in section 4.2 and included the following stations:

Outside Galveston (equipment shake down)

Galveston dump site

* Dry Tortugas
* Tampa Bay
* Apalachee Bay
* Mississippi River Delta
* Deep Water

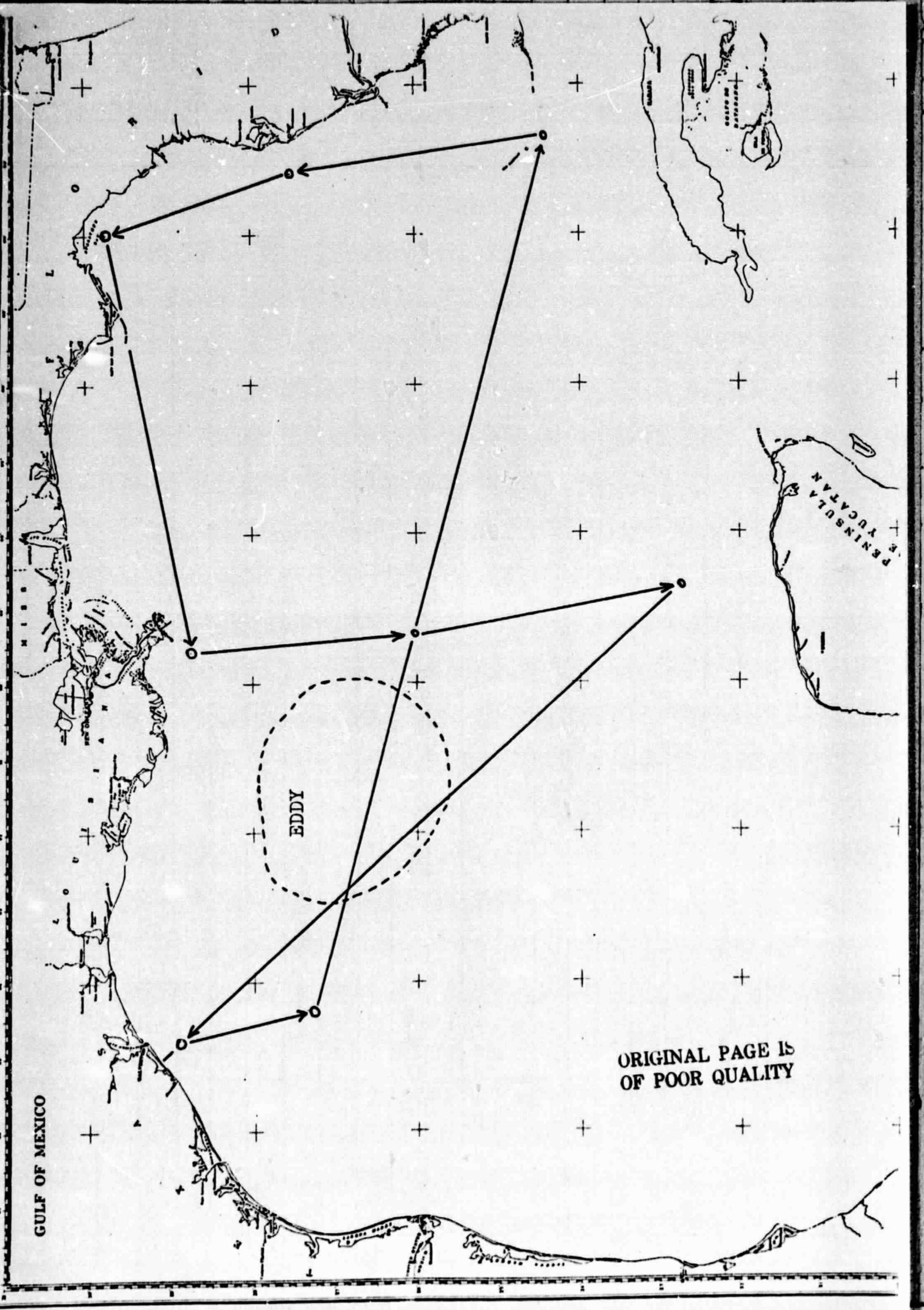

FIG. 1 : CRUISE PATTERN AND STATIONS

- Campeche Banks

(* Joint "Gyre" and "Researcher" operations)

As a result of "green" water spotted by the Cessna pilot, another station (* North of Tampa Bay) was added.

Due to bad weather conditions, none of the optical instruments were deployed at the station off the Dry Tortugas.

Due to the nature of the experiments, stations were occupied for most of the day, while travelling was done during the late afternoon and at night.

5. EXPERIMENTS AND EQUIPMENT

5.1 General

In spite of being dedicated to the remote sensing of water, a number of measurements were taken during the cruise, which are routine on any ocean-going research vessel. Since the main topics of this field experiment is water colour, only those experiments being directly relevant to this phenomenon are discussed in more detail in this section.

5.2 Airborne equipment

5.2.1 U-2 equipment

The water colour payload of the U-2 consists of the Ocean Color Scanner (OCS) and of four individually filtered Mitchell-Vinten Cameras.

5.2.1.1 Ocean Color Scanner

(i) The OCS is a 10-channel scanning radiometer, which was designed and built at NASA's Goddard Space Flight Center. Since the OCS was specifically designed for the remote sensing of water colour from high altitude, it has been used during the past in a large number of related missions. A slightly modified version of the existing OCS will also be flown on a mission of the Space Shuttle during 1979.

(ii) The general instrument and platform parameters are given in Table 3.

Aircraft speed	:	201 m/s (390 knots)
Aircraft altitude	:	19,8 km
IFOV	:	3,5 mr
Footprint	:	69,3 x 69,3 m
FOV	:	$\pm 45^{\circ}$ from nadir
Scan rate (mirror speed)	:	2,7 revolutions/s
Swath width	:	39,6 km

TABLE 3 : U-2/OCS SCANNER PARAMETERS

The critical radiometric and spectral parameters are listed in Table 4. When flown at the U-2's operational altitude of 19,8 km, the OCS swath width is about 39,6 km and the footprint at nadir is approximately 69 m x 69 m. The instrument utilizes a fully rotating scan mirror turning at a rate of 2,727 revolutions per second and viewing the earth through scan angles of ± 45 degrees from nadir.

Channel Number	Centre Wavelength nm	Half-width nm	Slope of calibration Function mw/cm^2 sr µm V
1	431	24,2	7,298
2	472	26,0	5,984
3	506	25,0	3,853
4	548	26,3	2,365
5	586	24,1	1,810
6	625	25,3	1,430
7	667	24,2	1,110
8	707	26,0	,9049
9	738	24,0	11,52
10	778	26,1	,6131

TABLE 4 : U-2/OCS SPECTRAL CHANNELS

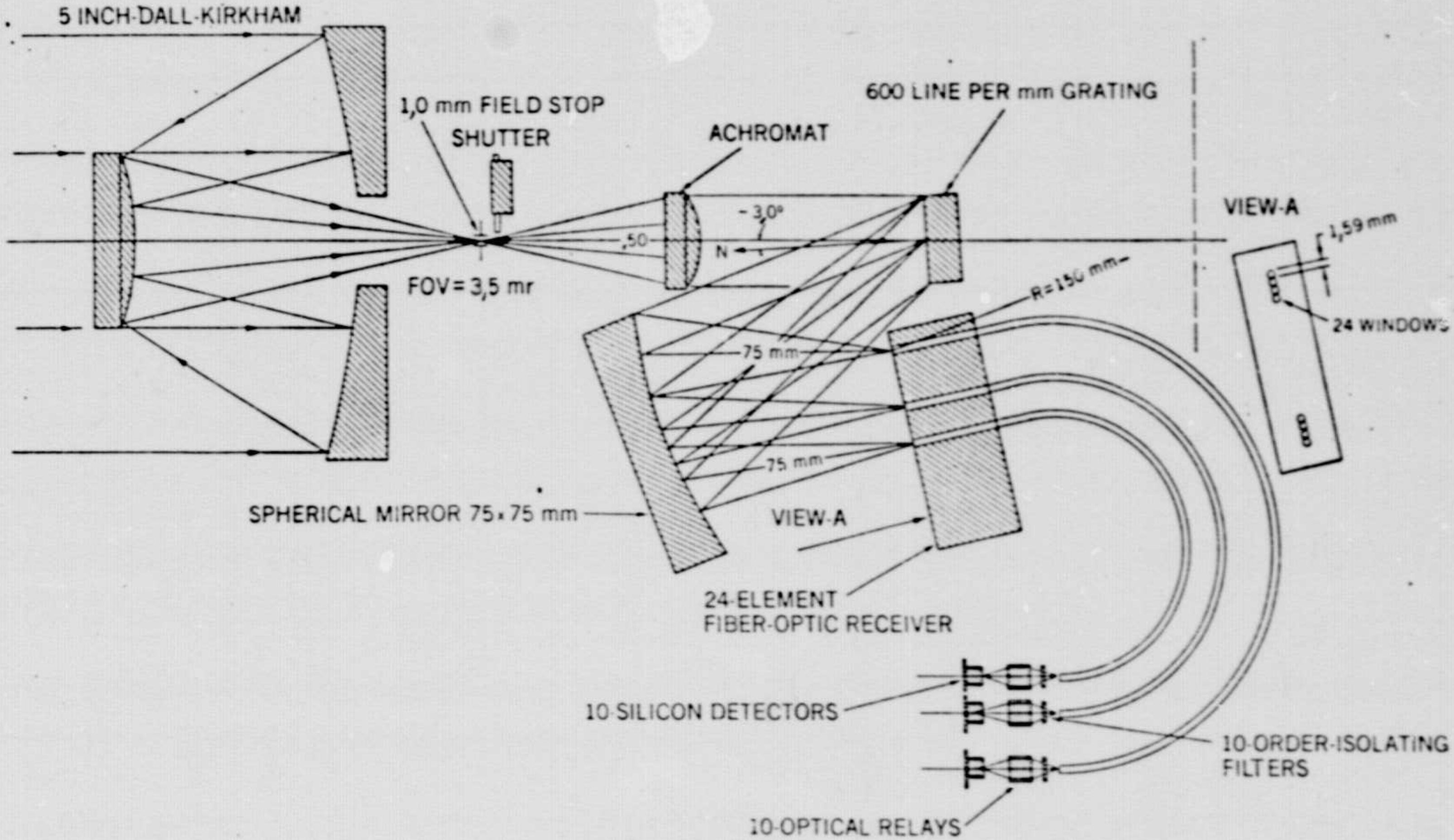

FIG. 2 : OPTICAL LAYOUT OF U-2/OCS

(iii) The optical system (Fig. 2) consists of a Dall-Kirkham telescope (12,7 cm), an optical disperser, a fiber optic receiver, and a cluster of 10 Si photodiodes. The telescope images the scene into a 1 x 1 mm field stop, past a solenoid shutter and into an achromatic collimator, which couples into the disperser. The field stop sets the IFOV at 3,5 mr, and the shutter serves as calibration zero.

The spectrometer section consists of a plane diffraction grating (26 x 26 mm, -600 lines/mm), a focusing mirror and an image receiving head composed of 24 fibre optic windows. The output of 10 selected bundles is coupled to 10 photodiodes by means of an optical relay.

(iv) The outputs from 10 preamplifiers are sampled simultaneously by a 10-bit digitizer. After adding some housekeeping data, the digital signals are multiplexed and recorded on a 14-track tape recorder.

5.2.1.2 Mitchell Vinten camera

In addition to the OCS, the ocean colour payload contains four Mitchell Vinten cameras using 70 mm film. This film provides an additional means of identifying large scale features. In most flights, the cameras are loaded and filtered as shown in Table 5.

The cameras are controlled by an intervalometer, that can be set to expose a frame at varying intervals. With the 1,75" focal length lens normally used, coverage of a 13,9 x 13,9 nautical mile area is acquired. Overlap of approximately 50 % is normally used in the along-flight direction.

Each frame of film is identified, as it is taken, by photographing a series

Camera	Film	Filter	Spectral Band
1	Panatomic-X	Wratten 12	510-700 nm
2	Panatomic-X	Schott GG	475-575 nm
		475 + Schott BG 18	
3	Panatomic-X	Schott OC	
		570 + Schott BG 38	580-680 nm
4	Aerial Color	-	400-700 nm
	SO 242		

TABLE 5 : SPECTRAL RESPONSE OF CAMERAS

of light emitting diodes in the margin of the film. The identity code contains flight number, aircraft identification, and the GMT time in hours, minutes, and seconds.

5.2.2 Lear jet equipment

(i) The water colour payload of the Lear Jet consists essentially of the Modular Multispectral Scanner (M^2S), which is a multichannel scanning radiometer designed and built by the Bendix Aerospace Systems Division. The M^2S was the first commercial digital multispectral scanner flown. Today Bendix has produced over nine systems, including systems delivered to NASA and to customers in Europe, South America and Asia.

(ii) The M^2S can be operated from an aircraft platform, flying at altitudes of 300 to 10000 m. Typical M^2S platform parameters are shown in Table 6. As shown, the M^2S collects data over a swath width of 100° beneath the aircraft. In addition, a roll compensation of $\pm 10°$ is incorporated into the system. The resolution of digital data samples is set equal to the IFOV at 2,5 mr. The rotational speed of the scanner mirror is adjustable to provide the same data sample resolution in the

Aircraft speed	:	75	100	150 m/s
Aircraft altitude	:	,5	4	10 km
Footprint	:	1,25	10	25 m
Swath width	:	1,2	9,6	24 km
IFOV	:	2,5 mr		
FOV	:	±50° from nadir		

TABLE 6 : TYPICAL M^2S OPERATION CONDITIONS

direction of flight, e.g. from scan line to scan line over a V/h range of ,25 to ,025 r/s.

(iii) The optical system (Fig. 3) consists of the 45° rotating mirror, a Dall-Kirkham telescope with an effective collecting aperture area of 65,2 cm^2. The thermal radiation is separated from the visible/near infrared one by means of a dichroic filter. The field stop is then imaged onto a Si detector array by two acromatic lenses. The first lens is at its focal length from the field stop, and, thus, collimates the beam before it falls on a reflecting diffraction grating. After dispersion of the beam, the second lens images the energy in a focal plane in which the detector array is aligned and calibrated. The thermal channel uses a Hg:Cd:Te detector peaked at 11,5 μ by using a high-pass filter with cut-on at 8,0 μ. The 11 visible, near infrared and thermal channels are listed in Table 7.

Dual thermal references and two types of visible/near i.r. references are provided. The thermal reference consists of two independently controlled blackbody sources, a heat exchanger and a dual-temperature control unit. The references occupy positions on either side of the scanner port and operate over a range from -10 to +50 °C. Either skylight or a calibrated lamp with six neutral density filters can be used for the visible/near i.r.

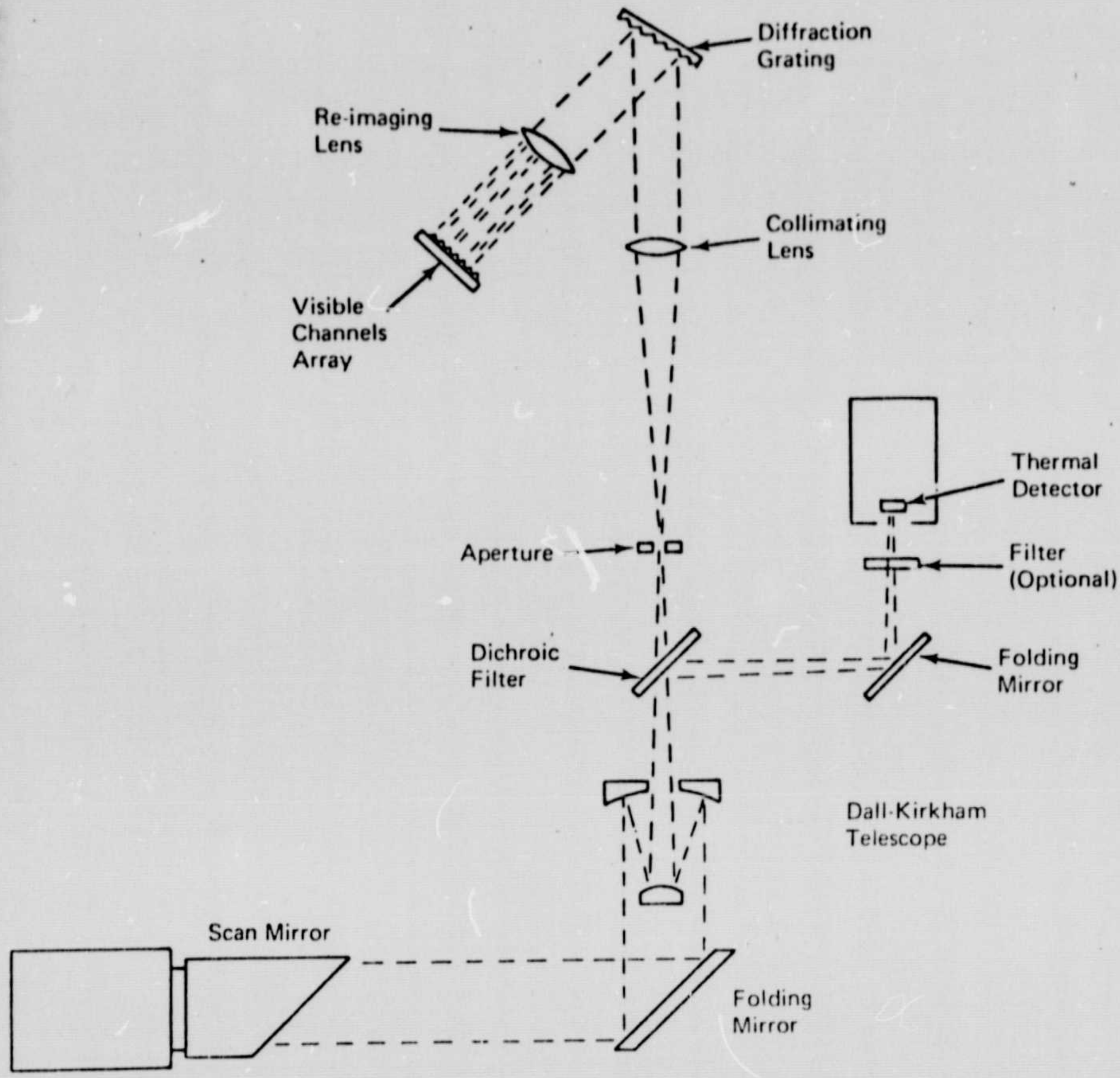

FIG. 3 : M^2S OPTICAL SYSTEM

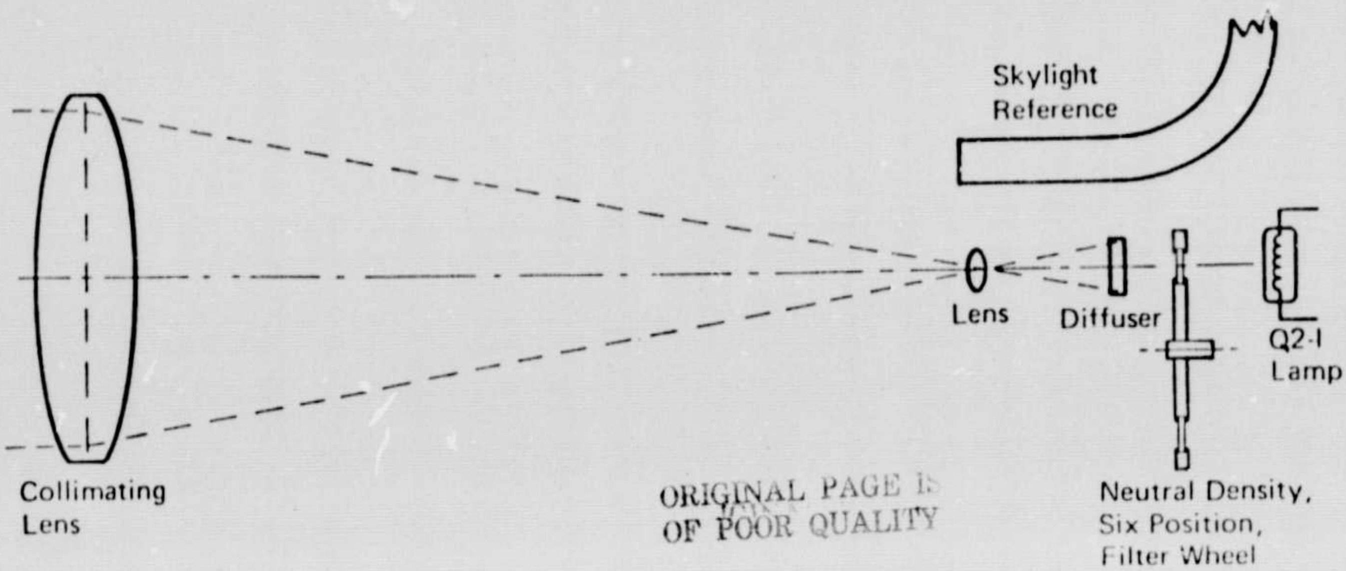

FIG. 4 : M^2S CALIBRATION SOURCES

Channel number	Centre wavelength nm	Halfwidth
1	410	60
2	465	50
3	515	50
4	560	40
5	600	40
6	640	40
7	680	40
8	720	40
9	815	90
10	1015	90
11	11000	2500

TABLE 7 : M^2S SPECTRAL CHANNELS

channels. Both sources share a common collimating optics assembly, which fills the scanner entrance aperture (Fig. 4).

The signals from the 11 preamplifiers are digitized (8 bit), intermixed with housekeeping and reference data and recorded on 11 tracks of magnetic tape.

5.2.3 Cessna equipment

The water colour payload of the Cessna consists of the Rapid Scan Spectrometer (RSS) and a thermal radiometer (PRTS).

5.2.3.1 Rapid Scan Spectrometer

The RSS is a commercial spectroradiometer (Tektronix), which basically consists of a vidicon spectrometer (J-20), an oscilloscope (series 7000) and a plug-in unit (7 J-20). Since the unique feature of this system is its capability to detect rapidly changing events, a data recording system (analogue tape recorder with the associated electronics) is usually added. (More sophisticated systems digitize the detected spectrum so that it can be entered into a computer together with other reference and calibration spectra.)

Referring to Fig. 5 it can be seen that in the RSS the measured radiation is dispersed by a Czerny-Turner monochromator and focused onto the vidícon target, which gathers spectral data at all wavelengths simultaneously. The spectral information is then electronically scanned from the target and the resultant signal (intensity vs. wavelength data) can be displayed on the CRT of the oscilloscope and recorded on magnetic tape. Spectral areas of interest are identified with a movable wavelength marker. Two modes of electronic scanning are provided in the RSS system: Normal repetitive and integrate mode.

The electronic plug-in provides the interface between the spectrometer/ detector assembly and the display or storage system. The plug-in contains the circuitry for scanning, signal processing and amplification. As a quick-look facility for rapidly changing spectra, a storage oscilloscope is used. Specifications for the system as used on the aircraft are listed in Table 8.

Grating	:	150 lines/mm
Scan range	:	400-800 nm
Resolution	:	4 nm
Slit height	:	7 mm
Slit width	:	10-1000 µm
Equivalent f-number	:	f/6,0 non-vignetting
Filters	:	neutral density 1,0
		neutral density 2,0
		500, 800 nm monopass
		$<$ 400 nm, $<$ 500 nm U.V. block
		250-330 nm U.V. pass
Scan time	:	20, 50 or 1000 ms
Integrate time	:	50-1000 ms (20 ms scan)

TABLE 8 : RSS SPECIFICATIONS

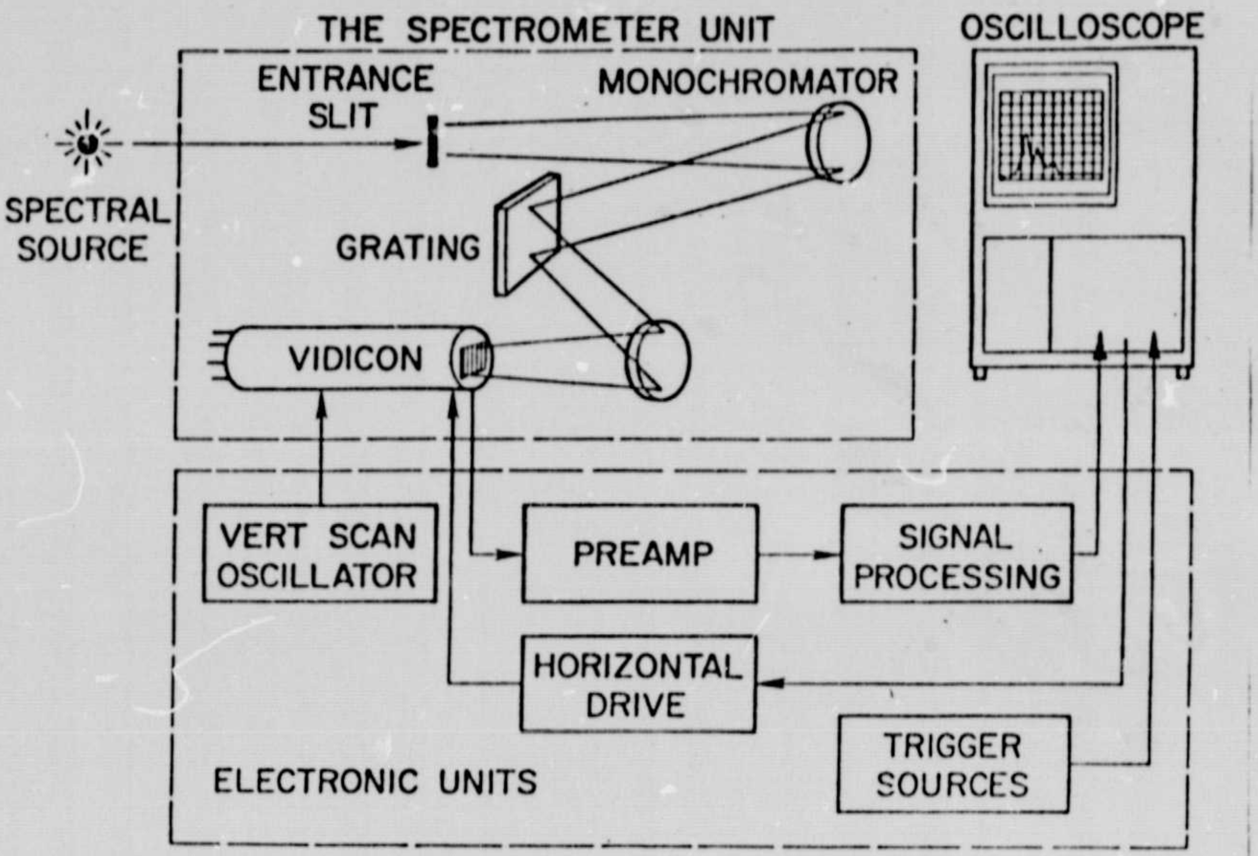

FIG. 5 : SCHEMATIC OF RAPID SCAN SPECTROMETER

5.2.3.2 Precision Radiation Thermometer

The Precision Radiation Thermometer (PRT, model 5) is a commercial infrared radiometer (Barnes), which is usually included in remote sensing operations so as to determine the variation of the water surface temperature.

The PRT-5 consists of an optical head and an electronic control unit. The optical unit compares the amount of radiant energy emitted by the target with that emitted by an internally controlled, optically chopped temperature cavity, thus providing absolute values of infrared radiation levels. The unit uses an immersed thermistor detector to sense the target temperature. An objective lens and special interference filter are used to limit the pass band to the atmosphere 8 to 14 μ window. With the 2° FOV the instrument covers a ground spot size of 10,7 m (at 305 m altitude).

The PRT-5 offers three selectable response times - 5, 50 and 500 ms. High and low level electrical outputs are available from the electronic unit for monitoring and recording purposes.

5.3 Shipborne equipment (R.V. "Gyre" only)

5.3.1 Secchi disc

(i) The Secchi disc has been used since the middle of the last century to obtain some measure of water transparency. It was used widely because of its simplicity although its optical properties were not well specified nor was the method for its use.

The Secchi disc experiment measures the attenuation of the contrast of a submerged object along a vertical path and could be described in theory by the equation

$$C_R = C_o \; e^{-(\alpha + K)R},$$

where C_o is the inherent contrast of the object against its background, C_R is its apparent contrast as seen by an observer at some distance, R is the length of the path of sight, and α and K are the attenuation coefficients for collimated and diffuse light. If the reflectance of the water column and that of the disc for the photopic band are known, C_o can be determined, while values for C_R are available from the literature. Thus, in theory the Secchi depth can be used to calculate the sum of the diffuse and the collimated attenuation coefficients. In order to determine α or K individually, additional measurements would have to be made.

(ii) Secchi disc readings are usually obtained on the shadow side of the ship to avoid, in so far as possible, the undesirable effects of surface reflection. In this case the disc will be lowered right through the ship's underwater shadow, which obviously can result in very large errors in the depth reading and makes comparison of different measurements difficult.

It is also essential that the disc should remain horizontal, otherwise the lighting on its surface will not be correct. The white painted surface of the disc must be maintained at a known reflectance. The practical value of C_R should best be determined experimentally and the parameters affecting its value should be specified.

In short, a Secchi disc should be calibrated against modern measurements of α and K. However, if modern instruments are available, Secchi disc readings do not really render useful additional information.

5.3.2 Irradiance measurements

5.3.2.1 General

These measurements are undertaken to determine the spectral properties of the underwater light field, its variation with depth, and the manner in which it is altered by the composition of the water mass.

A measurement of the downwelling spectral irradiance $H_z(\lambda)$ at different depths z for instance can be used to determine the diffuse attenuation coefficient $K(\lambda)$ in various parts of the water column according to the relation

$$H_{z_2}(\lambda) = H_{z_1}(\lambda) \cdot e^{-K(\lambda)\cdot\Delta Z}.$$

Similarly, measurements of the up- and downwelling spectral irradiance in the water can be used to determine the spectral reflectance $R(\lambda)$ of the water column at various depths according to

$$R(\lambda) = \frac{H(\lambda)\ \text{upwelling}}{H(\lambda)\ \text{downwelling}}.$$

Usually, radiation measurements underwater are referred to simultaneous measurements of the downwelling light field above the surface, for instance in the form of the spectral irradiance $H_o(\lambda)$.

Up- and downwelling irradiance measurements above and below the water surface were undertaken on the "Gyre" by means of various radiometers. Besides their degree of sophistication and accuracy, these instruments differed mainly with regard to their spectral coverage, spectral resolution and with regard to the manner in which they were deployed from the ship to avoid the ship's shadow.

5.3.2.2 Single channel radiometer

This instrument has been designed by SIO. Its spectral response is broad (halfwidth approx. 100 nm) and peaks in the green spectral region. The underwater cell is referred to a gimbal-mounted deck cell. The sea cell was lowered from a crane so as to determine the attenuation of the light as a function of depth. This information was used in an experimental simulation of the primary productivity.

5.3.2.3 Four channel radiometer

This instrument has been designed by NOAA/NESS for general use by all NET members and other interested people. The model used on the "Gyre" was a prototype to be tested during the cruise. It measures sequentially the up- and downwelling irradiance in the water in four narrow spectral bands, which correspond to those of channels 1-4 of the Nimbus G/CZCS (see: Table 1). Alternatively, light from a built-in calibration lamp and "Zero" light from a cavity can be monitored. The optical system makes use of a filtered diode array (Isotek Corp.) for spectral separation.

Other design features are:

(i) a chopped optical input to the diode array;

(ii) automatic and manual gain settings;

(iii) a pressure transducer as depth indicator;

(iv) a temperature sensor;

(v) 8-bit A/D conversion and parallel bit transfer of all signals through the cable;

(vi) a digital voltmeter and printer in the deck control unit.

The instrument was lowered from a crane in a position relative to the sun which minimized the effect of the ship's shadow.

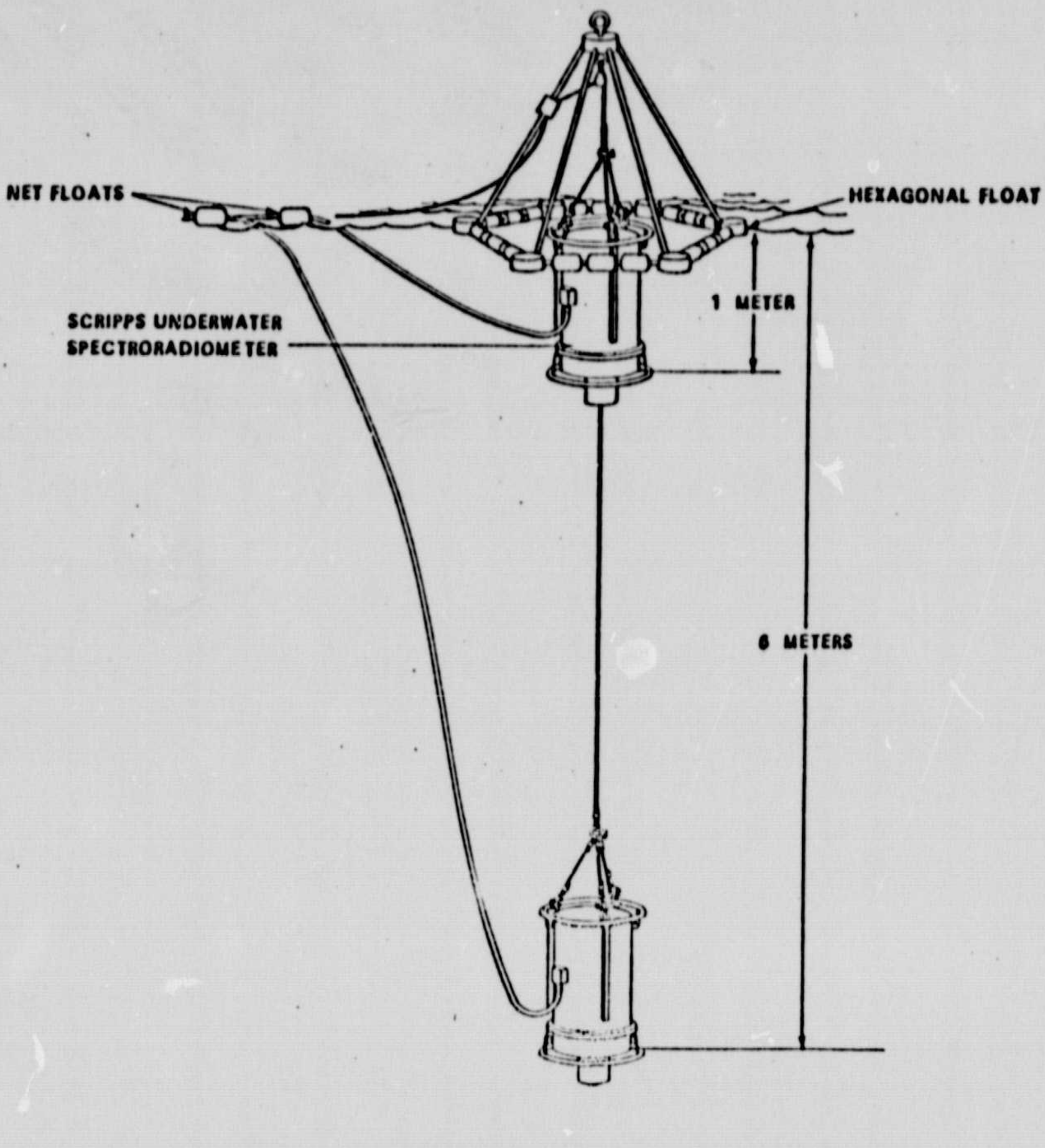

FIG. 6 : PRINCIPLE OF SUBSURFACE IRRADIANCE MEASUREMENT

5.3.2.3 Spectral scanning radiometer

This system was designed by SIO and built by Gamma Scientific Inc and consists of two submersible scanning spectrometers and one matched, gimbal mounted scanning spectrometer which is used simultaneously on deck. The two submersible spectroradiometers (one for upwelling, one for downwelling) are mounted in two floats which can drift up to approximately 50 m away from the main ship (Fig. 6). All three units are remotely controlled. Data are collected through the cables in a digital format with the aid of a central data acquisition and processing system, which also contains calibration spectra.

Spectral coverage is from 350 to 750 nm with a resolution of 5 nm. In reflectance measurements the inputs of the two submersible units are adjusted to the same depth. The units are serviced from a rubber dinghy, which somewhat limits their use to relatively calm weather conditions.

5.3.3 Transmittance measurements

(i) The principle of the beam transmittance meter is to produce a parallel beam of light which, after passing a water path of fixed length x, impinges on a detector (Fig. 7).

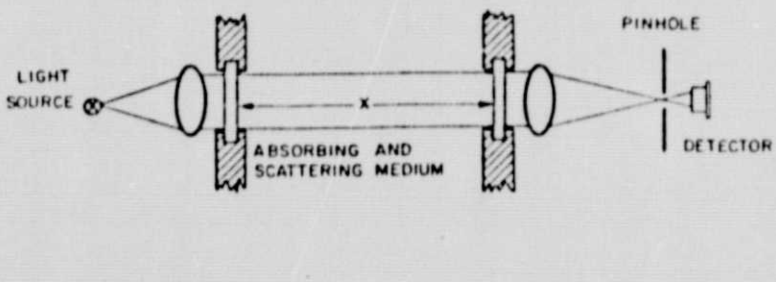

FIG. 7 : MEASUREMENT OF THE BEAM ATTENUATION COEFFICIENT

The instrument is designed for the purpose of measuring the attenuation coefficient $\alpha(\lambda)$, defined as the sum of the absorption coefficient plus total scattering coefficient. Therefore, it has to be highly efficient in excluding the scattered light. This can be achieved with some accuracy if the receiving optics is telescopic with a very narrow angular field of view.

(ii) The purpose of measuring the attenuation coefficient at various depths is to obtain quantitative values of $\alpha(\lambda)$ to be used in the calculation of the propagation of light, but also to correlate $\alpha(\lambda)$ with the concentration of suspended particles, especially with phytoplankton.

(iii) The in situ transmissometer on the "Gyre" was designed and built by SIO. The optical system consisted of a cylindrically limited light beam 1 m long with a diameter of 19 mm. The mean acceptance angle of the receiver is ,5°. The photocell is masked with one of four Wratten filters, which, combined with the spectral distribution of the source and the sensitivity of the detector, have spectral characteristics as shown in Table 9.

Filter No.	Centre wavelength	Half-width
98	450 nm	46 nm
45	491 nm	51 nm
61	536 nm	55 nm
25	615 nm	34 nm

TABLE 9 : SPECTRAL CHANNELS OF TRANSMISSOMETER

The transmissometer system includes a depth transducer, thermistor and X-Y recorder, so that transmissivity (per cent/meter) and temperature can be recorded continuously as a function of depth (Fig. 8).

The optical system is calibrated so that air transmittance is 85,5 % and the blank is 0 %. (The 85,5 % air setting accounts for the increase in the transmittance of the four optical surfaces in contact with water when the instrument is immersed.)

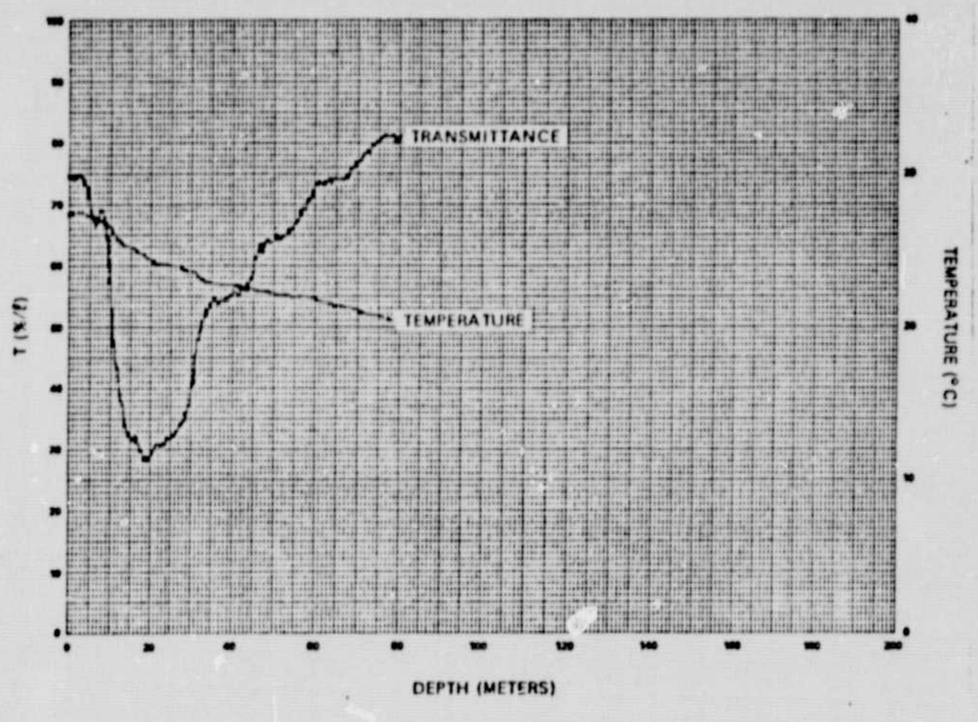

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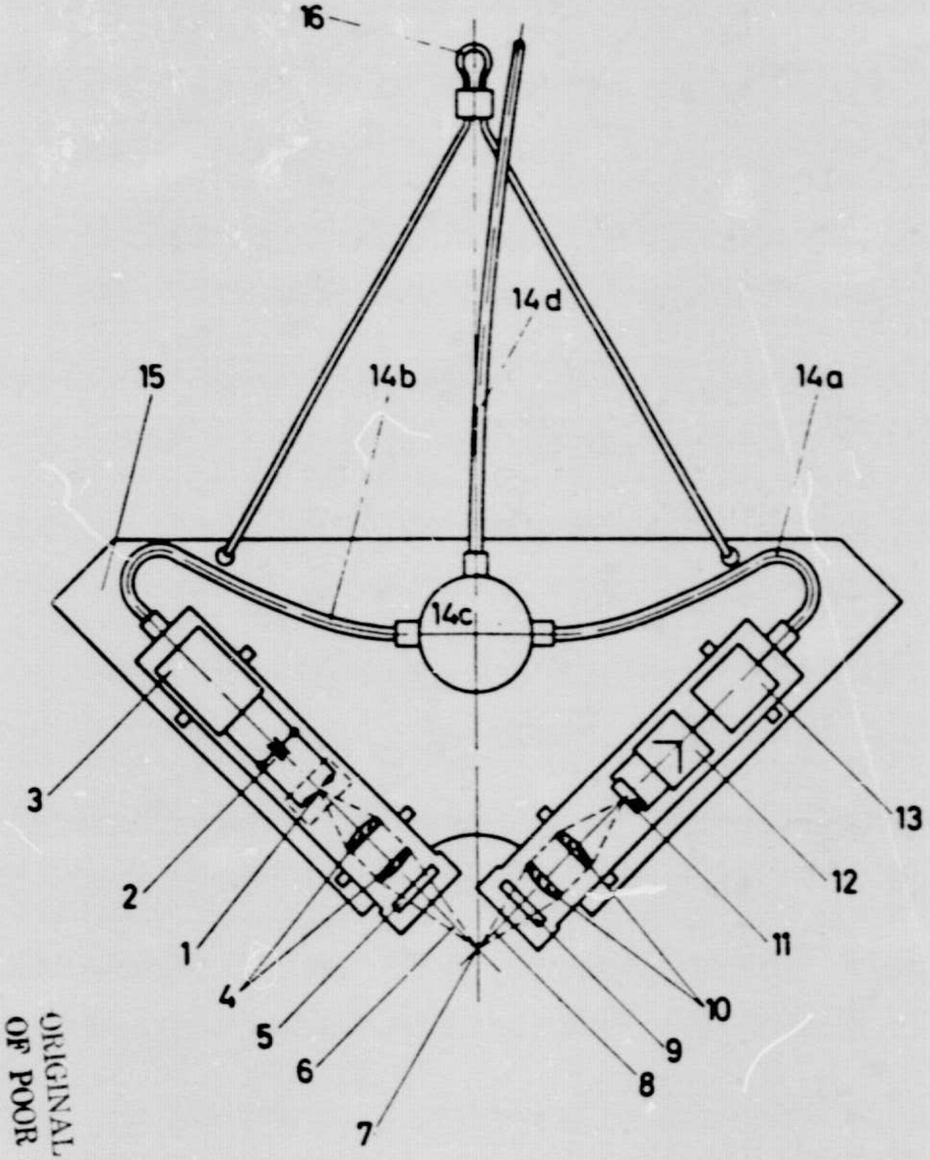
FIG. 8 : TYPICAL RECORDING OF BEAM TRANSMITTANCE

(iv) The transmissometer was lowered together with a submersible pump (model 1 P 809 Dayton Electric Mfg. Co.), which pumped the sea water through a hose into various laboratories.

5.3.4 Fluorescence measurements

5.3.4.1 General

(i) Cellular chlorophyll-a fluorescence is a



1 Xenon spark discharge lamp
2 Discharge capacitor
3 Pulse frequency generator
4 Condenser lenses
5 Optical filter passing fluorescence-exciting wave lengths (omitted if VARIOSENS used for turbidity measurements)
6 Radiation directed to intersection zone
7 Intersection zone
8 Emitted fluorescent radiation
9 Optical narrow band filter
If VARIOSENS used for turbidity measurements, a neutral gray filter is used
10 High aperture condenser lens system
11 Guard ring photodiode
12 Logarithmic amplifier
13 Stabilized power pack
14a Power and data lines
14b Power line
14c Connecting box
14d Main cable to the ship
15 Mounting plate
16 Hoist loop

FIG. 9 : SCHEMATIC OF VARIOSENS FLUOROMETER

convenient measure of phytoplankton concentration although it has been found that it depends on the physiological state of the cell. In particular, the intense sunlight that often falls on midday surface waters inhibits cell fluorescence. Only below a certain threshold irradiance, fluorescence is independent of ambient light intensity.

(ii) The standard technique for chlorophyll-a determination makes use of a flow-through Turner fluorometer with continuous excitation, which renders a continuous record of the fluorescent signal on a strip-chart recorder. This system is used on stations so as to obtain a depth profile, but also while the ship is moving with the aid of a water inlet in the bow of the ship. In the latter case a continuous record of surface chlorophyll is obtained along the track of the ship. Care has to be taken that no air bubbles are introduced into the flow-through system.

5.3.4.2 Variosens In Situ Fluorometer

(i) The Variosens Fluorometer has been designed and built by Impulsphysik GmbH. It consists of a transmitter and a receiver (Fig. 9). Intense blue light pulses from a flash lamp illuminate a small water volume to be tested. They excite fluorescence which is detected from a suitable photodiode in conjunction with a peak-height detecting circuit. This circuit delivers a continuous signal to be recorded in spite of the transient excitation (approx. 5 flashes/s). The spectral response of the filter combination (flash-lamp and detector) is matched to the absorption and fluorescent spectrum of chlorophyll-a (Fig. 10).

(ii) The instrument is submersible and thus can be used either stationary (depth profile) or while the ship is moving slowly.

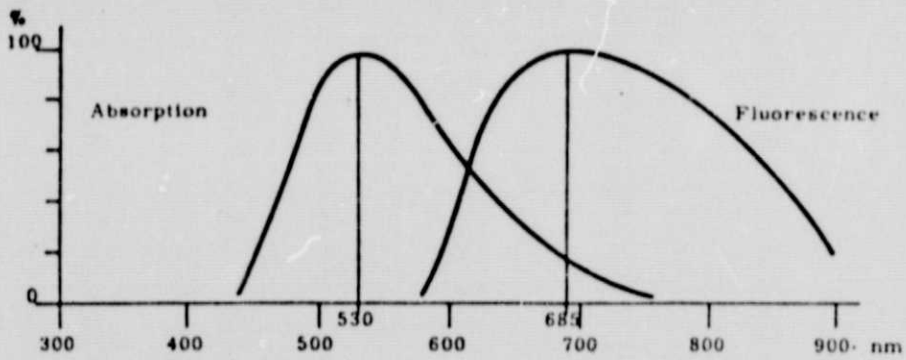


FIG. 10 : ABSORPTION AND FLUORESCENCE OF CHLOROPHYLL-A

During this cruise the Variosens was suspended 1 m below the water surface from a special float, which could be towed at speeds of up to 10 knots. The fluorescent signal was transferred through a cable to the electronic control unit on deck of the ship.

6. CONCLUDING REMARKS

6.1 Cruise data

Although weather conditions were not always favourable, the combined measurements taken on the various platforms will render a large amount of basic and CZCS-related data.

A preliminary discussion of the results will take place during the next NET meeting to take place in Miami at December 7-8, 1977. It is expected that during this meeting it will also be decided in which format the final data will be compiled and edited.

6.2 Acknowledgement

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