NIMBUS 7 Coastal Zone Color Scanner (CZCS)

Level 1 Data Product Users' Guide

S. P. Williams, E. F. Szajna, and W. A. Hovis

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1 THE COASTAL ZONE COLOR SCANNER EXPERIMENT

1.1 Introduction

The Nimbus-7 spacecraft was launched in October 1978, and has been producing data for over five years. The Coastal Zone Color Scanner (CZCS), flying on Nimbus-7, is a multispectral line scanner devoted principally to measurements of ocean color. It has six spectral bands (channels), four chiefly for ocean color, each of 20 nanometer band width and centered at 443, 520, 550, and 670 nanometers. These are referred to as channels 1 through 4, respectively. Channel 5 senses reflected solar radiance, but has a 100 nanometer band width centered at 750 nanometers and a dynamic range which is more suited to land. Channel 6 operates in the 10.5 to 12.5 micrometer region and senses emitted thermal radiance for derivation of equivalent black body temperature.

The CZCS scans a swath width of approximately 1600 kilometers with a spatial resolution at the nadir of 800 meters in each of the 6 co-registered channels. Data acquired from the CZCS are processed at the Goddard Space Flight Center into two product levels. Level-1 products contain earth located raw radiance counts and calibration information. Level-2 products contain derived information such as pigment concentrations, aerosol radiances, subsurface radiances, and diffuse attenuation coefficients which are obtained from the raw data using scientific processing algorithms developed by members of the CZCS Nimbus Experiment Team (NET). Digital tape and film products are produced and archived for both of the product levels.

The guide is intended for users of Nimbus-7 CZCS Level-1 data products. The CZCS instrument and theoretical foundations behind the experiment are described in Section 1.
tion 2, contains a brief description of the image location and calibration algorithms implemented for production of Level-1 products. The CZCS Level-1 tape format is described in Section 3. Finally, Section 4 contains information on data availability and costs.

1.2 Theoretical Foundations and Objectives

The CZCS is intended primarily as a tool for determining the content of water. It is well known that the content of water, be it organic or inorganic particulate matter or dissolved substances, affects its color. Ocean water, containing very little particulate matter, scatters as a Rayleigh scatterer with the well-known deep purple or bluish color of the ocean. As particulate matter is added to the water, the scattering characteristics are changed and the color is changed. Phytoplankton, for instance, have specific absorption characteristics and normally change the water to a more greenish hue although some phytoplankton, such as the various red tides, can change the water to colors such as red, yellow, blue-green, or mahogany. By sensing the color with very high signal-to-noise ratios, the CZCS provides a mechanism for analyzing that color for the content of the water. Inorganic particulate matter in water, such as the terrigenous outflow from rivers, has a different color from organic material typically brownish in color but sometimes varying with red.

1.2.1 Scientific Objectives

The scientific objective of the CZCS is to determine the specific nature of the contents of water as quantitatively as possible and to carry out such measurements over large areas in short periods of time in a way not possible with other techniques such as surface ship investigations. Specifically, the CZCS experiment attempts to discriminate between organic and inorganic materials in the water, determine the quantity of these materials in the water sample to the best degree possible and, in certain instances, attempts identification of organic particulates such as discriminating between various types of red tide organisms.

By conducting measurements over a large area in a short period of time, the CZCS allows oceanographers to view the ocean as never seen before from ships. As an example, in one two-
minute data segment, the CZCS covers approximately 1.3 million square kilometers of the ocean surface allowing examination, nearly simultaneously, on a scale never before accomplished Measurements on this scale allow oceanographers to determine such things as the standing stock of phytoplankton and its distribution in various fishing areas and, potentially, to assess the ability of that area to support a standing stock of fish In addition to examining the existing fisheries, the CZCS will be used to look for new areas of potential fish production around the globe

122 Technical Objectives

The technical objective of the CZCS program is to determine if remote sensing of color can be used to identify and quantify material suspended or dissolved in water If ocean color measurements can be used to derive such products as chlorophyll and sediment concentration, they will guide further development of the ocean color discipline and help to determine if such an instrument is a candidate for operational satellite use in the future

The algorithms being developed for the derived products from CZCS are the result of the most extensive ocean color measurements ever made and are a considerable step forward from those available in the past Corrections for such things as atmospheric backscatter and limb brightening are included in the CZCS processing algorithms The processing goal is to take the observed radiance, determine the radiance that would be seen directly above the ocean surface, and then derive from that radiance, the content of the water below the ocean surface

13 Instrument Description

The CZCS has considerable flexibility built into it to accomodate a wide range of conditions The first four spectral bands, for instance, have four separate gains that change, on command, to accommodate the range of sun angles observed during a complete orbit and throughout the various seasons The gains are changed to utilize the best dynamic range possible without saturating over water targets Normally, the gain used in the first four channels is determined by the solar elevation angle of the target to be acquired When a special circum-
stance is expected, such as a particularly bright material in the water, the gain can be changed to accommodate the special circumstances.

In addition to gain change, the CZCS scan mirror can be tilted from nadir to look either forward or behind the spacecraft's line of flight. It can tilt in two degree increments up to twenty degrees in either direction. This feature was built into the instrument to avoid the glint caused by capillary waves on the ocean that would obscure any scattering from below the surface. The angle of tilt of the scan mirror is determined by the solar elevation angle. It is normally tilted to avoid sunlight and would only be commanded to look into the glint for a special sunglint study.

The CZCS is a scanning multi-spectral radiometer with a recorded scan width of 1566 kilometers centered on spacecraft nadir. The scanner actually scans through 360 degrees, but the electronics limit the high data rate sampling to 39.34 degrees about nadir. The ground resolution of the IFOV is 0.825 kilometer at nadir and degrades somewhat as the instrument scans away from nadir on either side.

The CZCS has six spectral bands, five sensing backscattered solar radiance and one sensing emitted thermal radiance. The beam is split by a dichroic beam splitter, one portion of the beam going through a set of depolarizing wedges to a small polychromator where the radiance is dispersed and detected by five silicon diode detectors in the focal plane of the polychromator. Radiance in the 10.5 μm to 12.5 μm spectral band is reflected off the dichroic and then imaged onto an infrared detector of mercury cadmium telluride cooled to approximately 120 Kelvin. Table 1–1 shows the center wavelengths, the spectral bandwidths, and the minimum signal-to-noise ratio specified for the instrument at the most sensitive gain setting, that is, the gain setting that would be used for the darkest targets. The first four channels were selected to cover specific absorption bands and the so-called hinge point. These channels are meant to look at water only and saturate when the field of view is over most land surfaces and clouds.
<table>
<thead>
<tr>
<th>Performance Parameters</th>
<th>Channels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Scientific Observation</td>
<td>Chlorophyll Absorption</td>
</tr>
<tr>
<td></td>
<td>0.443 (blue)</td>
</tr>
<tr>
<td>Center Wavelength ( \lambda ) Micrometers</td>
<td>0.433 – 0.453</td>
</tr>
<tr>
<td>Spectral Bandwidth ( \Delta \lambda ) Micrometers</td>
<td>0.433 – 0.453</td>
</tr>
<tr>
<td>Instantaneous Field of View (IFOV)</td>
<td>0.865 x 0.865 Milliradians (0.825 x 0.825 km at sea level)</td>
</tr>
<tr>
<td>Co-registration at NADIR</td>
<td>&lt;0.15 Milliradians</td>
</tr>
<tr>
<td>Accuracy of Viewing Position Information at NADIR</td>
<td>&lt;2.0 Milliradians</td>
</tr>
<tr>
<td>Signal to Noise Ratio (min.) at Radiance Input ( N &lt; (mW/cm^2 \cdot \text{STER} \cdot \mu m) )</td>
<td>&gt;150 at 5.41</td>
</tr>
<tr>
<td>Consecutive Scan Overlap</td>
<td>25%</td>
</tr>
<tr>
<td>Modulation Transfer Function (MTF)</td>
<td>1 at 150 km target size, 0.35 min. at 0.825 km target size</td>
</tr>
</tbody>
</table>
Channel 5 has the same spectral response as channel 6 of the Landsat multi-spectral scanner series. The spectral response of channels 1 through 5 is illustrated in Figure 1-1.

The 10.5 μm to 12.5 μm channel measures equivalent blackbody temperature as seen by the sensor with a noise equivalent temperature difference of less than 0.35 Kelvin at 270 Kelvin. Atmospheric interference with this channel, principally from weak water vapor absorption in the 10.5 μm to 12.5 μm region, can produce measurement errors of several degrees. Temperature gradients, however, should be seen quite well because of the extremely low noise equivalent temperature difference of this sensor.

Prelaunch calibration of the CZCS was achieved utilizing a 76 centimeter diameter integrating sphere as a source of diffuse radiance for channels 1 through 5 and a blackbody source for calibration of channel 6. The integrating sphere was especially constructed for calibration of the CZCS and was, itself, calibrated from a standard lamp from the National Bureau of Standards utilizing a spectrometer and another integrating sphere to transfer calibration from the lamp to the sphere.

In addition to the sphere and the blackbody, a collimator was also used to calibrate the CZCS in vacuum testing. Calibration was transferred from the primary calibration standard, the sphere and the blackbody, to the collimator using the instrument itself.

In-flight calibration of the CZCS is accomplished for the first five bands by using a built-in incandescent light source. This in-flight calibration source was calibrated using the instrument itself as a transfer against the referenced sphere output. The light source is redundant in the instrument so that in case of failure of one of the lights, another one can be ordered to operate on command. After launch, light calibration source number one has been used routinely, with light source number two tested occasionally to verify its stability.

Channel 6 is calibrated by viewing the blackened housing of the instrument whose temperature is monitored. Deep space is another calibration viewed during the 360 degrees rotation of the scan mirror.
Figure 1-1  CZCS Spectral Response for Channels 1 through 5
Since Nimbus 7 flies from south to north in daylight, the scan mirror is positioned to look behind the satellite when the spacecraft is south of the subsolar point and ahead of the spacecraft when it is north of the subsolar point. Tilt and gain setting information is transmitted with the CZCS data and is part of the data product records.

The CZCS data is transmitted from the spacecraft to ground receiving stations at a rate of 800 kbs either in real time or in playback of the tape recorder. Whenever possible the data is recorded in real time. However, when the satellite is out of the range of tracking stations, the data is recorded on an on board tape recorder. The tape recorded data will normally be played back at the Alaska tracking station. Nine other STDN's also have the capability to receive these playbacks.

The most important aspect to be understood about the CZCS operation is that the operation is limited due to spacecraft power constraints to approximately two hours per day. Because of the requirement to operate the sensor two hours per day, data must be taken in carefully preselected locations. Minimum on-off data taking time is a two minute segment. Frequently, longer segments are taken—up to a maximum of ten minutes of continuous data.

All channels of the CZCS instrument operate simultaneously. During daytime operations all six channels provide useful information. If the sensor operates at night, only data from channel 6 is usable.

2.0 CZCS LEVEL-1 PROCESSING ALGORITHMS

2.1 Data Calibration

2.1.1 Active Calibration

The objective of the Level-1 processing system calibration algorithm is to derive the coefficients necessary to convert the raw 8-bit digital count values transmitted by the satellite, into observed radiance values in units of micro watts per square centimeter micrometer steradians.
The 8-bit digital data output from the satellite is functionally related to the radiance reaching the individual channel detectors by

\[
\text{RADIANCE (R)} \rightarrow \text{DETECTOR} \rightarrow \text{VOLTAGE (V)} \rightarrow \text{A-D CONVERTER} \rightarrow \text{COUNTS (C)}
\]

\[
V = a_s \cdot R \\
C = a_c \cdot V + b_c
\]

where \(a_s\), \(a_c\), and \(b_c\) are coefficients which must be derived from the prelaunch calibrations and/or the active calibration data sources.

The A-D converter coefficients \(a_c\) and \(b_c\) are computed once per scene using a voltage staircase which is generated by feeding 16 known voltages (zero to 9,960 in increments of 0.664 volts) into the A-D converter. Values of \(a_c\) and \(b_c\) are derived by fitting a straight line equation to the staircase data by the method of least squares such that

\[
a_c = \frac{\Sigma V \cdot C - \Sigma V \cdot C}{\Sigma V^2 - (\Sigma V)^2} \quad (1)
\]

\[
b_c = \frac{\Sigma C - a_c \cdot \Sigma V}{n} \quad (2)
\]

where counts of zero and 255 are ignored.

Once the A-D converter coefficients are known, the detector coefficient \(a_s\) can be determined from the count value which is returned when the detector is exposed to one of the two internal known radiance lamps. The detector coefficient for each visible channel is derived once per scene using

\[
a_s = \frac{C_a - b_c}{a_c} \frac{a_c}{C_x R} \quad (3)
\]
where \( C_a \) is the active calibration lamp count for the first calibration lamp exposure within the scene, \( R \) is the known lamp radiance in each visible channel (see table 2-1), and \( C_x \) is the prelaunch calibration lamp count (see table 2-2). Active calibration of the thermal channel (6) is performed using equation 3 by replacing \( C_a \) with the count obtained when the internal blackbody target is viewed and replacing \( R \) with the radiance derived from monitoring the temperature of the blackbody target.

Once the detector coefficient has been derived, the instrument calibration coefficients (combined A-D converter and detector coefficients) \( A_{R'} \) and \( B_{R'} \) are derived using

\[
A_{R'} = \frac{1}{a_s a_c} \quad (4) \quad B_{R'} = \frac{-b_c}{a_s a_c} \quad (5)
\]

These values are placed on the trailing documentation record of the CRT tape and may be utilized to convert counts, as contained on the CRT, to radiance units by

\[
R = C A_{R'} + B_{R'}
\]

where the radiance units computed are MW/CM\(^2\) Micrometers Ster.

**WARNING** THE CZCS NET DOES NOT RECOMMEND THE USE OF THESE COEFFICIENTS PRELAUNCH CALIBRATION COEFFICIENTS AS CONTAINED ON THE LEADING DOCUMENTATION RECORD ARE RECOMMENDED. SEE SECTION 2.1.2 FOR IMPLEMENTATION PROCEDURE.

In order to perform active calibration of the thermal channel (6) in terms of temperature, it is necessary to utilize the Planck Equation in its inverse form

\[
T(R) = \frac{b}{\left(\frac{a}{\lambda^5 R} + 1\right)} - 273.15 \quad (7)
\]

where \( b \) is a constant = 1.438833 *10\(^4\),

\( a \) is a constant = 1.61*11910 66.
Table 2-1 Prelaunch Calibration Lamp Radiances

<table>
<thead>
<tr>
<th>Channel</th>
<th>Lamp 1</th>
<th>Lamp 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 04</td>
<td>2 55</td>
</tr>
<tr>
<td>2</td>
<td>1 55</td>
<td>1 72</td>
</tr>
<tr>
<td>3</td>
<td>1 37</td>
<td>1 52</td>
</tr>
<tr>
<td>4</td>
<td>1 11</td>
<td>1 13</td>
</tr>
<tr>
<td>5</td>
<td>5 24</td>
<td>5 15</td>
</tr>
</tbody>
</table>

Table 2-2 Prelaunch Calibration Lamp Count

<table>
<thead>
<tr>
<th>Lamp 1</th>
<th>GAIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>045</td>
</tr>
<tr>
<td>2</td>
<td>048</td>
</tr>
<tr>
<td>3</td>
<td>051</td>
</tr>
<tr>
<td>4</td>
<td>096</td>
</tr>
<tr>
<td>5</td>
<td>056</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lamp 2</th>
<th>GAIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>056</td>
</tr>
<tr>
<td>2</td>
<td>053</td>
</tr>
<tr>
<td>3</td>
<td>058</td>
</tr>
<tr>
<td>4</td>
<td>099</td>
</tr>
<tr>
<td>5</td>
<td>055</td>
</tr>
</tbody>
</table>
\[ \lambda \text{ is the wavelength of channel 6} = 11.485, \]
\[ R \text{ is the equation 6 radiance} \times 10^{-3} \text{ and,} \]
\[ T(R) \text{ is the temperature in °C} \]

For user convenience, a table of 256 temperature values is placed on the CRT tape trailing documentation record (see Section 3). The user should note that the temperature conversion table is not corrected for atmospheric absorption.

212 Post Launch Corrections

As stated previously, the CZCS NET does not recommend the use of calibration coefficients as derived from the active calibration sources. The active calibration sources have been shown to fluctuate by one to two digital counts resulting in random banding when applied to the CZCS data. For this reason, the CZCS NET recommends using the prelaunch calibration coefficients (see table 2-3) with a surface truth based correction for instrument degradation. This procedure may be implemented by

\[ R = (AR \times C + BR) \times F \] (8)

where AR and BR are defined in table 2-3 and on the CRT tape leading documentation record, C is the raw digital count value as contained on the CRT tape, and F is the instrument degradation correction factor.

The instrument degradation correction factor (F) may be derived by

\[ F = \frac{d}{a + (b \times N) + (c \times N^2)} \] (9)

where a, b, c and d are as defined in table 2-4 and N is the orbit number.

The values listed in table 2-4 were derived by Dr. Howard Gordon et al.\(^1\) and are generally

---

\(^1\) H R Gordon, J W Brown, O B Brown, R H Evans, and D K Clark, Appl Opt 22, 3929 (1983)
### Table 2-3  Prelaunch Calibration Coefficients

<table>
<thead>
<tr>
<th>Channel</th>
<th>GAIN 1</th>
<th>GAIN 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AR</td>
<td>BR</td>
</tr>
<tr>
<td>1</td>
<td>04452</td>
<td>03963</td>
</tr>
<tr>
<td>2</td>
<td>03103</td>
<td>06361</td>
</tr>
<tr>
<td>3</td>
<td>02467</td>
<td>0799</td>
</tr>
<tr>
<td>4</td>
<td>01136</td>
<td>.01136</td>
</tr>
</tbody>
</table>

5-6 Use AR' and BR' as listed on trailing documentation record

### Table 2-4  Instrument Degradation Correction Coefficients

<table>
<thead>
<tr>
<th>ALL GAINS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
</tbody>
</table>
thought to be valid through orbit 19,000. Research is continuing to develop improved coefficients which will extend to later orbits. Any improvements will be published as an addendum to this guide.

2.2 Image Location

The objective of the CZCS Level-1 processing system image location algorithm is to compute geodetic locations of 77 predefined picture elements (pixels), known as anchor points, on each scan line. The algorithm implemented for computation of earth locations closely follows the formulation described by Puccinelli.\(^2\)

The basic concept is to define a primary cartesian coordinate system with its origin at the center of the earth such that the earth’s surface (approximated by a spheroid) is defined by

\[
\frac{x^2}{a^2} + \frac{y^2}{a^2} + \frac{z^2}{c^2} = 1
\]  

(10)

where \(a\) is the equatorial and \(c\) the polar radius of the earth. The Nimbus Operational Processing System (NOPS) produces Image Location Tapes (ILT’s) which provide spacecraft position, velocity, and attitude data as computed from world wide tracking data and the spacecraft ephemeris. For any given instant in time, the spacecraft position \(s\), and velocity \(v\) relative to the primary coordinate system may be interpolated from data contained on the NOPS ILT. Additionally, the spacecraft yaw, pitch, and roll may be computed relative to the satellite axis.

The satellite axis is defined relative to the primary coordinate system such that the roll axis is coincident with the velocity vector \(\vec{V}\), the pitch axis is defined as \(\vec{v} \times \vec{s}\), and the yaw axis is \(\vec{v} \times (\vec{v} \times \vec{s})\).

Finally, the scanner orientation may be derived relative to the spacecraft. This orientation, derived as a function of the pixel number \(N\) to be located and the scanner tilt angle, is defined by

\[
\vec{w}_1 = 0 \quad \text{(yaw)}
\]

\[ \vec{w}_2 = \text{TILT} \quad \text{(pitch)} \]
\[ \vec{w}_3 = \text{Scan Angle} \quad \text{(roll)} \]

where the tilt and scan angle are adjusted from the recorded values for the internal misalignment of the mirror rotation axis and the tilt axis with the spacecraft y-axis (see table 2-5).

Given the spacecraft position \( S \), velocity \( v \), roll \( R \), pitch \( P \), yaw \( Y \) and the scanner orientation \( w \), the point of intersection \( e \) of the scanners line of sight with the earth is computed by first forming the vector \( \vec{m} \)

\[
\vec{m} = \begin{bmatrix}
Cw_1 \cdot Sw_1 \cdot Cw_3 + Sw_1 \cdot Sw_3 \\
Sw_1 \cdot Sw_2 \cdot Cw_3 - Cw_1 \cdot Sw_3 \\
Cw_2 \cdot Cw_3
\end{bmatrix}
\]

where \( S \) and \( C \) are notational conventions for Sin and Cos respectively. Next, the product \( M \) is formed using the three spacecraft rotational matrices such that

\[
M = \begin{bmatrix}
CY - SY & 0 \\
SY & CY & 0 \\
0 & 0 & 1
\end{bmatrix} \begin{bmatrix}
CP & 0 & SP \\
0 & 1 & 0 \\
-SP & 0 & CP
\end{bmatrix} \begin{bmatrix}
1 & 0 & 0 \\
0 & CR & -SR \\
0 & SR & CR
\end{bmatrix}
\]

Next, the unit vector, \( \vec{g} \), representing the scanner’s line of sight in the primary coordinate system is defined as

\[
\vec{g} = DM \vec{m}
\]

where \( D = \{\vec{c}_1, \vec{c}_2, \vec{c}_3\} \) such that

\[
\vec{c}_1 = \frac{\vec{\gamma}}{\|\vec{\gamma}\|_2} \quad \text{(roll)}
\]

\[
\vec{c}_2 = \frac{\vec{c}_1 \times \vec{\gamma}}{\|\vec{\gamma}\|_2} \quad \text{(pitch)}
\]

\[
\vec{c}_3 = \vec{c}_1 \times \vec{c}_2 \quad \text{(yaw)}
\]
Table 2-5

External Input Required For Image Location

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equatorial Radius of Earth</td>
<td>6378 144 KM</td>
</tr>
<tr>
<td>Polar Radius of Earth</td>
<td>6356 759 KM</td>
</tr>
<tr>
<td>Tilt Misalignment</td>
<td>- 1 018109 x 10^{-4} rad</td>
</tr>
<tr>
<td>Mirror Rotation Axis Misalignment</td>
<td>1 599885 x 10^{-4} rad</td>
</tr>
<tr>
<td>Pixel 1 Mirror rotation angle</td>
<td>6813765 rad</td>
</tr>
</tbody>
</table>

The intersection point given in the primary coordinate system is then defined as the vector \( \mathbf{e} \) where

\[
\mathbf{e} = \mathbf{s} + \mathbf{g} \left( -\frac{\mathbf{B}}{\mathbf{A}} - \frac{\mathbf{B}^2 - \mathbf{A} \mathbf{C}}{\mathbf{A}^2} \right) \tag{16}
\]

where for equatorial radius (a) and polar radius (c)

\[
\begin{align*}
\mathbf{A} &= C^2 \left( g_x^2 + g_y^2 \right) + a^2 g_z^2 \\
\mathbf{B} &= C^2 \left( S_x g_x + S_y g_y \right) + a^2 S_z g_z \\
\mathbf{C} &= C^2 \left( S_x^2 + S_y^2 \right) + a^2 (S_z^2 - C^2)
\end{align*}
\tag{17, 18, 19}
\]

Finally, the geodetic earth location is computed as

\[
\begin{align*}
\text{latitude} &= \tan^{-1} \left( \frac{a^2}{c^2} \cdot \frac{\mathbf{e}_3}{\sqrt{\mathbf{e}_3^2 + \mathbf{e}_2^2}} \right) \\
\text{longitude} &= \tan^{-1} \left( \frac{\mathbf{e}_2}{\mathbf{e}_1} \right)
\end{align*}
\tag{20, 21}
\]

These computations are performed for 17 of the 77 anchor points along each scan line. Geodetic earth locations for the remaining 60 anchor points are computed by cubic spline interpolation between the 17 precisely located points. Table 2-6 lists the CZCS anchor point pixel numbers and notes those anchor points which are precisely located.
Table 2-6
Anchor Point Pixel Numbers

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1*</td>
<td>216</td>
<td>556</td>
<td>1172</td>
<td>1627*</td>
<td>1877</td>
</tr>
<tr>
<td>16</td>
<td>236*</td>
<td>591</td>
<td>1217</td>
<td>1652</td>
<td>1892</td>
</tr>
<tr>
<td>31*</td>
<td>256</td>
<td>626</td>
<td>1262</td>
<td>1672</td>
<td>1907**</td>
</tr>
<tr>
<td>46</td>
<td>276</td>
<td>666*</td>
<td>1302**</td>
<td>1692</td>
<td>1922</td>
</tr>
<tr>
<td>61*</td>
<td>296</td>
<td>706</td>
<td>1342</td>
<td>1712</td>
<td>1937**</td>
</tr>
<tr>
<td>76</td>
<td>316</td>
<td>751</td>
<td>1377</td>
<td>1732**</td>
<td>1952</td>
</tr>
<tr>
<td>91</td>
<td>341*</td>
<td>796</td>
<td>1412</td>
<td>1752</td>
<td>1968*</td>
</tr>
<tr>
<td>106</td>
<td>366</td>
<td>841</td>
<td>1442</td>
<td>1772</td>
<td></td>
</tr>
<tr>
<td>121</td>
<td>391</td>
<td>886</td>
<td>1472</td>
<td>1787</td>
<td></td>
</tr>
<tr>
<td>136*</td>
<td>416</td>
<td>931</td>
<td>1502</td>
<td>1802</td>
<td></td>
</tr>
<tr>
<td>151</td>
<td>441*</td>
<td>984*</td>
<td>1527**</td>
<td>1817</td>
<td></td>
</tr>
<tr>
<td>166</td>
<td>466</td>
<td>1037</td>
<td>1552</td>
<td>1832**</td>
<td></td>
</tr>
<tr>
<td>181</td>
<td>496</td>
<td>1082</td>
<td>1577</td>
<td>1847</td>
<td></td>
</tr>
<tr>
<td>196</td>
<td>526</td>
<td>1127</td>
<td>1602</td>
<td>1862</td>
<td></td>
</tr>
</tbody>
</table>

*Precise location computed at this pixel number

**Precise location computed at this pixel number +1

3.0 TAPE FORMATS

The CIPS program creates an output tape called the CRT tape. This tape can be described in terms of its physical structure and/or its logical structures.

3.1 Physical Structure of CRT Tape

The CRT tape is a multiple-file binary tape written in fixed block (FB) format on a MODCOMP machine. It contains up to three file pairs each consisting of a header file and a data file.
The first file, of each file pair, is a special file called the standard header or STD HDR. The STD HDR file is written in a standard format common to all archivable tapes produced by the Nimbus Operational System (NOPS) and contains two identical blocks of 630 characters written in EBCDIC. Each block consists of five 126-character lines.

Lines 1 and 2 of the standard header records contain the following information:

- Nimbus-7 NOPS tape product format specification number consisting of 30 characters written as "NIMBUS-7 NOPS SPEC NO T744041"
- Tape sequence number consisting of a two character code identifying the tape, a six character sequence number unique to each tape, and a one digit number specifying the copy number. An example for the CRT tape is "SQ NO ZE2201213"
- Subsystem identification code consisting of four characters preceded and followed by blanks. For the CRT tape this is "CZCS"
- Generation and destination facilities consisting of four characters each. An example is "IPD TO 22"
- Beginning and ending times of data coverage given as "START 19YYDDDHHMMSS TO 19YYDDDHHMMSS" where yy is the year, DDD is the Julian Day, and HHMMSS are the hour-minute-and second of the day.
- The tape generation date is given in a similar format as "GEN 19YYDDDHHMMSS"

Lines 3, 4, and 5 are used by the subsystem analyst to further identify the origin of the data tape. Figure 3-1 is an example of a CRT tape header record.

The second file, of each file pair, is the data file and consists of a leading documentation record, a variable number of scan data records, and a trailing documentation record. The leading and trailing documentation records have identical formats and contain 5328 8-bit bytes written in a single block of the same length. The scan data records are each 12730 8-bit bytes written in blocks of the same length.
Figure 3-1  Sample CRT Tape Standard Header Record
3.2 Logical Structure of CRT Tape

The CRT tape data file which follows the NOPS STD HDR file contains up to two minutes (970 scan lines) of CZCS radiance data. For most users of these tapes, it will be more convenient to treat the data files as a collection of logical records.

As stated previously, the leading and trailing documentation records have identical formats, however, depending on the processing mode, some of the information contained in the leading documentation record may not be valid. The documentation record format is illustrated in Figure 3-2 and detailed descriptions of selected data words appear in Table 3-1.

The scan data records, which appear on the tape between the leading and trailing documentation records, each contain calibration data, earth location data, and 1968 scaled radiances in each of the six CZCS channels for one earth scan of the CZCS instrument. The format of the scan data records is illustrated in Figure 3-3 and detailed descriptions of selected data words appear in Table 3-2.

Table 3-1

<table>
<thead>
<tr>
<th>WORD</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PHYSICAL RECORD NO (12 BITS)—This number is a sequential number beginning at 1 and incrementing by 1 for each physical record within the data files.</td>
</tr>
<tr>
<td></td>
<td>SPARES—All spare bits are set to zero.</td>
</tr>
<tr>
<td></td>
<td>FILE (2 BITS)—The MSB will be set to “1” to indicate the last record written in a file. The LSB will be set to “1” in all records of the last file on the tape.</td>
</tr>
<tr>
<td></td>
<td>RECORD ID (6 BITS)—The Record ID for the leading Documentation record will be equal to “1” The record ID in the trailing Documentation record will be “2”</td>
</tr>
<tr>
<td></td>
<td>VALID DATA FLAG (8 BITS)—This flag indicates whether or not certain data fields (designated by an asterisk) contain valid information. All bits off (0) indicates the data is invalid and all bits on (1) indicates the data is valid.</td>
</tr>
</tbody>
</table>
FILE NO (8 BITS)—This number identifies the file number on the CRT tape

TARGET AREA CODE (3 8 BIT WORDS)—Each code will describe a target area which was covered by the data in the file

TAPE SEQUENCE NO (32 BITS)—The 32 bit integer representation of the “SEQUENCE NO” field in the STANDARD HEADER records

FILM FRAME NO (32 BITS)—This 32 bit integer number is the unique film frame number of the film product corresponding to this archive data file

STARTING YEAR NUMBER (16 BITS)—This number is in the form 1978 in binary

START TIME IN MILLISECONDS GMT (32 BITS)—This number is in milliseconds of the DAY in GMT

INCREMENT IN MILLISECONDS TO END OF DATA (32 BITS)*—The number of milliseconds from the start time of the segment to the last data scan in the segment

ORBIT NUMBER (16 BITS)—The Nimbus-7 orbit number for the data in this file, 16-bit binary number

GEODETIC LATITUDE “CENTER” (16 BITS)*—The latitudes will be an integer number ranging from 0 at the south pole to (180° x 100) 18000 at the North Pole. This will provide a location to 01°. The center latitude is defined as being the Nadir sample latitude that occurs 1/2 way between the beginning and end of the frame by time

LONGITUDE CENTER (16 BITS)*—The longitude values will range from 0 at the Greenwich Meridian Eastward to 360° x 100 which provides longitude in 0.01 degrees

GEODETIC LATITUDES AND LONGITUDES (8 x 16 BITS)*—Frame corner latitudes and longitudes defined as in (9) above

ILT FLAGS (8 BITS)—Summary of information available in the CZCS-ILT for this data segment

MSB SUMMARY BIT

‘0’ At least one set of data not available

‘1’ All relevant data available
TIME CORRECTIONS ‘1’ Available
SOLAR EPHEMERIS ‘1’ Available
DATA QUALITY LOSS ‘1’ Available
VIP DATA ‘1’ Available

SPACECRAFT EPHEMERIS
(2 BITS)
‘00’ None available
‘01’ Predictive
‘11’ Definitive

PARAMETER PRESENCE CODE (8 BITS)—The 6 CZCS channels correspond to parameters 1-6, respectively. A single bit is used to indicate the presence (bit set to ‘1’) or absence (bit set to ‘0’) of data for the corresponding parameter in this data segment. The MSB is for channel 1 ranging to bit 6 for channel 6, while the 2 LSB’s are spares.

NO OF MISSING SCANS (16 BITS)—This 16 bit binary integer is the count of missing scans within the actual data segment. The missing scans can be identified by examining the time or the scan sequence number in the scan data records.

NO OF SCANS MISSING CHANNELS 1-6 (6, 16 BIT WORDS)*—The number of scans present in the data file in which the respective channel data should be present but is not. These data are 16 bit binary integers.

ALGORITHM I D NUMBERS (8, 8 BIT WORDS)—I D words identify the algorithms for channel 1 through channel 6 calibration and for the geographic location of the data, respectively, and the last word is undefined. These are 8 bit binary integer words.

DECOM RUN NO AND DECOM REEL NO (2, 32 BIT WORDS)—On the ARCHIVAL CRTT tapes these words will be zeroed. On the USER CRTT tapes these 32 bit binary integer words will be set by IPD to the decommutation run and reel numbers, respectively.

NO OF HDT SYNC LOSSES (16 BITS)*—This binary integer count states the number of sync losses that occurred reading the HDT_p tape.
NO OF HDT PARITY ERRORS (16 BITS)*—A count of the number of parity errors detected on the HDT_p tape during the 2 minute period covered in this file.

23. NO OF WBVT SYNC LOSSES (16 BITS)*—This count states the number of sync losses detected by the pre-processor during generation of the HDT_p tape from the Wide Band Video Tape (WBVT) containing the ZIP format CZCS data.

NO OF WBVT BIT SLIP OCCURRENCES (16 BITS)*—This count states the number of bit slip occurrences detected by the pre-processor during generation of the HDT_p tape from the WBVT tape containing the ZIP format CZCS data.

24/39 SUB-COMMUTATED HOUSEKEEPING DATA (32 16 BIT WORDS)—Average count values 32 housekeeping words. The data is scaled with 8 fractional bits.

40 BASE PLATE (BP) TEMPERATURE FLAG (8 BITS)—This flag indicates the source of the Baseplate temperature used in calibrating the infrared channel (6). If all bits are off (0), then the baseplate temperature is a normal preset value. If all bits are on (1), then the temperature is obtained from the CZCS-ILT.

BASEPLATE TEMPERATURE (16 BITS)—Either a nominal temperature value determined from flight experience or an average value computed from the data values in the time span covered by this file. This word is in binary with a fractional part of 7 bits. (This item will be zeroed except when the channel 6 calibration algorithm requires it).

175 GAIN (8 BITS)—An integer value of 1, 2, 3, or 4, indicating which CZCS gain setting was used for the scene contained in this file.

THRESHOLD (8 BITS)—An integer value of 1 (off) or 2 (on) indicating the status of the CZCS threshold function for the scene contained in this file.

TILT ANGLE (16 BITS)—The tilt angle of CZCS for the scene contained in this file. Values range from -20° to +20°.

Two’s complement integer, LSB weight is 1/1000°.
SCENE CENTER YEAR (16 BITS)*—The year (4 digits) associated with the geographic center of the scene contained in this file

SCENE CENTER DAY-OF-YEAR (16 BITS)*—The day-of-year (1 to 366) associated with the geographic center of the scene

SCENE CENTER MILLISECONDS-OF-DAY (32 BITS)*—The milliseconds-of-day (0 to 86399999) associated with the geographic center of the scene contained in this file

SOLAR ELEVATION AT SCENE (16 BITS)*—The solar elevation at the geographic center of the scene contained in this file. Values range from -90° to +90° Two's complement integer, LSB weight is 1/100°

SOLAR AZIMUTH AT SCENE CENTER (16 BITS)*—The solar azimuth at the geographic center of the scene contained in this file. Values range from 0° to 360° Unsigned integer, LSB weight is 1/100°

SCENE CENTER ROLL, PITCH, YAW (16 BITS each)*—The spacecraft attitude at the geographic center of the scene contained in this file. Values range from -32° to +32° Two’s complement integer, LSB weight is 1/1000°

SLOPES AND INTERCEPTS (12, 32 BIT WORDS)—Slope and intercept for the conversion of the 8 bit channel data in the scan data records to radiometric units (mw/cm²-ster-um) for channels 1 through 6, respectively. This data is signed and 7 bits whole part and 24 bits fractional. In the leading documentation record these are pre-flight calibration values and in the trailing documentation record these are derived from the active calibration and voltage staircases

TEMPERATURE CONVERSION TABLE (256, 16 BIT WORDS)—Table of Channel 6 data values in degrees Celsius. Each of the 256 positions in this table contains the temperature for the corresponding count of the channel 6 data in the scan data records. This data has 8 bits whole part and 8 bits fractional part
<table>
<thead>
<tr>
<th>WORD #</th>
<th>PHYSICAL RECORD NO. (12)</th>
<th>SPARE (4)</th>
<th>FILE (2)</th>
<th>RECORD ID (6)</th>
<th>VALID DATA FLAG (8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>TARGET AREA CODES</td>
<td>3 8-BIT WORDS</td>
<td></td>
<td>(24)</td>
<td>FILE NO. (8)</td>
</tr>
<tr>
<td>3</td>
<td>TAPE SEQUENCE NO.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>FILM FRAME NO.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>STARTING YEAR NO.</td>
<td>(16)</td>
<td>STARTING DAY NO.</td>
<td>(16)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>STARTING MILISECONDS OF DAY</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>INCREMENT IN MILISECONDS TO END OF DATA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>ORBIT NO.</td>
<td>(16)</td>
<td>NO. OF SCANS IN SEGMENT</td>
<td>(16)</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>LATITUDE OF CENTER OF DATA</td>
<td>(16)</td>
<td>LONGITUDE OF CENTER OF DATA</td>
<td>(16)</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>LATITUDE AND LONGITUDE OF CORNER (FIRST IN TIME-LEFT OF SCAN)</td>
<td>2 16-BIT WORDS (32)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>LAT. AND LONG OF CORNER (FIRST IN TIME-RIGHT OF SCAN)</td>
<td>2 16-BIT WORDS (32)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>LAT. AND LONG OF CORNER (LAST IN TIME-LEFT OF SCAN)</td>
<td>2 16-BIT WORDS (32)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>LAT. AND LONG OF CORNER (LAST IN TIME-RIGHT OF SCAN)</td>
<td>2 16-BIT WORDS (32)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>I LT FLAGS (8) PARAMETER PRESENCE (8)</td>
<td>NO OF MISSING SCANS-ALL CHANNELS (16)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15-17</td>
<td>NO. OF MISSING SCANS-CHANNEL 1,2,3,4,5,6</td>
<td>6 16-BIT WORDS (96)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>ALGORITHM ID's CHANNELS 1,2,3,4</td>
<td>4 8-BIT WORDS (32)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>ALGORITHM ID's CHANNELS 5&amp;6</td>
<td>(16) ALG ID LOCATION (8)</td>
<td>SPARE (8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>DECOM RUN NO.</td>
<td>32-BIT BINARY INTEGER</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>DECOM REEL NO.</td>
<td>32-BIT BINARY INTEGER</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 3-2 CRT TAPE DOCUMENTATION RECORD
<table>
<thead>
<tr>
<th>WORD #</th>
<th>NO. OF HDT SYNC LOSSES (16)</th>
<th>NO. OF HDT PARITY ERRORS (16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>NO. OF WBVT SYNC LOSSES (16)</td>
<td>NO. OF WBVT BIT SLIPS (16)</td>
</tr>
<tr>
<td>39</td>
<td>AVERAGE OF SUBCOMMITTED DATA</td>
<td>32 16-BIT WORDS (512)</td>
</tr>
<tr>
<td>40</td>
<td>SPARE (8)</td>
<td>BP. FLAG (8)</td>
</tr>
<tr>
<td>41</td>
<td>SPARES</td>
<td>4288</td>
</tr>
<tr>
<td>175</td>
<td>GAIN (8)</td>
<td>THRESHOLD (8)</td>
</tr>
<tr>
<td>176</td>
<td>SCENE CENTER YEAR (16)</td>
<td>SCENE CENTER DAY-OF-YEAR (16)</td>
</tr>
<tr>
<td>177</td>
<td>SCENE CENTER MILLISECONDS-OF-DAY</td>
<td></td>
</tr>
<tr>
<td>178</td>
<td>SOLAR ELEVATION AT SCENE CENTER (16)</td>
<td>SOLAR AZIMUTH AT SCENE CENTER (16)</td>
</tr>
<tr>
<td>179</td>
<td>SCENE CENTER ROLL (16)</td>
<td>SCENE CENTER PITCH (16)</td>
</tr>
<tr>
<td>180</td>
<td>SCENE CENTER YAW (16)</td>
<td>TOP/BOTTOM TICK LABEL FLAG (8)</td>
</tr>
<tr>
<td>181</td>
<td>TOP LEFT TICK LABEL (16)</td>
<td>TOP RIGHT TICK LABEL (16)</td>
</tr>
<tr>
<td>182</td>
<td>BOTTOM LEFT TICK LABEL (16)</td>
<td>BOTTOM RIGHT TICK LABEL (16)</td>
</tr>
<tr>
<td>183</td>
<td>LEFT TOP TICK LABEL (16)</td>
<td>LEFT BOTTOM TICK LABEL (16)</td>
</tr>
<tr>
<td>184</td>
<td>RIGHT TOP TICK LABEL (16)</td>
<td>RIGHT BOTTOM TICK LABEL (16)</td>
</tr>
<tr>
<td>185</td>
<td>TOP TICK INCREMENT (8)</td>
<td>BOTTOM TICK INCREMENT (8)</td>
</tr>
</tbody>
</table>

Figure 3-2 CRT TAPE DOCUMENTATION RECORD (Cont)
<table>
<thead>
<tr>
<th>WORD #</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>186</td>
<td>TOP TICK LOCATION ARRAY 27 16-BIT WORDS</td>
</tr>
<tr>
<td>199</td>
<td>BOTTOM TICK LOCATION ARRAY (432)</td>
</tr>
<tr>
<td>200</td>
<td>27 16-BIT WORDS (432)</td>
</tr>
<tr>
<td>213</td>
<td>LEFT TICK LOCATION ARRAY 27 16-BIT WORDS</td>
</tr>
<tr>
<td>225</td>
<td>RIGHT TICK LOCATION ARRAY (432)</td>
</tr>
<tr>
<td>227</td>
<td>27 16-BIT WORDS (432)</td>
</tr>
<tr>
<td>240</td>
<td>CHANNEL 1 SLOPE (RADIANCE)</td>
</tr>
<tr>
<td>241</td>
<td>CHANNEL 1 INTERCEPT (RADIANCE)</td>
</tr>
<tr>
<td>242</td>
<td>SLOPES, INTERCEPTS FOR CHANNELS 2-6 (RADIANCE) 10 32-BIT WORDS (320)</td>
</tr>
<tr>
<td>252</td>
<td>TEMPERATURE CONVERSION TABLE FOR CHANNEL 6 256 16-BIT WORDS (4096)</td>
</tr>
<tr>
<td>380</td>
<td>SLOPES &amp; INTERCEPTS FOR IMAGE ENHANCEMENT EQUATIONS FOR CHANNELS 1-6 12 16-BIT WORDS (192)</td>
</tr>
<tr>
<td>385</td>
<td>SPARES (64)</td>
</tr>
<tr>
<td>388</td>
<td>CZCS ILT (TAPE SPEC. 724011) TYPE &quot;A&quot; RECORD (30240)</td>
</tr>
</tbody>
</table>

1332 32-BIT WORDS

Figure 3-2 CRT TAPE DOCUMENTATION RECORD (Cont.)
<table>
<thead>
<tr>
<th>WORD</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PHYSICAL RECORD NO.</td>
<td></td>
<td>SPARE</td>
<td></td>
<td>FILE RECORD ID</td>
</tr>
<tr>
<td>2</td>
<td>SCAN SEQUENCE NO.</td>
<td></td>
<td>SPARE</td>
<td></td>
<td>TIME UPDATE FLAG</td>
</tr>
<tr>
<td>3</td>
<td>YEAR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>MILLISECONDS OF DAY</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>SUBCOMMUTED DATA VALUE COUNT</td>
<td></td>
<td>SUBCOM ID</td>
<td></td>
<td>SPARE</td>
</tr>
<tr>
<td>6-53</td>
<td>VOLTAGE STAIRCASE COUNTS-6 SETS (1 PER CH) OF 16 STEPS (8 BITS WHOLE, 3 BITS FRACTIONAL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>54-56</td>
<td>CALIBRATION LAMP RADIANCE COUNT-6 (1 PER CH) 16-BIT WORDS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>57</td>
<td>BLACKBODY TEMPERATURE COUNT</td>
<td></td>
<td>WBVT BIT SLIP/LOSS OF SYNC SUMMARY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>58</td>
<td>NO. OF HDT SYNC LOSSES</td>
<td></td>
<td>NO. OF HDT PARITY ERRORS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>59</td>
<td>NO. OF WBVT SYNC LOSSES</td>
<td></td>
<td>NO. OF WBVT BIT SLIPS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60-136</td>
<td>LATITUDES FOR 77 ANCHOR POINTS 77 32-BIT SIGNED INTEGERS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>137-213</td>
<td>LONGITUDES FOR 77 ANCHOR POINTS 77 32-BIT SIGNED INTEGERS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>214</td>
<td>PIXEL NO. AT 0 NADIR</td>
<td></td>
<td>CAL QUAL CH 1</td>
<td></td>
<td>CAL QUAL CH 2</td>
</tr>
<tr>
<td>215</td>
<td>CAL QUAL CHANNELS 3 THROUGH 6</td>
<td></td>
<td>4 8-BIT WORDS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>216-707</td>
<td>CHANNEL 1 RADIANCE COUNTS 1968 UNSIGNED 8-BIT WORDS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>708-3167</td>
<td>CHANNELS 2 THROUGH 6 RADIANCE COUNTS 5 SETS OF 1968 8-BIT WORDS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3168-3195</td>
<td>SPARES</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 3-3  CRT TAPE SCAN DATA RECORD
Table 3-2

CRT TAPE SCAN DATA RECORD

1 PHYSICAL RECORD NO (12 BITS)—This is the number of this record within a file. Starts at 2 and increments by 1's up to a maximum of 971 physical records.

FILE/RECORD ID (8 BITS)—Identifies record type and the last record written in a file, and records in the last file on the tape. The MSB will be set to “1” if that record is the last one written in the file. The second most MSB will be set on all records in the last file on the tape. The record type will use the 6 LSB of that byte to identify the type of record being read.

1 — LEADING DOCUMENTATION RECORD, 7 = DATA RECORD

2 — TRAILING DOCUMENTATION RECORD

CALIBRATION QUALITY SUMMARY (8 BITS)—The bits are defined as follows:

<table>
<thead>
<tr>
<th>MSB</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>‘1’ Questionable Ephemera (interpolated or extrapolated over more than minute time interval)</td>
</tr>
<tr>
<td>7</td>
<td>‘1’ Questionable spacecraft attitude (valid values not available - 0° used for all axis)</td>
</tr>
<tr>
<td>6</td>
<td>‘1’ At least one of the expected (power was on) channels not present</td>
</tr>
<tr>
<td>5</td>
<td>‘1’ At least one of the expected channels had active calibration value outside expected range</td>
</tr>
<tr>
<td>4</td>
<td>‘1’ At least one of the expected channels had voltage staircase count outside expected range</td>
</tr>
<tr>
<td>3</td>
<td>‘1’ Undefined</td>
</tr>
</tbody>
</table>

2 SCAN SEQUENCE NO (16 BITS)—A number from 1 to 970 that indicates the scan line number within the 2 minute data period of this file. Missing scan lines are accounted for.

TIME UPDATE FLAG (8 BITS)—This word indicates the trimester in which the time
update occurred in the CZCS/ZIP major frame. All bits equal zero indicates no update occurred in this scan.

3

YEAR NO (16 BITS)—This number is in the form “1978” in binary.

DAY NO (16 BITS)—The Julian day number. Day 1 = January 1.

4

MILLISECONDS OF THE DAY (32 BITS)—The number of milliseconds since the beginning of the GMT day.

5

SUBCOMMITTED DATA VALUE (16 BITS)—One of the 32 housekeeping data values that repeat every 32 scan lines. This data will be the average of the 8-bit counts of the four samples located in the channel #2 position in the last minor frame of each scan line. There will be 8 whole and 8 fractional bits in the word.

SUBCOM ID NO (8 BITS)—The channel number for the subcommutated housekeeping data value provided in this record. This number should increment by 1’s from 0 to 31.

6

RAW STAIRCASE STEP-VOLTAGE CAL (1536 BITS)—There will be one set of 16, 16-bit words for each of the 6 channels in step number order, then channel number order. Each count value is an average of the last two samples of the four data samples. Each count value is 16 bits with 8 bits whole and 8 bits fractional parts.

54

CALIBRATION LAMP RADIANCE COUNTS FOR CHANNELS 1 THRU 5 INCLUSIVE—This data is the output of each data channel when viewing a calibration lamp and will be output in a 16-bit word (8 bits whole part, 8 bits as the fractional part). The data for each channel will represent an average of the 4 samples received from each channel. These values are not valid except when the SUBCOM ID is either 15 or 31.

BLACKBODY CALIBRATION COUNT (16 BITS)—Same as above, except a blackbody is viewed instead of a lamp. The data is an average of 4 samples acquired from the channel 6 position.
BLACKBODY TEMPERATURE COUNT (16 BITS)—This value will be output, 8 whole part, 8 fractional, as an average of 4 samples located in the last minor frame (15) in the channel #6 position.

ANCHOR POINTS GEODETIC LATITUDES AND LONGITUDES (77, 32 BIT WORDS)—These words give the geographic locations for the 77 data pixels defined in Table 3-3. The geodetic latitudes are given in 77 successive words followed by the corresponding 77 longitudes. Each value is a signed 32 bit binary integer with 9 bit whole and 22 bit fractional parts.

SAMPLE NUMBER OF ZERO DEGREE NADIR SAMPLE (16 BITS)—This number will consist of 11 bits whole part and 5 bits fractional. The number will represent a maximum resolution of 1/32 of 0.04 degrees and is counted from the beginning of the earth scan.

CALIBRATION QUALITY CHANNEL 1-6 (6, 8-BIT WORDS)—Calibration quality flags for sensor channels 1-6. Each bit is defined as follows:

- MSB 8 – 7 = Undefined
- 6 = ‘1’ Data for channel expected (Power On) but not present
- 5 – 1 = Undefined

All undefined bits are set to zero.

RAW DATA VALUES FOR CHANNEL 1 PIXELS (1968, 8 BIT WORDS)—Each data word is representative of the radiance from observations taken at 0.04 degree intervals from scan angle -39.36 degrees to +39.32 degrees. The radiance values in mw/cm²-ster-um can be obtained by using these values in the linear relationship defined by the slopes and intercepts in the documentation records.

RAW DATA VALUES FOR CHANNELS 2-6 PIXELS (5 sets of 1968 8 BIT WORDS)—Same as above for channels 2-6, respectively. In addition, for channel 6, the values may be used as indices into the TEMPERATURE CONVERSION TABLE in the documentation record to obtain degrees Celsius.
Table 3-3

ANCHOR POINTS

<table>
<thead>
<tr>
<th>Pixel to Pixel</th>
<th>By increment</th>
<th>#Anchor pts / (#Anchor pts)</th>
<th>Scan angle to Scan angle (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 196</td>
<td>+ 15</td>
<td>14/14</td>
<td>- 39.36 to - 31.56</td>
</tr>
<tr>
<td>1968 to 1773</td>
<td>- 15</td>
<td>14/14</td>
<td>+ 39.32 to + 31.52</td>
</tr>
<tr>
<td>196 to 316</td>
<td>+ 20</td>
<td>6/20</td>
<td>- 31.56 to - 26.76</td>
</tr>
<tr>
<td>1773 to 1653</td>
<td>- 20</td>
<td>6/20</td>
<td>+ 31.52 to + 26.72</td>
</tr>
<tr>
<td>316 to 466</td>
<td>+ 25</td>
<td>6/26</td>
<td>- 26.76 to - 20.76</td>
</tr>
<tr>
<td>1653 to 1503</td>
<td>- 25</td>
<td>6/26</td>
<td>+ 26.72 to + 20.72</td>
</tr>
<tr>
<td>466 to 556</td>
<td>+ 30</td>
<td>3/29</td>
<td>- 20.76 to - 17.16</td>
</tr>
<tr>
<td>1503 to 1415</td>
<td>- 30</td>
<td>3/29</td>
<td>+ 20.72 to + 17.12</td>
</tr>
<tr>
<td>556 to 626</td>
<td>+ 35</td>
<td>2/31</td>
<td>- 17.16 to - 14.36</td>
</tr>
<tr>
<td>1413 to 1343</td>
<td>- 35</td>
<td>2/31</td>
<td>+ 17.12 to + 14.32</td>
</tr>
<tr>
<td>626 to 706</td>
<td>+ 40</td>
<td>2/33</td>
<td>- 14.36 to - 11.16</td>
</tr>
<tr>
<td>1343 to 1263</td>
<td>- 40</td>
<td>2/33</td>
<td>+ 14.32 to + 11.12</td>
</tr>
<tr>
<td>706 to 931</td>
<td>+ 45</td>
<td>5/38</td>
<td>- 11.16 to 2.16</td>
</tr>
<tr>
<td>1263 to 1038</td>
<td>- 45</td>
<td>5/38</td>
<td>+ 11.12 to 2.12</td>
</tr>
<tr>
<td>931 to 984</td>
<td>+ 53</td>
<td>1/77</td>
<td>- 2.16 to 0.04</td>
</tr>
<tr>
<td>1038 to 984</td>
<td>- 54</td>
<td></td>
<td>+ 2.12 to 0.04</td>
</tr>
</tbody>
</table>

*NOTE* Pixel numbers listed for positive scan angles are + 1 of actual pixel numbers. See Table 2-6 for true pixel numbers.

4 DATA AVAILABILITY

All of the data produced for the CZCS program is archived with the National Environmental Satellite Data Information Service of NOAA and is available to any user who wishes to purchase it. Requests for CZCS data should be addressed to
When ordering data from NESDIS, the user should specify the CZCS scene times (start and end times) and the scene location (corner latitudes and longitudes). In order to assist users in locating scenes of interest, NESDIS will run a computer search of its data base and provide the user with a listing of all scenes within a user specified geographic area and time frame. In addition, NESDIS has catalogs available which may be useful as an aid in data selection. One catalog lists all of the archived products, including date, time, orbit number, the coordinates of the four corners of the image, and an estimate of cloud cover. Another catalog shows the orbital passes for each day of CZCS operation in monthly increments and shows areas along the orbital tracks for which satisfactory data was acquired and will eventually be processed if not already processed.

In addition to NESDIS, there are several other places at which photographic data can be viewed. In the United States, there is a partial archive at the Scripps Institute of Oceanography, Visability Laboratory, in San Diego, and a full, geographically cataloged archive at the Satellite Experiment Laboratory of NOAA in Suitland, Maryland. European data is archived by the Joint Research Centre of the Commission of European Communities in Ispra, Italy and South African data is archived at the National Research Institute for Oceanology in Stellenbosch, South Africa. Questions concerning use of these archives, location of NET members, or location of centers that have computer facilities to analyze CZCS data, should be forwarded to Dr. Warren A. Hovis, Chairman, Nimbus Experiment Team.
This program is designed to show how one may read a CRT tape on the IBM 3081 computer in Bldg 1 at GSFC.

Programmer: Nick Iascone 1984 07 20

Programmer Nick Iascone

--- FIND OUT THE TAPE NAME AND SCENE ---
PRINT 10
READ ( 5, PARM1 )
PRINT 20, SCENE, INTAPE

--- CONVERT THE DESIRED SCENE TO FILES ---
IFILE1 = 2*SCENE - 1
IFILE2 = IFILE1 + 1

--- MOUNT THE DESIRED TAPE ---
IO = 1
CALL MOUNT ( IO, DDNAME, INTAPE )

--- READ THE STANDARD HEADER RECORDS FROM THE FIRST FILE ---
CALL REDHED ( IFILE1, IERR )
IF ( IERR .NE. 0 ) STOP

--- MOVE TO NEXT FILE TO CONTINUE PROCESSING ---
CALL POSH ( IO, DDNAME, IFILE2 )

--- PROCESS SECOND FILE ---
CALL CRTSCH ( IERR )

STOP

10 FORMAT ( 1X, 'START OF CRT TAPE READ PROGRAM' )
20 FORMAT ( / 1X, 'SCENE ', I2, ' FROM TAPE ', A8, ' REQUESTED.' )
END

SUBROUTINE REDHED ( IFILE, IERR )
C ----------------------------- 00000570
C TAPE PROCESSING RELATED ITEMS. 00000580
C ----------------------------- 00000590
C REAL * 8 DDNAME 00000600
DATA DDNAME '/CRITAPE '/ 00000610
INTEGER * 4 IFILE1, IERR 00000620
C ----------------------------- 00000630
C IERR = 0 00000640
C --- POSITION TO FIRST FILE --- 00000650
CALL POSH ( IO, DDNAME, IFILE1 ) 00000660
C --- READ FIRST STANDARD HEADER RECORD --- 00000670
LC = 0 00000680
IREAD = 1 00000690
CALL FREAD ( HDR1, DDNAME, LENGTH, LC, 160, 15 ) 00000700
IF ( LENGTH .NE. 160 ) IERR = 21 00000710
IF ( LENGTH .NE. 15 ) PRINT 30, IREAD, LENGTH, IERR 00000720
PRINT 40, IREAD, ( HDR1( J ), J = 1, 160 ) 00000730
C IREAD = 2 00000740
CALL FREAD ( HDR2, DDNAME, LENGTH, LC, 160, 15 ) 00000750
IF ( LENGTH .NE. 160 ) IERR = 22 00000760
IF ( LENGTH .NE. 15 ) PRINT 30, IREAD, LENGTH, IERR 00000770
PRINT 40, IREAD, ( HDR1( J ), J = 1, 160 ) 00000780
RETURN 00000790
C --- THIS SECTION OF CODE IS REACHED WHEN EOF ENCONCRERED --- 00000800
10 IERR = 23 00000810
PRINT 50, IREAD, IERR 00000820
RETURN 00000830
C --- THIS SECTION OF CODE IS REACHED WHEN I/O ERROR ENCOUNCRERED --- 00000840
20 IERR = 24 00000850
PRINT 60, IREAD, LENGTH, IERR 00000860
RETURN 00000870
C 30 FORMAT ( / 1X, 'STANDARD HEADER RECORD ', I1, ' HAD LENGTH = ', I6, ' WHICH WILL RESULT IN IERR = ', I3, ' AND SUBROUTINE RETURN.' ) 00000880
2/* ) 00000890
40 FORMAT ( / 1X, 'STANDARD HEADER RECORD ', I1, ' = */ 5( / 1X, 126A10000100020 1)/* ) 00000900
50 FORMAT ( / 1X, 'EOF ENCOUNCRERED INSTEAD OF STANDARD HEADER ', I1/ 00000910
11X, 'IERR WILL BE SET TO ', I3, ' AND REDHED WILL RETURN.' ) 00000920
60 FORMAT ( / 1X, 'I/O ENCOUNCRERED FOR STANDARD HEADER ', I1/ 00000930
10000100020 1X, 'LENGTH OF RECORD WAS ', I6/ 1X, 'IERR WILL BE SET TO ', I3, ' 2AND REDHED WILL RETURN' ) 00000940
END 00000950
SUBROUTINE CRTSCH ( IERR ) 00000960
C --------------------------------------------- 00000970
C SUBROUTINE CRTSCH READS THE DATA FILE OF THE CRT TAPE. 00000980
C IT SAVES THE 2 DOCUMENTATION RECORDS, WHICH ARE THE 00000990
C FIRST AND LAST RECORDS IN THE DATA FILE, FOR LATER 00001000
C USE. 00001010
C PROGRAMMER: NICK IASCON 1984 07 20 00001020
C ---------------------------------------------------------  
C        INPUT ARRAYS                                      
C        ------------------------------------------------- 
C        LOGICAL * 1 CRTDRL(5328), CRTDRT(5328)           
C        LOGICAL * 1 IMBUFF(12780)                       
C        COMMON /BLOCK3/ CRTDRL, CRTDRT                  
C        COMMON /BLOCK4/ IMBUFF                          
C --------------------------------------------------------- 
C        ITEMS RELATED TO PROCESSING                      
C        -------------------------------------------------- 
C        INTEGER * 4 GETRID, RECID, IERR                 
C        LOGICAL * 4 FIRST                               
C        INTEGER * 4 I4DUMB                               
C        EQUIVALENCE(IMBUFF(1), I4DUMB)                   
C --------------------------------------------------------- 
C        REAL * 8 DDNAME                                 
C        DATA DDNAME /'CRTTAPE'/                         
C --------------------------------------------------------- 
C        FIRST = .TRUE.                                  
C        IERR = 0                                         
C        IREC = 0                                         
C --------------------------------------------------------- 
C        READ A RECORD                                    
C        ------------------------------------------------ 
C        LC = 0                                          
C        CALL FREAD ( IMBUFF, DDNAME, LENGTH, LC, £40, £50 ) 
C        IREC = IREC + 1                                 
C        PRINT 60, IREC                                  
C        IF (.NOT.FIRST) GO TO 20                         
C --------------------------------------------------------- 
C        TO GET HERE, THIS MUST BE FIRST RECORD AND IT HAD 
C        BETTER BE A DOCUMENTATION RECORD.                
C        ------------------------------------------------ 
C        RECID = GETRID( I4DUMB )                         
C        IF ( LENGTH .LE. 5328 ) IERR = 31               
C        IF ( LENGTH .LE. 5328 ) PRINT 70, LENGTH, IERR   
C        IF ( LENGTH .LE. 5328 ) RETURN                  
C        IERR = 32                                        
C        IERR = 31                                        
C        IERR = 32                                        
C --------------------------------------------------------- 
C        SAVE THE FIRST DOC RECORD IN CRTDRL              
C        CALL EQUVL ( IREC )                             
C        PRINT 90                                         
C        FIRST = .FALSE.                                 
C        GO TO 10                                        
C --------------------------------------------------------- 
C        RECID = GETRID( I4DUMB )                         
C        IF ( RECID .NE. 2 ) GO TO 30                     
C --------------------------------------------------------- 
C        TO GET HERE, RECORD SHOULD BE DOC RECORD 2       
C        IF ( LENGTH .LE. 5328 ) IERR = 33               
C        IF ( LENGTH .LE. 5328 ) PRINT 100, IREC, LENGTH, IERR
IF ( LENGTH NE 5328 ) RETURN

C --- TO GET HERE, WE SHOULD HAVE GOOD TRAILING DOC RECORD ---
CALL EQUIVL ( IREC )
PRINT 110, IREC
RETURN

C --- TRAILING DOC RECORD WILL BE STORED IN CRTDRT ---
PRINT 110, IREC
RETURN

C --- TO GET HERE, WE SHOULD HAVE A DATA RECORD ---
30 IF ( RECID NE 7 ) IERR = 34
IF ( RECID NE 7 ) PRINT 120, IREC, LENGTH, RECID, IERR
IF ( RECID NE 7 ) RETURN

C --- TO GET HERE WE SHOULD HAVE A GOOD DATA RECORD ---
GO TO 10

C --- TO GET HERE, AN EOF WAS ENCOUNTERED ---
40 IERR = 35
PRINT 130, IREC, IERR
RETURN

C --- TO GET HERE, AN I/O ERROR WAS ENCOUNTERED ---
50 IERR = 36
PRINT 140, IREC, LENGTH, IERR
RETURN

60 FORMAT ( 1X, 'SUCCESSFULL READ OF RECORD ', I4 )
70 FORMAT ( / 1X, 'FIRST DOC RECORD HAD LENGTH = ', I6/ 1X, 'IERR WILL BE SET TO ', I3, ' AND CRTSCN WILL RETURN.' )
80 FORMAT ( / 1X, 'IERR WILL BE SET TO ', I3, ' BECAUSE DOC RECORD HAD LENGTH = ', I6/ 1X, 'IERR WILL THEN RETURN.' )
90 FORMAT ( 1X, 'FIRST DOC RECORD SAVED.' )
100 FORMAT ( / 1X, 'RECORD ', I4, ' HAD A LENGTH OF ', I6, '. ' 1X, 'IERR WILL BE SET TO 33 AND CRTSCN WILL RETURN.' )
110 FORMAT ( / 1X, 'RECORD ', I4, ' WAS TRAILING DOC RECORD.' )
120 FORMAT ( / 1X, 'RECORD ', I4, ' HAD LENGTH OF ', I6, ' AND ID = ', I4/ 1X, 'IERR WILL BE SET TO ', I3, ' AND CRTSCN WILL RETURN.' )
130 FORMAT ( / 1X, 'EOF ENCOUNTERED FOR RECORD ', I4, ' IERR SET TO 00002160 1' I3/ )
140 FORMAT ( / 1X, 'RECORD ', I4, ' WITH LENGTH OF ', I6, ' HAD I/O ERROR ' 1X, 'IERR SET TO ', I3/ )

END

INTEGER FUNCTION GETRID*Q (I4VAL)

C ________________________________
C - FUNCTION GETRID CONVERTS THE INPUT VALUE I4DUMB INTO A DATA RECORD ID. GETRID = 1 CORRESPONDS TO A DOCUMENTATION RECORD. GETRID = 7 CORRESPONDS TO A DATA RECORD. PROGRAMMER: NICK IASCOME 1984 07 20
C ________________________________
C
INTEGER * 4 I4DUMB, I4VAL
INTEGER * 2 I2TEST
LOGICAL * 1 I1TEST(2), I1DUMB(4)
EQUIVALENCE(I2TEST, I1TEST(1))
EQUIVALENCE(I4DUMB, I1DUMB(1))

I4DUMB = I4VAL
I2TEST = 0
SUBROUTINE E2UIVL (IREC)

C -------------------------------------------------------------
C - SUBROUTINE E2UIVL ASSIGNS THE FIRST 5328 BYTES OF INBUFF -
C - TO THE INDICATED DOCUMENTATION RECORD ARRAY.             
C - PROGRAMMER: NICK IASCOME 1984 07 20                         
C -------------------------------------------------------------

LOGICAL * 1 CRTDRL(5328), CRTDRT(5328)
COMMON /BLOCK3/ CRTDRL, CRTDRT
LOGICAL * 1 INBUFF(12780)
COMMON /BLOCK4/ INBUFF

IF ( IREC .NE. 1 ) GO TO 20
C --- IREC = 1 INDICATES THIS IS FIRST DOC RECORD ---
DO 10 I = 1, 5328
     CRTDRL( I ) = INBUFF( I )
10 CONTINUE
C RETURN

C --- IREC .NE. 1 INDICATES THIS IS NOT THE FIRST RECORD, ---
C --- THEREFORE THIS IS NOT THE FIRST DOCUMENTATION RECORD ---
DO 30 I = 1, 5328
     CRTDRT( I ) = INBUFF( I )
30 CONTINUE
C RETURN
END
//ZMDPISAM JOB (C0007,SAS,3),CRT-READ,TIME=(,15),
//CLASS=A,MSGCLASS=A,NOTIFY=ZMDPI,MSGLEVEL=(1,1)
//JOBPARM QUEUE=FETCH
//STEP1 EXEC OFORTH,PARM='OPT=2,XREF,ID',OUT=A
//SOURCE.SYSIN DD DSN=ZMDPI.NSI.FORTCSAMPLE),DISP=SHR
//STEP2 EXEC OLINKGOH,REGION.GO=250K,OUT=A,TERMOUT=A,BKSIZE=141
//SYSPRINT DD SYSOUT=A
//GO.FT05F001 DD *
//&PARM1 SCENE=1,INTAPE='DPI02 ', &END
//GO.FT06F001 DD SYSOUT=A
//GO.CRTTAPE DD UNIT=(6250,,DEFER),LABEL=(1,NL,,IN),
//DCB=(RECFM=U,BKSIZE=12780,DEN=5),
//VOL=SER=PHLEGM,DISP=SHR
//GO.SYSUDUMP DD SYSOUT=A
//NOTE EXEC NOTIFYTS

*** END OF MEMBER ***  15 RECORDS PROCESSED  **********

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APPENDIX B

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Zwick, H H and S C Jain, RECENT WORK IN PASSIVE OPTICAL IMAGING OF WATER
1. **Title and Subtitle**
   NIMBUS 7 Coastal Zone Color Scanner (CZCS) Level 1 Data Product Users' Guide

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5. **Abstract**
   The CZCS is a scanning multispectral radiometer designed specifically for the remote sensing of Ocean Color parameters from an earth orbiting space platform.

   This Technical Manual is intended for users of NIMBUS 7 CZCS Level 1 data products. It contains information needed by Investigators and Data Processing personnel in order to operate on the data using digital computers and related equipment.

6. **Key Words (Suggested by Author(s))**
   Multispectral line scanner
   Remote Sensing
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