DMSP PRIMARY SENSO

By

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DMSP PRIMARY SENSOR

DATA ACQUISITION

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ABSTRACT

A Data acquisition system which provides global pictorial cloud cover data for operational military meteorological purposes is described with emphasis on significant design features. These features include near constant geometric resolution through use of an oscillating scanner and variable instantaneous field of view (IFOV), thermal infrared channel output linear with temperature, visible wavelength sensitivity continuous from sub-solar to sub-lunar, along scan gain control permitting albedo images through the terminator, glare suppression enabling sensing of nighttime scenes in the presence of solar illumination on the spacecraft, wow/flutter correction of video data sampling to that of a reference scan motion, and dual geometric resolution capability from a single detector by synthesis of low resolution data.

INTRODUCTION

The Operational Linescan System (OLS) is a complete self-contained data collection system, built by the Aerospace Division of Westinghouse Electric Corporation, which serves as the primary sensor for the Defense Meteorological Satellite Program (DMSP). DMSP is a joint service program providing operational military meteorological data in a timely manner to both strategic and tactical users. Since 1976, the 5D-1 OLS has provided global cloud cover imagery in the visible and thermal infrared spectral bands. This paper describes the data acquisition portion of the new 5D-2 OLS which provides data nearly identical to 5D-1 with higher reliability through added redundancy.

CHARACTERISTICS OF OLS IMAGERY

Earth scene data is sensed by the OLS in two complementary spectral bands -- the visible light (L-channel) and the thermal infrared (T-channel). In each channel the scene resolution across scan is made nearly constant by use of variable IFOV in conjunction with near constant surface velocity of sensed area achieved by selection of scan motion. For global coverage the nominal smoothed mode resolution in each channel is 2.78 km; for selected regional coverage of higher resolution a nominal 0.56 km fine mode is provided in each channel.

The L-channel senses scene radiance in the 0.4 to 1.1 um spectral band for scene illuminations from sub-solar to sub-lunar at quarter moon -- a range of over ten million to one. Throughout this range, continuous adjustment of channel gain compensates for the changing scene incident illumination. By this means, useful imagery is obtained even in the terminator region where the illumination changes a factor of ten every two geocentric degrees. The L-channel output data may be made either linear or two-decade logarithmic compressed with scene radiance.

The T-channel senses scene radiance in the 10 to 13 um spectral band over the scene temperature range from 190 K to 310 K. The output data is made linear with temperature over the dynamic range.

OPTICAL SYSTEM OF THE OLS

Wideband scene radiant energy is collected by a scanning telescope selectively processed in two spectral paths by a relay optics subsystem and focused on one T-channel detector and two L-channel detectors located at three different focal planes of the optical system (see Figure 1). The L-channel detectors are a silicon high resolution diode (HRD) for daytime scenes and a photomultiplier tube (PMT) for nighttime scenes.

Scan Motion - The OLS employs a scanning telescope to scan the earth scene in the cross track direction while the forward motion of the satellite in its 833 km circular, sun synchronous, polar orbit provides the along track incremental motion. The telescope scans in a precisely controlled sinusoidal scan motion of ±57.85° amplitude to cause the surface velocity to be nearly constant throughout the earth scan of ±1482 km cross track necessary for contiguous equatorial coverage at 833 km altitude. This scan motion has the added advantage of yielding a relatively high (0.85) ratio of active scan time to total scan time. The 101 minute orbit period and the nominal 0.56 km resolution along track constrain the frequency of scan motion to be 5.94 Hz.

Scan Drive - The scan drive, with minimal power expenditure, produces a sinusoidal scan motion with time whose amplitude and frequency are 57.85° and 5.94 Hz respectively. A high Q spring/mass torsional pendulum system provides the sinusodal scan motion. Four flat, spirally wound springs provide torque; one end of each spring is attached to the fixed structure and the other end is attached to the oscillating shaft. Matching the spring constant and the angular inertia of the oscillating assembly provides the proper scan frequency. Since the system is mechanically resonant, frequency stability is inherent and the scan drive must only supply energy to overcome the low damping losses to maintain amplitude stability. The energy is provided by pulsing a dc torque motor twice each cycle of the scanner with a pulse whose width is controlled in a feedback loop based on scan amplitude.

Image Motion Compensation (IMC) - Because of the sinusoidal scanning motion of the OLS, received data without IMC would be distorted such that regions near the end of scan would be alternately compressed and expanded along track. Compensation has been mechanically incorporated into the scanner optics by oscillating mirror M3 ±0.4 mr in the along track direction at twice the telescope scan frequency.

Telescope - The telescope, a five reflective surface Cassegrain assembly, receives the scene radiant energy through an effective aperture of 239 cm^2. Figure 1 shows the basic optical configuration of the telescope and illustrates the size of the light bundles along the optical paths. The primary mirror (M1) is 20.3 cm, f/1.0 parabolic. The secondary mirror (M2) is hyperbolic with a focal length of -6.35 cm. The resulting telescope focal length is 122 cm. Energy reflected from M2 is intercepted by a flat mirror (M3) on the rotational center line. M3 redirects the energy at an angle of about 30° away from the rotational center line in the plane determined by the telescope axis and rotational axis. M3 also provides the IMC that converts the scan motion to rectilinear.

An elliptical mirror (M4) approximately 0.5 cm in front of the telescope image plane has a dual function: it redirects the line of sight radially inboard toward the rotational axis where the line of sight is intercepted by a flat mirror (M5) and it serves as a field stop. M5 reflects the line of sight away from the telescope assembly both coparallel to and concentric with the rotational axis. As the telescope scans, the mirror M4 traverses an arc in space. Near the end of scan in either direction, the line of sight is interrupted by calibration mirrors M4' and M4", which are near M4. These calibration mirrors direct the view from the detectors into cone shaped near-blackbody sources of known temperature for T-channel calibration. The L-channel also uses the -Z (anti-sun) calibration source as a dark reference.

Relay Optics - The configuration of the relay optics, the stationary portion of the OLS optics, is also shown in Figure 1. The wideband radiant energy received from the telescope is first split spectrally by a dichroic beamsplitter which reflects the 10 to 13 um thermal infrared energy for the T-channel while transmitting the 0.4 to 1.1 um visual and near infrared energy for the L-channel.

The T-channel energy reflected from the beamsplitter is refracted into a slightly coverging beam by a germanium lens (L1) before being directed by two flat mirrors (MT1 and MT2) along the optical axis of the T detector optics. The final T-channel optical transformation is performed by an f/1.0 germanium meniscus lens. This lens uses spherical first and second surfaces to focus the T-channel energy on the T detector through a germanium flat for correction of spherical aberration.

The L-channel energy transmitted by the beamsplitter is directed by a folded optical system utilizing two mirror surfaces to the field splitter focal point. The central core of the field of view is reflected by the field splitter into a series of lenses that focus the energy on the HRD detector focal plane. The rest of the field of view is transmitted through the field splitter into a series of lenses and redirecting flat mirrors that focus the energy on the PMT detector focal plane.

Glare Suppression - Loss of data due to on-axis scattering of incident sunlight is minimized by incorporating antiglare features into the optical/mechanical design of the telescope and by providing sunshades. Glare is suppressed in the telescope in four ways. First, the geometric configuration of the telescope limits the maximum input acceptance angle to 14°. Second, the low scatter finishes on M1 and M2 reduce the amount of energy scattered into the field of view from sources off the optical axis. Third, a field stop at M4 limits the maximum field half angle to 2.5 mr. Fourth, an aperture stop mask between M5 and the relay optics blocks glint from the edges of the hat-shaped part of the telescope, the outer edge of M1, and the support spiders for M2. M4 is an elliptical mirror that provides a soft focus of these glare sources at the mask position.

For glare suppression in orbits having sun angles between 75° and 95°, planar first surface specular mirror sunshades are mounted immediately adjacent to the aperture area of the telescope. These highly specular mirrors prevent direct impingment and minimize primary scatter of sunlight on any part of the telescope or surrounding diffuse scattering surfaces.

For glare suppression in orbits having sun angles between 0° and ±45°, the spacecraft provides an additional sunshade comprised of a large stationary opaque glare obstructor (GLOB) at the +Z (Sunward) end of the spacecraft. It projects in the +X (Earthward) direction and prevents sunlight from impinging directly on any part of the telescope or surrounding diffuse surfaces.

DETECTORS

The T detector is a two-segment Mercury-Cadmium-Telluride (HgCdTe) photoconductive detector cooled to a temperature near 108 K and maintained within ±0.1 K of the chosen set point by an active temperature control loop using a small heater on the inner stage of a two-stage passive cryogenic cooler. The detector consists of two orthogonal elements, designated T-left and T-right.

The HRD detector is a three segment silicon photoconductive PIN diode with the N side (cathodes) common for all three elements. The dc dark leakage currents are so small below +10° C, that no cooling is required for the HRD.

The PMT detector is a cesiated GaAs (gallium arsenide) opaque photocathode, image dissector type, multiple dynode photomultiplier tube that serves as the low resolution detector for the nighttime visible wavelength energy. With the proper focusing fields in the front end (determined by the photocathode, focus, cone, and plate voltages), only photoelectrons emitted from the effective photocathode area will pass through the defining aperture hole, undergo secondary emission multiplication in the dynode chain and subsequently be collected by the anode. To vary the field of view (FOV), the image dissector magnetically deflects the defining electron aperture image referred to the photocathode. This effect, in conjunction with the physically limited (masked) photocathode area, allows IFOV control by varying the size of the overlap region between the limited photocathode area and the defining electron aperture image. The magnetic deflection is accomplished by controlling the currents in two orthogonal coils on the PMT yoke. Figure 2 shows the PMT detector aperture configuration.

Each of the detectors make use of the rotation, as a function of scan angle, of the detector image on the scene to improve the IFOV in the along scan direction. The along scan projection of the detector on the earth enlarges as the scan angle increases, due to decrease of the incident angle of the line of sight and increase in slant range, so that at the ±1482 km ends of scan the projection is six times that at nadir. At the side quarters of scan (between ±766 km and ±1482 km surface distance) only the detector segment which has a favorable along scan projection is selected to cause spatial resolution to be more nearly constant throughout the scan. The central half of the scan uses the total available detector area to improve the signal-to-noise performance in this region where projection enlargement is not a problem. Figure 3 shows segment switching for the HRD and T detectors. PMT segment switching is similar to that shown for the HRD.

ANALOG SIGNAL PROCESSING

The channel analog electronics convert the three primary detector low level electrical signals into full scale analog signals using amplification, dark level dc restoration, switching, summing, commanded gain changes, and low-pass video filtering. The analog portion of smoothed resolution data processing is simply low pass filtering to an 8 KHz instead of the 40 KHz fine mode bandwidth. Four OLS data outputs result from analog processing: L-fine (LF), L-smoothed (LS), T-fine (TF) and T-smoothed (TS). Significant amounts of commandable redundant analog hardware blocks and fallback modes are provided in the 5D-2 OLS.

L-Channel Analog Signal Processing

The L-channel block diagram is shown in Figure 4 from the detector input through the channel output to the A/D converters. After amplification, the detector signal is dc restored to the dark reference that is viewed during the -Z overscan period by the postamplifier. Selection of detector, detector segment, postamplifier and VDGA gain value are provided under processor control. Amplification may be made linear or two-decade logarithmic compressed and switching transients are suppressed before presample five pole active filters limit the LF signal to 40 KHz and the LS signal to 8 KHz bandwidth. Redundancy is provided in both normal and fallback modes.

Gain Control - The ability of the L-channel to follow the rapid decrease in scene illumination through the terminator by varying the gain of the channel in a compensating manner is called along scan gain control (ASGC). ASGC is controlled by a digital processor which determines the gain required using knowledge of scan angle, solar position data provided by the spacecraft and a stored table of gain value versus scene solar elevation (GVVSSE) which can be modified by ground command. The voltage gain is calculated over a 140 dB range in 1/8 dB steps and is dynamically composed of 30 dB in the PMT postamplifier, 46 DB in PMT/HRD sensitivity ratio, and 64 dB in the variable digital gain amplifier (VDGA) which can be varied in 1/8 dB steps. The ASGC mode is capable of following the desired gain well within 1 dB in most scenes with peak deviations of less than 4 dB under worst case conditions. The ASGC mode is backed up with an along track gain control (ATGC) mode and a preset gain control (PGC) mode. ATGC uses the gain calculated at mid scan throughout the scan and PGC relies on stored commands to establish gain.

Transient Blanking - As large blocks of gain are switched within the channel for ASGC or segment switching, some undesirable transients result. These transients are blocked out by a switching transient blanker which holds the prior video value during the transient.

Normal Operation Redundancy - In the analog hardware all circuits after the postamplifier outputs are duplicated. The redundant source selection gates, VDGA, lin/log amplifier, switching transient blanker, and LF and LS low pass filters are all identical to the primary hardware. They are continuously active and the choice of which hardware source of data outputs (LF and LS primary or LF and LS redundant) to use is made by ground command selection.

Fallback Mode Redundancy - An HRD Segment C fallback postamplifier is provided which can be selected by ground command for use across the entire scan in the event that the HRD postamplifier were to malfunction. In addition, ground command can select either HRD left or HRD right for use across the entire scan line to bypass a failure in one detector segment, preamplifier or postamplifier.

T-Channel Analog Signal Processing

The T-channel block diagram is shown in Figure 5 from the detectors through the output to the A/D converters. After amplification, the detector signal is dc restored to the known reference temperature of the clamp source that is viewed during the -Z overscan period by a gated clamp in the postamplifier. The T video from the postamplifier is shaped by a six line segment shaper function which linearizes output signal to equivalent blackbody temperature. The T left/mid/right switching for TF data is located after the shaper function so that continuous T video is available for TS data. Switching is at a high signal level so transient suppression is excellent. The T left and T right video signals from the shaper are summed into the TS five pole, 8 kHz active low-pass filter. The T right, T mid and T left switching for TF video are followed by the TF five pole, 40 kHz active low-pass filter. Again redundancy is provided in both normal and fallback modes.

Normal Operation Redundancy - In the analog hardware all circuits after the postamplifier are duplicated. The redundant buffer amplifiers, shaper networks, segment switching gates and TF and TS low pass filters are all identical to the primary hardware. They are continuously active and the choice of which hardware source of data outputs to use (TF and TS primary or TF and TS redundant) is made by ground command selection.

Fallback Mode Redundancy - If a failure occurs in one detector element, preamplifier, commandable gain amplifier or post amplifier, the opposite detector segment signal can be used across the entire scan to provide TF and TS data by ground command selection.

SCAN MOTION SIGNAL PROCESSING

Scan angle information is needed in the OLS for control of scanner amplitude, synchronization of control functions, and to enable accurate video data sampling under non-ideal scanner motion conditions.

Optical Encoder - The indication of scan angle is provided by an optical encoder that produces a series of 2049 clock pulses spaced at equal 0.98551 mr increments throughout the scan. The nominal scan is ±1024.5 clock pulses or 57.85° peak scan angle. Control pulses at the middle of scan (nadir), 146 clock pulses on the +Z side of nadir to differentiate -Z from +Z, and at ±1018 clock pulses (near the ends of scan) are used as reference positions within the scan.

The optical encoder consists of a polygon, encoder optics and an auxiliary encoder. A multifaceted polygon ring having fifteen mirror surfaces is mounted to the oscillating assembly and is "viewed" by the encoder optics which contains light sources, slits and detectors to produce clock and control pulses. A backup mode for providing control pulses is supplied by a separate light source/detector combination in the encoder optics. Since the optical generation of the encoder clock pulses can not readily be made redundant, a digital encoder simulator has been incorporated which synthesizes clock pulses from scanner control pulses. A synthetic clock track is generated by reading delay values from a read only memory. Frequency and position are corrected by the processor in order to make this synthetic clock track closely match the actual scanner motion.

Video Data Sampling Correction - A wow/flutter clock generator processes the encoder pulses and generates a clock whose frequency varies from a nominal 512 kHz as a direct function of the amount the actual scanner motion deviates from the reference scanner motion. The reference scanner motion is defined to be a sine wave of amplitude 57.85°, frequency 5.94 Hz, and zero offset. This wow/flutter clock is then divided down to frequencies appropriate for video data sampling and for wow/flutter data for ground use. The wow/flutter clock generator mechanization is that of an oscillator whose frequency is corrected in a feedback control loop which periodically compares the oscillator output count since beginning of scan to that required by the reference scanner motion at that point in scan.

SYNTHESIS OF SMOOTHED DATA

The OLS uses along scan and along track smoothing of fine data to produce a lower bandwidth video (smoothed data) without requiring a second detector. The along scan smoothing is accomplished using an analog filter which reduces the 40 kHz fine data to 8 kHz along scan smoothed data. The along track smoothing digitally integrates along-scan-smoothed data samples in five-successive-scan-line groups to produce 1.6 kHz smoothed data. The along track integration algorithm consists of a prescaler, an 8 bit A/D converter (which is shared by L and T video), a digital adder and memory and a postscaler. The prescaler is required to allow the full scale analog input to produce the full scale digital output and to allow individual data samples to exceed full scale. The digital adder works in conjunction with ping-pong memories for both L and T video. Each of the L video memories is 1465 words by 8 bits in size while each of the T video memories is 1465 words by 10 bits in size. After each group of five lines is integrated, the ping-pong memories switch functions so that the one which stored partial-integration sums becomes the source for output readout and vice-versa. The digital adder for the L video has the further memory hardware saving feature of using only 8 bit memory word length. This is accomplished by truncating the 8 bit adder output to 6 bits prior to loading into the memory and by setting to 10 the two least significant bits of the 8 bit memory input to the adder for the last four lines. This method provides an L video algorithm transfer function which does not skip any output states for dc no noise inputs. Upon readout from a memory the postscaler truncates the word length by two bits to provide the required 8 bit T data from the 10 bit T memory output and 6 bit L data from the 8 bit L memory output.

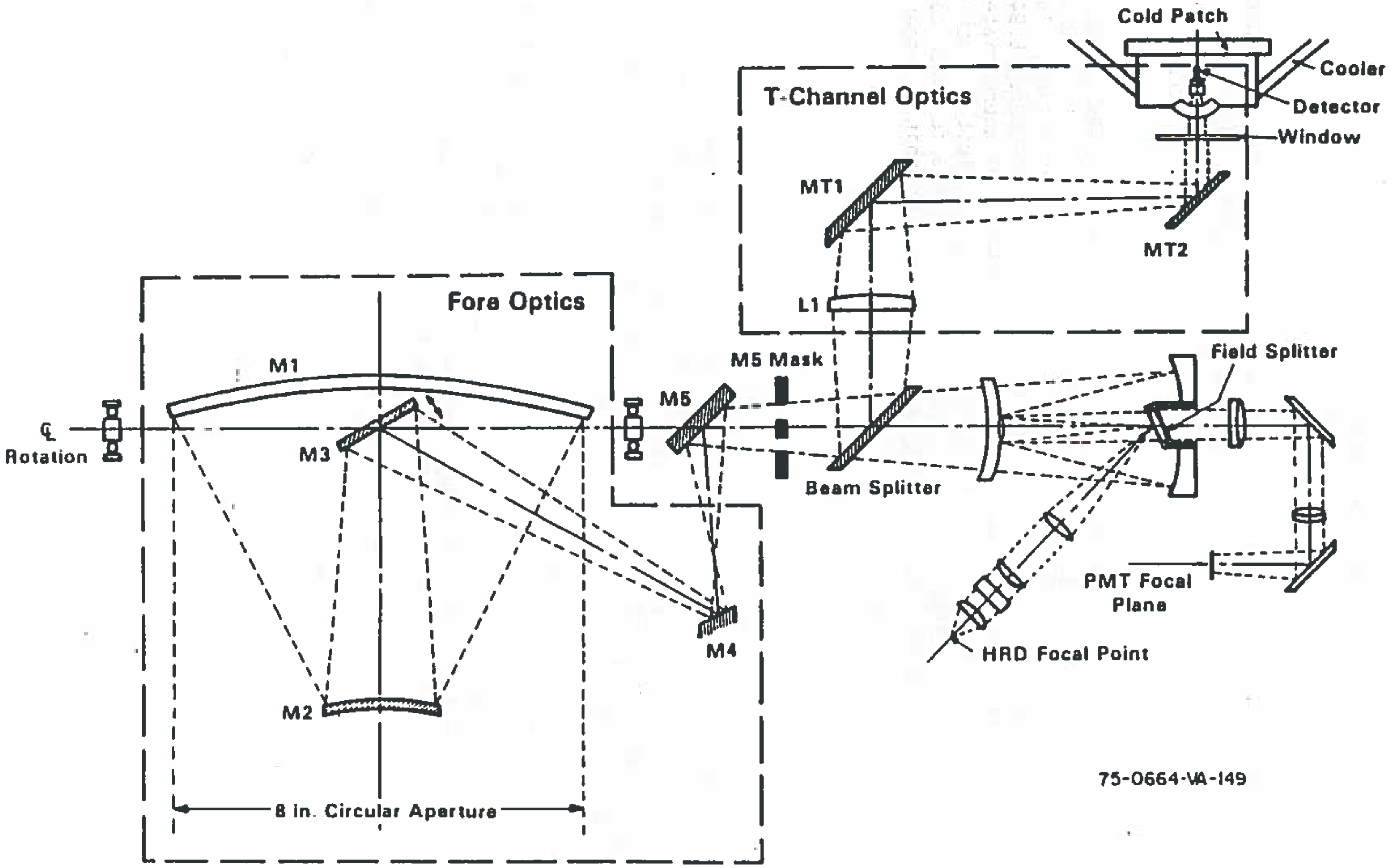

Figure 1. OLS Optics

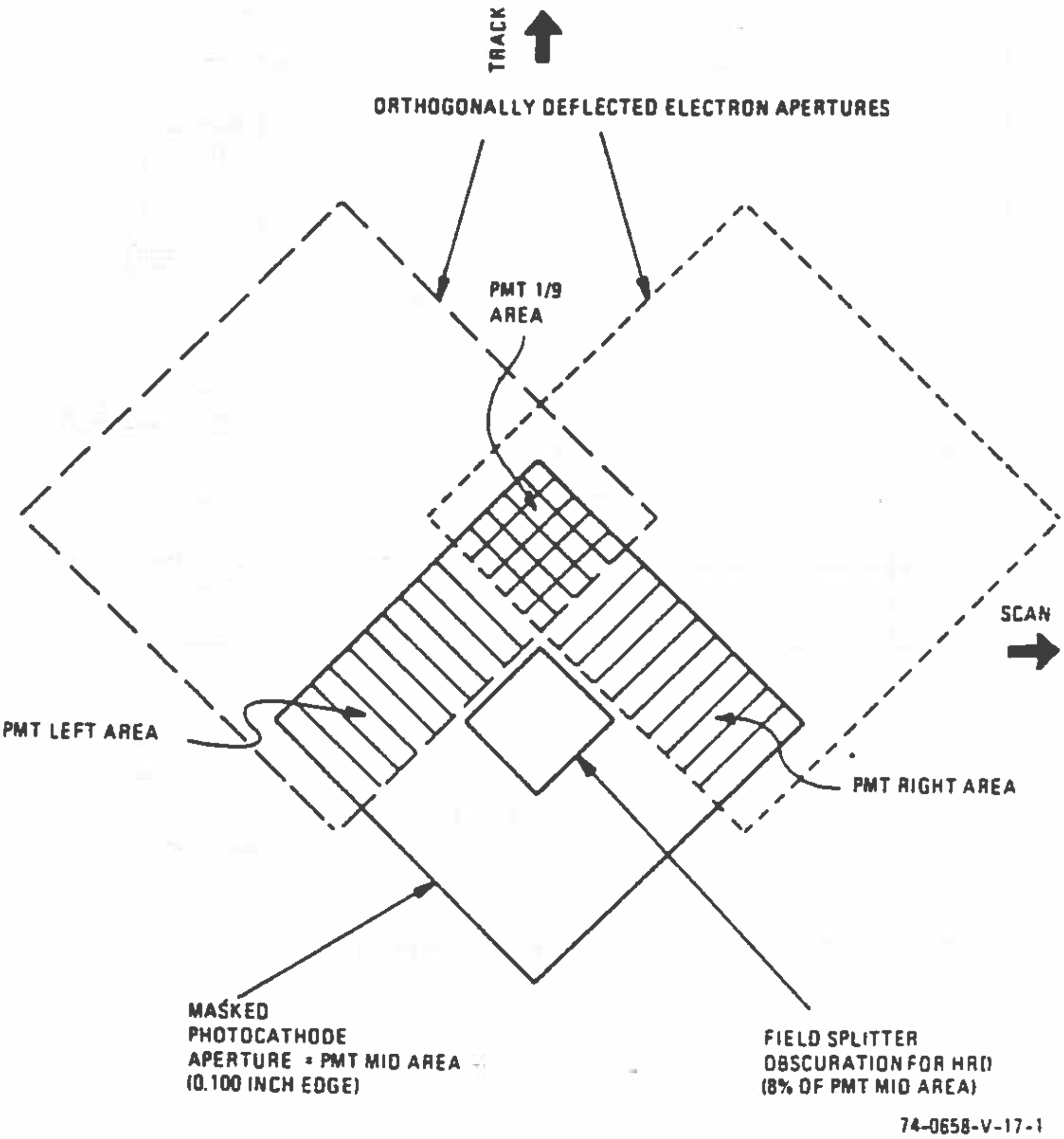

Figure 2. PMT Detector Aperture

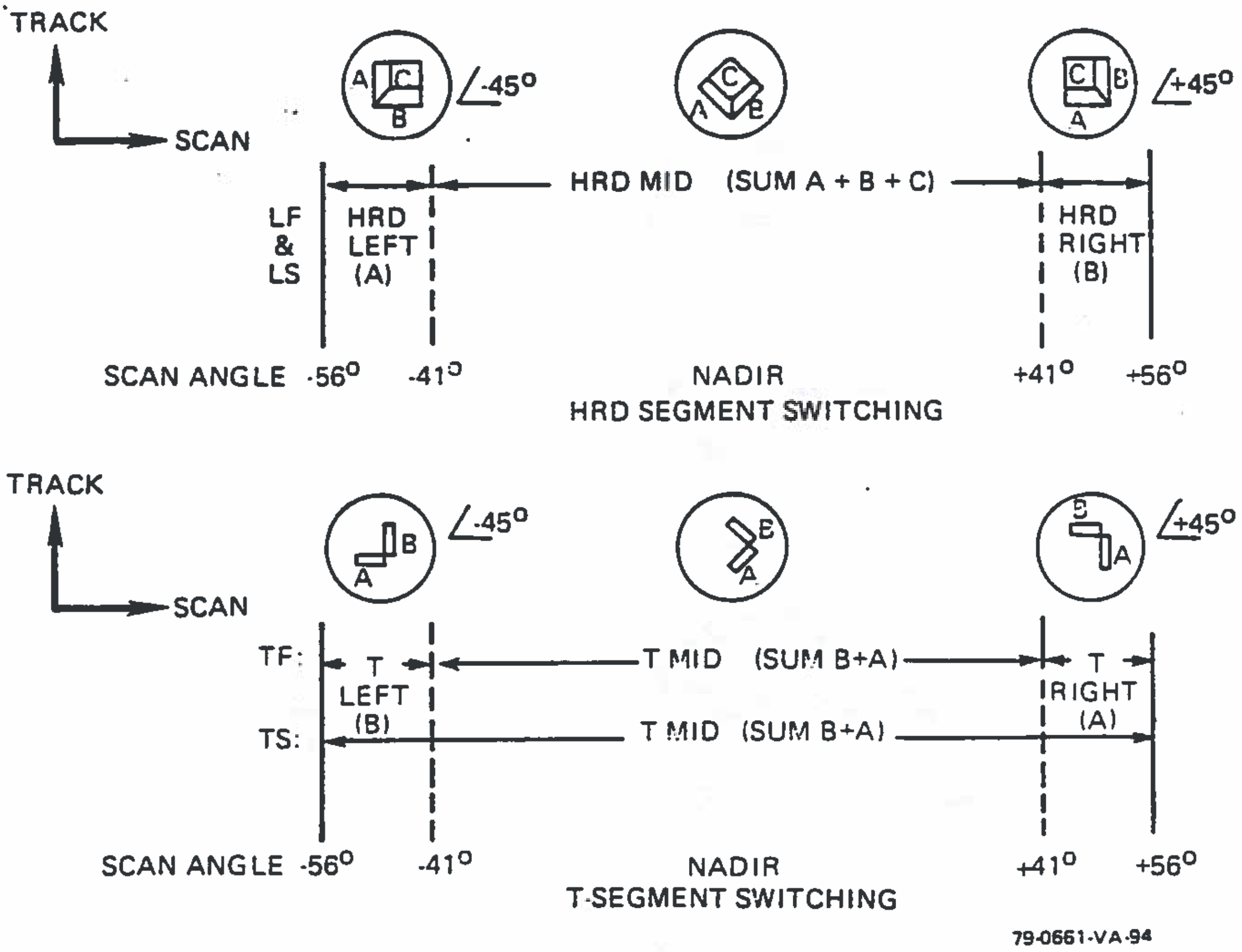

Figure 3. HRD & T Detector Segment Switching

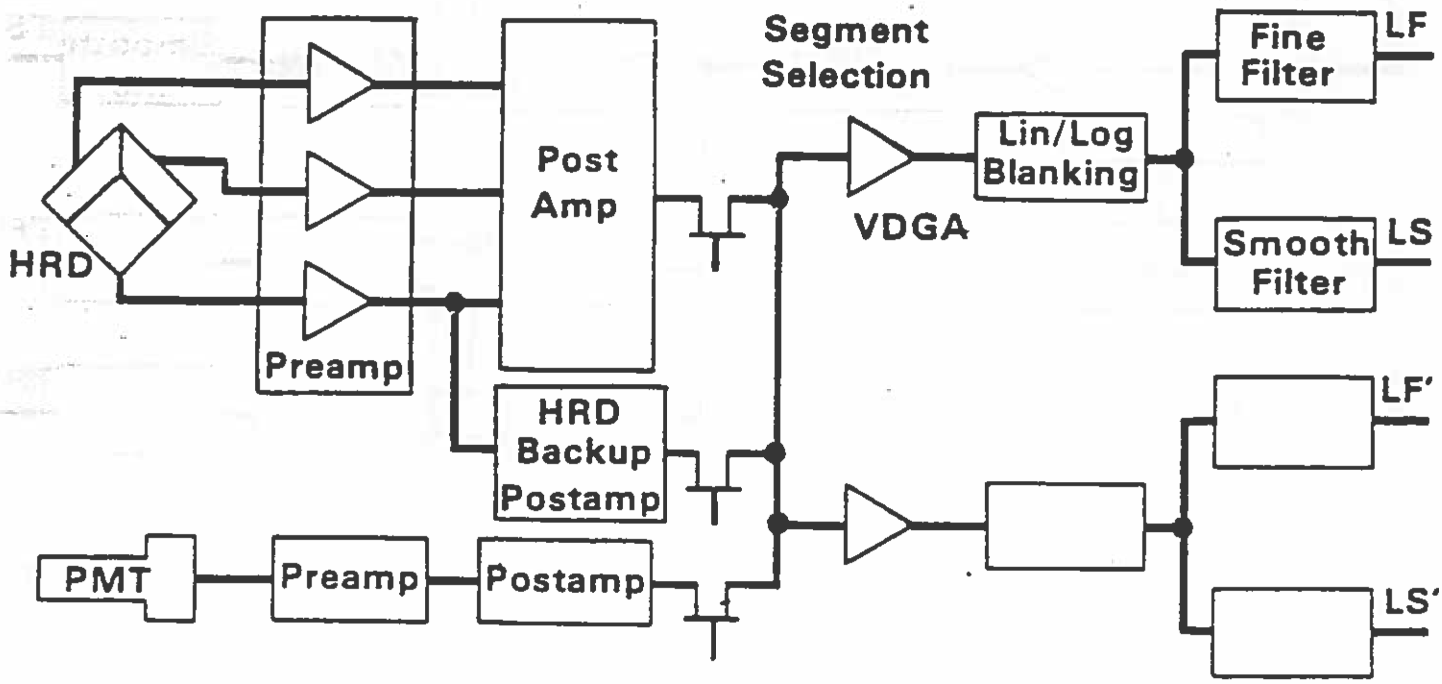

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Figure 4. L-Channel Analog Processing

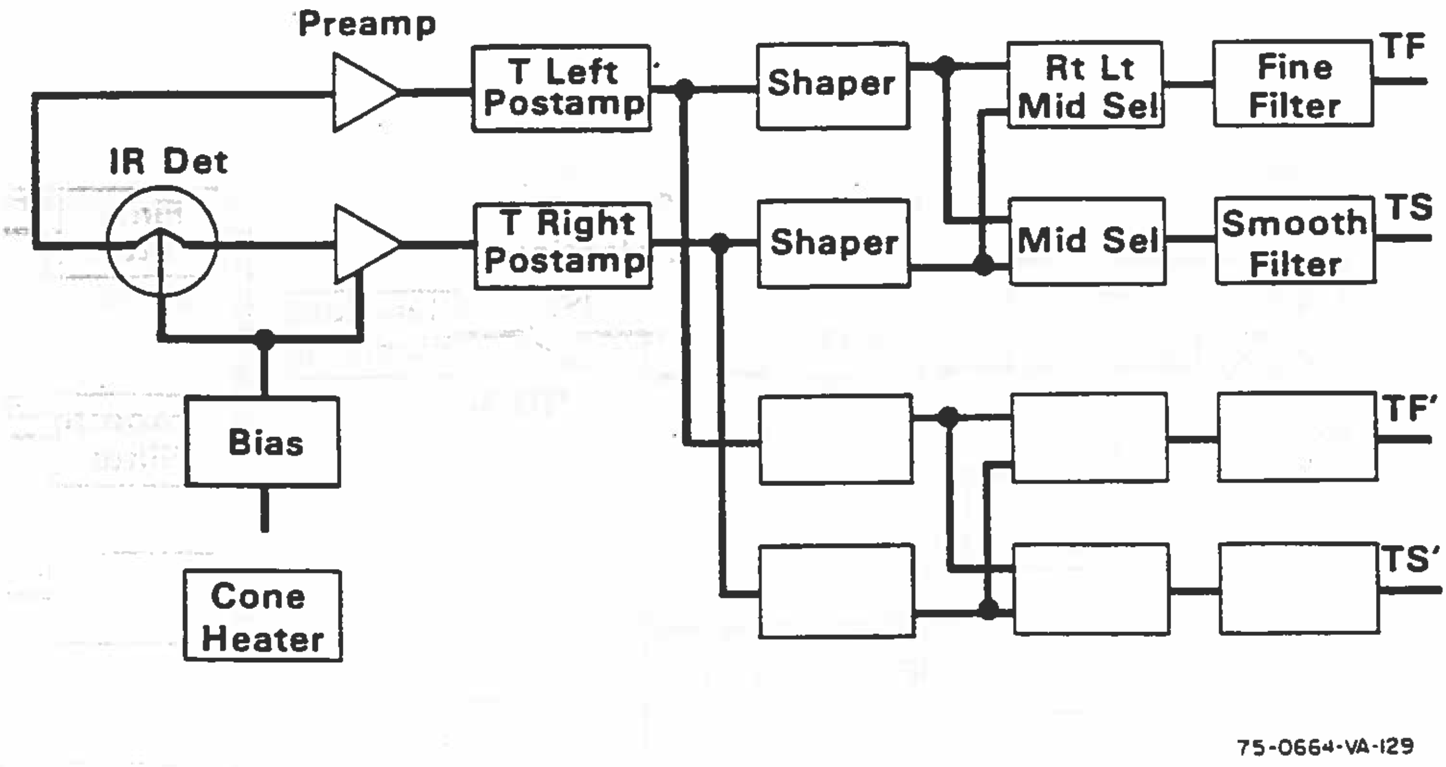

Figure 5. T-Channel Analog Processing

DMSP PRIMARY SENSOR ON-BOARD PROCESSING

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ABSTRACT

An overview of the DMSP sensors has been described in the literature. Most of these descriptions have been limited to the data acquisition system. This paper will try to fill a void by describing the on-board processing system of the DMSP Primary Sensor, designated the Operational Linescan System (OLS).

The OLS is a complete self-contained data collection system, built by the Space Division of Westinghouse Electric Corporation. This system gathers and outputs in real time or stores multi-orbit day, night and infrared spectrum data from earth scenes and provides such data, together with other mission sensors data to the data transmitters for transmission to ground stations.

INTRODUCTION

Satellites developed, launched and managed by the U.S. Air Force Defense Meteorological Satellite Program office carry a varied assortment of sensing instruments for collecting meteorological information on a daily basis. One of these instruments, designated the Primary Sensor, is carried by all satellites. A complement of up to twelve other mission sensors may be carried. The types as well as the number of mission sensors on any one spacecraft will vary. The Primary Sensor, designated the OLS, interrogates these sensors and formats their data into the primary data bit stream for either delayed or real time transmission to the ground. On the ground, the data is computer processed to extract meteorological information such as cloud cover, cloud height, vertical temperature profiles, vertical relative humidity profiles, atmospheric ozone content, etc.

DMSP satellites are the primary source of global meteorological satellite data for the Air Force Global Weather Central (AFGWC) data base. From this data base, AFGWC routinely generates a family of meteorological products which are used by all the major Air Commands as well as the National Military Command and elements of the Army and Navy. The information is also made available to the National Oceanic and Atmospheric Administration (NOAA) and its National Weather Service meteorologists for their use in day-to-day forecasting as well as to any other interested user in the scientific community.

OPERATIONAL LINESCAN SYSTEM (OLS) DATA FLOW

The OLS's line-scanning radiometer provides pictorial meteorological data for contiguous global coverage twice daily. The sensor employs a moving mirror technique to scan the earth in the cross-track direction, while the forward motion of the satellite provides along-track incremental motion. The energy from earth scenes is collected by a scanning optical system and focused onto the detectors through a stationary beam splitter and a field splitter relay optical system. The OLS has two separate and independent channels for collecting visual and infrared spectral energy.

A silicon diode senses the daylight visual energy while a photo-multiplier tube (PMT) provides the low light level capability. Collectively, these detectors make up the visual channel (L channel) and provide a dynamic range from full sunlight to quarter moonlight. A cooled mercury cadmium telluride detector provides the infrared sensing (T channel). Signals from the detector segments are amplified and selected as required to control the field of view, resulting in a nearly-uniform constant ground resolution element size in the cross-track direction. This is followed by a switchable gain amplifier (visual channel only) whose gain can be controlled in 1/8 dB steps. This allows data collection in the terminator region to be free of light level variations. The infrared channel does not require this gain changing but does have circuitry which linearizes the detector output with temperature. After A/D conversion, the video signals may either be smoothed for multi-orbit storage, stored directly for limited fine resolution storage, or transmitted directly to the ground.

Fine resolution data is collected continuously, day and night, by the segmented infrared detector (TF data) and continuously during daytime only by the segmented, silicon diode detector (LF data). Fine resolution data has a nominal linear resolution of 0.3 nm. Tape recorder data storage capacity and transmission constraints limit the quantity of fine data LF or TF which can be provided in the Stored Data Fine (SDF) mode to a total of either 40 minutes of LF or TF or 20 minutes of LF and TF data per ground station contact. Data smoothing permits global coverage in both the infrared (TS) and visible (LS) spectrum to be stored on the tape recorders in the Stored Data Smooth (SDS) mode. Smoothing is accomplished by electrically reducing the sensor resolution to nominally 1.5 nm in the along scan direction, then digitally averaging five such 0.3 x 1.5 nm samples in the along track direction. A near-uniform resolution of 1.5 nm results. Up to 400 minutes of LS and TS data can be transmitted in a single ground station contact. A combination of one type of fine resolution data and the complementary smoothed resolution (LF and TS, TF and LS) data, less the 5 line averaging, is provided in the Real Time Data (RTD) mode.

The spacecraft provides three S-band transmitters for primary data transmission and are under the control of the OLS system. Two of these transmitters are typically used for stored data playbacks but can also be used for direct data transmissions. The two spacecraft telemetry transmitters can also be put in a backup mode to handle this data. The third S-band data transmitter is dedicated to direct data transmission to tactical sites around the world.

Supporting this primary data flow are the digital signal processing functions in the processor, operational program memory, and the input/output (I/O) circuitry. The software stored in the operational program memory in conjunction with the hardware in the processor and I/O provide control of the primary data flow and support functions as commanded from the ground. The sensor and gain control causes the signal level of the primary data to be appropriate for the input received. Mission Sensor control is provided for up to twelve sensors whose outputs are needed to support the spacecraft mission and are integrated into the primary data streams.

The scanner monitor and control analog processing function, together with the encoder and wow/flutter digital processing function, provides the ability to collect scene data and assign it the proper geographic location.

The power supply system converts the spacecraft provided power to the voltage levels and regulation needed throughout the OLS.

DIGITAL PROCESSING SUBSYSTEM OVERVIEW

The Digital Processing Subsystem consists of two Processors, two operational program Memories, two I/O's, two Formatters, four Digital Tape Recorders, three Encrypters and an Output Switching Unit.

The Processor is a low-power general-purpose computer. Its operational program is contained in the Memory which has both Read Only Memory and Random Access Memory sections. The Processor and Memory sections communicate by "Signal BUS A" or "Signal BUS B", so that there are eight possible combinations for increased reliability.

The I/O Units contain several switchable functions under processor control. An I/O unit responds to processor commands coming over either BUS A or BUS B. With both I/O X and I/O Y powered choices may be made as to which I/O controls each of the functions which are: Spacecraft Interface, Clock Control, Gain Control, Sensor Control, Output Data Multiplexing and Tape Recorder Control, Encoder and Wow/Flutter Processing. The basic "I/O Control" section within each I/O must be working properly to use any of the functions in that I/O.

The formatter units contain the circuitry which performs A/D conversion on the video signals, processes the digital video, adds additional information and organizes the result, using synchronization codes, into various formats for transmission to the ground. If both Formatter G and Formatter H are powered, each of the following functions may be performed by either Formatter unit: Real Time Data Formatting, Stored Data Fine Formatting, Stored Data Smooth Formatting, Special Sensor Processing.

The formatters communicate with the processor through the I/O unit selected. It does not matter whether one or both I/O units are powered, or what functions are being performed by either I/O. The Formatter Memory, which is used mainly by Stored Data Smooth and to a certain extent by Stored Data Fine, is connected only to the SDS and SDF blocks within the same Formatter.

PROCESSOR AND MEMORY

Processor - The OLS processor is a 16-bit, fractional, two's complement, stored program data processing unit that uses low power MSI technology. This processing unit consists of a microprogrammed control matrix, eight registers, (including four accumulators), and decoding and execution control logic. The instruction set includes algebraic, logical, I/O and control instructions. The multiply and divide instructions are fractional.

Operational Program Memory - Program and data storage for the processor is provided by the Operational Program Memory. 3072 16-bit words of non-volatile, nonalterable Read Only Memory (ROM) are allocated for an initial "bootstrap" program and lookup tables. 13,312 16-bit words of Random Access Memory (RAM) contain the main operational program which will be loaded by way of the command uplink.

Bus Switching - The memory control section of the Processor provides the interface between the processor and the two bi-directional buses, BUS A and BUS B. Each of these buses consists of 16 bi-directional data lines and a number of single-directional control lines. The processor input and output buses are connected to either BUS A or BUS B, depending on the state of PROCSEL, which is set by a spacecraft interface signal to the OLS. Similarly, the memory is connected to either BUS A or BUS B, depending on the state of MEMSEL (another input signal to the OLS).

INPUT-OUTPUT

The I/O performs a number of communication and control functions. Each I/O is connected to both BUS A and BUS B. It can accept processor I/O instructions from either bus, with BUS A arbitrarily having priority when instructions arrive simultaneously over the control lines of the two buses.

Clear/Clock Drivers - The Clear/Clock drivers consist of redundant clock oscillators in the Output Switching Unit (OSU), redundant line receivers in the Red/Black units, level shifters to CMOS levels, selection switches to select either OSU "X" or OSU "Y" as the clock source, and drivers to distribute the clocks throughout the system.

Spacecraft Interface - Of the six digital serial information interfaces between the OLS and the spacecraft, four carry information from the spacecraft to the OLS: Command Data - basically used for program data loads, real and stored commands; Elapsed Time Count - timing synchronization for the ground, spacecraft subsystems and OLS subsystems; Location Data - cosine solar azimuth, S/C altitude and solar elevation components of the Location Data from the S/C are used in the determination of scene solar elevation for L-channel gain control; and Telemetry Data - serialized slow mode Equipment Status Telemetry (EST) Data is received for incorporation in the SDS primary data to provide stored EST information throughout the orbit. The other two interfaces carry information from the OLS to the spacecraft: Real Time Command Verification and OLS CPU Memory Data.

Gain Control - The Gain Control function controls the L channel gain configuration so as to select the proper value from the 150 dB range that is available. There are three modes of L channel gain control. Along Scan Gain Control (ASGC), where the processor automatically selects the appropriate sensor and gain state for each portion of the active scan; Along Track Gain Control (ATGC), where the processor automatically selects the appropriate sensor and gain state for the nadir point of the scan and uses these values for the entire scan line; and Preset Gain Control (PGC), where the processor is only involved in the execution of the appropriate gain and sensor select via real time or stored OLS command.

Sensor Control - The various sensors require a number of control signals for segment switching and calibration purposes. The processor keeps track of the current scan angle and switches these control signals. In some cases, where timing is critical, a hardware timing chain is used to synchronize certain sensor control signals. Also in the Sensor Control section is a 10-bit A/D converter which samples calibration signals from the PMT and the Thermal detectors. This calibration is done during the overscan region so as not to interfere with normal video. The processor inputs the values and outputs them to the formatter memory for insertion into the SDF and SDS data streams.

Encoder Processing - The encoder processing circuitry determines when the scanner motion is up to full amplitude and then begins using the encoder outputs to sample and format data. The encoder outputs consist of three signals that provide OLS line of sight information. They are: Delphi - pulses of equal increments of angle throughout the scan; Nadir - a pulse at the middle of scan; and Control Track - a group of pulses that provide information on scanner amplitude and direction.

Since the Delphi detection electronics on the actual scanner is not redundant, a precision encoder simulator has been incorporated in the digital hardware. This simulator can operate in a "locked" mode, where it receives the Nadir and Control Track pulses (which are redundant) from the actual scanner. A synthetic Delphi track is generated by reading delay values from a read only memory. In this way, usable video can continue to be taken in the event of loss of the Delphi generation circuitry. Frequency and position correction is done by the processor in order to make this synthetic Delphi track match the actual scanner motion as closely as possible. Position correction may be optimized by using ground commands to uplink appropriate values in two locations of the operational constants memory.

A "free run" mode of the encoder simulator is also available for use when the scanner is not moving. This mode is entered due to detected lack of scanner motion, or by ground command if the scanner is in motion. This mode provides simulated Delphi, Nadir and Control Track pulses which represent nominal scanner motion. The formatters are then able to provide proper line structure for the output data streams. Video has no meaning, of course, without a scanner, but stored telemetry and mission sensor data can be processed normally on the ground.

Wow/Flutter Processing - The function of the wow/flutter clock generator is to process the center detected Delphi pulse train from the encoder and generate a clock whose frequency varies from the nominal 512 KHz as a direct function of the amount the actual scanner motion deviates from the reference scanner motion. The reference scanner motion is defined to be a sine wave of amplitude 57.85 degrees, frequency 5.94 Hz, and offset zero degrees. This wow/flutter clock is then divided down to frequencies appropriate for SDF video data sampling, SDS video data sampling, and RTD wow/flutter data to enable ground correction. The basic mechanization is that of an oscillator whose frequency is corrected in a feedback control loop which periodically compares the oscillator output count since beginning of scan to that required by the reference scanner motion at that point in scan.

Output Data Multiplexer - The Output Data Multiplexer (ODM) performs the data management function in the OLS. The ODM controls the data, clocks, gap sync and controls sent to the four Digital Tape Recorders during a record mode. The SDF or SDS digital formatted data are selected by uplink or stored command, rate-changed to provide a gap for tape recorder synchronization codes, and gated to one of four tape recorders selected by command. The SDF or SDS digital formatted data from the playback of one of four tape recorders are gated to one of four data channels (three of which have operational use), encrypted or sent plain text, and gated to one of four independent data transmitters (three of which have operational use). The tape recorder, data channel, encrypter mode and data transmitter selections are in response to uplink or stored command. The RTD formatted data from the Data Processing function is gated to one of four data channels, encrypted or sent plain text, and gated to one of four data transmitters. The channel selected, encrypter mode selection, and data transmitter selection are in response to uplink or stored command.

FORMATTERS

There are three primary data formatters in the OLS: Real Time Data (RTD), Stored Data Fine (SDF) and Stored Data Smooth (SDS). Each formatter provides digitized video data as well as line and frame synchronization codes. Other types of data are also included. Real Time Data is transmitted directly to the ground, while the Stored Data streams are recorded for later playback. The Special (Mission) Sensor Processing (SSP) function is treated as a fourth formatter even though its output data is incorporated into the RTD and SDS data streams.

Processor Interface - Formatter mode control and some of the formatter data are provided by the processors. The processor information is available in both I/Os if they are both powered. The Interface Select (IFSEL) signal determines which I/O actually provides output words to the Formatter Buses and which I/O provides the input flags from the formatters to the processor. Based on uplink or stored commands, the processor selects which video source and formatters are selected, which set of encoder information is used, which clock source drives the formatters, and which modes the formatters use. The processor sends: 1) ancillary and stored telemetry data to the formatter memory for use in the SDF and SDS formatting; 2) direct mode data messages to the RTD formatter; 3) offset information to a register in the formatter which is used in the RTD, SDS, and SDF formatters; 4) mode and type information to the SSP formatter and format information to the SSP memory based on the information in the uplink memory; and 5) mission sensor power enables and serial commands to the SSP hardware based on real time or stored commands.

Formatter Memory - The Formatter Memory consists of a 4-K word by 18-bit Core memory and associated access logic. This word length is needed for holding the SDS video data (8 bits of L data and 10 bits of T data) in a single memory location. There is a Formatter Memory with its associated controls in each formatter section (G and H). Whenever a formatter section is powered, its formatter memory is available. The SSP memory is a separate unit.

Real Time Data (RTD) Processing

The RTD processing function selects the desired analog inputs for the fine and smoothed portions of the RTD transmission, samples the analog values at the proper fixed clock rate, digitizes the sampled values, formats the samples into a frame format and formats the frames into a line format.

RTD Line and Frame Structure - The RTD line is made up of Video, Blank, Line Sync and Subsync Frames. The RTD Line Sync, Subsync and Blank Frames are used to provide synchronization and fillers outside the region of active video data. In the overscan period, all zeros are transferred into the Data Memories until Line Sync is detected prior to the beginning of active data. The frame bit count at which line sync occurred is stored in a hold register for transfer in the next frame. The next frame after line sync contains an alarm code followed by the line sync count and in the frame after that, the samples of video begin. Video Frames cease to be formatted beginning with the frame following the detection of the End of Active Data line sync. That frame is the RTD Subsync Frame, which is used by the ground deformatter to locate the line sync reference pulse on alternate scan lines. This enables one direction line scans in the ground equipment although the data was collected in alternate directions. As before, the frame bit count at which line sync occurred is stored for transmission in the RTD subsync frame. RTD blank frames are used to fill the interval between the RTD Subsync Frame and the next RTD Line Sync Frame which begins another line format. The RTD frame is 150 bits long and is subdivided into eighteen words. The frame format is repetitive and is output at a bit rate of 1.024 MHz. The RTD Video Frame is organized with word 1 as a frame sync to maintain proper synchronization at the decoder. Word 2 through 16 are video data with 6 bits of Fine and 2 bits of Smooth. Word 17 contains the wow/flutter count as it occurred in the previous frame and word 18 contains Teradaps data.

RTD Video Sampling - A processor output bit selects either LS and TF or TS and LF data mode in response to a stored or real time command. Video sampling begins at the line sync pulse entering the active scan and ends at line sync leaving active scan. The Fine video is sampled at a 102.4 KHz fixed rate, and converted to a 6-bit digital value using a successive approximation A/D converter. One smooth sample value corresponds to five fine samples in the along-scan direction. Thus, the smooth video is sampled at a 20.40 kHz fixed rate, held, and converted to a 8-bit digital value using a similar A/D. It should be noted that no along-track smoothing of RTD smooth video is done within the OLS.

RTD Ancillary Data - The Teradaps bits of every frame consist of either Direct Mode Data Message (DMDM), Mission Sensor data, or a fixed "No Data" code. The DMDM data is obtained from the processor and appears in the Line Sync Frame. Mission Sensor data is obtained as needed from the active SSP unit and appears in the Subsync Frame and the Blank Frames.

Stored Data Fine (SDF) Processing

The SDF processing function accepts both LF and TF analog inputs, samples the analog values at the proper wow/flutter clock rate, digitizes the sampled values, holds the data in elastic buffers for correct timing, formats the samples into TF and LF frame formats and formats the frames into line formats. The SDF processing consists of two parallel identical processors - one each for LF and TF - whose outputs may be interleaved.

SDF Line and Frame Structure - The SDF line is made up of Video, Blank, Line Sync and Subsync Frames. The SDF Line Sync, Subsync and Blank Frames are used to provide synchronization, ancillary data and fillers outside the region of active video data. The SDF video frame format is 208 bits long and is subdivided into 33 words. This frame is repetitive and is output at a bit rate of 665.6 kHz.

SDF Video Sampling - The fine video (both L and T) is sampled at a "Wow/Flutter divided by 5" rate (nominally 102.4 kHz). The first sample occurs at a point which is time-corrected to make it line up with the actual 996th delphi pulse (Start of Active Data), thus correcting for differential delays of video and encoder information. Parallel 6-bit successive approximation A/D converters are used for L and T video, and the 6-bit samples are loaded alternately into holding registers to reduce the speed of data through the elastic buffers. This continues until 7322 samples have been digitized, which coincides with End of Active Data. Elastic buffers, each 12 bits wide and 256 bits long, are required because the A-to-D converters provide data at a non-uniform wow/flutter clock rate, while the SDF Formatter requires data at a fixed clock rate. The buffers start out empty at the beginning of scan and they are allowed to accumulate 128 loads (256 video samples) before the formatter begins to output data. Inputs then continue simultaneously until End of Active Data when the inputs are cut off and the formatter empties the buffers.

SDF Ancillary Data - SDF has its own access to a fixed area of the Formatter Memory which contains ancillary data. The ancillary data includes present L channel and T channel gain states, PMT and T channel calibration values, vehicle I.D. and Location Data. Scanner offset information is output by the processor. Elapsed time data is read from the Elapsed Time Clock.

Stored Data Smooth (SDS) Processing

The SDS processing function accepts both LS and TS analog inputs, samples the analog values at the proper wow/flutter clock rate, digitizes the sampled values, averages the sampled values along track for five scan lines, formats the averaged samples into LS and TS frame formats and formats the frames into LS and TS line formats. The SDS processing consists of a time-shared A/D converter followed by two parallel identical processors, one each for TS and LS, whose outputs are interleaved.

SDS Line and Frame Structure - The SDS line is made up of Video, Blank, Line Sync, Subsync, Stored Telemetry, SSP and Telemetry/SSP Frames. The SDS Line Sync, Subsync and Blank Frames are used to provide synchronization, ancillary data, and fillers outside the region of active video data. The SDS Video Frame format is 208 bits long and is subdivided into 28 words. This frame is repetitive and is output at a bit rate of 33.28 kHz. The various components of the L and T data streams are gated together and the resulting 33.28 kHz data streams are interleaved to give a 66.56 kHz bit rate. SDS Video Frame is organized with words 1 through 27 containing 7 bits of smoothed video data. Word 27 contains mode tag bits and Mission Sensor data while word 28 contains a frame sync. Each even bit in the 7-bit video data word is complemented. The T video word contains the 7 MSB's of the 8-bit T value. The L video word contains the 6-bit L value plus the LSB of the T value.

SDS Video Sampling - The Smooth video (8 kHz bandwidth, both L and T) is sampled at a "wow/flutter divided by 25" rate (nominally 20.48 kHz). The position of the first sample is corrected in a fashion similar to that described for SDF. A single 8-bit successive approximation A/D converter is used to sample L and T video alternately. This process continues until 1465 samples have been digitized, which coincides with End of Active Data. Thus, video samples at the SDS A/D converter provide a nominal 1.5 nm resolution along scan by 0.3 nm along track. Five scan lines are digitally averaged so that the SDS video values in the downlinked data become 1.5 nm along track.

SDS Ancillary Data - The SDS Format contains ancillary data (as described in the SDF section), Elapsed Time data and Scanner OFFSET data. In addition, the SDS LS and TS data streams also contain Mission Sensor data which is extracted from the Mission Sensor Data Memory. The spacecraft equipment status telemetry subsystem multiplexes and formats analog and discrete information from all satellite subsystems. In addition, certain software information from both the spacecraft CPU's and the OLS CPU's are monitored because of their unique information. The orbit mode telemetry (2K-bit data) is formatted with the SDS LS data for subsequent transmission to ground terminals. This feature allows the ground command and control function to have knowledge of satellite status on a continuous basis.

Special (Mission) Sensor Processing (SSP)

The OLS, with its processing subsystem, is the data manager for up to twelve Mission Sensors carried on board the satellite as part of the payload package. The OLS data processor interrogates these sensors and formats their data into the primary data bit stream for either recorded storage (SDS) or real time transmission (RTD).

The Special Sensor Processing section consists of a 1024 word by 16-bit RAM memory, Mission Sensor control circuitry, and circuitry for inserting Mission Sensor data into RTD and SDS data streams. The CMOS Random Access memory used for Mission Sensor processing is divided into two identical 512 word by 16-bit halves. One half is used for sensor control and inputting of SSP data while the other half is being read out by the formatters. The functions of the two halves are swapped once per second. There is priority logic to order the various memory accesses which are taking place independently and simultaneously.

When a mode requiring SSP data (e.g., RTD or SDS) is turned on, the processor outputs four words of sync code, two words of Elapsed Time Count (ETC) and 12 words of Mission Sensor Formats to each half of SSP memory. This information is used to control the Mission Sensor interrogation for that second, and then appears at the beginning of the SSP data stream to the formatters in the following second, followed by the Mission Sensor data. The processor outputs ETC and a "start" bit every second to control the swapping of the SSP memory halves. The SDS L data format contains 18, 16-bit header words and at least 50 36-bit data words. The SDS T data format contains 18 16-bit header words and at least 98 36-bit data words. The RTD data format contains 18 16-bit header words and at least 139 36-bit data words.

DATA STORAGE AND SECURITY

Data Storage - The Data Storage function is implemented by four identical digital tape recorders each with their associated control, record, playback and data buffering electronics. Each of the four recorders can record serial digital data at any one of the three data rates and playback the data at either one of two data rates. Data played back from a recorder is a serial bit stream, synchronized with the proper frequency clock. Each tape recorder can record a digital data bit stream of 66.56 kbps (400 minutes capacity), 665.6 kbps (40 min.) or 1331 kbps (20 min.) and reproduce this data at a rate of 1331 kbps (20 min.) or 2662 kbps (10 min.). Total storage capacity per recorder is 1.67×10^9 bits.

Data Security - The Data Security function provides cryptographic security for RTD or stored data transmissions from the spacecraft to the ground. The plain text of the data streams is input under control of the Output Data Multiplexer to one of three encrypters (BBT's) which enciphers the data and outputs a data stream of encrypted data to the OSU.

5D-2 OLS FUNCTIONAL SYSTEM

The primary objective of the 5D-2 OLS development was to increase on-orbit life through improved reliability. The 5D-2 OLS design for reliability improvement is based on "functional module redundancy". The OLS is subdivided into primary and redundant functional modules which are independently selectable. This approach allows selection of functioning units until both modules of a required function have failed.

The OLS contains functional module redundancy in all power and data handling systems as shown in Figure 1. The operational system configuration which determines which functional blocks are "on-line" is controllable from ground commands or from a stored program in the on-board memory.

Redundant functional modules include:

Power Supply - switching between two independent supplies is provided.

L Channel - redundant analog signal processing.

T Channel - redundant analog signal processing.

Scan Monitor - redundant encoder control track generation.

Motor Drive Circuitry - redundant Drive Motor Electronics (DME) independent of the processor.

Processor - dual processors where each processor can handle the entire data processing function.

Memory - redundant memories where either memory may be accessed by either processor.

I/O Interface - redundant I/O control, S/C interface, sensor control, gain control, encoder and wow/flutter processing, output data multiplex and formatter controls where any functional block of either I/O may be placed on line.

Formatters - dual formatter memories, RTD formatters, SDF formatters and SDS formatters and SSP processors where each block can be connected independently.

Output Switching Unit - dual oscillator and clock circuitry.

In addition to full redundant modes, there are fallback modes which result in slightly degraded performance. The modes are:

IMC Shut-Off - The elimination of IMC in the event of failure in the IMC drive.

Encoder Simulator - The digital generation of the encoder delphi clock from encoder control track signal. The control track is redundant but the encoder delphi clock generation is not. The digital generation of the delphi clock is redundant.

T Channel - Use of a single detector segment, preamp and postamp (left or right) across scan in the event of a failure.

HRD Backup - Use of a back-up HRD postamplifier to be used only with the "C" detector segment across scan. This fallback mode covers the eventuality of an A or B detector segment or primary postamplifier failure.

OLS PHYSICAL DESCRIPTION

The OLS consists of fourteen components, all shown interconnected in Figure 2 except for the GSSA/DOC. Figure 3 is a photograph of most of these components. The GSSA/DOC, BB's and CHA are not shown and the SSS is shown without thermal blankets. The GSSA/DOC mounts on the SSS which mounts on the spacecraft Precision Mounting Platform (PMP). The rest of the OLS components mount on the internal panels of the spacecraft Equipment Support Module (ESM). The complete system has a mass of less than 300 pounds. The power dissipation can range from 111 watts to a maximum of 268 watts depending on the OLS configuration and mode of operation.

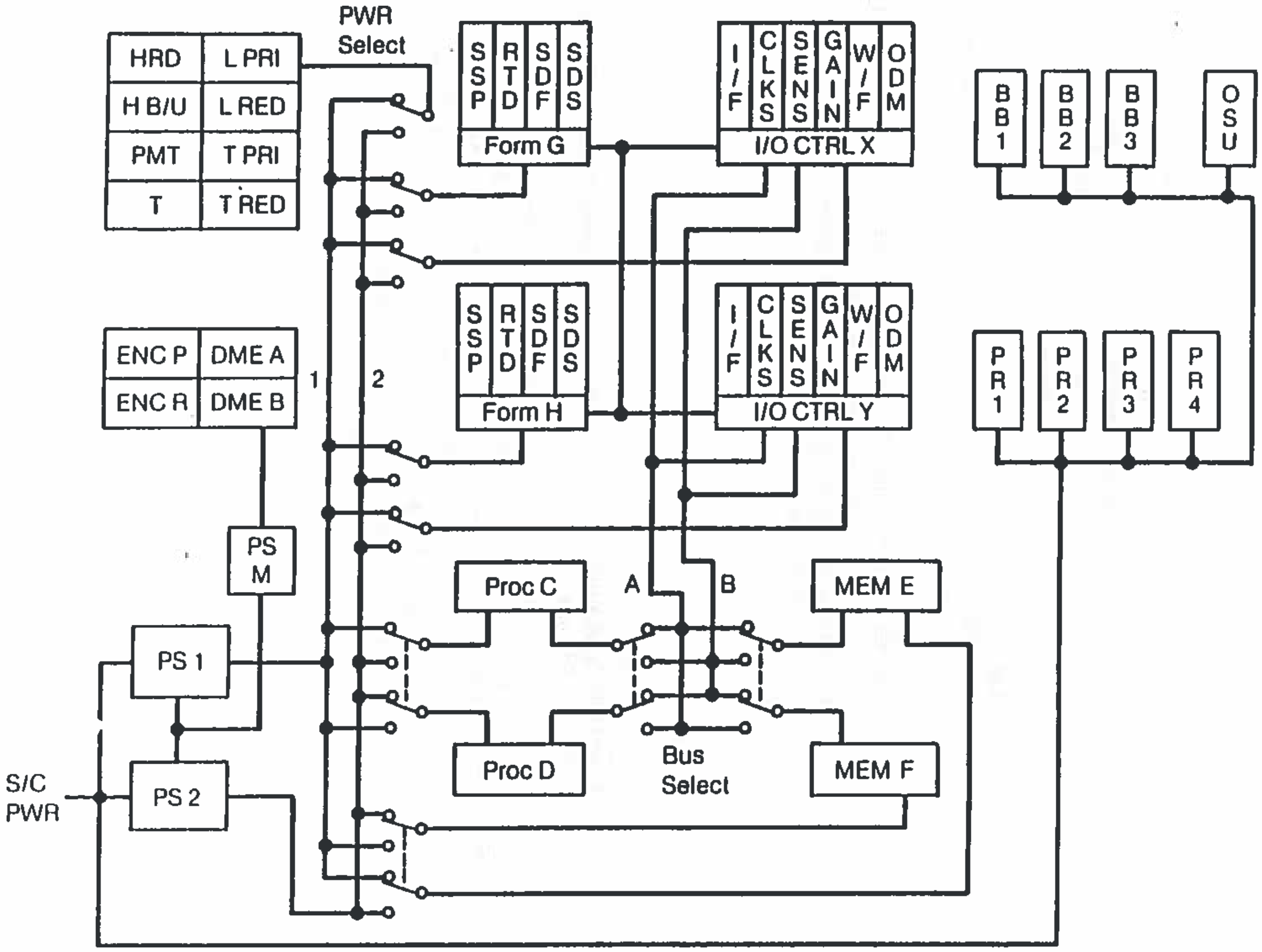

Figure 1 - OLS 5D2 SYSTEM CONFIGURATION DIAGRAM

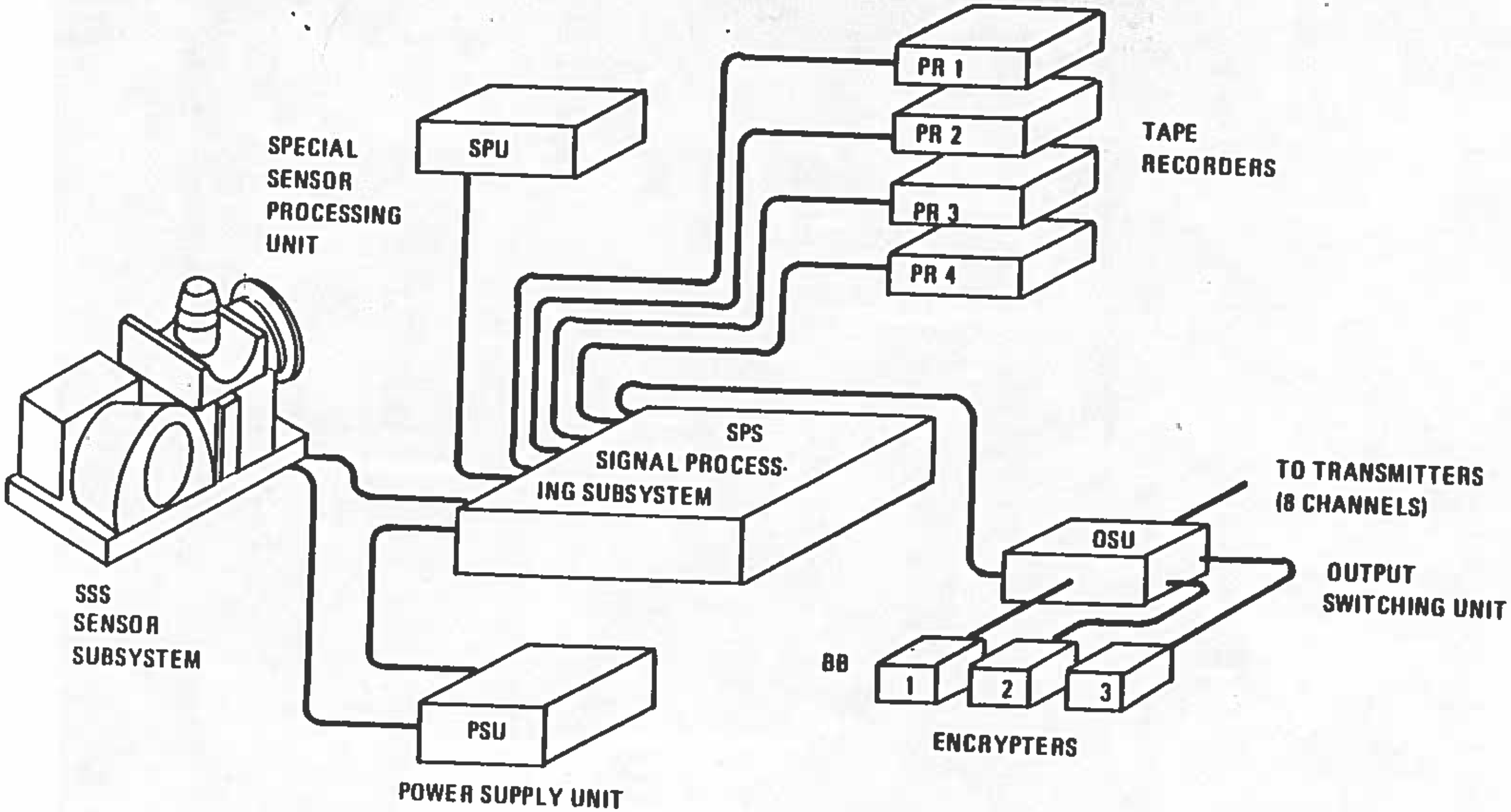

Figure 2 - 5D2 OLS SYSTEM EQUIPMENTS

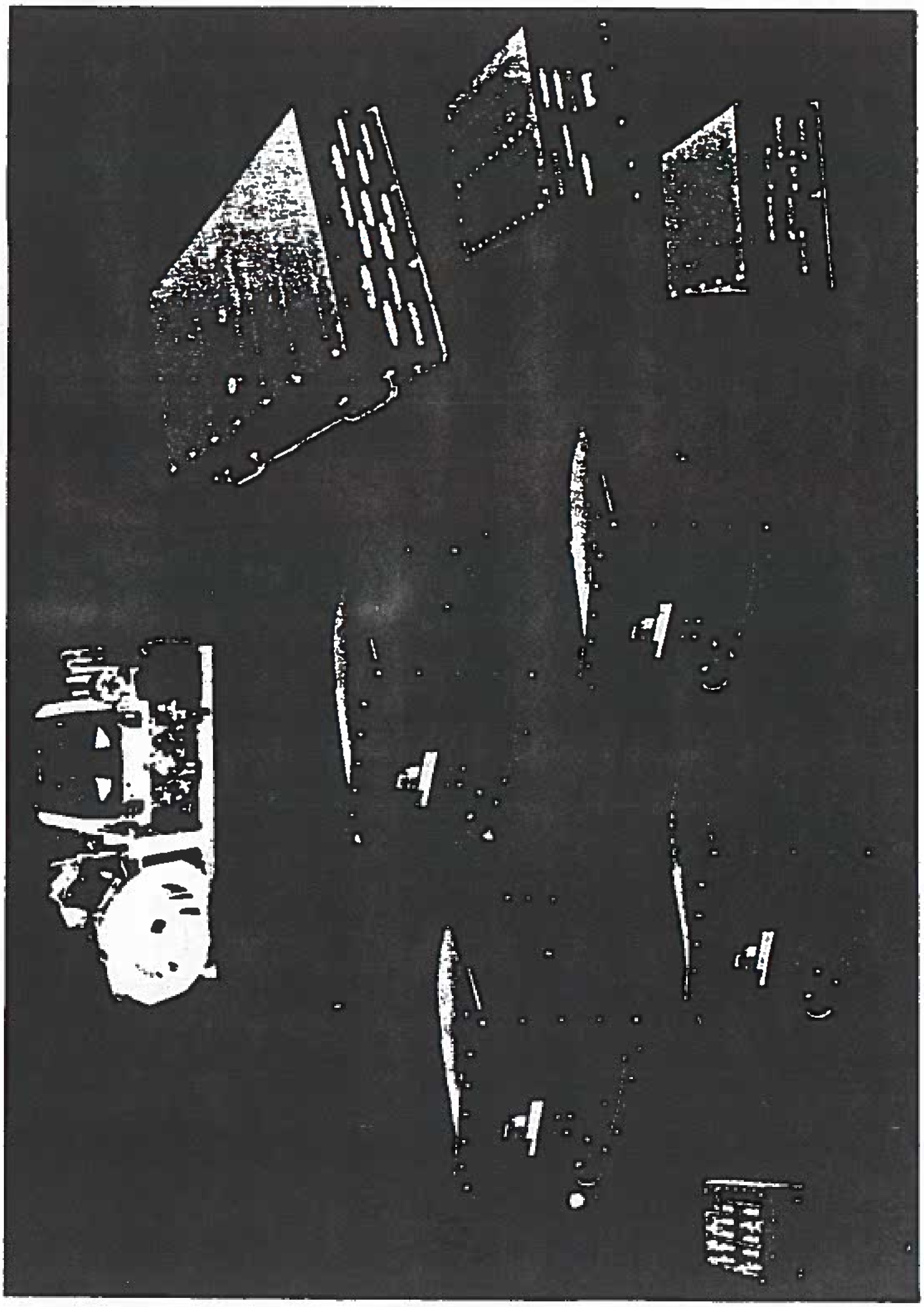

Figure 3 - 5D2 OLS SYSTEM