ATTACHMENT 3

IMAGING SATELLITE SEGMENT FUNCTIONAL REQUIREMENTS

1.0 INTRODUCTION

The purpose of this document is to define the functional requirements of the Imaging Satellite (I/S) segment and subsystems for use in conducting Phase I System Definition studies. In the event of differences between I/S Segment Functional Requirements and the System Functional Requirements (Attachment 1), the latter shall take precedence.

The I/S segment shall consist of [redacted] deployed in near sun-synchronous low altitude orbits, and shall be designed to operate in circular or elliptical orbits from about 180 to 420 n. mi. [redacted] I/S shall provide for the acquisition and near-real-time return of image data by combining large diameter optics and solid state photosensitive detectors with the necessary subsystems to process and transmit this data. Launch shall be from WTR using a Titan IIID booster and either a kickstage or integral propulsion as required to achieve the desired orbit. The I/S shall provide propulsive capability to maintain the initial orbit and shall also

provide for controlled deorbit of a maximum dry-weight satellite at the end of useful life as required.

2.0 SEGMENT FUNCTIONAL REQUIREMENTS

The I/S segment shall provide the necessary capabilities to satisfy the requirements specified in Attachment 1 and provide the following specific functions:

o Utilize an optical subsystem to image pre-selected ground scenes on a solid-state photosensitive detector assembly (Transducer).

o Utilize the transducer to provide data in the form of an electrical signal which is representative of the imaged scene.

o Provide signal processing to convert the electrical signal into a digital stream at a rate that is compatible with the EOI System communications capability and in a format which allows subsequent ground reconstruction of the image.

o Provide a temporary storage and playback capability for the image data as required.

o Provide a communications capability to perform the following functions:

a) Transmit digital image data to the Receiving Facility (R/F) via the Relay Satellite (R/S) at a selected frequency in the [redacted]

b) Receive I/S commands and range signals from the R/F via the R/S on a selected frequency in the [redacted] or directly from the R/F on a selected frequency in [redacted]

c) Transmit I/S telemetry data and range signals to the R/F via the R/S on selected frequencies in the [redacted]

d) Transmit I/S telemetry data directly to the R/F in the [redacted]

e) Receive I/S commands and range/range rate signals directly to the R/F or designated SGLS-compatible ground stations of the O/F net on a selected frequency in the S band.

f) Transmit I/S telemetry data and range/range rate signals directly to the R/F or designated SGLS-compatible ground stations of the O/F net on a selected frequency in the S band.

g) All command, range, range rate and telemetry signals shall be SGLS compatible.

o Provide a command and control capability to perform the following functions:

a) Execute all I/S program commands (both real time and stored) according to preassigned time labels.

b) Verify all commands.

c) Perform digital computations to generate command sequences.

d) Distribute generated commands at the the required solution rates.

e) Verify the command status of I/S subsystems for ground control operational information.

o Provide the capability during the imaging period to point the optical line of sight at preselected target coordinates in response to ground determined requirements.

o Provide the capability to rate stabilize the image at the image plane for specified scan rates in three axes.

o Stabilize the attitude and control the orientation of the I/S during non-imaging periods in response to ground determined operational requirements.

o Provide attitude reference and timing data for image evaluation and utilization.

o Provide thermal control to maintain the I/S subsystems at required bulk temperatures and temperature gradients during the pre-launch phase (with the aid of ground air conditioning) and throughout the launch, ascent, and orbital phases of the mission.

o Provide equipment mounting, enclosures and handling points to protect the I/S during ground handling, launch, ascent and orbital phases to assure that the I/S requirements are met.

o Provide access to equipments located in the structure for test and replacement.

o Provide the necessary stiffness and mass distribution in the launch and ascent configuration.

o Provide I/S-to-booster adapter and/or I/S-to-kick-stage adapter separation mechanisms.

o Provide deployment means and supporting structure for the thermal control, electrical power, and communications subsystems.

o Provide required sensor view ports and covers.

o Provide required power needs for launch, ascent and orbital operations; distribute the electrical power and electrical signals as required by I/S equipment and assure the electro-magnetic compatibility of the I/S during prelaunch, launch, ascent and orbital phases.

o Provide the capability to change the orbital velocity vector in response to ground determined operational requirements and provide a source of torque to change the angular momentum state of the I/S.

o Satisfy all the boundary conditions as determined by the interface specifications with other elements of the EOI System.

o Provide the capability to deboost the I/S to ocean impact on command as applicable.

3.0 SUBSYSTEM FUNCTIONAL REQUIREMENTS

The functional requirements for each of the I/S subsystems are identified in this section. It is intended that these requirements should establish certain guidelines for the expected performance of each functional subsystem for definition and design activities.

3.1 Optical Subsystem

The Optical Subsystem (OS) shall consist of a large

[redacted] and required [redacted] to collect and focus the radiant energy from a target scene on the transducer. The OS shall have the following characteristics:

[redacted]

o Provisions for illuminating the transducer for calibration purposes upon activation by ground command.

o Provision shall be included to adjust the optical system alignment [redacted] An optical system alignment sensor shall be included to provide telemetry information regarding element positions.

o Provision to adjust the optical focus.

3.2 Transducer/Data Processor Subsystem

The Transducer/Data Processor Subsystem (TDPS) is composed of photosensitive detectors which measure the incident illumination focused upon it by the optical subsystem, and integrated electronics required for processing the image data.

The transducer will be composed of [redacted] arrays of photosensitive detectors.

The image data processor is integrated with the transducer and translates the output signal of each detector into a coded digital representation for transmission or storage by the Communications Subsystem (CS). The analog signal of each detector sample shall be converted to digital form. The digital data shall be compressed to be compatible with the CS and with the image quality requirements. The encoded output of each detector in an array shall be combined into a serial data stream which is multiplexed with the output of the other transducer arrays. Output from each single array of detectors (one image line) will be combined with digital data which provides for line identification, line synchronization and line position in the frame. The combined data stream shall not exceed an information bit rate of [redacted] Mbps.

3.3 Communications Subsystem

The Communications Subsystem (CS) shall provide all functions associated with the transmission or receipt of signals between the I/S and the R/S, R/F and any alternate

ground stations. The subsystem shall also provide for necessary on-orbit storage and readout of image and non-image data. Encryption and decryption will be provided by the Command/Control Subsystem (C/CS).

3.3.1 Internal I/S Interfaces

The CS shall provide the following interfaces internal to the I/S:

o Accept image data from the TDPS or recorder(s) for transmission.

o Accept telemetry data from the C/CS and analog telemetry signals as necessary to monitor powered flight vibrations or [redacted] vibration performance during selected portions of the mission.

o Accept power and mode switching and antenna pointing commands from the C/CS, and provide status of all auto-track loops.

3.3.2 External I/S Interfaces

The CS shall interface with the RS and provide the following interfaces external to the I/S:

o Communicate with the R/S segment on [redacted] utilizing one or more antennas.

o Provide the ability to acquire, lock onto and communicate with the R/S, the R/F, or an alternate ground station. (Alternate ground stations will be utilized only for TT&C and only on S band.)

o Provide for a total image transmission time of up to a maximum of four hours per day.

o Provide the capability to receive commands and ranging via S band at all times after I/S launch in the event of communications failure on the primary TT&C links [redacted]

3.3.3 Signal Characteristics

Signal characteristics and nomenclature for the various system communications links shall be in accordance with Attachment 5. (Note: all frequencies shown are nominal; no formal allocation has been made.) Stability of the transmitted [redacted] band signals shall be better than one part in 10^9 per second and 5 parts in 10^7 over 24 hours, exclusive of Doppler corrections. Total frequency drift over an I/S lifetime shall not exceed [redacted] and [redacted]

3.3.4 Modulation

Modulation of [redacted] band signals shall be [redacted] for Configuration A. Modulation of image data for Configuration B is (TBD). Baseband structures for all TT&C services shall be in accordance with SGLS practices regardless of the radio frequency being used.

3.3.5 Doppler Corrections

Appropriate Doppler corrections shall be provided on all transmitted and received [redacted] signals. Prior to link lock-on, the necessary frequency shift commands will be provided by the C/CS.

3.3.6 Jamming

The command receivers of Links L4 and L8 (Attachment 5) shall provide protection against a [redacted] located anywhere on the surface of the earth. The auto-track receivers of link L4 shall be capable [redacted] [redacted] located anywhere outside of CONUS.

3.3.7 Ranging

Ranging data shall be transmitted to the I/S over links L4, L6 and L8 (one at a time) using a 1 Mbps pseudo-random noise (PRN) code. Range measurement shall be limited to a single spacecraft at any one time. A signal from the C/CS will determine whether the I/S must respond to the incoming range signal. No other return ranging signal shall be provided.

3.3.8 Acquisition and Tracking

Upon command from the C/CS the I/S shall activate its telemetry carrier and point its broad beam antenna at the predicted position of the R/F or the R/S. The R/F or R/S shall then be commanded to execute a search plan. When an adequate signal is received, the search shall be stopped and the R/F or R/S receiver shifted to the narrow beam antenna. The link will be locked up and auto-tracking will commence. The command channel beacon of the R/F or R/S shall then be turned on and the broad beam antenna on the I/S shall execute a programmed search

mode under control of its C/CS. When an adequate signal is received, the I/S shall stop the search, shift to its narrow beam antenna lockup, and commence auto-tracking on the R/F or R/S. At that time full wideband data and TT&C services for the I/S between an R/S or the R/F will be available.

Until commanded otherwise, the I/S shall remain locked to the R/S or R/F on both the command and telemetry links for the entire time they are in view of each other, whether or not wideband data is being transmitted. Loss of lock shall initiate automatic re-acquisition under control of the C/CS. Acquisition lockup and auto-track operation between the I/S and any other segment shall be accomplished within 30 seconds with a 0.95 probability commencing at turn-on of the R/F or R/S command channel beacon.

3.3.9 Data Storage

The CS shall include digital tape recorders as required for the temporary storage of the image data. A capacity for at least 80 frames shall be provided. A [redacted] rate shall be used for both the data recording and playback.

3.4 Attitude Control Subsystem

The Attitude Control Subsystem (ACS) is required

[redacted] which will be supplied as functions of time as generated by the C/CS. The commands will be shaped so as to control the resulting structural excitation within acceptable limits. The ACS is to function as a command follower, in response to the commands from the C/CS. The capability is required to provide a high-rate slew, during which accuracy is not a primary consideration, and also a precise tracking of ground targets.

The local-vertical coordinate system shall be right-handed and defined by the following unit vectors:

$\hat{x} = \hat{y} \times \hat{z}$ (forward)

$\hat{y}$ = along the negative orbit angular momentum vector (to the right)

$\hat{z}$ = down along the geocentric vertical

The vehicle body-fixed axes ($\hat{x}_b$, $\hat{y}_b$, $\hat{z}_b$) are defined to be coincident with the corresponding local-vertical axes when the vehicle is in nominal orientation (pointing down).

Thus, the $\hat{z}_b$ axis is along the optical axis; the $\hat{y}_b$ axis is along the rows of detector arrays, positive to the right, and the $\hat{x}_b$ axis is forward.

The vehicle attitude is defined relative to the local-vertical coordinate system by the following ordered sequence of right-handed rotations, starting with the vehicle axes aligned with the local-vertical axes:

a) ϕ -- Roll angle, about $\hat{x}_b$, positive left

b) θ -- Pitch angle, about $\hat{y}_b$, positive up

c) Ψ --Yaw angle, about $\hat{z}_b$, positive clockwise

The ACS shall have the following functional characteristics:

o Operation

The ACS shall control the attitude of the I/S immediately upon injection into orbit utilizing a Propulsion/Reaction Control Subsystem (P/RCS). This mode shall have the capability to stabilize the I/S for up to three hours while the [redacted] capability is being established and also during the de-orbit phase as required. Sun-orientation of the solar array shall be accomplished within one hour after launch. The ACS shall control the attitude of the

I/S during non-imaging periods on-orbit utilizing [redacted] The P/RCS shall be used to compensate for angular momentum changes due to aerodynamic or other disturbances [redacted].

o On-Orbit Performance - The ACS shall cause the I/S to follow pre-programmed inertial maneuvers while in the non-imaging mode. The ACS shall cause the I/S to follow the commanded precision tracking maneuver while in the imaging mode.

o Slewing - The ACS shall follow commands which cause the vehicle to be slewed between targets which may lie anywhere within range of up to $\pm$ 50 deg on both roll and pitch angles. Slewing commands will be shaped to control the resulting structural excitation within the acceptable limits. There is no requirement on the accuracy with which the attitude control system must follow slew commands, except as determined by the settling-time.

o Orbit Adjust - The ACS shall control all three vehicle axes during firing of the orbit-adjust engine (if applicable).

o Mode Recovery Requirements - The ACS shall provide the capability to determine if primary attitude control of the I/S is lost and to signal the C/CS of this condition.

3.5 Command/Control Subsystem

The Command/Control Subsystem (C/CS) shall provide the computation, telemetry processing, timing and command capability required for all I/S operations from launch to mission completion. Incoming commands from the CS shall be decrypted and outgoing PCM telemetry shall be encrypted using GFE hardware. The subsystem shall be configured as an integrated data system using one or more (identical) processors and memory units and specialized input-output units inter-communicating on a data buss. Failure of any one major subsystem element (processor, memory, I/O unit, power supply, buss) in any way shall result in only degraded system performance. The functional requirements are as follows:

o The C/CS shall receive, check and process commands from the CS providing accept/reject information and execution verification

on PCM telemetry.

o The C/CS shall provide storage and proper delay execution of stored commands and execution of real-time commands to all I/S subsystems. Capability for at least 15 hours of stored program commands shall be provided.

o A time base shall be generated for all I/S functions both internal and external to the C/CS. Fundamental long-term stability shall be equal to or better than one part in 10^7.

o The C/CS shall accept analog, digital and discrete telemetry signals from all I/S subsystems and combine them into a single serial digital signal for transmission by the CS.

o The C/CS shall accept and provide analog, digital, discrete, and relay drive pulse inputs and outputs as required by the I/S subsystems.

o The C/CS shall receive, check and process numerical and reprogramming data for the I/S memory and processor elements from the CS.

o The C/CS shall perform arithmetic computations in support of health/status determinations, attitude determination and control; antenna slewing/searching, Doppler corrections, T/M processing/formatting, power system control, slant range compensation, [redacted] and image tape recorder searching. These computations shall include coordinate transformations, integrations, interpolations and extrapolations.

3.6 Propulsion/Reaction Control Subsystem

The Propulsion/Reaction Control Subsystem (P/RCS) shall provide means of mass expulsion to change the inertial velocity or attitude of the satellite. It will also be used for [redacted] by changing the angular momentum state of the satellite. The P/RCS shall have the following functional characteristics:

o Velocity Change - The P/RCS shall be capable of performing the following:

a) Orbit injection including trim from T-IIID launch vehicle with launch from WTR.

b) Aerodynamic Drag Makeup.

c) Altitude Change.

d) De-orbit.

Orbit injection and initial orbit trim may be provided by a separate kickstage independent of the I/S.

o Angular Impulse - The P/RCS shall provide the thrust to achieve initial stabilization after injection and for the de-orbit phase as required. Momentum exchange capability by the P/RCS shall be provided [redacted] for a limited period over the design life. The P/RCS shall provide thrust for attitude stabilization during orbit injection if no separate kickstate is used.

3.7 Thermal Control Subsystem

The Thermal Control Subsystem (TCS) shall maintain the required temperatures for all the I/S components in the presence of launch and orbital environments. The TCS shall have the following functional characteristics:

o Pre-Launch Phase - The TCS shall provide for acceptance of cooling air flow or other ground

conditioning as required by I/S components.

o Ascent and Initial Orbital Phase - The I/S shall be capable of withstanding the ascent heating thermal input and shall achieve the required operating temperatures at the times required by each subsystem.

o Orbital Requirements - The TCS shall utilize passive techniques. Electrical heating or mechanical devices shall be permitted where operational requirements dictate.

o Equipment - The TCS shall maintain the equipment mounting surfaces within their specified temperature range.

o Structure - The TCS shall provide thermal control of the structure to maintain optical subsystem and attitude reference alignments necessary to meet orbital tracking requirements.

3.8 Electrical Power Subsystem

The Electrical Power Subsystem (EPS) shall provide an array of solar cells, a storage capability of nickel-cadmium batteries and a control and distribution network adequate to

satisfy the electrical power needs of the I/S during its entire life for a range of orbital parameters. No single failure in the EPS shall result in loss of operational capability. The EPS shall have the following functional characteristics:

o Duty Cycles - The EPS shall be designed to satisfy the operational power requirements of the I/S without discharging the storage batteries more than once per orbit.

o Overload Capacity - The EPS shall be capable of supplying 150 percent of the maximum steady state power level on any buss for a period of 5 minutes or 150 percent of any pyrotechnic device load for 50 milliseconds without degradation of performance after removal of the overload.

o External Power - The EPS shall have the capability to accept electrical energy from an external source during ground test operations of the I/S. Capability to recharge batteries from ground power shall be provided.

o Grounding - The EPS shall use a unipoint ground.

o Protection - Power system protection devices, if used, shall achieve a net increase in probability of performing the specified mission. Protection methods shall not create a safety hazard during any portion of the ground test cycle.

3.9 De-Orbit Subsystem

The De-Orbit Subsystem (DOS) shall provide the capability, as applicable, to establish and control the attitude of the I/S in a predetermined manner using ground controlled commands and provide a means to deboost the I/S after the occurrence of any one of the following events but only by decision issued from the Operations Facility:

a) Loss of primary electrical power

b) Loss of primary command reception

c) Loss of primary control capability

The DOS shall have the following functional characteristics:

o Command Data Reception Requirements - The DOS shall provide command data reception capability throughout the life of the satellite.

Security against unauthorized commands shall be provided.

o Attitude Control Requirements - The DOS shall provide the capability to align the axis of the I/S de-orbit engine along the required vector. The capability for stable attitude control of the satellite shall be provided for a duration of 72 hours after DOS enabling.

o Attitude Recover Requirements - The DOS shall provide the capability to establish control from a random tumbling condition.

o De-Orbit Velocity Impulse Requirements - The DOS shall be capable of changing the I/S velocity by an amount required for broad ocean impact.

o Electrical Power Requirements - The DOS shall provide the required power and distribution network to satisfy the direct current electrical power needs of the elements of the DOS for a period of three days to allow time for malfunction correction, work around methods and decision to de-orbit.

3.10 Structure and Mechanisms Subsystem

The Structures and Mechanisms Subsystem (SMS) shall be designed to withstand non-flight loads (handling, erection and hoisting) and flight loads (launch, ascent and injection). The structure will adequately dampen shock loads due to pyrotechnic device operation. Orbital structural vibrations and motions due to propellant slosh, when coupled with the ACS dynamics, shall be such that motion of the line of sight does not exceed precision tracking requirements. The SMS shall have the following functional characteristics:

- o Non-Flight Loads
  - a) The I/S shall be designed for a limit load of 1.5 g during handling and erection.
  - b) The I/S hoist fittings shall be designed with a safety factor of four.
- o Flight Loads
  - a) Sensitive subsystem components shall be supported by structure that will sufficiently dampen pyrotechnic produced

shock loads to assure that equipment will operate as specified.

b) The structures and mechanisms shall be designed to meet the launch, ascent, injection and operational limit load requirements.

c) The design ultimate load shall be 1.25 times the limit load.

o Launch Dynamic Requirements

a) The I/S launch configuration mass distribution c.g. location, and natural frequencies shall be compatible with the launch vehicle flight control capability.

b) The structural configuration shall constrain launch and ascent dynamic excursions such that no part of the I/S encroaches upon the dynamic envelope of the booster payload shroud.

o Mechanical Deployment Requirements - The SMS shall provide for the deployment of the solar array extended panels (if required), the communication

antennas, and all other deployable appendages, on command. The deployment scheme shall be designed such that no single failure will result in a reduction of image quality.

o Antenna Gimbal and Stops - The SMS shall provide for the gimbals as required by the antenna configuration. Stops shall be provided to engage immediately outside of the free gimbal range and stop the antenna traveling at maximum slew rate without structural damage.

o Sun Shield - The structure shall provide a sun shield as required for the Optical Subsystem.

o Optical Subsystem Cover - The structure shall provide a protective cover for the Optical Subsystem entrance aperture. This may be ejected after orbital insertion or operated by command for imaging sequences if the reliability of successful operation is adequate for the mission.

o View Ports - The structural configuration will provide the required field of view for optical equipment such as sun and star sensors.