SeaStar™ (OrbView-2) Flight Operations and Data Delivery

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Abstract. SeaStar is the result of a ground-breaking arrangement between Orbital Sciences Corporation and NASA, in which the U.S. Government is procuring space-based environmental remote sensing data for research purposes from a commercial operator. The SeaStar system incorporates the Sea-viewing Wide Field-of-view Sensor (SeaWiFS), a visible to near-infrared, multi-spectral scanning radiometer developed by the Hughes Santa Barbara Research Center (SBRC). The ocean color data provided by this mission supports more efficient and profitable environmental monitoring and marine industries.

The data purchase arrangement with NASA results in a unique mission operations scenario. Orbital is responsible for conducting full mission operations and maintaining the health of the spacecraft. The NASA Goddard Space Flight Center (GSFC) SeaWiFS project office provides daily command files to Orbital to control SeaWiFS instrument operations, perform data recorder memory allocation, and ensure stored data transmission to NASA ground stations. Orbital adds tasking to fulfill commercial data customer requirements. Extensive use of autonomous operations capability further reduces labor requirements and mission cost over the 5-10 year lifetime.

The SeaStar spacecraft was successfully launched by a Pegasus™ XL rocket on 1 August 1997. After a short orbit-raising and initialization period, the ORBIMAGE® mission team will begin nominal operations and data delivery to NASA researchers and ORBIMAGE commercial customers.

Introduction

The purpose of the SeaStar mission is to provide a minimum of five years of ocean color data to NASA and commercial customers. In a unique contractual arrangement, NASA placed a contract with Orbital for a data buy versus the traditional spacecraft/booster/ground station acquisition. The contract also allows Orbital to market the data commercially to a variety of customers worldwide. Thus, ownership of the spacecraft and responsibility for successful data delivery remains with Orbital rather than transferring to NASA after launch. NASA, however, as the anchor data customer, plays a key role in ongoing mission operations. The NASA GSFC SeaWiFS Project Office provides expertise in science data, instrument operations, and mission planning, and is responsible for generating instrument commanding and scheduling stored data downlinks.

The SeaWiFS sensor carried onboard the spacecraft is designed to make global observations of ocean color as the follow-on sensor to the Coastal Zone Color Scanner (CZCS). The data generated by the SeaWiFS instrument will be downlinked daily from the spacecraft in High Resolution Picture Transmission (HRPT) format and delivered to NASA, approved researchers and ORBIMAGE commercial customers.

The SeaStar spacecraft is the second in a series of remote sensing spacecraft built, launched and operated by Orbital's wholly owned subsidiary, ORBIMAGE. Hence, we now refer to the SeaStar spacecraft as OrbView-2™ and will do so through the remainder of this paper.

The OrbView-2 spacecraft was successfully launched on a Pegasus XL from Vandenberg Air

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The OrbView-2 mission elements are illustrated in Figure 1. The mission is initiated by launch of the spacecraft aboard a Pegasus XL rocket, carried by Orbital's L-1011 aircraft. Once the spacecraft has reached its final orbit, nominal operations involve downlinks to multiple sites worldwide. OrbView-2 carries redundant GPS receivers to determine its position around the earth. Telemetry and command functions are performed by the ORBIMAGE Satellite Control Network (SCN), with facilities in Virginia and West Virginia. The command uplink is performed at 19.2kbps in S-band.

To further describe the mission, an explanation of mission data is necessary. The SeaWiFS instrument produces two types of science data. Local Area Coverage (LAC) data with 1.13km resolution at na-
dir are directly broadcasted and selectively recorded on board the spacecraft. Global Area Coverage (GAC) of ocean color is created by subsampling every fourth line, every fourth pixel of LAC data and is saved in the spacecraft data recorder and downlinked only on command.

OrbView-2 has two downlink frequencies, one in L-band and one in S-band. LAC data is continuously broadcast on the L-band downlink at 665.4 kbps when the instrument is on, generally whenever the spacecraft is in sun. The L-band link also contains realtime spacecraft state-of-health telemetry and log files. In the event of contingency and during the early phases of the mission prior to instrument operations, the L-band downlink may be switched to a lower data rate of 57.6 kbps to increase link margin. The S-band downlink at 2.0 Mbps is used only after instrument operations commence in nominal mode, and is turned on twice per day at approximately noon and midnight local to downlink GAC and LAC data that are stored in the onboard data recorders.

Realtime L-band data are received by NASA-approved research facilities including science users and research vessels, as well as licensed commercial users and data distributors. ORBIMAGE archives and distributes commercial data through its OrbNet Active Archive. The S-band data is downlinked only over NASA's Wallops Flight Facility (WFF), which is the primary data acquisition site for the stored SeaWiFS data. Because they are in the same footprint, the ORBIMAGE SCN and a Data Capture Facility (DCF) at GSFC also receive the S-band data, but serve primarily as backup sites to WFF in the event of ground anomaly.

**Spacecraft Description**

The OrbView-2 spacecraft design is based on one of Orbital's multi-purpose spacecraft buses called PegaStar™. The PegaStar platform combines functions common to both satellites and launch vehicles, including guidance and control, power, communications, and data systems. This approach eliminates the cost and weight of complete duplicate systems, enabling launch of heavier, more sophisticated payloads at lower cost. By integrating the appropriate Pegasus launch vehicle functions with the spacecraft, the PegaStar concept reduces the total structure and electronics required, increases the packing efficiency, and reduces cost and integration time. The PegaStar bus tailored for the OrbView-2 mission is shown in a deployed configuration in Figure 2.

![Figure 2. OrbView-2 Spacecraft Deployed Configuration Carries Pegasus XL Avionics.](image)

For the OrbView-2 spacecraft, the PegaStar concept was implemented by modifying the standard Pegasus/payload configuration. The existing Pegasus payload interface plate (or avionics deck) is removed, as is the thrust tube which connects it to the third stage motor. The thrust tube is replaced with six aluminum honeycomb bus panels and an aft deck, which connects directly to the third stage motor via a 38-inch Marmon band clamp. The Pegasus avionics which were previously attached to the thrust tube and avionics deck were moved and mounted to two of the bus panels, as shown in Figure 2. The four remaining spacecraft panels house the spacecraft electronics. The Pegasus reaction control system (RCS), a cold nitrogen propulsion system that provides payload pointing after third stage burnout, is also integrated into the OrbView-2 structure above the mid-deck. The net weight savings achieved by the integration of the Pegasus launch vehicle avionics onto the spacecraft structure is nearly 25 lbm. Total wet mass of the OrbView-2 spacecraft is 870 lb.

The OrbView-2 bus structure, payload truss and shelf, and solar arrays are designed in accordance with the Pegasus launch vehicle environments and design criteria including quasi-static and transient acceleration, random vibration, shock and thermal environments, with factors of safety for all launch phases. The primary bus structure is lightweight aluminum honeycomb structure supporting the mounting of all space-
craft subsystems and the solar arrays. The 37-inch wide hexagonal bus provides efficient load transfer to the launch vehicle interface, and stiffness for a 20 Hz (minimum) spacecraft natural frequency. The truss system mounted above the mid-deck consists of an aluminum tubular truss supporting a payload shelf. The truss also supports two body mounted side solar array panels. The aft deck supports mounting the four larger solar arrays with canted extensions in a fixed configuration after deployment.

The SeaWiFS instrument is the only payload on the OrbView-2 spacecraft. It consists of an off-axis scanning telescope which rotates at 6 revolutions per second in the cross-track direction to provide contiguous scan coverage at nadir with the SeaWiFS spatial resolution of 1.6 mrad (1.13 km [0.6 nmi] at nadir). The sensor has eight spectral bands, six in the visible spectrum and two in the near infrared spectrum, and outputs 665.4 kbps LAC and 33.3 kbps GAC continuously during daylight. Sensor signals are digitized into redundant LAC video streams, each buffered with a peak rate of 1.885 Mbps.

The OrbView-2 bus avionics are redundant and cross-strapped to increase mission reliability, with a 5-year mission life requirement and a 10-year design goal. The Data Management Subsystem (DMS) includes redundant multi-module spacecraft computers, instrument interface units, and two digital data recorders to perform ground interface, payload services, and spacecraft control functions. The data recorders provide 128 Mbytes of usable memory, protected by Error Detection and Correction (EDAC) functionality.

The Attitude Control Subsystem (ACS) must provide knowledge sufficient to meet a one pixel (1.6 milliradians, 2 sigma) requirement at all normal scan and tilt angles utilizing a three-axis, momentum-based design. The ACS hardware suite consists of the Attitude Control Electronics (ACE), two momentum wheels, three orthogonal magnetic torque rods, two scanning horizon sensors, three 2-axis sun sensors, and two 2-axis magnetometers. The ACE is internally redundant and provides converted sensor and actuator power in addition to sensor data preprocessing, actuator command execution, and self-diagnostics with continuous background checks. The ACE also incorporates an autonomous “safe hold” mode which will ensure nadir-pointing orientation of the arrays in the event communication with the spacecraft computer is lost. The spacecraft also flies redundant GPS receivers which provide one-per-second clock and position updates.

The Electrical Power Subsystem (EPS) provides primary power to the spacecraft avionics and instrument on a 28V bus. The EPS employs conventional silicon solar cells, nickel-hydrogen (NiH2) batteries, and redundant microprocessor controlled Battery Charge Regulators (BCR). Other electronics include the Power Module (PM), the Load Control Module (LCM), and the Battery Sensor Electronics (BSE). The four aft-mounted solar array panels are individually deployed using High Output Paraffin (HOP) thermal actuators releasing a clevis restraint pin. Built-in passive locking devices within the spring-driven hinge mechanisms secure the panels in place once deployed. The BCR performs pulse width modulated switching regulation with peak power tracking capability. This conditions the solar array power while maintaining higher efficiency and using less hardware than a conventional shunt regulator. The BCR also controls battery charging mode and has the capability to autonomously shed loads in the event of an overcurrent or high depth-of-discharge condition. The solar panels generate approximately 344 Watt Hours of BOL energy in the OrbView-2 mission orbit.

Propulsion capability is provided by an integrated hydrazine propulsion system with a 21-inch diameter cylindrical tank and four thrusters mounted to the aft deck. Propulsion functions, including individual thruster activation, valve status, and tank pressure and temperature monitoring are performed by the Spacecraft Maintenance Unit (SMU). The SMU also monitors panel deployment status and heater telemetry for the entire spacecraft. The propulsion system is used primarily for orbit-raising, as minimal station keeping will be required once the spacecraft reaches its nominal orbit at 705 km.

The communications system utilizes two L-band transmitters, two S-band transmitters, and two S-band command receivers. A total of seven antennas are used for data transmission and command receipt. Redundant command reset decoders (CDR) are located at the output of the command receivers and

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housed in the SMUs. These decoders are used to perform a hard reset of the spacecraft computer in the event an on-orbit reset from the ground is required.

Spacecraft thermal control is accomplished passively by using anti-solar radiator areas with selected optical properties and multi-layer insulation (MLI) blankets that balance orbital fluxes and internal power dissipations. Resistive heaters on the batteries proved contingency against thermal excursions. The payload shelf is thermally decoupled from the primary bus, allowing for independent control of instrument thermal environments and separate resistive heater control for both bus and instrument components.

**Ground Facilities**

Orbital's ORBIMAGE subsidiary owns and operates the ORBIMAGE SCN, which provides ongoing flight support for several of Orbital's present and future remote sensing programs. This support includes realtime spacecraft command, monitoring and control, data storage and analysis, mission data collection and distribution; mission planning, anomaly diagnosis and resolution as well as orbit determination, maneuver planning, and analysis. The network presently includes the Satellite Operations Control Center (SOCC) at Orbital's Dulles, Virginia headquarters, and a remote tracking site (RTS) located approximately 200 miles away in Fairmont, West Virginia as well as eight HRPT sites located around the world. A dedicated, full duplex T1 communications line connects the SOCC and RTS.

The SOCC houses all equipment, tools, and software required for realtime spacecraft command and telemetry monitoring, data analysis, short-term and long-term data archiving, mission planning and specialized engineering analyses. The SOCC layout includes multiple Sun workstations running both in-house developed and off-the-shelf software. All realtime operator workstations are redundant to allow switching to an alternate workstation in the event of realtime failure. Post-pass telemetry analysis and trending are performed using a combination of off-the-shelf analysis tools (i.e. Matlab) and mission-unique software. Short-term data archiving is provided primarily on hard drive for immediate access long-term archiving uses CD-ROM or magnetic tape. A photograph of the SOCC is shown in Figure 3.

Figure 3. ORBIMAGE's SOCC and RTS Support OrbView-2 Mission Operations.

The SOCC is capable of interfacing with both remote tracking facilities and with spacecraft simulators for training, testing, and on-orbit anomaly resolution. Orbital maintains high fidelity spacecraft simulators at various facilities for all its on-orbit spacecraft, including OrbView-2. The SOCC accesses each spacecraft simulator via the Orbital network and automatically sets all parameters for that simulation environment, including screen configurations, downlink and uplink rates and formats, data source, command and telemetry databases and limits, and operating constraints. The operations teams have used these simulators extensively for training, testing software uploads, verifying command and telemetry databases, and as a data source for operations rehearsals prior to launch.

The RTS in West Virginia is located at 39.43° North, 80.20° West and includes tracking and control software, a 6.1 meter dual-feed L- and S-band antenna, tracking and telemetry receivers, signal generators, descrambling equipment, analog recorders, bit synchronizers, and high speed front ends. Figure 3 shows a photo of the RTS radome and blockhouse. All equipment at the RTS, with the exception of the

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pedestal, antenna, and feed assembly, is fully redundant and remotely switchable. The RTS is an unmanned, remotely-controlled facility which requires only part-time maintenance support by a local technician who is on-call in the event of anomaly. The RTS is fully spared with all critical components. With the exception of large antenna mechanical assemblies, most RF equipment units can be replaced and tested in less than four hours.

Communications links between the RTS and the SOCC have been demonstrated to be extremely reliable. A commercially leased T1 line with a high priority maintenance and repair assignment has provided virtually 100% connectivity for all available passes.

For NASA data, the WFF Orbital Tracking Station (WOTS) is the primary acquisition site for the S-band (stored) SeaWiFS data for the five-year mission. WOTS will also collect L-band direct broadcast downlink during the noon passes and process this data on site at WOTS. The primary acquisition antenna is a 9 meter, x-y tracker, with two 7.5 meter, az-el tracking antennas as backups. WOTS will send S-band data to the GSFC Data Capture Facility (DCF) via the NASA Integrated Services Network (NISN). Data may be delivered from WOTS to DCF in a network File Transfer Protocol (FTP)/Internet Protocol (IP) or in Nascom 4800-bit block interface.

During the post-launch orbit-raising maneuvers lasting approximately 1 month, additional ground support will be provided by the Poker Flat Transportable Orbital Tracking Station (TOTS), which has S-band uplink and L-band downlink capability, and the McMurdo Sound station in Antarctica, which can only monitor the L-band downlink. The Poker Flat facility is a WFF resource located in Fairbanks, Alaska, while the McMurdo resource is provided by the National Science Foundation. These two stations greatly increase the number of spacecraft visibilities and reduce mission risk during the critical post-launch and orbit-raising phases.

The OrbView-2 L-band downlink is compatible with existing NOAA and ORBIMAGE HRPT stations located worldwide, with minimal modification and software upgrades. Any station receiving the L-band data must obtain a SeaStar Ground Processor (SGP) decryption unit from ORBIMAGE or through the NASA Project Office in order to utilize the data for either research or commercial purposes.

ORBIMAGE operates its Data Ordering Processing Distribution and Archiving system (known as OrbNet) at its Dulles facility. Data received from its HRPT facilities is data linked via internet on a daily basis and used to generate fishing maps which are then e-mailed to ships at sea, via Inmarsat. Other data products are also generated at the HRPT sites for local distribution.

Flight Operations and Mission Timeline

Multiple organizations play critical roles in successful flight operations for OrbView-2 during all mission phases including Launch, Orbit Raising, Instrument Checkout, and Nominal Operations. Figure 4 illustrates the nominal mission timeline from launch through the beginning of full instrument operations. The duration of these activities is roughly 5 weeks.

Operations Roles

The operations activities required to conduct the OrbView-2 mission are performed primarily at ORBIMAGE and the NASA GSFC, with support from WFF and data collection stations located around the world. Figure 5 shows the major mission elements, the interfaces between them, and the data that are transferred.

ORBIMAGE has responsibility for performing regular daily contacts with the OrbView-2 spacecraft, including all command activities and monitoring state-of-health telemetry. ORBIMAGE personnel generate the daily command schedules that are loaded to the vehicle, including instrument schedules from GSFC Mission Operations. ORBIMAGE archives all downlinked spacecraft telemetry for the duration of the mission and is responsible for maintaining spacecraft performance. Both L- and S-band data are received at the RTS; the L-band data are transferred to the ORBIMAGE OrbNet archive, while S-band data are stored temporarily and provided to NASA if needed. SOCC personnel generate antenna directives to operate the RTS at designated contacts, and provide orbit data to Poker Flat and McMurdo during the early mission phase.

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Figure 4. Routine Operations Start About 5 Weeks After Launch.

Figure 5. NASA & ORBIMAGE Work Together to Accomplish Mission Operations & Data Delivery.

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In the nominal mission phase, ORBIMAGE is also responsible for maintaining and updating all encryption key information. A unique key is required by each SGP unit installed at any research or commercial HRPT stations that receive OrbView-2 data. Key information is updated every two weeks. ORBIMAGE also forwards updated orbital elements, mission status, and upcoming event information to all receiving stations. This information is easily transferred via Internet.

The GSFC Mission Operations (GMO) facility has several primary functions including: generating the sensor operations schedule; navigating pixel observation; monitoring SeaWiFS instrument health and safety; performing testing and simulations; and generating and providing antenna pointing data to WOTS. Sensor schedules are generated using calibration target and navigation input from the Calibration/Validation (Cal/Val) group at GSFC, which in turn works closely with the Project Scientist and Science Team who establish mission requirements, science objectives and priorities. Sensor command schedules are transferred and verified on a daily basis between the ORBIMAGE SOCC and GMO.

GMO provides orbit position and velocity vectors daily to WOTS in Improved Interrange Vector (IIRV) format. The IIRV data span is at least 48 hours. GMO also provides pointing information in the form of Predicted Site Acquisition Tables (PSAT) to WOTS to allow resource scheduling and conflict analysis.

WOTS responds with deconflicted acquisition schedules to GMO. Once scheduled passes are complete, WOTS transfers downlinked OrbView-2 data in near realtime to the Data Capture Facility (DCF), also located at GSFC. WFF will also store data for 7 days after acquisition.

The DCF receives realtime L-band data from the OrbView-2 spacecraft with an on-site antenna system, as well as the stored S-band from WOTS in near realtime. Both these data sets are transferred to the Science Data Processing System (SDPS) at GSFC for analysis and development into higher level data products. DCF also archives the realtime LAC data for seven days and makes them available for immediate on-line access, and performs quick-look quality control of all raw Level-0 data files. Finally, DCF provides software support for NASA-approved HRPT stations that are licensed through the SeaWiFS Program Office.

Once SDPS processes the data, files are transferred to the GSFC Distributed Active Archive Center (DAAC) for distribution to science users. Processed data also flows back to Cal/Val to allow sensor calibration tuning and designation of future calibration targets.

**Launch**

Launch of the OrbView-2 spacecraft occurred at 1:25 PM PDT on August 1, 1997 from VAFB. A photo of the L-1011 carrier aircraft carrying the Pegasus XL is shown in Figure 6. The spacecraft was launched in a powered condition with spacecraft telemetry downlinked through the Pegasus flight computer to ground controllers. Spacecraft engineers monitored realtime spacecraft telemetry throughout captive carry and after Pegasus drop, to roughly L + 420 seconds (LOS). Following a nominal trajectory and insertion into a 300 x 303 km orbit at 98.2° inclination, the Pegasus third stage separated from the spacecraft. This event initiated a separation schedule of commands that were loaded into the spacecraft computer prior to launch.

The onboard computer executed the separation schedule commands to power up the ACE and spin

![Figure 6. L-1011 Carrier Aircraft Takeoff with Pegasus XL.](image-url)
up the momentum wheels. The Pegasus RCS, which is integrated into the spacecraft bus and controlled by the Pegasus avionics, performed cold-gas thruster firings to orient the spacecraft toward nadir. The four solar arrays were successfully deployed, and the L-band transmitter was powered up for continuous downlink at the contingency data rate to facilitate initial contacts.

The first spacecraft visibility after launch occurred at approximately L+25 minutes at McMurdo. Due to the preliminary nature of the injection data, McMurdo was able to obtain carrier signal, but not transfer telemetry packets to the SOCC. The second available contact occurred at approximately L+90 minutes at Poker Flat, and was fully successful. Spacecraft engineers commanded the spacecraft to download telemetry logs and verified the health of all subsystems. Subsequent passes were used to obtain at least three orbits of GPS data for initial orbit determination, and to transition to the use of stored command schedules to control L-band transmitting over ground stations. Spacecraft performance throughout this period was virtually flawless.

**Orbit Raising**

Orbit raising operations commenced at L+4 days following verification that all subsystems were ready for this mission phase. The first activity was an ACS slew maneuver, which verified the attitude control subsystem’s ability to accurately slew the spacecraft from nadir to burn attitude and back to nadir. Over the next three days, the spacecraft executed three calibration burns of 50 - 200 seconds duration to verify propulsion subsystem performance. At this writing, these calibration burns have been successfully completed. Following the calibration burns, the final burn plan will be fine tuned based on the current parking orbit parameters and thruster performance data obtained from the burns.

The spacecraft is in orbit-raising configuration during this period, with the SeaWiFS sensor powered off and stowed, data recorder powered off, and using the contingency L-band downlink rate.

Orbit raising will commence with two sets of three burns each, with the sets performed roughly three days apart to achieve a 450 x 450 km parking orbit. No inclination correction is anticipated during this burn series. Following a three-day period of no burns to allow node drift and planning, three more sets of six burns each will occur to raise the orbit to 690 x 690 km, and perform initial inclination correction. After approximately four days of further node drift and planning activities, “touch-up” burns will be performed as required to achieve final operational orbit at 705 x 705 km, 98.2° inclination. The entire orbit raising sequence is expected to last approximately three weeks. ORBIMAGE mission planners will then conduct a final precise orbit determination and long-term orbit analysis to support estimates of future orbit maintenance activities. At this point, orbit raising will be considered complete.

ORBIMAGE has gratefully accepted support from GSFC’s Flight Data Facility (FDF), NORAD, and NAVSPASUR to provide additional tracking data and support collision avoidance analysis during the orbit raising process.

**Instrument Checkout**

Instrument initialization and checkout will commence only after verifying that the final mission orbit is acceptable, all subsystems are ready to start imaging operations, and that sufficient time has passed since launch to allow instrument and spacecraft outgassing. The OrbView-2 spacecraft must also demonstrate the ability to perform a power pointing maneuver, which requires tilting the spacecraft arrays toward the sun as it nears the South Pole. This maneuver focuses more direct sun on the arrays and increases available power over the life of the mission.

GMO will be directly involved in the initial SeaWiFS power up and checkout activities. Once instrument performance is verified, the first imaging pass (4-minute duration) will occur over WFF, the RTS, and the ORBIMAGE HRPT station located at Dulles Virginia. The data from this pass will be both directly downlinked on L-band and stored to the flight data recorder (FDR). Following that imaging pass, the first FDR dump using the S-band downlink will occur. WFF, GMO, DCF, Cal/Val and ORBIMAGE will verify correct operation of all instrument, spacecraft, and ground functions based on telemetry and science data gathered during that pass. If all telem-
etry indicates nominal functionality, initial operations may commence and will last approximately 90 days. During this time the data will be unencrypted.

**Routine Operations**

The routine operations phase of the OrbView-2 mission will start after the initial operating period. Initial operations will begin when the first stored command load based on GMO payload command inputs begins to execute. The first command schedules are expected to include preliminary ground truth and calibration targets, as well as ensuring realtime data downlinks to researchers around the world. These early imaging operations will also verify FDR partitioning capability and data integrity.

OrbView-2 operations are controlled using stored command schedules based on GMO instrument command inputs. Imaging occurs on the sun lit side of the orbit, where realtime image data is transmitted continuously in HRPT format on the L-band downlink. The S-band downlinks are controlled by GMO and occur twice per day at near noon and near midnight passes over WFF. GMO also schedules special operations for the spacecraft including lunar calibrations, solar calibrations, and intergain/detector checks, which are performed periodically to optimize SeaWiFS instrument performance. The organization for routine mission operations is shown in Figure 7.

This figure illustrates the interfaces and data flow between the key operations functions. The SeaWiFS
Project Office at GSFC is the primary data customer; with the Mission Operations function generating payload command inputs and receiving operations reports from the ORBIMAGE mission planning function. Spacecraft engineering support is provided on an on-call basis for anomaly resolution and to perform routine telemetry data checks. The spacecraft operators execute the pass plans and uplink command loads provided by mission planning. Commands are sent to and telemetry data received from the RTS, and from Poker Flat and McMurdo in the early mission phases. An operations director supervises all mission planning, controller, and antenna site activities on a day-to-day basis, is responsible for assigning priority and deconflicting among multiple missions, and reports status to the OrpView-2 and Ground Segment Program Managers. Ground software and network/data management functions support all elements of the ORBIMAGE team.

The process of generating Command Sequence Messages (CSM), which contain all stored spacecraft commands, begins with acceptance of GMO instrument command inputs. Those commands are run through a rule-based command generation tool, which wraps instrument commands with associated spacecraft subsystem commands according to a verified set of rules and timing parameters. Once the CSM is generated, ORBIMAGE sends each file back to GMO for verification prior to upload to the spacecraft. This function is performed on a daily to weekly basis, depending on work schedules and planned mission activities.

ORBIMAGE personnel are also responsible for monitoring and archiving spacecraft and instrument telemetry, maintaining knowledge of spacecraft hardware and software configuration, performing trend analysis, and responding to any anomalies that may occur. Mission planners perform daily orbit determination functions using GPS data from the on-board receivers as the primary data source. In the event valid GPS data is not available, NORAD data is sufficient to support planning activities. ORBIMAGE must also track and publish the appropriate encryption keys to authorized users; these keys are changed every two weeks on-board the spacecraft, with associated key changes in the SGPs at each station. ORBIMAGE plans to downlink L-band data unencrypted for the first three months of the mission.

Once routine operations have been established, ORBIMAGE will man only one command pass per day for OrpView-2, typically the noon pass. The midnight pass will be conducted in a fully automated mode which requires no staff onsite at the SOCC. The RTS antenna is preprogrammed to track OrpView-2 at the appropriate rise time, with transmitter on/off times and file dumps controlled by the stored schedules in the spacecraft flight computer. If stored file sizes do not increase as expected in the ground data storage equipment, the on-call operator is automatically paged to return to the SOCC and assess whether the problem is space- or ground-based. This typically happens in time to take the next pass (approximately 99 minutes after the first) and perform any necessary corrective actions. This autonomy in both space and ground systems greatly reduces manpower requirements and saves operating cost over the life of the mission.

The OrpView-2 Program Manager will provide periodic status reports and upcoming mission event schedules to NASA and science data users throughout the mission life.

**Data Delivery**

OrpView-2 data products are available to research and commercial users by a variety of delivery methods.

**Data for NASA-designated Researchers**

NASA's contract with Orbital allows GSFC to receive the L-band realtime data, and allows NASA to designate 12 other research receiving stations to also receive the data in realtime. These stations have rights to the data for research purposes only and must agree to control distribution and use of the data so that ORBIMAGE's commercial and operational markets are not adversely affected. For these realtime sites, ORBIMAGE provides decryption keys. NASA may periodically redesignate these real-time stations, which may include research ships positioned for field experiments.

The contract also provides for multiple NASA-designated receiving stations which may directly downlink and archive the L-band data, but which do not receive the appropriate decryption key until 30 days
after that encryption period begins. This prevents processing the data during the first two weeks after receipt, when it is most valuable in the commercial marketplace. These stations are still held to the same restrictions on data use as the realtime stations.

ORBIMAGE has the right to suspend the right to receive data of support contractors, grantees, and/or research users who are engaged in unauthorized use or otherwise violate their confidentiality agreement.2

The GSFC SDPS receives data from WFF and the DCF over the entire five-year mission, processes it to Level 3, and routes it to the DAAC where it is stored indefinitely. NASA may place all data collected under this contract by its research users into the public domain beginning five years after the data are collected. Research results may be published at any time.

Data for Commercial Customers

OrbView-2 data are available to commercial customers via either direct downlink licenses or image set sales through ORBIMAGE’s OrbNet Active Archive and exclusive distributors worldwide. The direct downlink licenses are restricted to the regional area visible when the spacecraft overflies the licensed site. Obtaining the L-band downlink directly requires an HRPT station modified with installation of the SGP unit and mission unique software to allow data access and processing. ORBIMAGE provides the SGP and decryption key updates as part of the licensing agreement. Data rights are limited to in-house commercial use only and are not for resale.

Purchase of image sets directly from ORBIMAGE or authorized distributors allows users to view data before purchase and gives them selected global data access, rather than being limited to regional coverage. ORBIMAGE will create Regional Image-sets with 1500 km x 1500 km geographic coverage and spatial resolution of 1.1 km, with 9 images per Image-set (each spectral-band and color composite). Global Image-sets will also be available, covering virtually the entire Earth with a spatial resolution of 4.5 km, with processing and images similar to Regional Image-sets. Commercial customers and value-added resellers may purchase data via the ORBIMAGE Internet Home Page.

Summary

The unique nature of the OrbView-2 data purchase contract awarded by NASA has established a mutually beneficial relationship between the Government, Orbital, and ORBIMAGE where operations teams from both organizations work together to accomplish both science research goals and successfully market the data to commercial customers. The success of this mission will support the viability of this type of contractual arrangement for future data procurements.

At this writing, the OrbView-2 spacecraft has successfully initiated the orbit raising phase of the mission. We anticipate the start of initial operations in early Fall 1997.
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