Space Shuttle Instrumentation

KSC Space Shuttle Reference Manua

http://www.spaceflight.nasa.gov/shuttle/reference/shutref/orbiter/comm/inst/

INSTRUMENTATION

Orbiter operational instrumentation is used to collect, route and process information from transducers and sensors throughout the orbiter and its payloads. This system also interfaces with the solid rocket boosters, external tank and ground support equipment. Over 2,000 data points are monitored, and the data are routed to OI MDMs. The instrumentation system consists of transducers, signal conditioners, two pulse code modulation master units, encoding equipment, two operational recorders, one payload recorder, master timing equipment and onboard checkout equipment.

The OI system senses, acquires, conditions, digitizes, formats and distributes data for display, telemetry, recording and checkout. It provides for PCM recording, voice recording and master timing for onboard systems.

Dedicated signal conditioners convert digital and analog data signals received from the various sensors to a usable form. Some raw sensor data may need to be conditioned for compatibility with a multiplexing system. Signal conditioning provides the multiplexer with compatible inputs. The DSCs provide input from transducer signals, such as frequency, voltage, current, pressure, temperature (variable resistance and thermocouple), displacement (potentiometer), 28- or 5-volt-dc discrete output signals, analog and digital level changes, polarity changes or an ac signal change to a dc signal. The DSCs send these converted signals to the appropriate MDMs and displays and to the C/W system.

MDMs can operate in two ways. As multiplexers, they take data from several sources, convert the data to serial digital signals (a digitized representation of the applied voltage) and interleave the data into a single data stream. As demultiplexers, the MDMs take interleaved serial digital information; separate and convert it to analog, discrete or serial digital; and send each separate signal to its appropriate destination. The payload MDMs generally act as demultiplexers. They take interleaved commands from the orbiter GPCs, separate them and send each command to its appropriate destination, such as payload ground command interface logic.

The OI MDMs generally act only as multiplexers. Upon request from the pulse code modulation master unit, the MDMs send these interleaved streams to the PCMMU through the OI data buses. When the MDM is addressed by the PCMMU, the MDM selects, digitizes and sends the requested data to the PCMMU in serial digital form. The PCMMU/OI MDM interface is based on demand and response: that is, the OI MDMs do not send data to the PCMMU until the PCMMU makes the request.

- ### PULSE CODE MODULATION MASTER UNIT (PCMMU)

  The PCMMU receives the data requested from the OI MDMs, downlists data from the GPCs under control of flight software and payload telemetry from the payload data interleaver and Spacelab computers, interleaves the data, formats data according to programmed instructions stored within the PCMMU, and sends the interleaved data to the network signal processor to be mixed with the analog air-to-ground voice data from the audio central control unit for transmission through the S-band PM downlink or Ku-band system return links. Telemetry from the PCMMU also is sent through the NSP to the operational recorders for storage and future payloads to be downlinked on the S-band FM or Ku-band system. OI and payload data collected by the PCMMU are sent to the onboard GPCs for display and monitoring purposes upon request. All data received by the PCMMU is stored in memory and periodically updated.

  The PCMMU has two formatter memories: programmable read only and random access. The read-only memory is programmed only before launch; the random-access memory is reprogrammed several times during flight. The PCMMU uses the format memories to downlink data from the computers and OI MDMs into PCM telemetry data streams.

  Only one of the redundant PCMMUs and NSPs operates at a time. The one used is controlled by the crew through the flight deck display and control panel. The primary port of an MDM operates with PCMMU 1 and the secondary port operates with PCMMU 2.

  The PCMMUs receive a synchronization clock signal from the master timing unit. If this signal is not present, the PCMMU provides its own timing and continues to send synchronization signals to the payload data interleaver and network signal processor.

  The payload data interleaver is programmed onboard from mass memory through the GPCs to select specific data from each payload PCM signal and to store the data within its buffer memory locations.

- ### NETWORK SIGNAL PROCESSOR (NSP)

  The network signal processor is the nucleus of the communication systems. It is responsible for processing and routing commands, telemetry and voice between the orbiter and the ground.

  Commands and voice uplinked to the orbiter are received by the S-band PM uplink or the Ku-band system's forward link. The NSP accepts this digitized, time-division-multiplexed data stream for further processing.

Encrypted data are routed to Comsec, decrypted and returned to the NSP. Comsec interfaces with the NSP to provide communication security during Department of Defense and NASA missions. Digitized air-to-ground voice data are demultiplexed from command data and converted to analog signals before being routed to the ACCU. Command data are routed to the GPCs of the data processing system through the flight forward MDM.

Telemetry and voice are downlinked from the orbiter by the S-band FM, S-band PM and Ku-band systems' return link. The NSP accepts and digitizes analog air-to-ground voice data from the ACCU. The digital voice is multiplexed with telemetry from the PCMMU for real-time transmission to the ground through the S-band PM and Ku-band systems. The multiplexed data also are routed to the operational recorders for later transmission through the S-band FM system or mode 2 of the Ku-band system. Encrypted data are routed to a Comsec encryptor and returned to the NSP before being downlinked.

Instrumentation equipment, except sensors and selected dedicated signal conditioners, is located in the forward and aft avionics bays. Sensors and dedicated signal conditioners are located throughout the orbiter in areas selected on the basis of accessibility, minimum harness requirements and functional requirements. Effective use of remote data acquisition techniques was considered for optimizing equipment location. The factors that were considered in the determination of equipment location were weight, power, physical size, redundancy and wire density, and length to each compartment and interconnect wiring. Abbreviations used to designate the locations of equipment are as follows: OA refers to operational aft, OF to operational forward, OL to operational left, OR to operational right, OM to operational mid.

- **MASTER TIMING UNIT (MTU)**

  The master timing unit is a stable crystal-controlled timing source for the orbiter. It sends serial time reference signals to the onboard computers, PCMMUs, payloads and various time display panels. It also provides synchronization for instrumentation payloads and other systems. It includes separate time accumulators for Greenwich Mean Time and mission elapsed time, which can be reset or updated from the ground via uplink through the onboard computer or by the flight crew through the use of the flight deck display and control panel keyboard and CRT time displays.

  The signal flows from the 4.608-MHz oscillators to the output of the GMT and MET accumulators. GMT or MET can be displayed on the mission time displays on panels O3 and A4 by positioning the mission timer switch on the respective panel to GMT or MET . In addition, event time displays are located on panels F7 and A4. Separate time accumulators used for the GMT and MET clocks accumulate time in days, hours, minutes, seconds and milliseconds. The GMT capacity is 366 days, 23 hours, 59 minutes, 59 seconds and 999.875 milliseconds. For MET, the capacity is 365 days, 23 hours, 59 minutes, 59 seconds and 999.875 milliseconds. Before flight, both time displays can be updated and reset by ground equipment or by the flight crew using onboard controls. During flight, the GMT and MET accumulators are updated at a predetermined time by uplink and the onboard computer or by voice command. They are entered through the flight deck display and control panel keyboard and CRT display.

OPERATIONAL RECORDERS

Two recorders are used for serial recording and dumping of digital voice and PCM data from the OI systems. The recorders normally are controlled by ground command, but they can be commanded by the flight crew through the flight deck display and control panel keyboard or through switches on a recorder panel. Input to the recorders is from the network signal processor, either in the form of 128-kbps PCM data or a 192-kbps composite signal that includes the 128-kbps PCM data and two 32-kbps voice channels. The network signal processor receives the PCM data from the PCMMU and voice signals from the audio control center. In addition, during ascent, operations recorder 1 receives three channels of main engine data at 60 kbps. A single recorder can store and reproduce digital data at many rates.

The operations recorders can be commanded to dump recorded data from one recorder while continuing to record real-time data on the other. The dump data are sent to the FM signal processor for transmission to the ground station through the S-band FM transmitter on the S-band FM return link or to the Ku-band signal processor. When the ground has verified that the received data are valid, the operations recorders can use that track on the tape to record new data.

The tape recorders contain a minimum of 2,400 feet of 0.5-inch by 1-mil magnetic tape. They operate at a tape speed of 24 inches per second in the recording mode and 120 inches per second in the playback mode.

- **Recorder functions can be summarized as follows:**

  Data in, recorder 1

  1. ***Accept three parallel channels of engine data at 60 kbps during ascent.***
  2. ***Accept 128 and 192 kbps of interleaved PCM data and voice that serially sequences from track 4 to track 14.***
  3. ***Accept real-time data from network signal processor. Recording time is 32 minutes for parallel record and 5.8 hours for serial record on tracks 4 through 14 at a tape speed of 15 inches per second.***

  Data in, recorder 2

  1. ***Accept 128 and 192 kbps of interleaved PCM voice and data that serially sequences from track 1 to track 14.***
  2. ***Accept real-time data from network signal processor. Recording time is 7.5 hours at a tape speed of 15 inches per second for serial record on 14 tracks.***

  Data out, recorder 1

  1. ***Play back in-flight engine interface unit data and network signal processor digital data through S-band FM transponder or Ku-band transmitter.***
  2. ***Play back in-flight anomaly PCM data for maintenance recording.***
  3. ***Play back data serially to ground support equipment to T-0 ground support equipment umbilical.***

  Data out, recorder 2

  1. ***Play back digital data through S-band FM transponder or Ku-band transmitter in flight.***
  2. ***Play back anomaly PCM data in flight for maintenance recording.***
  3. ***Play back preflight and postflight data serially to GSE T-0 umbilical.***

  Recorder control

  1. ***Recorders are manually controlled from the mission specialist flight deck aft station display and control panel or uplink and onboard computer keyboard.***
  2. ***Recorder speeds of 7.5, 15, 24 and 120 inches per second are provided by hardwire program plug direct command.***

PAYLOAD RECORDER

The payload recorder records and dumps payload analog and digital data in flight through the S-band or Ku-band transmitter. The recorder can record one of three serial inputs or a maximum of 14 parallel digital or analog inputs or combinations of analog and digital data (up to 14 inputs) from the payload patch panel. In flight, all data dumps are serial; capability for parallel dumps does not exist. The recorded digital data can range from 25.6 kbps to 1.024 Mbps. Analog data inputs can be recorded only in parallel with a bandwidth from 1.9 kHz to 1,600 kHz. There are also 14 selectable tape speeds; however, only four speeds are available per flight. Recorder tape speeds are 15, 30, 60 and 120 inches per second. Total recording time ranges from 56 minutes at 1.024 Mbps to 18 hours 40 minutes at 25.6 kbps.

The recorder normally is controlled by ground command but can be commanded by the flight crew through the flight deck display and control panel keyboard or through switches on the recorder panel.

ORBITER EXPERIMENTS SUPPORT SYSTEMS (OV-102 COLUMBIA)

The support system for the orbiter experiments was developed to record data obtained and to provide time correlation for the recorded data. The information obtained through the sensors of the OEX instruments must be recorded during the orbiter mission because there is no real-time or delayed downlink of OEX data. In addition, the analog data produced by certain instruments must be digitized for recording.

The support system for OEX comprises three subsystems: the OEX recorder, the system control module and the pulse code modulation system. The SCM is the primary interface between the OEX recorder and the experiment instruments and between the recorder and the orbiter systems. It transmits operating commands to the experiments. After such commands are transmitted, it controls the operation of the recorder to correspond to the experiment operation. The SCM is a microprocessor-based, solid-state control unit that provides a flexible means of commanding the OEX tape recorder and the OEX and modular auxiliary data system.

The PCM system accepts both digital and analog data from the experiments. It digitizes the analog data and molds it and the digital data received directly from the experiments into a single digital data stream that is recorded on the OEX recorder. The PCM also receives time information from the orbiter timing buffer and injects it into the digital data stream to provide the required time correlation for the OEX data.

The SCM selects any of 32 inputs and routes them to any of 28 recorder tracks or four-line driver outputs to the T-0 umbilical; executes real-time commands; controls experiments and data system components; and provides manual, semiautomatic and automatic control.

The recorder carries 9,400 feet of magnetic tape that permits up to two hours of recording time at a tape speed of 15 inches per second. After the return of the orbiter, the data tape is played back for recording on a ground system. The tape is not usually removed from the recorder.

The following 5 experiments were part of the Developmental Flight Instrumentation (DFI) experiment package.

1. SHUTTLE INFRARED LEESIDE TEMPERATURE SENSING (SILTS)

The SILTS experiment will obtain high-resolution infrared imagery of the upper (leeward) surface of the orbiter fuselage and left wing during atmospheric entry. This information will increase understanding of leeside aeroheating phenomena and will be used to design a less conservative thermal protection system. SILTS provides the opportunity to obtain data under flight conditions for comparison with data obtained in ground-based facilities.

Six primary components make up the SILTS experiment system: (1) an infrared camera, (2) infrared-transparent windows, (3) a temper ature-reference surface, (4) a data and control electronics module, (5) a pressurized nitrogen module and (6) window protection plugs. These components are installed in a pod that is mounted atop the vertical stabilizer and capped at the leading edge by a hemispherical dome. (The SILTS pod replaces the top 24 inches of the vertical stabilizer.) Within this dome, the infrared camera system is mounted in such a way that it rotates to view the orbiter leeside surfaces through either of two windows-one offering a view of the orbiter fuselage and the other a view of the left wing. The camera is sensitive to heat sources from 200 to 1,000 F.

The camera's indium-antimonide detector is cooled to cryogenic temperatures by a Joule-Thompson cryostat. The camera's field of view is 40 by 40 degrees. Its rotating prism system scans four 100-line fields each second, with a 4-1 interlace, resulting in a 400-line image.

Each of the two infrared-transparent window assemblies consists of dual silicone windows constrained within a carbon-phenolic window mount. The windows and window mount assemblies are designed to withstand the entry thermal environment to which they would be subjected without active cooling. They are, however, transpiration cooled with gaseous nitrogen during experiment operation so that they do not reach temperatures at which they would become significant radiators in the infrared. A small thermostatically controlled surface between the two window assemblies provides an in-flight temperature reference source for the infrared camera.

The pressurized nitrogen system comprises two 3,000-psi gaseous nitrogen bottles and all associated valves and plumbing. The pressure system supplies gaseous nitrogen to the cryostat for camera detector cooling, to the external window cavities for window transpiration cooling, and to pin pullers that initiate the ejection of the advanced flexible reusable surface insulation window protection plugs upon SILTS activation to expose the viewing ports and camera.

The information obtained by the camera is recorded on the OEX tape recorder. The data, when reduced and analyzed, will produce a thermal map of the viewed areas.

The SILTS experiment is initiated by the onboard computers approximately five minutes before entry interface, which occurs at an altitude of approximately 400,000 feet. The camera operates for approximately 18 minutes through the forward-facing window and left-facing window, alternating evenly between the two about every five seconds.

After the six planned SILTS missions, an analysis of structural loads will determine whether the SILTS pod should be removed and replaced with the original structure or remain in position for other uses. The pod thermal protection system is high-temperature reusable surface insulation black tiles, whose density is 22 pounds per cubic foot.

2. SHUTTLE ENTRY AIR DATA SYSTEM (SEADS)

Accurate aerodynamic research requires precise knowledge of vehicle attitude and state. This information, commonly referred to as air data, includes vehicle angle of attack, angle of sideslip, free-stream dynamic pressure, Mach number and total pressure. An evaluation of the orbiter baseline air data system indicated that flight air data would not be available above approximately Mach 3.5 and that the accuracy of the air data would not satisfy aerodynamic research requirements. Therefore, SEADS was developed under the orbiter experiments program to take the measurements required for precise determination of air data across the orbiter's atmospheric flight-speed range (i.e., hypersonic, supersonic, transonic and subconic Mach numbers) or from lift-off to 280,000 feet during ascent and from 280,000 feet to touchdown during entry.

The key to incorporating SEADS in the shuttle orbiter was the development of a technique for penetrating the orbiter's reinforced carbon-carbon nose cap to obtain the required pressure measurements. The SEADS nose cap penetration assembly evolved as a result of extensive design, fabrication and test programs that evaluated high-temperature (greater than 2,600 F) materials and configuration concepts. The coated columbium penetration assembly selected then was fabricated for installation in a specially modified baseline geometry nose cap. The SEADS nose cap contains an array of 14 penetration assemblies, associated coated columbium pressure tubing, support structure, pressure transducers and system-monitoring instrumentation. Data from the SEADS pressure transducers are transmitted to the OEX support system and stored on the OEX tape recorder for postflight data analysis.

3. SHUTTLE UPPER ATMOSPHERE MASS SPECTROMETER (SUMS)

The SUMS experiment will obtain measurements of free-stream density during atmospheric entry in the hypersonic, rarefied flow regime. These measurements, combined with acceleration measurements from the companion high-resolution accelerometer package experiment, will allow calculation of orbiter aerodynamic coefficients in the flow regime previously inaccessible to experimental and analytic techniques. SUMS complements SEADS by providing data at higher altitudes. The resultant flight data base will aid in future development of analysis techniques and laboratory facilities for predicting winged-entry-vehicle performance in hypersonic rarefied flow. Furthermore, SUMS will measure equilibrium gas composition at the inlet port, making the experiment a pathfinder for future mass spectrometer application in the study of aerothermodynamic properties of the transition flow field.

The SUMS experiment system consists of a sample orifice, an inlet system and a mass spectrometer. The sample orifice penetrates a thermal tile just aft of the fuselage stagnation point and just forward of the orbiter nose wheel well. The orifice is connected to the inlet system by a short tube through the forward nose wheel well bulkhead. The inlet system is connected through a longer tube to the mass spectrometer, which is mounted above the inlet system on the forward nose wheel well bulkhead. SUMS is designed for easy removal and reinstallation between flights to accommodate modification or repair.

The mass spectrometer is a flight spare unit from the Viking project's upper atmosphere mass spectrometer system. The unit has been modified to be compatible with the orbiter's mechanical, electrical and data systems. The mass spectrometer measures gases from hydrogen through carbon dioxide at a five-second rate. The inlet system contains two switchable flow restrictors that expand the measurement range of the mass spectrometer and position its measurement interval over the desired altitude range. Data from SUMS are output to the OEX data system for recording during flight operation.

SUMS is controlled by stored commands that are transmitted to the orbiter during flight and by internal software logic. Application of power for vacuum maintenance or for normal operation is controlled by stored commands; while internal control of system operation, such as opening and closing valves, is performed by preprogrammed logic. SUMS will be powered on shortly before deorbit burn initiation and will sample the inlet gases down to an altitude of 40 nautical miles. At an altitude of about 59 nautical miles, the range valve will close to switch between the two flow restrictors. At 59 nautical miles, the inlet valve and protection valve will close; but the mass spectrometer will continue to operate until landing, observing the pump-down and background signals after entry.

Operation of SUMS on repeated shuttle flights will not only build a substantial body of aerothermodynamic data for future winged-entry-vehicle design applications, but also add to the knowledge of mass spectrometer applications in aerothermodynamic research. As a further benefit, data will be obtained on atmospheric properties in the altitude range where experimental data are, to date, extremely sparse.

4. AERODYNAMIC COEFFICIENT IDENTIFICATION PACKAGE (ACIP)

Although all of the generic data types required for aerodynamic parameter identification are available from the baseline orbiter systems, the data are not suitable for experimentation because of such factors as sample rate deficiencies, inadequate data resolution or computer cycle time and core size interactions. In addition, the baseline data are operational measurements that are not subject to the desired changes for conducting experiments. The ACIP is a group of sensors that will be placed on the orbiter to obtain experiment measurements unavailable through the baseline system.

The primary ACIP objectives are as follows: (1) to collect aerodynamic data in the hypersonic, supersonic and transonic flight regimes, regions in which there has been little opportunity for gathering and accumulating practical data; (2) to establish an extensive aerodynamic data base for verifying and correlating ground-based test data, including assessments of the uncertainties in such data; and (3) to provide flight dynamics state-variable data in support of other technology areas, such as aerothermal and structural dynamics.

Implementing the ACIP program will benefit the space shuttle because the more precise data obtained through the ACIP will enable earlier attainment of the spacecraft's full operational capability. Currently installed instrumentation provides sufficiently precise data for orbiter operations, but not for research. The result is that constraint removal would either be based on less substantive data or would require a long-term program of gathering the less accurate data.

The ACIP incorporates three triads of instruments: one of linear accelerometers, one of angular accelerometers and one of rate gyros. Also included are the power conditioner for the gyros, the power control system and the housekeeping components for the instruments. The ACIP is aligned to the orbiter's axes with extreme accuracy. Its instruments continually sense the dynamic X, Y and Z attitudes and the performance characteristics of the orbiter during the launch, orbital, entry and descent phases of flight. In addition, the ACIP receives the indications of orbiter control surface positions and converts the information into higher orders of precision before recording it with the attitude data. The output signals are routed to the pulse code modulation system for formatting with orbiter time data and data from the orbiter experiments. The data are then stored in the OEX tape recorder.

5. HIGH-RESOLUTION ACCELEROMETER PACKAGE (HiRAP)

This experiment uses an orthogonal, triaxial set of sensitive linear accelerometers to take accurate measurements of low-level (down to micro-g's) aerodynamic accelerations along the orbiter's principal axes during initial re-entry into the atmosphere, i.e., in the rarefied flow regime.

The aerodynamic acceleration data from the HiRAP experiment, output on existing ACIP channels, have been used to calculate rarefied aerodynamic performance parameters and/or atmospheric properties pertaining to several flights, beginning with the STS-6 mission. These flight data support advances in predicting the aerodynamic behavior of winged entry vehicles in the high-speed, low-density flight regime, including free molecular flow and the transition into the hypersonic continuum. Aerodynamic performance under these conditions cannot be simulated in ground facilities; consequently, current predictions rely solely on computational techniques and extrapolations of tunnel data. For improvement or advances, these techniques depend on actual flight data to serve as benchmarks, particularly in the transition regime between free molecular flow and continuum flow.

Advancements in rarefied aerodynamics of winged entry vehicles may also prove useful in the design of future advanced orbital transfer vehicles. Such OTVs may use aerodynamic braking and maneuvering to dissipate excess orbital energy into the upper atmosphere upon return to lower orbits for rendezvous with an orbiter from the space station. A key aerodynamic parameter in the OTV design is the lift-to-drag ratio, which is measured directly in the HiRAP experiment. Furthermore, an OTV may require a flight-proven, sensitive onboard accelerometer system to overcome uncertainties in the upper atmosphere. The experience gained from the planned multiple HiRAP flights may provide valuable test data for the development of future navigation systems. In addition, the experiment provides data on key atmospheric properties (e.g., density) in a region of flight that is not readily accessible to orbital vehicles or regular meteorological soundings.

MODULAR AUXILIARY DATA SYSTEM (MADS)

This onboard instrumentation system measures and records selected pressure, temperature, strain, vibration and event data to support payloads and experiments and to determine orbiter environments during flight. It supplements existing orbiter operational instrumentation by conditioning, digitizing and storing data from selected sensors and experiments.

The MADS collects detailed data during ascent, orbit and entry to define vehicle response to flight environments. It permits correlation of data from one flight to another and enables comparison of flight data from one orbiter to another orbiter.

All MADS equipment installed in the orbiter is structurally mounted and environmentally compatible with the orbiter and mission requirements. Because of its location, the MADS does not intrude into the payload envelope. Equipment consists of a pulse code modulation multiplexer, a frequency division multiplexer, a power distribution assembly and appropriate signal conditioners mounted on shelf 8 beneath the payload bay liner of the midfuselage.

In OV-102 (Columbia), MADS inputs its information to the system control module and records it on the OEX recorder located below the crew compartment middeck floor. In OV-103 (Discovery) and OV-104 (Atlantis), a MADS control module and recorder are mounted below the crew compartment middeck floor.

MADS records approximately 246 measurements from the orbiter airframe, skin and orbital maneuvering system/reaction control system left-hand pod.

The MADS interfaces with the orbiter through the orbiter's electrical distribution system and operational instrumentation inputs for status monitoring. Coaxial cables and wire harnesses from the sensors are routed through the orbiter payload bay harness bundles to the signal conditioners, PCM multiplexer and FDM, attached to the midfuselage shelf. After the signal conditioners and the multiplexers have processed the data, four outputs of the FDM and one output of the PCM multiplexer are routed forward to the SCM in OV-102 for recording on the OEX recorders. In OV-103 and OV-104, the four outputs of the FDM and one output of the PCM multiplexer are routed forward to the MCM for recording on five tracks of the MADS recorder. In addition, the MADS recorder is used during ascent to record additional space shuttle data consisting of solid rocket booster wide band and external tank signals.

The MADS is not considered mandatory for launch, and its loss during flight does not cause a mission abort. It measures and records data for predetermined events established by test and mission requirements.

For a typical mission, approximately five hours before launch, the MADS is powered on from the preset switch configuration to supply a prelaunch manual calibration. (Power is supplied from the orbiter's main buses A and B.) After calibration, all switches are returned to the preset configuration, leaving the MADS in the standby position and only the MCM receiving power. This mode continues until nine minutes before launch, at which time the MADS attains the full-system mode through uplink commands and all its components are powered on. In this mode, the MADS recorder is operating at a continuous tape speed of 15 inches per second, recording aerodynamic coefficient identification package, flight acceleration safety cutoff, ET, SRB, wide-band and PCM data. The MADS PCM bit rate is 64 kbps.

The wide-band-only mode is used during the prelaunch automatic and manual calibrations. This mode records the ac and dc calibration levels provided by the FDM. Each manual calibration level is recorded for 10 seconds at a tape speed of 15 inches per second in the continuous mode.

Approximately 12 minutes after launch, the MADS is commanded into the PCM-snapshot-with-strain-gauge-signal-conditioner mode. In this mode, the recorder is in the sample mode, conserving power and recorder tape by recording data for 10 seconds every 10 minutes at a PCM bit rate of 32 kbps and a tape speed of 3.75 inches per second. Two minutes before the second orbital maneuvering system thrusting period, the MADS is commanded into the full-system mode until the thrusting period is completed. Then it is commanded into the PCM-only mode, which continues during the orbit until a quiescent period is reached. In OV-102 only, one minute of ACIP calibration is required during this period, after which the MADS continues in the PCM-only mode. The system is switched to the full-system mode for the OMS separation thrusting periods and can be returned to the PCM-only mode for the majority of the on-orbit mission.

The PCM-with-SGSC mode is similar to the PCM-only mode, but strain measurements are also recorded during this period. The SGSC operation is cycled along with the other MADS equipment and signal conditioners by uplink commands to maintain the required operational temperatures. This mode occurs between two full-system modes to minimize flight crew participation and conserve power and recorder tape. It can be initiated from the full-system mode or returned to the full-system mode by one uplink command. To shift this mode to the PCM-only mode, the SGSC must be commanded off manually by the flight crew. This mode is used on orbit.

Two minutes before the deorbit thrusting period, the MADS is put into the full-system mode for one hour to record descent (entry) data. At the conclusion of the one-hour period, it is placed in the PCM-only mode for approximately four hours to measure postlanding thermal data and is then powered down for the entire postlanding period.

With the use of the MADS switches located in the crew compartment, control can be initiated by the flight crew. To reduce the flight crew's participation, all commands are uplinked from the Mission Control Center in Houston and transmitted to the onboard payload forward 1 multiplexer/demultiplexer. The MDM then routes the commands to the SCM for processing in OV-102 and to the MCM in OV-103 and OV-104. Power for the MADS will be supplied by the orbiter's 28-volt dc main buses A and B.

The flight acceleration safety cutoff system interfaces 12 orbiter main engine vibration measurements with the MADS. The variety of MADS measurements is collected by thermocouples, resistance thermometers, radiometers, vibration sensors, strain gauges or pressure transducers.

The MADS shelf 8 components are protected from overheating by shelf temperature monitoring and control of MADS operation by ground commands. The MADS is thermally isolated from the orbiter structure by 0.049-inch thin-wall titanium struts. It is also protected from the orbiter environment by a 1.5-inch bulk-insulation enclosure.

The MADS recorders in OV-103 and OV-104 are Data Tape/Kodak 28-track, wide-band, modular, airborne recording systems similar to the OV-102 orbiter experiments recorder. The recorders are capable of simultaneously recording, and subsequently reproducing, 28 tracks of digital biphase L data or any combination of wide-band analog and digital biphase L data up to 28 tracks.

After OV-103 and OV-104 return from a mission, the recorder tape is played back to record the data on a ground recording system. The tape is not removed from the flight recorder. The total MADS weight is 641 pounds.