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Results of Demonstration Test for Receiving and Processing of Flight Data From the Space Transportation System

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Abstract

This report presents the methodology used for receiving, processing, and analyzing flight data from the Space Transportation System at NASA Langley Research Center (LaRC) on a near real time basis. The task was performed in October 1993 during STS-58 mission using data from the Orbital Acceleration Research Experiment (OARE). The transmitting and receiving of OARE data on a near real time basis at LaRC were highly successful. The time to receive and record the data from the payload tape recorder required 20 to 30 minutes. Payload tape recorder data were downlinked at intervals of 4 to 6 hours rather than continuously. The quality check of the data at LaRC required 2 minutes. Four to 5 minutes of time was required to obtain preliminary acceleration levels of the Orbiter that are within 1 micro-g of the absolute accelerations. This demonstration has shown that with operational modifications LaRC has the capability to serve as User Operation Center for receiving and processing flight data from the Space Shuttle and Space Station.

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Introduction

This report summarizes the methodology for receiving, processing, and analyzing data at the NASA Langley Research Center (LaRC) on a near real time basis from experiments being conducted on the Space Transportation System. This task was performed in October 1993 during the STS-58 mission using near real time data from the Orbital Acceleration Research Experiment (OARE).

This report is a follow up to the "Demonstration Plan For Real Time Receiving and Processing of Flight Data From the Space Transportation System" published in January 1993 (ref 1). The OARE data is transmitted as part of the payload tape recorder data stream, whereas the mission data is received and processed at NASA Johnson Space Center (JSC) and NASA Goddard Space Flight Center (GSFC). As stated in Reference 1, analysis of the OARE data involves not only the OARE instrument data, but also selected Space Shuttle mission data.

This report includes the methods employed at LaRC for receiving and processing both the OARE data and the required Space Shuttle Mission data. The descriptions of the OARE instrument, the Space Shuttle data flow, and the OARE Instrument data flow presented in this report are essentially the same as that presented in reference 1.

OARE Instrument

The OARE instrument is a triaxial electrostatic accelerometer package with unique on-orbit calibration capabilities. It has a measurement resolution of 3 nano-gs on the X axis and 4.6 nano-gs on the Y and Z axes. Figure 1 shows the instrument package and Figure 2 shows the package installed in the floor of the Space Shuttle cargo bay near the Space Shuttle center of gravity.

Space Shuttle Data Flow

Space Shuttle data is transmitted to the Tracking and Data Relay Satellite System (TDRSS) on three channels, the S-Band, the Ku-Band, and the K-Band channel. The K-Band channel is used for special high data rate transmission. The S-Band channel is used to transmit mission data and voice on a real time basis during the time when Space Shuttle is in view of either the east satellite or west satellite of TDRSS. However for a period of approximately 10 minutes of each 90 minute orbit, the Space Shuttle is out of view of both TDRSS satellites and no data is transmitted. All mission data are recorded on board the Shuttle for transmission to TDRSS at a high rate on the Ku-Band channel. The Ku-Band channel also transmits recorded payload data including OARE data, and real time video data.

The data are transmitted from Space Shuttle via TDRSS to the NASA ground station near White Sands Missile range. At the White Sands ground station all data are retransmitted over the NASA Communications System Time Division Multiple Access (NASCOM-TDMA) via the Domestic Satellite (DOMSAT) to both the JSC ground station and the GSFC ground station. The data transmitted to JSC and GSFC are on a C-Band channel in the same format as they were transmitted from Space Shuttle to TDRSS. Figure 3 shows a schematic of the Space shuttle data flow. This is a simplified version of the Space Shuttle data flow path presented in the Payload Operations Control Center Capabilities Document (ref 2). Although the flow paths of the OARE data and the mission data are similar, they are processed differently.

OARE Instrument Data Flow

Anti-alias filtering is performed on each of the three orthogonal sensor signals in OARE to minimize acceleration signals above 1 Hz. The acceleration data is then sampled at a rate of 20 Hz. The OARE instrument software then averages sample pairs for each sensor to obtain a data rate of 10 Hz. The OARE instrument has onboard data storage and a data buffer that interfaces with the Space Shuttle tape recorder as shown in Figure 4. During orbit operations, the buffer dumps the OARE data in 64 bit words to a continuously running tape recorder approximately every 10 minutes at a rate of 32 Kilobits per second (Kbps). Thus each 10 minute interval of tape has about 12 seconds of OARE data. The payload tape recorder data is transmitted on the Ku-band channel every four to six hours at a data rate of 640 Kbps. Four hours of OARE data requires 12 minutes of data transmission time on the Ku-Band and C-Band channels. During reentry, the OARE data is stored internally in electronic memory as well as on the real time buffer. After landing the buffer data is dumped to a tape recorder. After the Orbiter is moved to the Orbiter Processing Facility, the OARE electronic memory is transferred to an OARE Ground Support Equipment computer.

The on-orbit OARE data are transmitted through White Sands to the JSC ground station and recorded at JSC on tape in pulse code modulated (PCM) format. Prior to STS-58, after each Space Shuttle flight was completed, the OARE PCM tape was converted at JSC to a computer compatible tape in 8 bit bytes that was then mailed to OARE researchers at LaRC. For flight STS-58 the OARE PCM data were transmitted near real time to LaRC for processing.

Near Real Time Processing of OARE Data at LaRC

The near real time processing of OARE data at LaRC consisted of three steps: (1) receiving and processing OARE data at LaRC, (2) receiving pertinent mission data at LaRC, and (3) performing preliminary analysis of the OARE data.

Receiving and Processing OARE Data at LaRC

The OARE data was received on a near real time basis at the LaRC Flight Control Center (FCC). The FCC consists of the Flight Control Room and the Flight Monitor Room. The FCC supports research aircraft flights out of NASA LaRC and other NASA centers including AMES, Dryden, and Wallops. The OARE data was received via NASCOM-TDMA from DOMSAT at the same time that JSC and GSFC received the signal. Figure 5 shows the OARE data being transmitted to LaRC. The FCC is equipped with a receiver and a deblocker capable of picking the OARE data from the 640 Kbps NASCOM-TDMA stream. The deblocked data was then transmitted to the Research Aircraft Ground Station (RAGS) using a circuit designed and fabricated at LaRC, where it was converted to biphase PCM format and recorded on tape. The 4 to 6 hours of real time OARE data required approximately 20 to 30 minutes to be received and recorded. Software was developed at LaRC under another program to convert recorded PCM data directly to an 8-bit byte data stream for analysis. Figure 6 shows a block diagram of the OARE data as it was received and processed at LaRC and passed to the researchers for analysis.

The FCC and RAGS were staffed on a 24 hour a day basis from the time of launch until late in the evening on the tenth day, when the payload tape recorder failed and OARE data could no longer be telemetered. During this mission flight time, the OARE data was received every three or four orbits which was every 4 to 6 hours. The total amount of data received included all the orbit data over the mission flight time, except for the 20 minutes or so during each payload tape recorder dump, when the OARE buffer could not transmit data to the recorder. This corresponds to roughly 210 hours of OARE accelerometer data for STS-58.

Receiving Pertinent Space Shuttle Mission Data at LaRC

In order for LaRC researchers to analyze the OARE data certain mission state parameters were required such as the Shuttle position, velocity, and quaternions. Table 1 lists the pertinent mission parameters required for analyzing the OARE data.

The mission data were transmitted over the C-Band channel to JSC and GSFC as shown in Figure 5. At the Orbiter Data Reduction Center (ODRC) at JSC, the mission data are further processed and converted to engineering units and put on file in IBM format (floating point and integer values). These files contain pertinent data for more than 21000 different mission parameters and are accessible through a user friendly software code developed at JSC called the Mission Evaluation Workstation System (MEWS). MEWS provides a simplified method for obtaining the mission state parameters and data that are required for analysis of OARE by allowing the user to specify the Measurement/Stimuli Identification (MSID). MSIDs for OARE analysis include Space Shuttle position, velocity, and quaternions. The Space Shuttle location and altitude are derived from the position. The wind angles and wind speed are derived from the velocity. The angular body rates and attitude are derived from the quaternions. Table 1 lists the MSIDs used in the preliminary OARE analysis. MEWS allows the user to scan the ODRC files to find the MSID names and to identify the times when specific events occurred. Thus for each MSID the user can specify the time for which he desires the data values. MEWS has many options that allow the user to easily obtain mission parameter data for previous STS flights. MEWS allows users to obtain mission parameters much quicker than waiting for the Calibrated Ancillary System (CAS) mission data that must first be processed by the ODRC and then further processed and transmitted through GSFC to the users. Furthermore, CAS users are required to specify all the pertinent mission parameters prior to the flight.

Performing Preliminary Analysis of OARE Data

The calibration of the acceleration data to counts and engineering units is a complex process that is driven by the on-orbit calibrations and the mission parameters. Therefore, calibration of acceleration data was part of the analysis procedure performed by the OARE researchers. The LaRC researchers developed and wrote software for obtaining data quality measurements using LaRC supercomputers. The recorded PCM data were converted to 8-bit bytes and written to hard disk. These data were then transferred to a digital computer file on an LaRC supercomputer that required approximately 60 seconds of time. Certain housekeeping data were then spot checked to obtain a data quality measurement as a percentage of valid science values. The data quality check required 30 seconds. Another 30 seconds was required to make the decision that the data quality was satisfactory. The data quality check required approximately 2 minutes from the time the data were received. A data quality check was also performed at JSC to measure the percentage of data received rather than the percentage of valid accelerations. During the STS-58 mission there were approximately four instances where the LaRC science quality checks were poor and JSC was asked to transmit their recorded data over NASCOM-TDMA to LaRC. Figure 6 shows the process for retransmitting OARE data from JSC to LaRC. The data were then further processed by applying the calibration biases and scale factors to the converted acceleration data to obtain preliminary acceleration levels. These preliminary uncorrected acceleration values can generally be confirmed within 1 micro-g of the true accelerations. Four to 5 minutes of time was required to obtain the preliminary acceleration levels. Thus the elapsed time for initial processing of OARE data after it is received and recorded is 6 to 7 minutes to obtain preliminary acceleration values.

Within 2 to 3 hours of receiving OARE data the mission data was made available to the OARE researchers at LaRC from ORDC at JSC. This allowed detailed analysis of OARE data to be performed near real time to define absolute Space Shuttle acceleration levels.

Results

The methodology employed to receive and process OARE data on a near real time basis at LaRC for the STS-58 mission was highly successful. OARE data were received for 93 percent of the total elapsed time from the time OARE was first turned on until the payload tape recorder failed 10 days later. It took 20 to 30 minutes to receive and record the OARE data at LaRC. The quality check of the OARE data required approximately 2 minutes from the time the data were received. Feedback of the results to Space Shuttle mission control was performed over land communications system, rather than by transmission over NASCOM-TDMA. The OARE data quality was very good in that only four times during the mission were there requirements for JSC to retransmit recorded data. The preliminary processing of OARE data at LaRC required 4 to 5 minutes to obtain preliminary calibrated acceleration values that were within 1 micro-g of the absolute acceleration levels. Receiving Orbiter mission data parameters and calibration and analysis of OARE data required 2 to 3 hours to define the calibrated absolute acceleration values.

LaRC has demonstrated the capability to receive and process space flight data on a near real time basis. The Flight Control Center and the Research Aircraft Ground Station were staffed at all times during the 10 days when the OARE instrument was operating. LaRC has demonstrated that it could build the capability to serve as a User Operations Facility for Space Shuttle and Space Station science investigators.

References

1. Russell, J. W., Avery, D. E., "Demonstration Plan for Real Time Receiving and Processing of Flight Data from the Space Transportation System," NASA TM 107725, NASA Langley Research Center, January 1993.

2. "Payload Operations Control Center Capabilities Document, Revision A PCN-1," NSTS-21063-POC-CAP, NASA Johnson Space Center, October 1991.

List of Acronyms

CAS	Calibrated Ancillary System
DOMSAT	Domestic Satellite
FCC	Flight Control Center
GSFC	NASA Goddard Space Flight Center
JSC	NASA Johnson Space Center
Kbps	Kilobits per second
LaRC	NASA Langley Research Center
MEWS	Mission Evaluation Workstation System
MSID	Mission/Stimuli Identification
NASCOM	NASA Communications System
OARE	Orbital Acceleration Research Experiment
ODRC	Orbiter Data Reduction Center at JSC
PCM	Pulse Code Modulation
RAGS	Research Aircraft Ground Station at LaRC
STS	Space Transportation System
TDMA	Time Division Multiple Access
TDRSS	Tracking and Data Relay Satellite System

TABLE 1. Mission State Vectors Required for OARE Analysis

Measurement/Stimuli Identification	State Vector Description
V95H0185C	X component of Shuttle position vector, M50, ft.
V95H0186C	Y component of Shuttle position vector, M50, ft.
V95H0187C	Z component of Shuttle position vector, M50, ft.
V95L0190C	X component of Shuttle velocity vector, M50, ft/s
V95L0191C	Y component of Shuttle velocity vector, M50, ft/s.
V95L0192C	Z component of Shuttle velocity vector, M50, ft/s
V90U2240C	M50 to Shuttle body quaternion element 1
V90U2241C	M50 to Shuttle body quaternion element 2
V90U2242C	M50 to Shuttle body quaternion element 3
V90U2243C	M50 to Shuttle body quaternion element 4

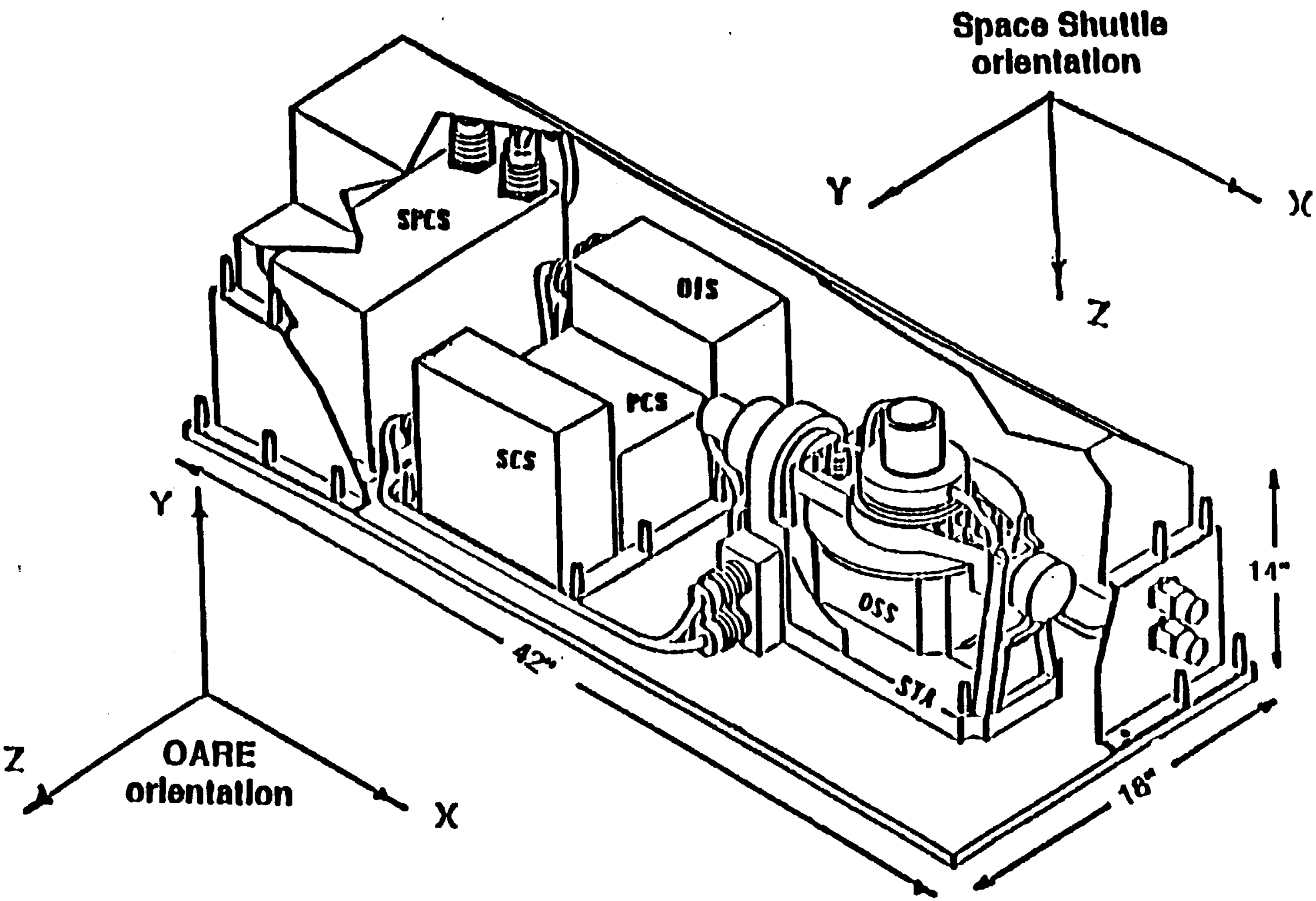

Figure 1. - Orbital Acceleration Research Experiment Package

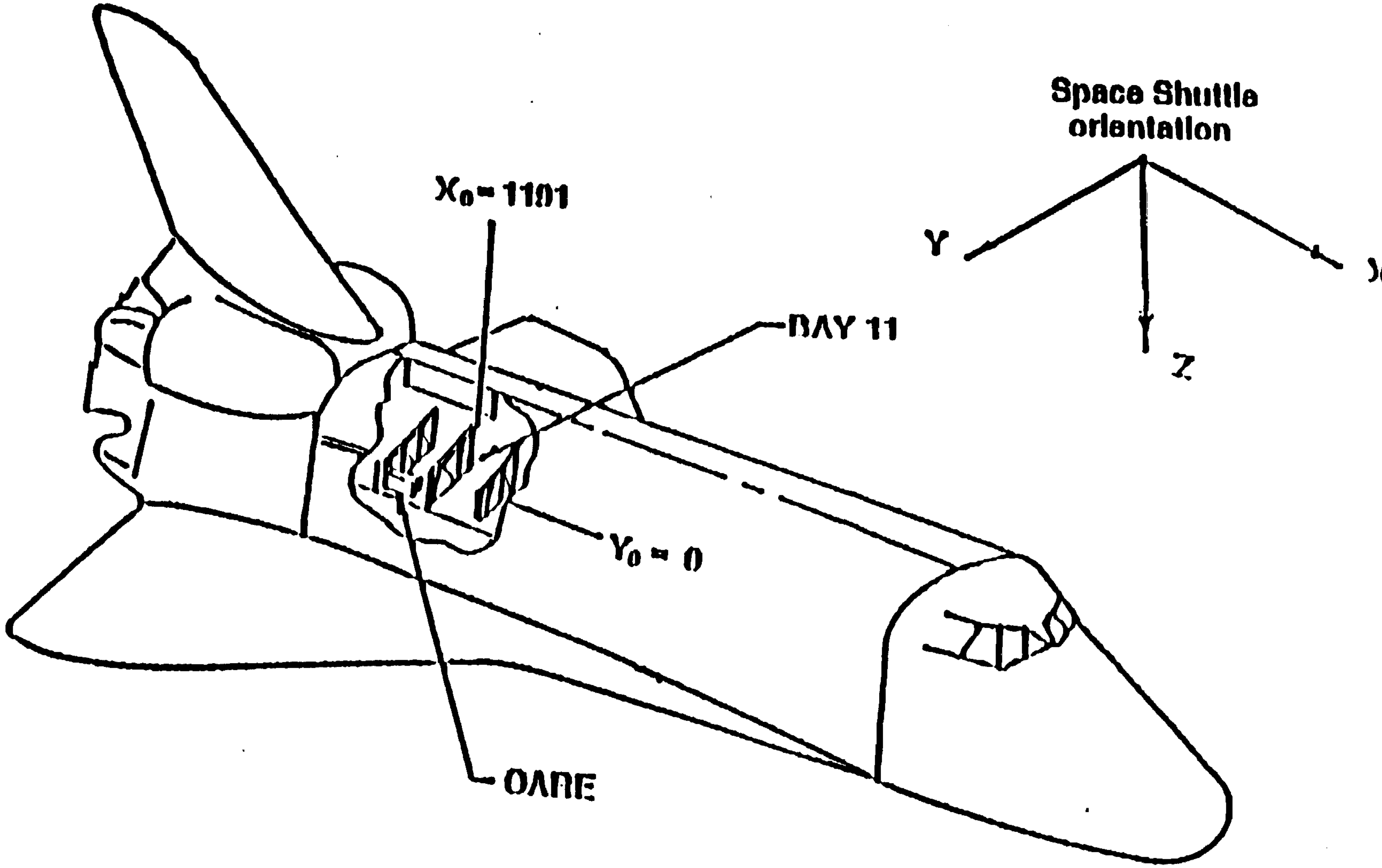

Figure 2. - Installation of Orbital Acceleration Research Experiment

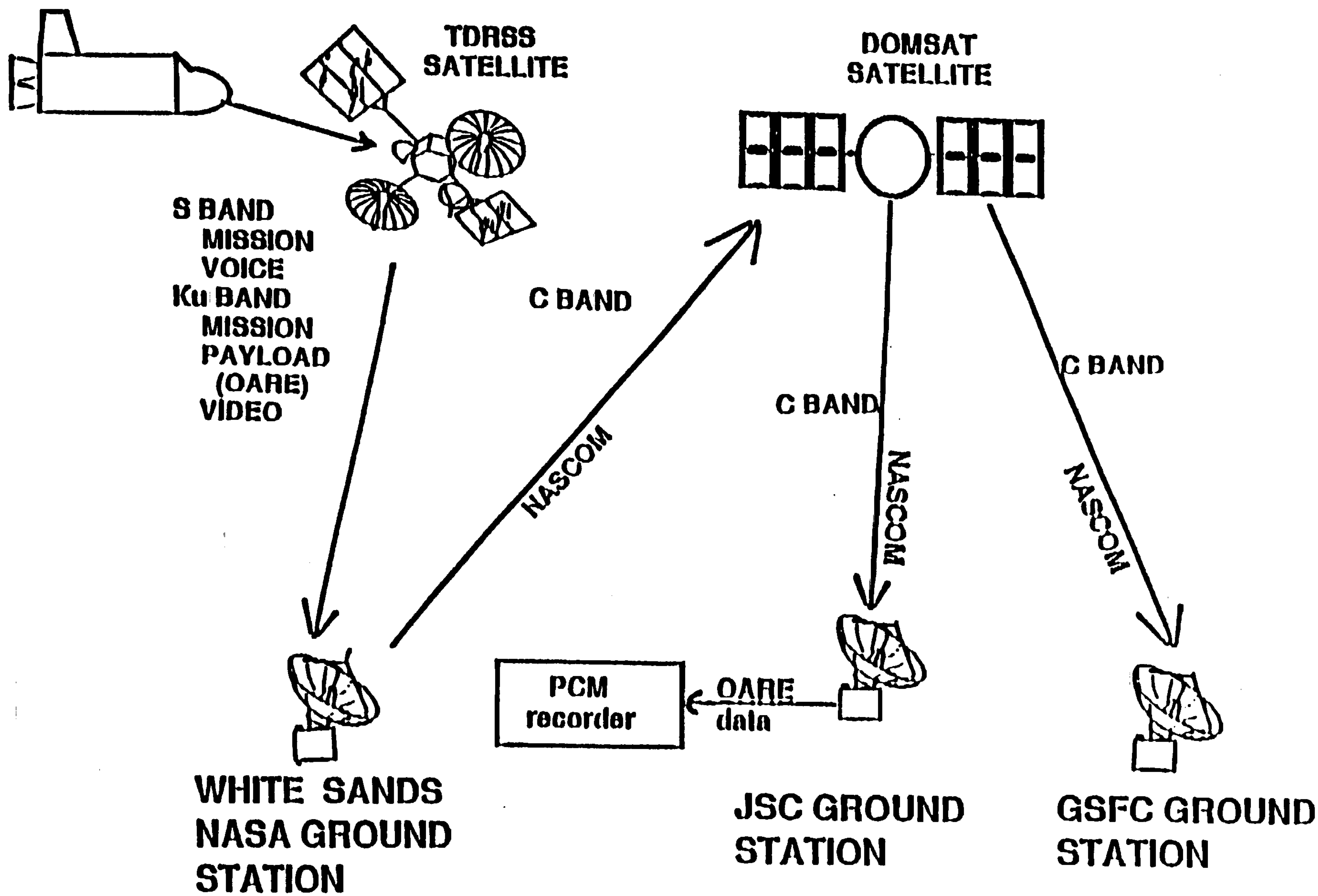

Figure 3. - Space Shuttle Data Flow

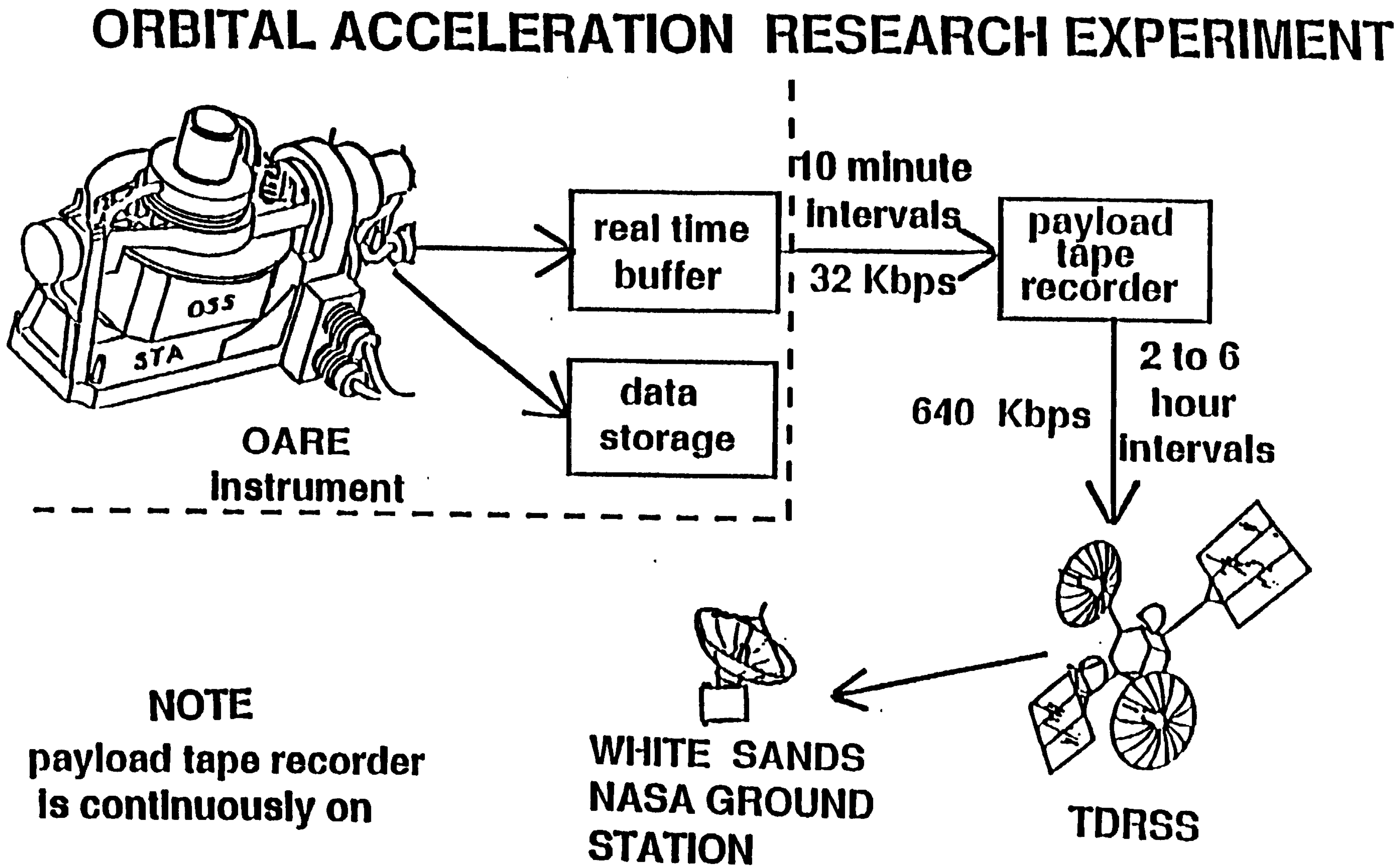

Figure 4. - Orbital Acceleration Research Experiment Data Flow

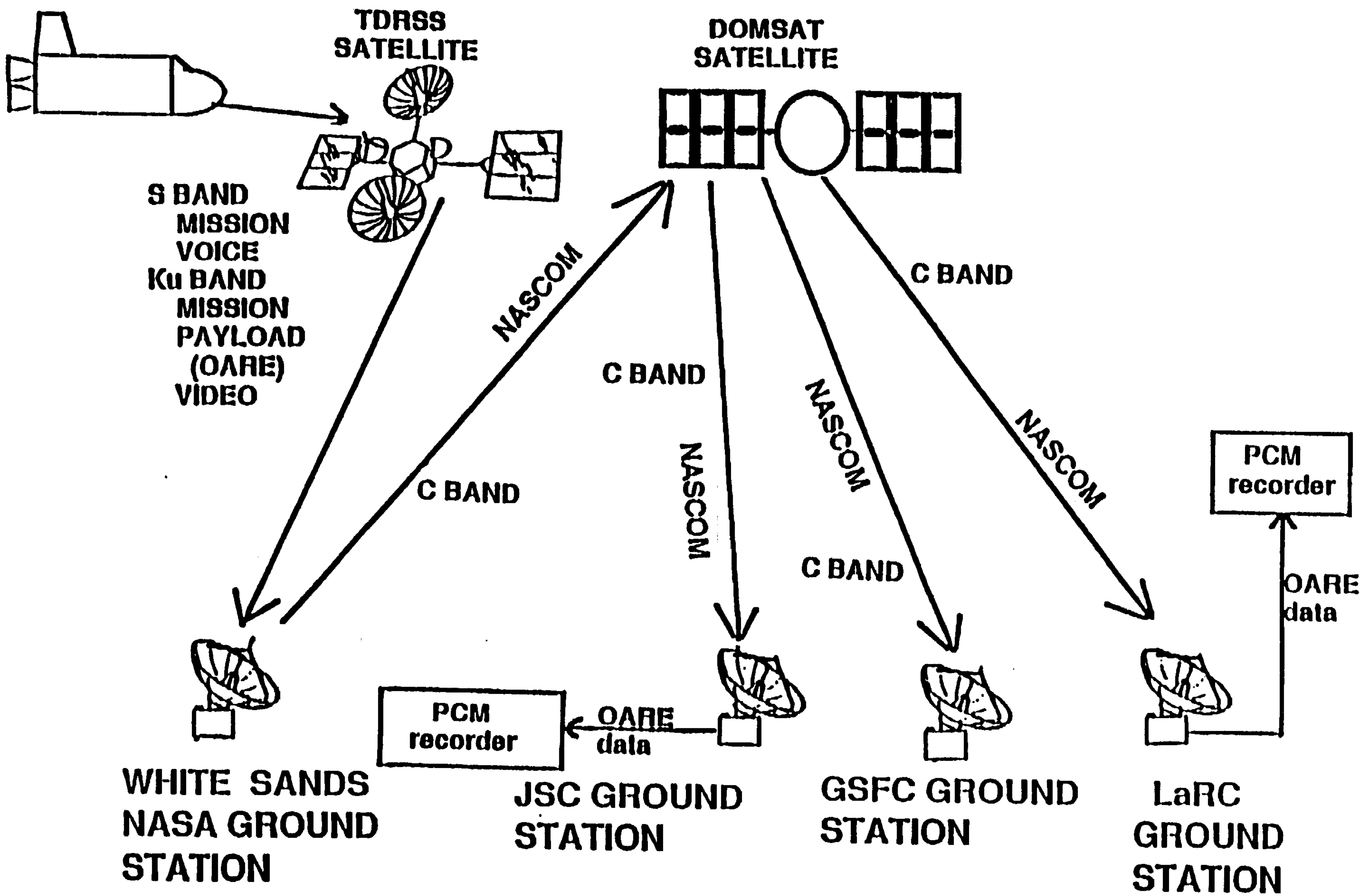

Figure 5. - Space Shuttle Data Flow with Orbital Acceleration Research Experiment Data Transmitted to LaRC

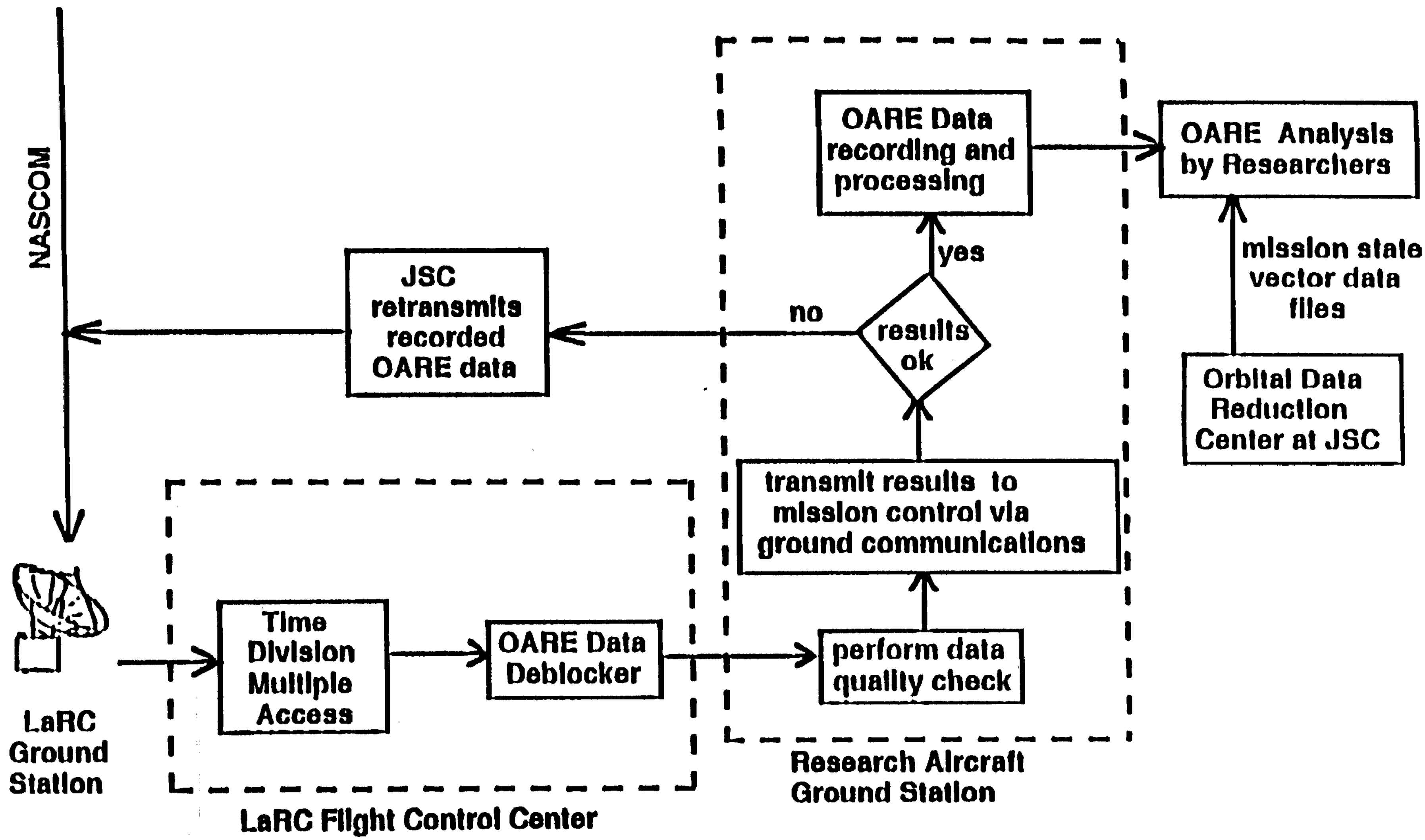

Figure 6. - Orbital Acceleration Research Experiment Data Flow at LaRC

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13. ABSTRACT (Maximum 200 words)

This report presents the methodology used for receiving, processing, and analyzing flight data from the Space Transportation System at NASA Langley Research Center (LaRC) on a near real time basis. The task was performed in October 1993 during the STS-58 mission using data from the Orbital Acceleration Research Experiment (OARE). The transmitting and receiving of OARE data on a near real time basis at LaRC were highly successful. The time to receive and record the data from the payload tape recorder required 20 to 30 minutes. Payload tape recorder data were downlinked at intervals of 4 to 6 hours rather than continuously. The quality check of the data at LaRC required 2 minutes. Four to 5 minutes of time was required to obtain preliminary acceleration levels of the Orbiter that are within 1 micro-g of the absolute accelerations. This demonstration has shown that, with operational modifications, LaRC has the capability to serve as a User Operation Center for receiving and processing flight data from the Space Shuttle and Space Station.

14. SUBJECT TERMS

Orbital Acceleration Research Experiment (OARE), OARE data, flight data, payload data, STS data, real-time data processing, user operations center.

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