EXPLORER SATELLITES
EXPERIMENT DESIGN
RADIO TRANSMITTERS
PAYLOAD INTEGRATION

SPACE SHUTTLE MISSION 51G
DOWNLINKING
REAL TIME OPERATION
THERMAL STRESS
VIBRATION TESTS
STRESS ANALYSIS

D10-12

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GET AWAY SPECIAL EXPERIMENTER'S SYMPOSIUM
OCTOBER 8-9, 1985
GODDARD SPACE FLIGHT CENTER

PROJECT EXPLORER GAS #007
MARSHALL AMATEUR RADIO CLUB EXPERIMENT (MARCE)

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MARCE PRINCIPAL INVESTIGATOR

ND736801

INTRODUCTION

The effort involved in preparing the PROJECT EXPLORER, GAS #007 Experiments Package for the STS-41G flight, yielded a close knit team experience. The mission operations phase provided the "hands on" experiences which the space crews witness daily. This could not have happened without the cooperation and help of the GAS teams at the MSFC, GSFC, JSC, KSC, JPL, DFRF, the AIAA, the Alabama Space and Rocket Center, the University of Alabama-Huntsville, the Alabama A&M University and the many amateur radio operators and commercial organizations that supported the GAS #007 and MARCE efforts.

The Alabama Space and Rocket Center Director, Edward O. Buckbee, paid the GAS canister fee. Konrad Dannenberg is the GAS #007 Project Manager. The student science experimenter Principal Investigators are: Arthur Henderson, Experiment #1, Materials Solidification, A&M University, Huntsville, AL; Guy Smith, Experiment #2, Plant Biology, University of AL, Huntsville, AL (UAH); Jonathan Lee, Experiment #3, Superconductivity Crystal Growth, UAH. Experiment #4 is MARCE. See NASA Conference Publication 2324, August 1-2, 1984, pages 69-76.

The student experimenters (long graduated) have maintained interest and endured to keep the experiment team together and to complete their experiment.

Polls have been taken at the Project Explorer meetings regarding flying without the radio experiment transmitting. The radio downlinks require extra coordination and are sensitive to certain payloads. The poll results were unanimous. The radio down links are vital in providing data on the health and status of the total experiments package, in real time, during the flight. The amateur radio operators, prepared to receive the downlinks and OSCAR-10 relays, revealed that there was enormous interest throughout the world, to participate. This sets the stage for the reflight opportunities which the GAS PROGRAM has kindly provided.

BACKGROUND

Major activities, pertinent to the STS-41G flight preparations by the GAS #007 Team and Support Groups, are listed ~~below~~.

The Functional Test or Simulated Flight Test was conducted for 120 hours, starting March 3 and was completed March 16, 1984. This was the first time the total experiments package was put through an integrated test. A fully charged SPAR battery was used. This battery had flown a SPAR mission in June 1983, returned and was put in cold storage. The SPAR battery has a 120 day activated life. No problems were encountered. The test was a great success. A casette recorder recorded the voice messages during the three eight hour downlinks. Information and data is sent to the MARCE memory every 10 minutes, during the mission, after power-on. Strip chart recorders measured the battery voltage and current and the transmitter input voltage and current. This test confirmed the ambient prediction parameters and the experiment package integration.

The Thermal Test was conducted for 120 hours, starting April 7 and was completed April 13, 1984. A new fully charged battery was used, although it was two years beyond the two year shelf life. The GAS Thermal Design Summary Report X-732-83-8, July 1983, revealed the maximum and miniumum temperatures reached during the STS-3 GAS Flight Verification Payload. This was both a GAS flight test and qualification of the GAS carrier system. Table 4, in the report, shows the maximum and minimum internal canister temperatures were +35 and -3 degrees C. Using this data, the GAS #007 thermal test limits were set at +45 and -15 degrees C. At the -15 level, it was found that the Experiment #2 nutrient solution froze. The pump did not operate, when commanded. As a result, the following changes were made. The heater capacity was increased three times and the heat up time was increased by four. The nutrient pump was set to operate at four hours after GAS #007 power-on instead of 1 hour. Likewise, the Experiment #3 heater capacity was doubled. All other systems worked without any anomalies. The thermal test margins qualified the GAS #007 system, thermally.

The EMI test was conducted on June 13, 1984, in a screen room. The MIL-STD-462A, RE02 test was conducted on the total package from 14KHz-10GHz. A trial run was made with the GAS lid off. The radiated emission, electric field readings were within acceptable levels. With the lid on, the readings were ambient, like an empty room. The GAS canister was provided by the GSFC, for the EMI test.

The Vibration Test was conducted July 18-26, 1984. Normally, a package to be tested has a functional test performed prior to and after the vibration test. GAS #007's system was ON during all three axis of vibration. The intent was to find any intermittent connections. None were found. The systems worked with no anomalies. Recommended composite vibration criteria, for GAS payloads-based on STS-1 through STS-5 flight data: X axis = 4.9; Y axis = 7.8; Z axis = 8.0 grms. Test data shows that GAS #007 received the following: X = 4.935; Y = 7.861; Z = 8.204 grms for 60 seconds each axis. The antenna was attached to the vibration fixture.

A Stress Analysis, using a Finite Model of the GAS #007 internal structure , was created and run on SPAR. The model was subjected to the following accelerations:

TYPE	X-DIRECTION(G's)	Y-DIRECTION(G's)	Z-DIRECTION(G's)
RANDOM	14.7	23.4	24.0
QUASI-STATIC (NASTRAN MODEL ANALYSIS)			
LIFT-OFF	+3.8/-6.4	+/-6.5	+/-5.6
LANDING	+/-5.9	+/-5.0	+7.1/-4.9
WORST CASE COMBINED TOTAL			
	21.1	29.9	31.1

32 G's and 516 degrees of freedom were used to cover all canister orientations. The lowest frequency (47 Hz) found relates to the component mounting plate, in the direction perpendicular to the plates surface. The Shuttle's resonant frequency of concern is 3 Hz. The resulting stresses were subjected to the appropriate factors of safety (fos), for untested hardware, per MSFC-HDBK-505A. These are 2.0 for Ultimate and 1.25 for Yield. All structures have positive margins.

A Containment Analysis was performed on all of the components within GAS #007. All components were found to be adequately contained, which eliminated all of the experiments, inside the canister, from the requirements of a fracture mechanics analysis.

The antenna is the only item attached outside the canister. The antenna is a polarized rod dipole consisting of two rods welded to two channels, which are separately welded to a base plate. The antenna structures have high margins of safety, when subjected to 55 G's, in all axis; the antenna rod = 14.4 fos, bending stress mode and the antenna base = 9.5, bending. It was determined that three of the four fasteners are adequate to support the antenna. If one weld fails, tuning brackets between the antenna halves will restrain the broken half. The antenna was, therefore, exempt from a fracture mechanics analysis. A load test to 2.0 times limit stress was performed on the antenna, with no anomaly.

EMI tests, on the 5 watt Motorola Transmitter, consisted of MIL-STD-462A, CE06-3, where emissions were measured from 2.0 MHz to 10.0 GHz. Emissions at 1,330, 1,770 and 2,180 MHz were above the -55 dBW limit. No broad band signals were observed - all were narrow CW signals. To suppress the three signals, a HP 630A low pass filter was added. All signals, above 860 MHz are now no higher than -64 dBW. A broadband transient emissions test was made by keying the transmitter, on and off, several times. The only large signals found were near the transmitter carrier, which uses a phase lock loop to determine the transmitter frequency. Signals observed were the transmitter carrier, as the loop locked. The emissions are present only for a few milliseconds, at the beginning of each transmission.

MARCE Antenna Tests were conducted using a GAS canister mockup, a HP 4191A Impedance Meter, a HP 85 Computer and a plotter. The computer program swept the impedance meter between 400 and 500 MHz. Reflection coefficient (Rc) was converted to Voltage Standing Wave Ratio (VSWR) by:

$$VSWR = \frac{1 + Rc}{1 - Rc}$$

The minimum Rc measured (0.2084) occurred at 435.033 MHz, the transmitter frequency and equals a VSWR of 1.52 to one. Tuning the antenna, by adjusting the shorting bars (tuning stub) distance, yielded a 1.2 to one VSWR, for the flight antenna #1. A transmission line length sensitivity test was conducted by adjusting the transmission line length, between the antenna and transmitter, over a range of 0 to 1.5 wavelengths. A one wavelength variation is required to simulate all possible impedances. The transmitter, as observed on the spectrum analyzer, was stable at all times during the test. The antenna and transmitter performed well. The conclusion was that the transmitter should have no problem completing a GAS #007 mission.

A MARCE Link Analysis was conducted, using an antenna gain = 1.7 dB, path loss = -151.4 dB (1,266 miles), receiver gain = +10.0 dB, polarization loss = -3.0 dB, receiver bandwidth = 20.0 KHz, receiver noise temperature = 290 deg. K, KBT = -131.00 dBM, carrier to noise = 5.0 dB and cable loss = -0.25 dB, with the following assessment:

TRANSMITTER POWER	+36.02 dBM(4w)	+30.00 dBM(1w)	+25.82 dBM(0.382w)
LINK MARGIN	+19.07 dB	+13.05 dB	+8.87 dB
EFF. RADIATED PWR	5.58 w	1.40 w	.53 w
PWR DENSITY @ 1Mtr.	.44 w/m2	.11 w/m2	.042 w/m2
FIELD STRENGTH	12.94 v/m	6.48 v/m	4.00 v/m

Orbiter limit at 435.033 MHz = 4.00 v/m

During all testing, on GAS #007, the transmitter system never failed to respond to a turn-on command.

STS-41G CONFIGURATION

Figure 1 shows the student experiments. Note the battery vent line connections into the GAS provided redundant pressure relief valve assembly. The coax cable connector is connected to the lid coax feed through. The internal support structure is a rounded plate (1/2 X 19 3/4 in. Dia.), with a machined rib. The rectangular experiment mounting plate (1/2 X 27 3/4 X 19 3/4 in.) is attached to the machined rib, on the plate. Both plates are Aluminum 2219-T87. The mounting holes are on 2 inch centers over the total plate area. 1/4 X 24 303 cres bolts, with 303 cres Keenserts, are used to attach the experiment hardware to the plate. The heater batteries, around the experiment #2 crystal chamber, are to keep the potassium cyanide solution above freezing.

Figure 2 shows the MARCE experiment #4. Pressure transducer P1, measures canister pressure, thermisters T5, mounted on the DC-DC converter, measures canister temperature and T6 measures the SPAR battery case temperature. The two malfunction thermal switches, mounted on the battery brackets, provide safety control switch closures, should a battery cell short circuit heat the battery. The 10 dB attenuator is connected between the transmitter output and the low pass filter input. The fuse holders, on the electronic support assembly, protect the positive and negative power circuits. The double shielded cables are attached to the plate with self sticking pads. The battery mounting bracket was added to make sure the battery cells were not inverted during launch or landing. Quality Control stickers were attached after final inspection.

Figure 3 shows the battery vent line installation.

In Figure 4, the flight antenna is being disassembled. The antenna coax must be connected to the lid feed through connector first. The antenna is then assembled around the coax. Next, the coax is connected to the antenna and final installation of the antenna mount is made to the lid, after the experiment package is installed into the GAS canister.

Figure 5 shows the experiment #2 camera and crystal growth chamber installation. Figures 1 through 5 pictures were taken August 6, 1984, immediately prior to GAS #007 installation into the flight canister.

FLIGHT OPERATIONS PREPARATIONS

Extensive coordination was required to inform the amateur radio community of the timelines, locations of the downlinks, how to read the down link messages, the RF link parameters, ground track data for antenna pointing, OSCAR-10 tracking and receiving parameters and data handling techniques. Continual updates were necessary, due to the Shuttle schedule changes and the resultant timeline changes. The American Radio Relay League (ARRL) provided the service of being the link to the amateur radio operators, around the world, for information and updates. The American Radio Satellite Corp. (AMSAT) provided the information link on the OSCAR-10 relay information, to the radio community. The ARRL and AMSAT members, plus Hams in general and Short Wave Listners are the volunteer ground stations for receiving the experiment data. The Johnson Space Center Amateur Radio Club (JARC) provided updates and general information, on regularly scheduled nets, to the world amateur radio community. The JARC also provided Orbiter tracking data and charts, on timeline and position information. This allowed the radio community to know the exact time and location for the downlinks over the Orbiter ground track, around the world.

STS-41G FLIGHT

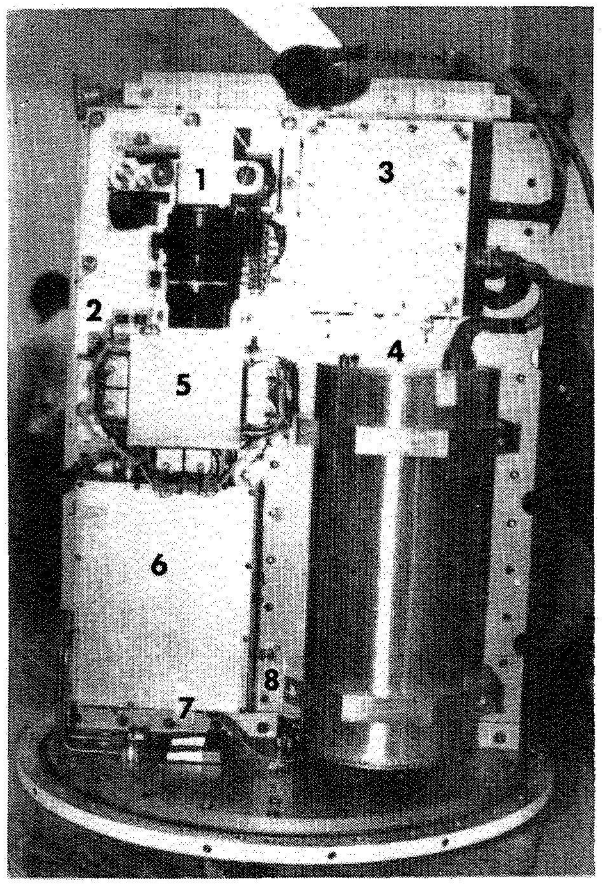

FIGURE 1. STUDENT EXPERIMENTS

1. CAMERA
2. HEATER BATTERIES
3. EXP. 1 ELECTRONICS
4. OVENS 1 & 2 CASE
5. EXP. 3 CRYSTAL CHAMBER
6. EXP. 2 ROOT CHAMBER
7. BATTERY PRESSURE RELIEF ASSEMBLY
8. LID FEED THROUGH

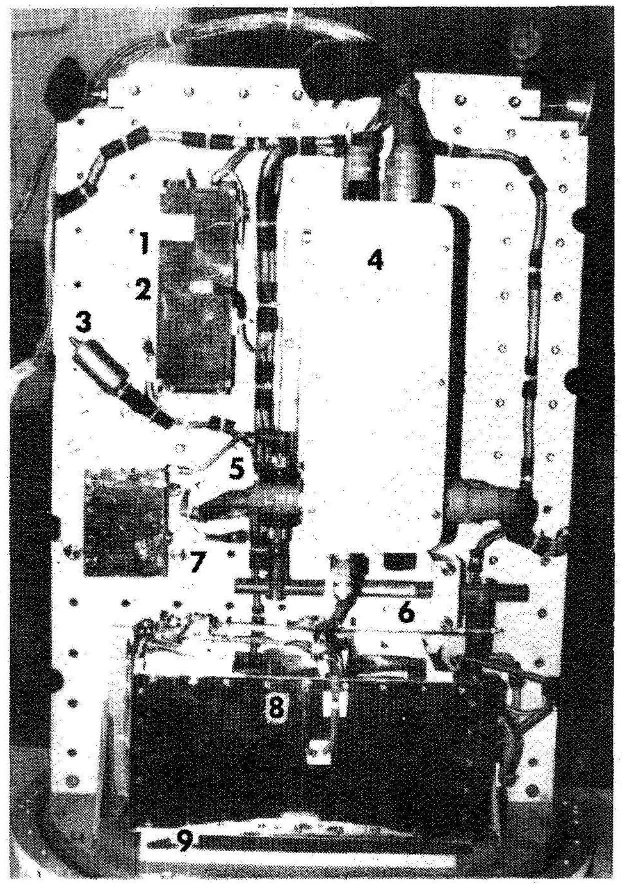

FIGURE 2. MARCE RADIO EXPERIMENT

1. DC-DC CONVERTER
2. T6
3. P1
4. ELECTRONIC SUPPORT ASSEMBLY
5. 10dB ATTENUATOR
6. LOW PASS FILTER
7. 5W TRANSMITTER
8. T6
9. BATTERY

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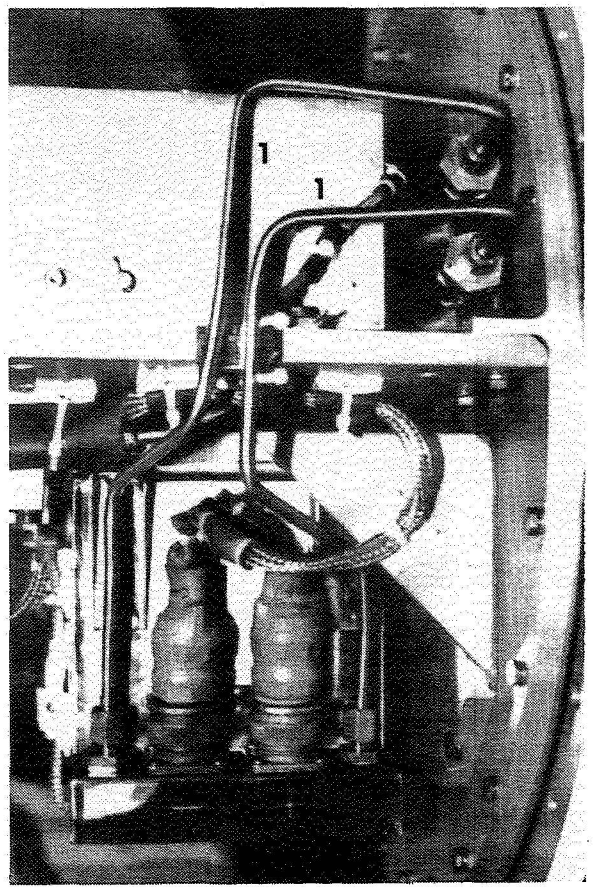

FIGURE 3. 28VDC BATTERY INSTALLATION

1. VENT TUBES

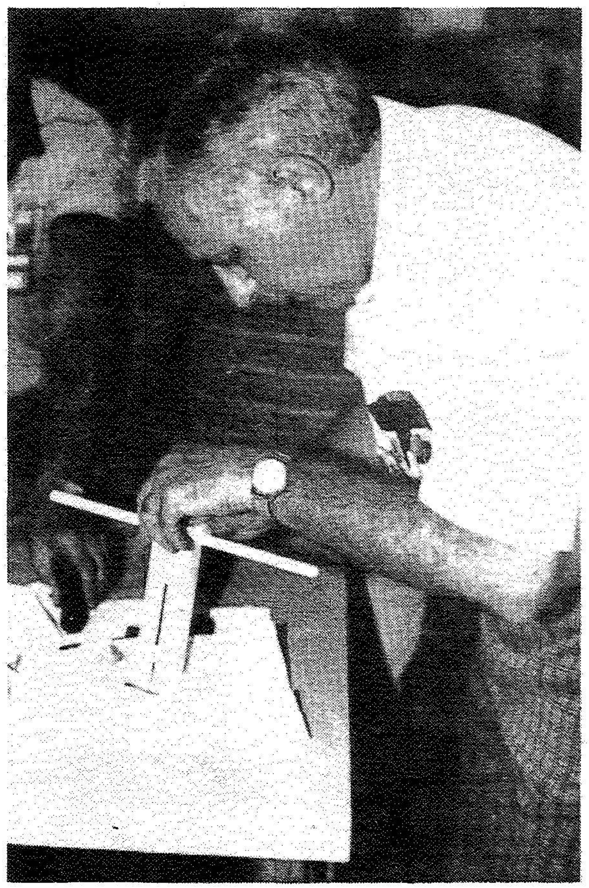

FIGURE 4. MARCE ANTENNA INSTALLATION

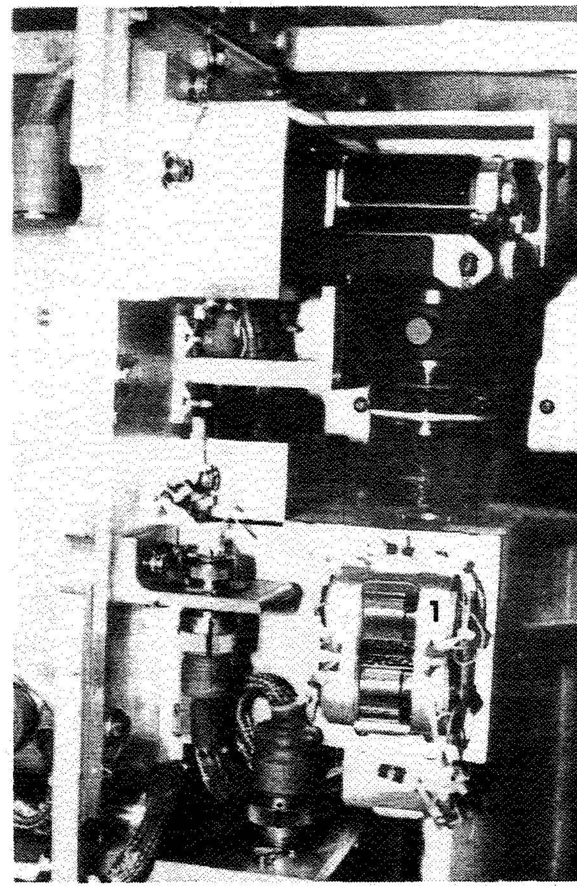

FIGURE 5. EXPERIMENT 2 CRYSTAL GROWTH CHAMBER AND CAMERA INSTALLATION

1. HEATER BATTERIES

GAS #007 completed the 7 day mission on Challenger (October 5, 1984 launch) in the starboard, bay 6, forward position. The 57 degree inclination and an earth facing mission were ideal conditions for the radio downlinks. The RF power was limited to 0.5 watts due to the 4 volts per meter payload to payload interface limitation. A 10 dB attenuator and slight adjustment of the transmitter output produced the 0.5 watt RF level. 5 watts would provide a comfortable margin for extra distance and for OSCAR-10 relay opportunities. Since the mid and eastern United States would not have any direct downlink passes, OSCAR-10 was the only alternative. There was high controversy as to whether an OSCAR-10 relay could be completed. There was a large group of radio amateurs around the United States, Canada and Ireland that were on the OSCAR-10 relay frequency (145.972 MHz) during the October 6,7 and 8, eight hour, downlink periods.

An October 4, 1984 cablegram, from Dr. John Kennewell, Principal Physicist, Learmonth Solar Observatory, Australia, requested that GAS #007 be turned ON two orbits (3 hours) early, to ensure maximum USA & Australia coverage. Some very interested and capable Australian experimenters wanted a chance to participate in this exciting venture. No orbits are favorable to receiving MARCE, in Australia.

Likewise, in a letter from Hans Ngfzger, HB9AQZ, Kloten, Switzerland was very upset that the European hams would not be able to receive MARCE.

The GAS #007 power was not turned on, due to an operational error.

STS-51G REFLIGHT OPPORTUNITY

The post flight testing revealed no anomalies in GAS #007. Therefore no changes were made, although some were considered, to improve experimentation. 5 watts RF transmitter power output was approved for this flight. Transmit times included good passes over the USA. Only two SPAR batteries remained, for this flight. After activation of the primary flight battery, a ground terminal to case leakage resistance was found, indicating a cracked cell case. At about the same time, the back-up battery showed a lower than normal voltage on one cell. The decision was immediately made to cancel GAS #007 on STS-51G. Previous SPAR battery experience, as noted in BACKGROUND, above, indicated such batteries could perform without problems.

REFLIGHT PLANNING

A new battery is planned for the reflight. A 50 AH silver-zinc battery will be installed, which provides 150 percent more power. The eight hour down link is being changed to transmit voice data once each minute instead of every four minutes. Heater power, on experiment #2, will be increased, for added confidence. Since STS-61B is only a 5 day mission, less than 120 hours are available, for experimentation. With a higher capacity heater, Pump A will be turned ON one hour after GAS #007 Power ON, for maximum growth time. A warmer chamber would expedite root growth.

Reflight approval has been received. GAS #007 is now assigned to STS-61B, scheduled for launch on November 8, 1985.

CONTRIBUTORS

The following companies and individuals made significant contributions of hardward and effort to MARCE and GAS #007.

MOTOROLA-5 watt UHF MX300 transmitter and a telpager receiver. Jim Warsham, WA4KXY, Bill Pence, KI4UF and Norman Alexander, VP, Ft. Lauderdale, FL; NATIONAL SEMICONDUCTOR CORP.-2 Data System Module sets. Peter Lami, Interep Associates, Huntsville, AL; RCA-Data System Parts, including an 1802 micro processor system. Ivars Lauzums, Micro Systems, Somerville, NJ; ZERO CORP.-Electronic Support Assembly enclosure. Jay Shorett, Monson, MA; SPAR PROGRAM-20 AH battery; 7.5 vdc converter regulator; measurement sensors; connectors; UNIVERSITY OF ALABAMA, HUNTSVILLE-Fabrication, Assembly, Testing in the Environmental Lab., Guy Smith; MIDWEST COMPONENTS INC.-Thermal Sensitive Switches. John Saling, Muskegon, MI; ICOM AMERICA INC.-IC-271A 2 meter tranceiver; IC-471A 70 cm transeiver, for OSCAR-10. Evelyn Garrison, Bellvevue, WA; KLM & MIRAGE-2M-22C and 435-18C OSCAR antennas. Evert Gracey, Gilroy, CA; TRIO-KENWOOD COMMUNICATIONS-TS430S transceiver, power supply and speaker; TL-922A linear amplifier. Tom Wineland, Compton, CA; BDM Corp.-GAS #007 transportation to KSC, Stanley E. Harrison, Washington, DC.

VOLUNTEERS

MARCE could not have been completed without the following who responded to the request to contribute their time and talents on STS-41G and STS-51G Flight preparations.

EXPERIMENT MANAGER-Leigh Du Pre', WB4WCX; ASSISTANT EXP. MANAGER-Ed Clark, K4KFH; DATA SYSTEMS & SOFTWARE-Chris Rupp, W4HIY; TRANSMITTER, RF & EMI TESTING, LINK ANALYSIS-Leon Bell, WB4LTT; FABRICATION & PLANNING-BILL RICHARDSON, WA4LRE; POWER, NETWORKS, CONTROL, INSTRUMENTATION-Art Davis, WB4KKA; BATTERY-Al Henry; ANTENNA DESIGN AND TESTING-Reggie Inman and Ed Martin; ASSEMBLY & OPERATIONS-Tom Poole, WA4RRA; Joe Appling, W4WIA; Guy Smith, U of AL; INSPECTION & QUALITY-Wiley Bunn, NO4S; STRESS ANALYSIS-Tim Stinson; MECHANICAL DESIGN-Ken Anthony & Jerry Hudgins; VIBRATION TESTING-Clif Kirby; VIBRATION CRITERIA-Jim Mc Bride; EMI TESTING-Jimmy Rees.

AMATEUR RADIO SUPPORT

ARRL-Bernie Glassmeyer, W9KDR; Dale Clift, WA3NLO; AMSAT-John Champa, K8OCL; Vern (Rip) Riportella, WA2LQQ; John McDonald, WB4ZXS; Rich Zwirko, K1HTV; Gordon Hardman, KE3D; Bill Tynan, W3XO; Dr. Perry Kline, K3KP; Doug Loughmiller, KO5I; Art Feller, KB4ZJ; FCC-Robert Foosaner, John Johnston & James McKinney; NASA HQ-Chet Lee; Donna Miller.

NASA AMATEUR RADIO CLUBs, MARCE TECHNICAL REPRESENTATIVES and key GAS #007 support:

NASA HQ-Richard Daniels, W4PUJ; GSFC-Frank Bauer, KA3HDO; Jack Gottlieb; Clark Prouty; Jim Barrowman; John Annen, KB3DN; Susan Oldin; Dennis Roth, N3AZB; Gary Walters, David Miller and Steve Granillo installed GAS #007 into the flight canister. JSC-Dick Fenner, WA5AVI; Gil Carman, WA5NOM, provided all of the Orbiter ground track and timelines, Keplerian Element Sets, Orbiter Ascending Nodes for tracking during the 3 downlinks and the OSCAR-10 relay tracking and timelines, for the primary receiving stations; Dale Martin, KG5U, coordinated the NET CONTROL STATION at the JARC, prior to and during the mission; Art Reubens. KSC-J.D. Collner, W4GNC; Eric Olseen, WB4BNQ, coordinated the SPAR battery activation activities; Al Belsky conducted the primary and backup flight battery activation and tests; Andy Wheeler, WB4ZLW; Haley Rushing. JPL-Jim Lumsden, WA6MYJ; Stan Sanders, N6MP. DFRF-Gary Barr, WA6TWT.