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GET AWAY SPECIAL EXPERIMENTERS SYMPOSIUM
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MARSHALL AMATEUR RADIO CLUB EXPERIMENT (MARCE) POST FLIGHT DATA ANALYSIS

by

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ABSTRACT.

This report briefly describes the Marshall Amateur Radio Club data system, the data that was recorded during the flight of STS-61C, the manner in which the data was reduced to engineering units, and the performance of the student experiments determined from the data.

MARCE DATA SYSTEM.

A detailed description of the data system is presented in the Safety Data Package and will only be summarized here. The system is a specially designed single board computer employing National Semiconductor Corporation's (NSC) NSC800™ CMOS microprocessor, an NSC Digitalker™ subsystem, analog to digital converters, and input/output ports. The purpose of the system is to acquire housekeeping data during the flight and to sequence the operation of the student experiments. In addition, a specially designed analog circuit is provided to monitor the silver-zinc battery temperature for safety purposes. Secondary monitoring of the temperature is provided by one of the analog to digital converter (ADC) channels. MARCE also provided safety backup for disabling the ovens in Experiment 1, and a bias voltage for the crystal growth cell of Experiment 3. A pressure transducer is included which allows the data system to inhibit the transmitter to preclude corona in the event of a pressure leak. The battery voltage is monitored by an ADC channel so that the computer can drop all loads if the battery voltage decays. A secondary voltage sensor is provided by the Schmitt trigger action of the NOT-RESET INPUT of the microprocessor. A block diagram of the data system is shown in Figure 1.

This Get Away Special (GAS) flight was unique in that an amateur radio transmitter was included to send real time status of experiment operation to the ground. Radio amateurs around the world were requested to tune in to the transmissions and record the data for relay to the Marshall Amateur Radio Club. The facilities of the Amateur Radio Satellite Corporation (AMSAT) were the focal point for the near real-time signal reports. The results of the amateur radio portion of the experiment were highly successful and will be reported in a separate document.

Early in the development of MARCE, a decision had to be made to use an available set of hardware or design a new system from scratch. The available hardware did not include a Digitalker subsystem and would have required integrating separate printed circuit boards for the micro-processor, memory, analog converters, and input/output ports. In addition, there was no volunteer experienced in programming the micro-processor. Finally, mother board systems are always suspect because of the large number of connector pins involved.

A relatively new CMOS microprocessor chip set was available from National Semiconductor which has the 8080 microprocessor bus structure but uses the Zilog Z80™ instruction set. An analysis showed all the required functions could be accommodated on one card the same size as the pre-built cards. A software development system was available for programming and the programmer was already familiar with the Z80 instruction set. The disadvantages of starting from scratch with a new chip set involve learning the pin functions and operation of the peripheral chips in the set. Even though the chip set was relatively new, the documentation was very complete and understandable. A printed circuit development system was also available which made the conversion from routing sketches to negatives a relatively painless job.

The MARCE flight program used the interrupts available in the NSC800 to allow multiprocessing. Mission elapsed time, and two serial input channels used three of the interrupts with the actual functions provided in software. These interrupts were carefully masked at the proper time to preclude external signals from taking control improperly and causing the computer to "hang up". The ADC and Digitalker subsystems were checked by software for proper operation and the software was designed to continue other functions if failures occurred in these two subsystems. The software was designed to disable safety critical functions if the ADC failed while providing safety critical measurements.

Software provided debounce protection of the GCD relays. The relays allowed the crew to trigger the operation of the ovens in Experiment 1 so the alloys would resolidify during sleep periods when crew induced accelerations are the lowest. The relays were also used to trigger additional transmission sequences providing mission flexibility. In the event the mission had to be terminated early, a switch sequence operated the second pump in the radish seed experiment inhibiting further growth.

The Digitalker speech data memory was specially programmed on a 4K byte EPROM using a speech development system. This simplified the support required of the microprocessor by allowing phrases to be spoken with a single call to the Digitalker.

A steady stream of data was generated by software to dump memory contents continuously. This data was formatted to be printable directly on a data terminal or printer operating at 300 baud. The data was not in engineering units so external processing had to be provided.

DATA REDUCTION SYSTEM

A Commodore C-128 computer was programmed to receive serial data from the MARCE data system, store the data on a floppy disk, and later convert the data to engineering units. Figure 1 describes the measurements that were recorded in the memory every 10 minutes. Voltage, pressure, and current measurements required simple linear conversion to engineering units. Temperature, measured by thermistors, was non-linear, so conversion consisted of a table lookup and interpolation routines to convert the voltage measured by the analog to digital converter first to resistance, and then to temperature. Three different sets of conversion tables were required because of the different ranges required of T1 and T2, compared to T3 through T5. Also, T6 located in the battery used a different type of thermistor than T1-T5 which required its own conversion table. Actually, it was found that the shape of the temperature/resistance curve for T6 was nearly identical to the shape of the curves for the T1-T5 thermistors so the same lookup table was used by multiplying the values by a correction factor. The results were accurate to within the published range for the battery thermistor.

DATA REDUCTION RESULTS.

A sample of the results of the data reduction are shown in Figure 2. The time is measured from the activation of the GAS by the crew and can be correlated to GMT time by consulting the crew check list. Another way to calibrate the time is using the radio down link transmission times. The transmissions begin on the minute as measured by the MARCE mission timer. The temperatures, battery voltage, battery current, and pressure are shown in degrees C, volts, amperes, and pounds per square inch respectively. The last eight columns of data is a decoding of the status word. The columns are as follows:

VTL A 1 in this column means the battery voltage is too low and the data system has turned off all battery loads.

E23 A 1 in this column indicates that the data system has operated the camera in experiment 2 or the pumps in experiment 3.

1OT A 1 in this column indicates the data system has detected an overtemperature condition in experiment 1 and has removed power to this experiment.

SWC A 1 in this column indicates switch C is latent.

SWB A 1 in this column indicates switch B is latent.

XMT A 1 in this column indicates the digitalker has kept the transmitter on for longer than 59 seconds. This could be the result of a digitalker subsystem failure or power supply failure. The data system turns off the transmit relay and will not operate the transmitter until switch B is cycled to reset the failure indication.

PTL A 1 in this column indicates the pressure inside the GAS can is too low. The data system inhibits the transmitter until the condition is reset by cycling switch B.

ADC A 1 in this column indicates the analog to digital converter has not completed conversion of a channel within the allotted time.

The status indications remain set to one for 10 minutes on the radio transmissions even though the cause of the status might have been only momentary.

Many entries in the data have been lined out. This data has been contaminated by errors caused by cycling power on the data system. See the section on anomalies which follows.

The temperature data indicates conditions were colder than expected. The attitude of the orbiter during some of the operation was Y-axis to the sun to alleviate a thermal problem on the orbiter. The attitude timeline should be obtained before drawing any detailed conclusions from the thermal performance. The performance of the heater on the radish seed experiment (T3) was adequate for some of the mission but provided insufficient power to overcome the coldest ambient temperatures experienced. This heater was designed with a set point of about 17 degrees and had enough power to raise the experiment about 16 degrees above ambient. The heater on the crystal growth experiment (T4) failed to provide significant thermal rise. This heater was powered by a separate battery supply. The batteries were renewed before flight, but cold pad conditions might have partially depleted them. Thermal gradients between the heater and the thermistor could have resulted in an error in the measurement. Thermistors connected to experiment 1, the alloy resolidification experiment, indicated 20.0 degrees which is offscale low and a normal indication. The current measurements also indicated that experiment 1 completed the oven operations successfully.

Battery voltage was nominal throughout the mission. Even though the temperature was cold, the battery voltage did not drop more than 1.5 volts under load.

The flight plan was changed during the mission to return a day early so this GAS was turned off at an elapsed time of 79:40 as indicated by the data system. Log information shows the crew operated Switch C as provided in the Payload Accommodations Requirements prior to removing power using Switch A. This terminated the growth of the radish seeds.

Bad weather at the landing site forced a delay in the landing. This presented an opportunity to provide additional experiment time for this GAS. It was also decided to reactivate the transmitter to provide a fourth set of transmissions. Analysis of this data shows the proper switch sequence was not seen by the data system to reactivate the transmitter. It is noted that there was no documentation of the proper sequence provided in the PAR. The data system must see a latent to hot transition for transmitter reactivation. Lack of the "one" status for Switch B and absence of transmitter current shows the transmitter was not reactivated. Turn on of the package was profitable since additional time was available for additional crystal growth and addition thermal data was received. The package was again turned off at an elapsed time of 92:40.

Further delay of landing again afforded a third operational period. This time the switches were sequenced in a manner which turned on the transmitter. The status indication shows Switch B was latent, then hot, and the current indicated the transmitter was operating. The decision to turn on the package for the second and third times was welcomed by the experimenters but there was insufficient time to alert the radio amateurs in other parts of the world. Transmitter operation did serve to provide some additional heating of the experiments but the amount of this heating was only about one degree and is not really significant. The GAS was turn off for a final time at an elapsed time of 110:20. This additional time again allowed more thermal data to be taken and the crystal growth experiment was powered so additional crystals could grow. The camera for the crystal growth experiment was not operated for the second and third operating periods as planned.

ANOMALIES.

Anomalies pertaining to the experiments as noted in MARCE data were reported above. This section will deal with data system anomalies. Actually, operation of the data system as a sequencer was nominal. The only anomaly to report is errors in data. During the thermal tests, some RAM data was corrupted by switching transients. A bypass capacitor on the CMOS RAM power line was thought to be too high. The value was reduced from 2.2 mfd to 0.1 mfd which shortened the turn on delay of the RAM. The fix appeared to work at room temperature but was not verified at cold temperatures. During development of a second generation data system, the problem was again observed, this time with a different type of CMOS RAM chip. More flexible checkout software was developed by this time to facilitate memory retention tests. Attention this time was focused on the cleanliness of the RAM disable signal especially during power-up and power-down. Attempts were made to trap the offending signal but these were unsuccessful. Then, the line was bypassed with a .001 mfd capacitor and the switching problem was eliminated. Evidently, the transient was being caused by the NSC810 I/O chip during the power-down sequence. The bypass capacitor shunts the short transients that were not seen on the oscilloscope. This fix should be verified by sequencing the power during thermal tests of the new system.

The errors could also be caused by radiation upset but there is insufficient evidence to support this theory. Another microprocessor with CMOS RAM was in experiment one and no abnormal data was detected in the post flight analysis of that data. The results of the GAS experiment named CRUX (Cosmic Ray Upset Experiment) will be reviewed when available to determine if the susceptability of this type of RAM warrants further analysis of this data.

The effect of the problem on the overall performance was more of an aggravation because the thermal data is changing slowly. There was no problem with the program memory because EPROM is used for storing the program.

CONCLUSIONS.

The tabular data presented in this paper had to condensed to conserve space. This data could be of benefit in thermal design analysis for other payloads. A complete set of data is available from the author.

This contributor to the Project Explorer has enjoyed working with the student experimenters, and the NASA employees associated with the project, and the sponsors: The Alabama Section of the AIAA and the Alabama Space and Rocket Center. I am looking forward to participating in future experiments. Please address any comments to me at the above address.

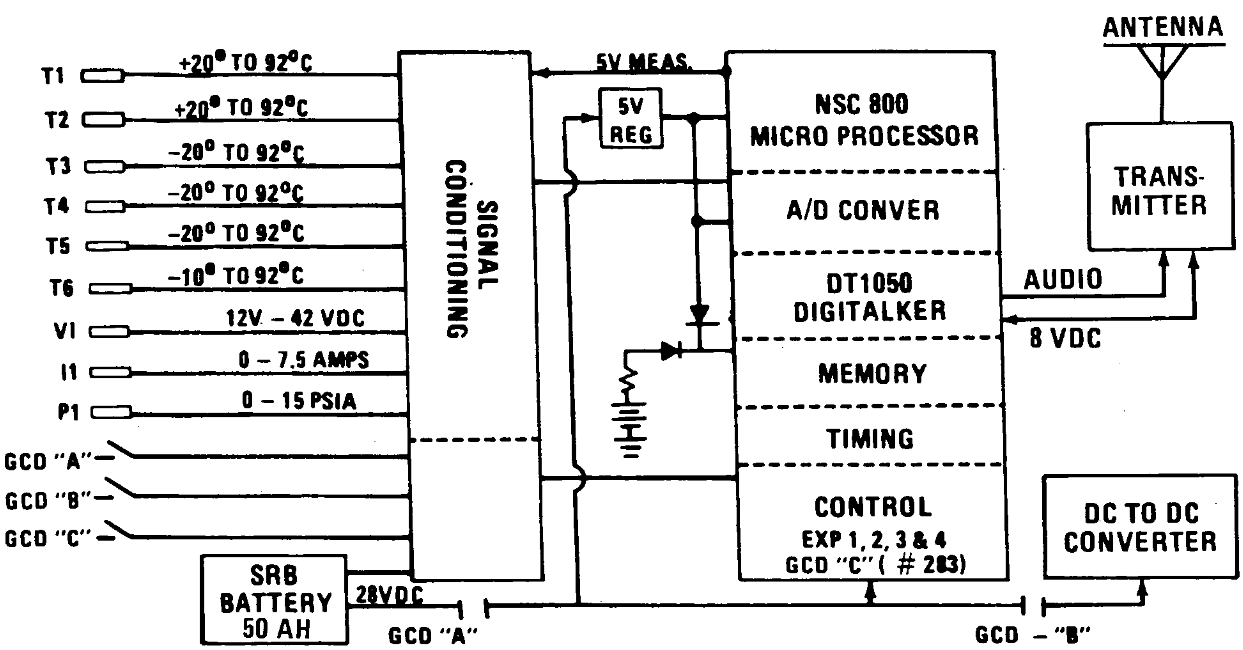

FIGURE 1. MARSHALL AMATEUR RADIO CLUB EXPERIMENT DATA SYSTEM

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GAS 007 MISSION TIME	T1	T2	T3	T4	T5	T6	V1	I1	P1	VTL	E23	1OT	SWC	SWB	XMT	PTL	ADC
0:00	20.0	20.0	4.7	5.6	4.7	6.2	29.3	.12	14.1	0	0	0	1	1	0	0	0
0:10	20.0	20.0	6.9	5.4	5.4	6.6	30.8	.65	14.1	0	0	0	1	1	0	0	0
0:20	20.0	20.0	9.7	5.1	5.4	6.6	31.0	.62	14.1	0	0	0	1	0	0	0	0
0:30	20.0	20.0	12.2	5.1	5.4	6.4	31.1	.65	14.1	0	0	0	1	0	0	0	0
0:40	20.0	20.0	13.3	4.9	5.4	6.2	31.1	.65	14.1	0	0	0	1	0	0	0	0
0:50	20.0	20.0	14.5	4.7	5.1	6.2	31.1	.62	14.1	0	0	0	1	0	0	0	0
1:00	20.0	~~52.4~~	15.4	4.4	5.1	6.0	31.1	.62	14.1	0	0	0	1	0	0	0	0
1:10	20.0	20.0	15.7	4.2	4.9	5.8	32.2	.47	14.1	0	0	0	1	0	0	0	0
1:20	20.0	20.0	16.0	4.2	4.7	5.8	31.1	.62	14.0	0	0	0	1	0	0	0	0
1:30	20.0	20.0	16.3	3.9	4.7	5.8	31.1	.68	14.1	0	0	0	1	0	0	0	0
1:40	20.0	20.0	16.6	3.9	4.2	5.4	31.1	.62	~~10.1~~	0	0	0	1	0	0	0	0
1:50	~~24.5~~	~~90.7~~	16.6	3.7	4.2	5.2	31.0	.62	14.0	0	0	0	1	0	0	0	0
2:00	20.0	20.0	16.9	3.7	3.9	5.0	31.1	.62	14.0	0	0	0	1	0	0	0	0
2:10	20.0	20.0	16.9	3.5	-~~20.2~~	~~53.2~~	31.1	.62	14.0	0	0	0	1	0	0	0	0
2:20	20.0	20.0	16.9	3.2	3.5	4.8	31.1	.65	14.0	0	0	0	1	0	0	0	0
2:30	20.0	20.0	16.9	3.0	3.2	4.5	31.1	.62	13.9	0	0	0	1	0	0	0	0
2:40	20.0	20.0	16.9	2.7	3.0	4.5	31.1	.62	14.0	0	0	0	1	0	0	0	0
2:50	20.0	20.0	16.9	2.5	2.7	4.1	31.1	.62	13.9	0	0	0	1	0	0	0	0
3:00	20.0	20.0	16.6	2.5	2.5	3.9	31.1	.62	13.9	0	0	0	1	0	0	0	0
3:10	20.0	20.0	16.6	2.3	2.5	3.9	31.1	.62	13.9	0	0	0	1	0	0	0	0
3:20	20.0	20.0	16.6	2.0	2.0	3.5	31.1	.65	13.9	0	0	0	1	0	0	0	0
3:30	20.0	20.0	16.3	1.8	1.8	3.5	31.1	.62	13.9	0	0	0	1	0	0	0	0
3:40	20.0	20.0	16.3	1.6	1.8	3.3	31.1	.62	13.9	0	0	0	1	0	0	0	0
3:50	20.0	20.0	16.0	1.3	1.6	3.1	32.0	.47	13.9	0	0	0	1	0	0	0	0
4:00	20.0	20.0	16.0	1.1	1.3	2.9	31.1	.65	13.9	0	0	0	1	0	0	0	0

FIGURE 2A. GAS007 MEMORY DUMP--FIRST TRANSMISSION CYCLE.

20:00	20.0	20.0	6.9	-11.7	-9.5	-9.8	31.0	.06	13.4	0	0	0	1	0	0	0	0
20:10	20.0	20.0	7.1	-11.2	-8.2	-9.8	30.0	1.03	13.5	0	0	0	1	0	0	0	0
20:20	20.0	20.0	7.1	-10.8	-7.4	-9.8	30.3	1.03	13.5	0	0	0	0	0	0	0	0
20:30	20.0	20.0	7.4	-10.6	-6.5	-9.8	30.3	1.03	13.5	0	0	0	0	0	0	0	0
20:40	20.0	20.0	7.4	-10.2	-5.8	-9.8	29.3	3.06	13.5	0	0	0	0	0	0	0	0
20:50	20.0	20.0	7.4	-9.7	-5.4	-9.8	29.4	3.06	13.5	0	0	0	0	0	0	0	0
21:00	~~48.3~~	~~28.6~~	7.4	-9.5	-4.7	-9.8	29.4	3.06	13.6	0	0	0	0	0	0	0	0
21:10	20.0	24.0	7.6	-9.1	-4.1	-9.3	~~41.3~~	3.71	13.6	0	0	0	0	0	0	0	0
21:20	20.0	31.3	7.9	-8.6	-3.4	-8.9	30.6	1.03	13.6	0	0	0	0	0	0	0	0
21:30	20.0	36.0	8.2	-8.2	-2.3	-8.4	30.3	1.06	13.7	0	0	0	0	0	0	0	0
21:40	20.0	37.3	8.4	-7.8	-1.6	-8.2	30.6	1.06	13.7	0	0	0	0	0	0	0	0
21:50	20.0	32.8	8.9	-7.1	-1.0	-8.0	30.6	1.03	13.7	0	0	0	0	0	0	0	0
22:00	20.0	27.1	9.2	-6.5	-.5	-7.7	30.6	1.03	13.7	0	0	0	0	0	0	0	0
22:10	20.0	21.9	9.4	-6.3	.4	-7.5	30.7	1.06	13.8	0	1	0	0	0	0	0	0
22:20	20.0	~~52.4~~	10.0	-5.6	.6	-7.5	30.6	1.03	13.8	0	0	0	0	0	0	0	0
22:30	20.0	20.0	10.5	-5.2	1.1	-7.1	~~39.0~~	~~.00~~	~~14.9~~	0	0	0	0	0	0	0	0
22:40	20.0	20.0	10.8	-4.7	1.1	-6.8	30.6	1.03	13.8	0	0	0	0	0	0	0	0
22:50	20.0	20.0	11.0	-4.3	1.3	-6.8	30.6	1.03	13.8	0	0	0	0	0	0	0	0
23:00	20.0	20.0	11.6	-3.6	1.3	-6.6	30.6	1.06	13.8	0	0	0	0	0	0	0	0

FIGURE 2B. SECOND TRANSMISSION CYCLE.

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GAS 007 MISSION TIME	T1	T2	T3	T4	T5	T6	V1	I1	P1	VTL	E23	1OT	SWC	SWB	XMT	PTL	ADC
42:50	20.0	20.0	8.2	-8.6	-9.5	-7.3	31.1	.09	13.4	0	0	0	0	0	0	0	0
43:00	20.0	20.0	7.9	-8.9	-8.4	-7.3	30.7	1.03	13.4	0	0	0	1	0	0	0	0
43:10	20.0	20.0	7.6	-9.1	-8.0	-7.3	30.6	1.06	13.4	0	1	0	1	0	0	0	0
43:20	20.0	20.0	7.4	-9.1	-7.8	-7.1	29.4	3.09	13.4	0	0	0	1	0	0	0	0
43:30	20.0	20.0	6.9	-9.3	-7.6	-6.6	29.4	3.06	13.4	0	0	0	1	0	0	0	0
43:40	~~25.3~~	~~95.4~~	6.6	-9.5	-7.4	-6.4	29.4	3.06	13.4	0	0	0	1	0	0	0	0
43:50	20.0	20.0	6.6	-9.5	-6.9	-6.2	~~33.1~~	~~7.06~~	~~11.7~~	0	~~1~~	0	~~0~~	0	0	~~1~~	~~1~~
44:00	20.0	20.0	6.6	09.5	-6.5	-6.2	29.7	3.09	13.5	0	0	0	1	0	0	0	0
44:10	20.0	20.0	~~3.5~~	-~~14.7~~	-6.1	-6.2	30.7	1.03	13.5	0	0	0	1	0	0	0	0
44:20	~~46.5~~	~~34.8~~	6.4	~~27.6~~	-5.6	-6.2	30.7	1.03	13.5	0	0	0	1	0	0	0	0
44:30	20.0	20.0	6.9	-6.5	-5.4	-6.2	30.8	1.03	13.5	0	0	0	1	0	0	0	0
44:40	20.0	20.0	6.9	-6.1	-5.0	-6.2	30.7	1.03	13.5	0	0	0	1	0	0	0	0
44:50	20.0	20.0	7.1	-6.1	~~2.5~~	~~3.3~~	30.7	1.03	13.5	0	0	0	1	0	0	0	0
45:00	20.0	20.0	7.4	-5.8	-4.3	-6.4	30.7	1.06	13.5	0	0	0	1	0	0	0	0
45:10	20.0	20.0	7.6	-5.8	-4.5	-6.4	30.7	1.03	13.5	0	0	0	1	0	0	0	0
45:20	20.0	20.0	7.6	-5.8	-4.3	-6.4	30.7	1.03	13.5	0	0	0	1	0	0	0	0
45:30	20.0	20.0	7.9	-6.1	-4.1	-6.2	30.7	1.03	13.5	0	0	0	1	0	0	0	0
45:40	20.0	20.0	8.2	-6.3	-3.9	-6.4	30.7	1.06	13.5	0	0	0	1	0	0	0	0
45:50	20.0	20.0	8.4	-6.5	-3.9	-6.4	30.7	1.06	13.5	0	0	0	1	0	0	0	0
46:00	20.0	20.0	8.7	-6.3	-3.6	-6.4	30.6	1.03	13.5	0	0	0	1	0	0	0	0

FIGURE 2C. THIRD TRANSMISSION CYCLE.

79:00	20.0	20.0	5.9	-12.3	-12.1	-9.8	31.1	.09	13.3	0	0	0	1	0	0	0	0
79:10	20.0	20.0	5.9	-12.3	-12.3	-9.8	31.1	.06	13.3	0	1	0	1	0	0	0	0
79:20	20.0	20.0	5.6	-12.3	-12.1	-9.8	31.2	.09	13.3	0	0	0	1	0	0	0	0
79:30	20.0	20.0	5.6	-12.3	-12.3	-9.8	31.2	.09	13.3	0	0	0	1	0	0	0	0
79:40	20.0	20.0	5.6	-12.3	-12.5	-9.8	31.2	.09	13.2	0	0	0	1	0	0	0	0
79:50	20.0	20.0	-15.1	-17.3	-17.3	-9.8	31.4	.06	13.0	0	0	0	1	0	0	0	0
80:00	20.0	20.0	-11.4	-17.3	-17.3	-9.8	31.0	.06	13.1	0	0	0	1	0	0	0	0
80:10	20.0	20.0	-8.9	-17.5	-17.3	-9.8	31.0	.09	13.0	0	0	0	1	0	0	0	0
80:20	20.0	20.0	-6.9	-17.5	-17.5	-9.8	31.0	.09	13.0	0	0	0	1	0	0	0	0
80:30	20.0	20.0	-5.4	-17.5	-17.5	-9.8	31.1	.09	13.1	0	0	0	1	0	0	0	0
80:40	20.0	20.0	-4.7	-17.5	-17.3	-9.8	31.1	.06	13.1	0	0	0	1	0	0	0	0
80:50	20.0	20.0	-3.6	-17.3	-17.3	-9.8	31.1	.12	13.0	0	0	0	1	0	0	0	0

FIGURE 2D. FIRST REACTIVATION--NO TRANSMISSIONS.

92:30	20.0	20.0	5.9	-12.1	-11.9	-9.8	31.1	.09	13.2	0	0	0	1	0	0	0	0
92:40	20.0	20.0	5.9	-12.3	-12.3	-9.8	31.1	.09	13.2	0	0	0	1	0	0	0	0
92:50	20.0	20.0	-15.1	-16.4	-15.5	-9.8	31.0	.65	13.1	0	0	0	1	1	0	0	0
93:00	20.0	20.0	-11.4	-16.4	-15.1	-9.8	31.0	.62	13.1	0	0	0	1	0	0	0	0
93:10	20.0	20.0	-8.6	-16.2	-15.1	-9.8	30.9	.62	13.1	0	0	0	1	0	0	0	0
93:20	20.0	20.0	-6.5	-16.4	-14.9	-9.8	31.0	.62	13.1	0	0	0	1	0	0	0	0
93:30	20.0	20.0	-5.0	-16.4	-14.9	-9.8	31.0	.62	13.1	0	0	0	1	0	0	0	0
93:40	20.0	20.0	-4.1	-16.4	-14.7	-9.8	31.0	.65	13.1	0	0	0	1	0	0	0	0
93:50	20.0	20.0	-3.0	-16.4	-14.5	-9.8	31.0	.62	13.1	0	0	0	1	0	0	0	0
94:00	20.0	20.0	-2.3	-16.4	-14.5	-9.8	30.9	.62	13.1	0	0	0	1	0	0	0	0

FIGURE 2E. SECOND REACTIVATION--FOURTH TRANSMISSION CYCLE.