RCA SATCOM BATTERY IN-ORBIT PERFORMANCE UPDATE

AND ACCELERATED LIFE TEST RESULTS

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ABSTRACT

The oldest operating RCA Astro geostationary spacecraft, SATCOM F1 and F2, have now completed almost 8 and 7-3/4 years in orbit, respectively, with no significant degradation of their nickel-cadmium battery performance. Battery minimum discharge voltage data are presented for these spacecraft.

In addition, 2 groups of nickel-cadmium cells which are representative of those in orbit are undergoing real time eclipse-reduced suntime cycling in the laboratory. These groups of cells, which are being cycled at a maximum of 53% and 62% depth of discharge (based on actual capacity), have completed 14 and 15 eclipse seasons, respectively. Data for these groups of cells are presented and are compared with the in-orbit battery data.

INTRODUCTION

Eight (8) geostationary spacecraft, manufactured by RCA Astro, are presently operating in orbit. As described previously, in References (1) and (2), the nickel-cadmium batteries in all of these spacecraft contain unique battery reconditioning circuitry which permits individual cell reconditioning to practically zero volts without the danger of cell reversal.

The oldest and longest operating of these spacecraft, SATCOM F1 and F2, have now completed almost 8 and 7-3/4 years, respectively, in orbit without any noticeable degradation in battery performance. Battery data for both of these spacecraft are summarized herein.

In addition, data from the real time eclipse-reduced suntime life cycling of groups of representative cells in the laboratory at two depths of discharge have been overlayed over the in-orbit data. The results show a remarkable similarity in "Minimum Discharge Voltage vs. Eclipse Season" results between the laboratory life-cycling cells and actual in-orbit battery performance over the 15 eclipse seasons presently achieved.

BATTERY PERFORMANCE IN ORBIT

RCA Astro has manufactured 8 geostationary spacecraft which are presently operating in orbit using nickel-cadmium batteries. Their nomenclature and launch dates are listed in Table 1. All batteries are performing well.

The battery performance of SATCOM F1 and F2 is of prime interest since they have been operating the longest in orbit, almost 8 and 7-3/4 years, respectively. Their design and earlier mission performance were reported in 1980 (Reference 1) and at the 1976 through 1982 Goddard Space Flight Center Battery Workshops.

Figure 1 shows the maximum average depth-of-discharge (DOD) for the SATCOM F1 and F2 batteries as a function of eclipse season. For both F1 and F2 it ranges from 57% to 52% based on the nominal capacity for their first 14 and 12 eclipse seasons, respectively. For F2 on eclipse season 13 the DOD was reduced to 42% since traffic was transferred to the SATCOM 3 and 4 satellites. The loads on both spacecraft were further reduced this year when SATCOMS 6 and 7 were launched.

Figure 2 shows the minimum average battery voltage for SATCOM F1 and F2 as a function of the number of eclipse seasons in orbit. SATCOM F2 had received a forced daily eclipse of approximately 27% depth-of-discharge during the continuous suntime duration until eclipse season number 6. This daily eclipse, in conjunction with a less than full recharge achieved between these eclipses, had resulted in some voltage degradation. This voltage however, recovered when the daily eclipse sequence was discontinued following eclipse season number 6. The batteries of both spacecraft in general show very small, if any, voltage degradations, excluding eclipse season number 1 on F1 and correcting for the different regime applied to F2 during the first 6 seasons as described above.

Figure 3 shows the same data as for Figure 1, except it presents the minimum average cell voltage using an expanded scale and shows the predicted voltage degradation established earlier using Crane data of packs 207A and 209A (Reference 3). It can be noted that the voltage degradation was considerably less than was predicted and cell voltage is substantially above the minimum required for a full payload operation.

CELL PERFORMANCE IN ACCELERATED LIFE CYCLE TESTING

In early 1981, RCA began a real time eclipse-reduced suntime life test of two groups of 17Ah (nameplate) nickel-cadmium cells as used on the ANIK B and SATCOM 3 and 4 spacecraft. The cells were manufactured by G.E. in 1979 and are of the same generic design as used in the other RCA spacecraft batteries (Ref. GE P/N 42B017AB01).

The cells are being cycled in a typical 44-day geosynchronous eclipse-cycling regime. Maximum depth of discharge is based on an initial average capacity of 19.8 Ah at 5°C. Group A (control) is being discharged at 8.9 amperes; its maximum DOD is 8.9 A x 1.183 hours/19.8 AH = 53.2% based on actual and 62% based on nameplate capacity. Group B (higher DOD) is being discharged at 10.4 amperes; its maximum DOD is 62% based on actual and 72% based on nameplate capacity. These data have been added to Figure 1 as shown in Figure 4. In this test, the "suntime" duration has been reduced from 138 days to 4 days for reconditioning.

The depth of discharge for the test cell groups, relative to the batteries in orbit, and minimum average battery voltages (7 cell data scaled to 22 cell battery voltages) have been added to Figures 1 and 2 as shown in Figures 4 and 5. Although the absolute voltage values are lower than the in-orbit results, as would be expected due to the higher depths of discharge applied, the trends over 15 eclipse seasons of simulated orbit testing are remarkably similar to those in the spacecraft. Testing of these cells will continue until failure, to provide an input for predicting the life of nickel-cadmium batteries at these higher depths of discharge in orbit.

CONCLUSIONS

1) On RCA Geostationary Battery In-Orbit Performance

Both SATCOM F1 and F2 batteries reported herein have been operating successfully in orbit for about 8 and 7-3/4 years, respectively. Their end-of-discharge voltage degradation with increase in eclipse seasons has been minimal for approximately equal depth-of-discharges. This degradation is considerably lower than originally predicted. This can be attributed to a large extent to the unique RCA Astro reconditioning procedure applied prior to each eclipse season.

2) On Real Time Eclipse-Reduced Suntime Life Cycling in the Laboratory

The extended depth-of discharge group of cells (62% based on actual capacity) and the control group (53% DOD based on actual capacity) have shown only minimal voltage degradation over the equivalent of 15 eclipse seasons. Comparing these data to the in-orbit data shows good concurrence to date.

REFERENCES

1. Gaston, S. J.: RCA SATCOM F1 and F2 Ni-Cd Battery Orbital Performance, Proceedings of the 15th Intersociety Energy Conversion Engineering Conference, 1980, Reference 809320.

2. Gaston, S. J.: Unique Battery Reconditioning Cycle for RCA's Geostationary Satellites and Its Applicability for Low Earth Spacecraft, 1982 Goddard Space Flight Center Battery Workshop Proceedings, Page 311.

3. Harkness, J. D.: Evaluation Program for Secondary Spacecraft Cells, Synchronous Orbit Testing of Nickel-Cadmium Cells, WQEC/C 81-120A, 1 June 1981, Page 212.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge Mr. Dave Stewart of RCA Americom for the valuable SATCOM spacecraft battery flight performance data.

Table 1

RCA Astro Geostationary Spacecraft Operating in Orbit

SPACECRAFT	LAUNCH DATE	CUSTOMER	CELL CAPACITY * (AMP-HOURS) (NAME-PLATE)
o SATCOM F1	DECEMBER 1975	RCA AMERICOM	12
o SATCOM F2	MARCH 26, 1976	RCA AMERICOM	12
O ANIK B	NOVEMBER 1978	TELESAT OF CANADA	17
o SATCOM 3	NOVEMBER 1981	RCA AMERICOM	17
o SATCOM 4	JANUARY 1982	RCA AMERICOM	17
o SATCOM 5	OCTOBER 27, 1982	ALASCOM INC	24
o SATCOM 6(IR)	APRIL 11, 1983	RCA AMERICOM	24
o SATCOM 7(IIR)	SEPTEMBER 8, 1983	RCA AMERICOM	24

* 22 CELLS PER BATTERY, 3 BATTERIES PER SPACECRAFT

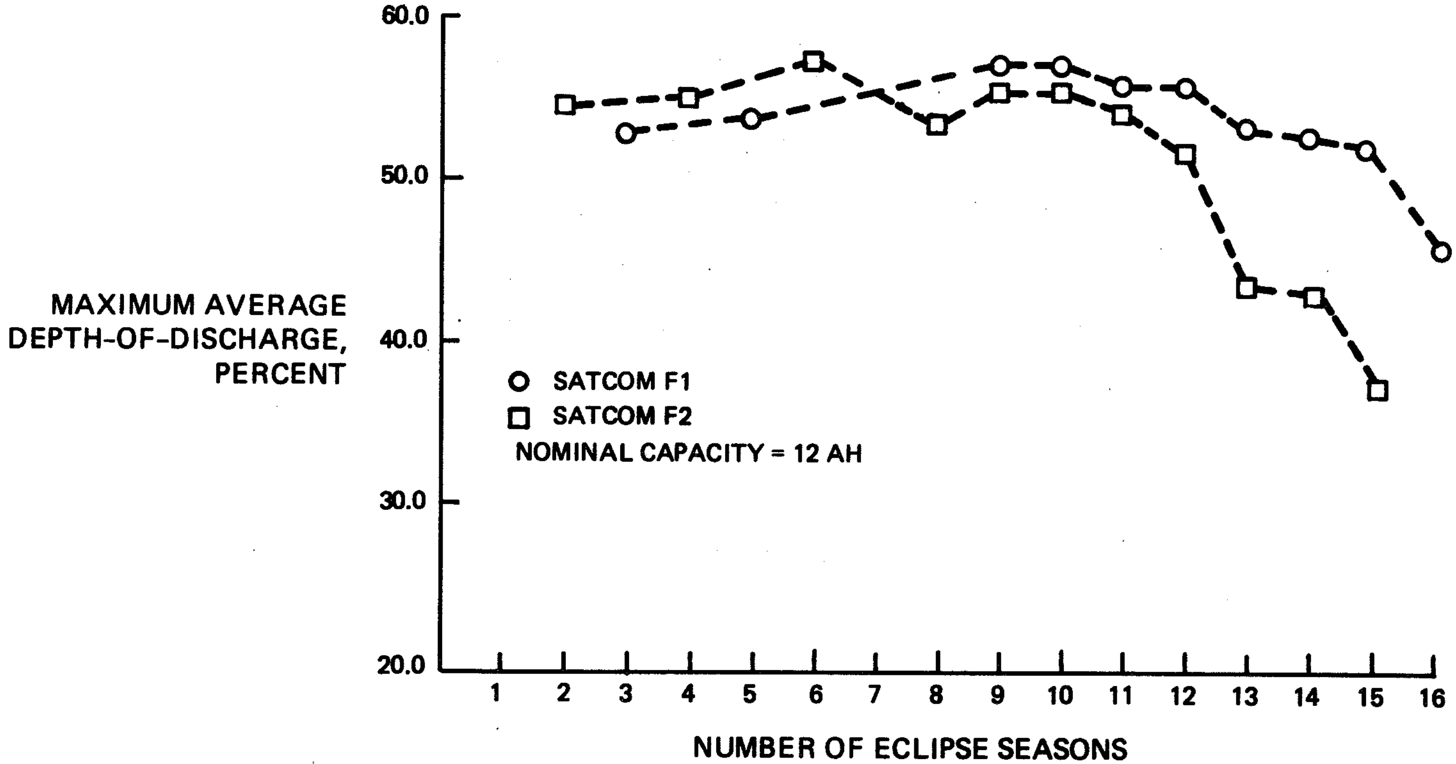

Figure 1. Maximum average depth-of-discharge during eclipse vs. number of eclipse seasons.

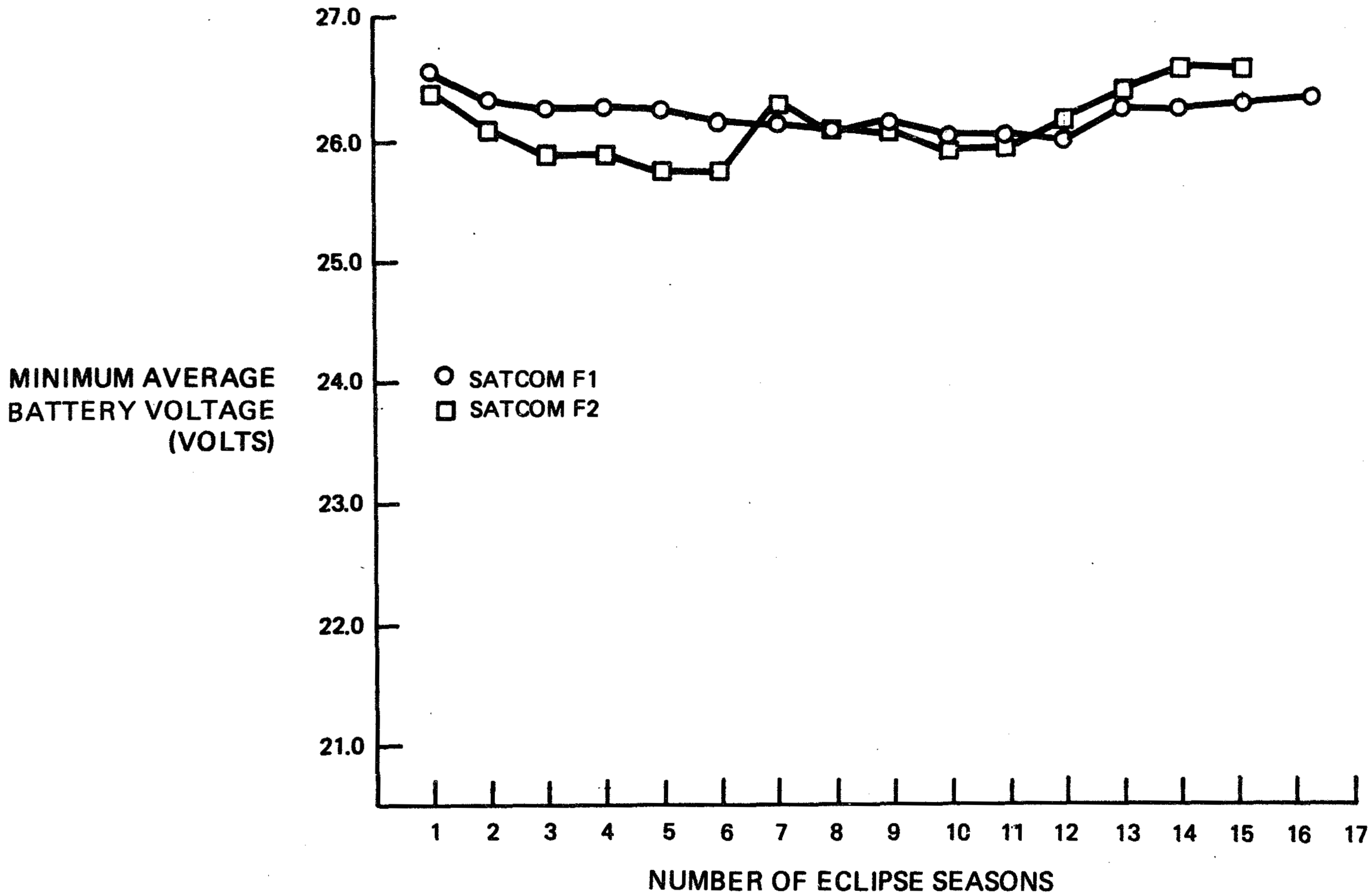

Figure 2. Minimum average battery voltage vs. number of eclipse seasons.

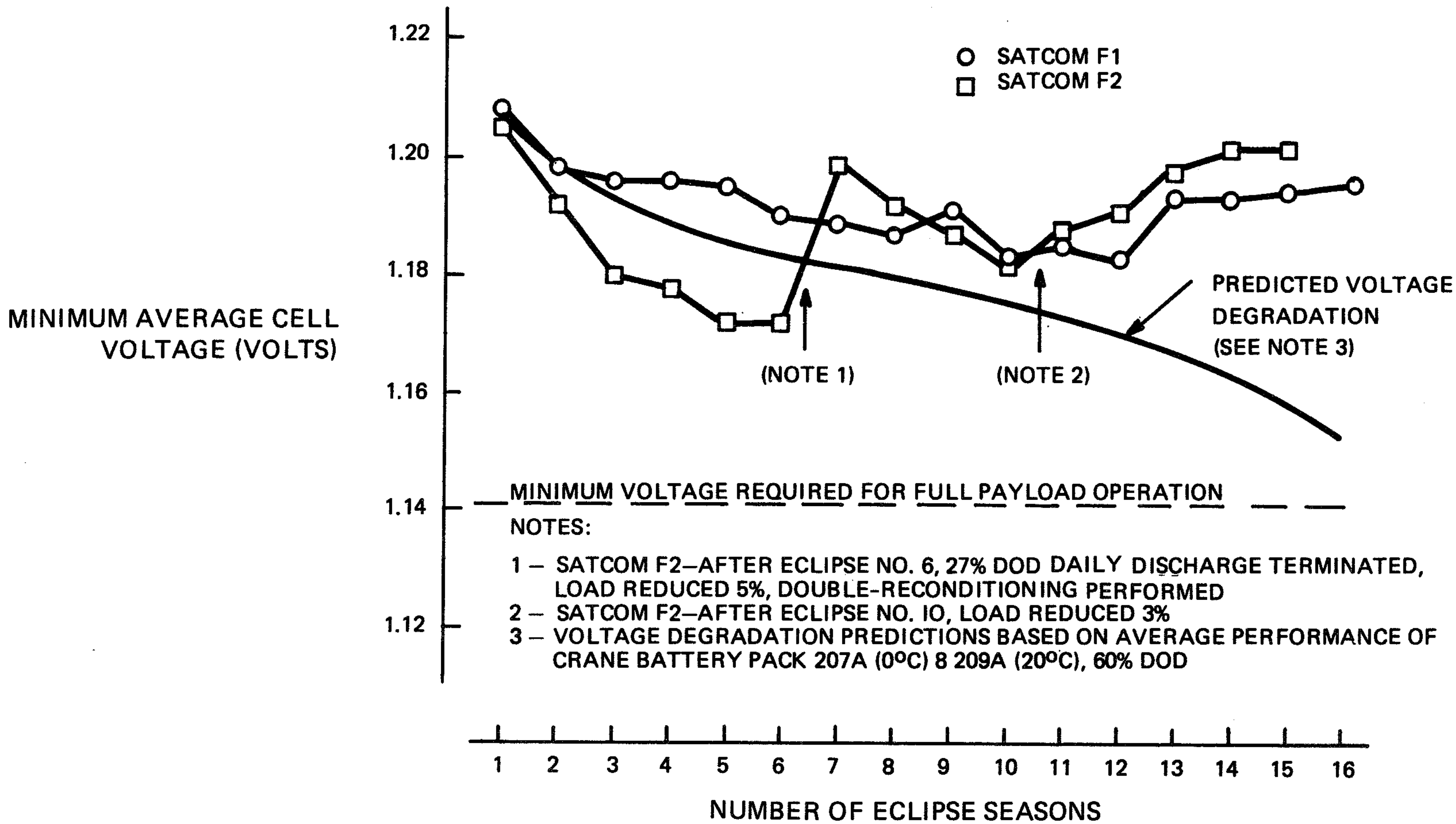

Figure 3. Minimum average cell voltage during eclipse vs. number of eclipse seasons.

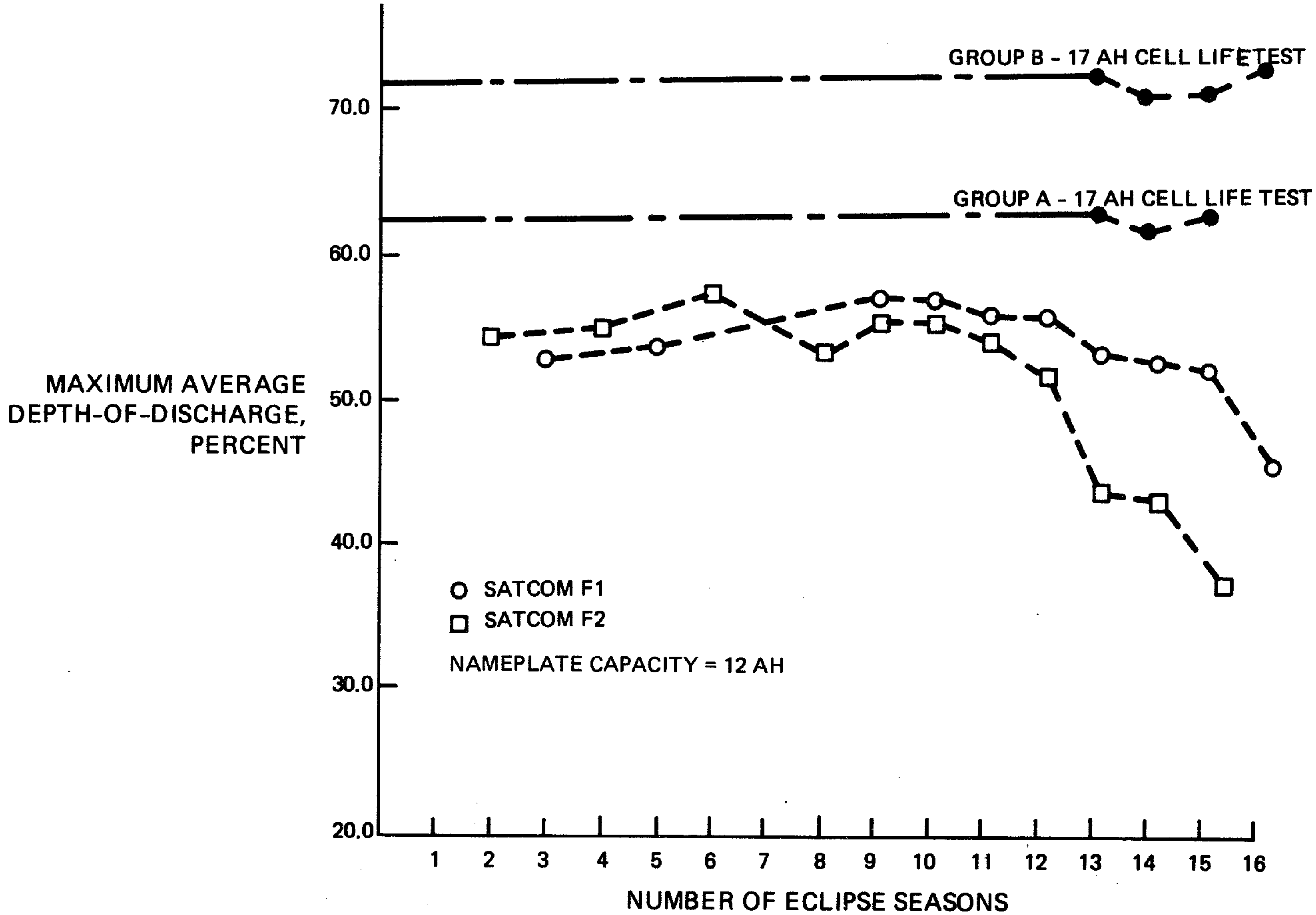

Figure 4. Maximum average depth-of-discharge during eclipse vs. number of eclipse seasons.

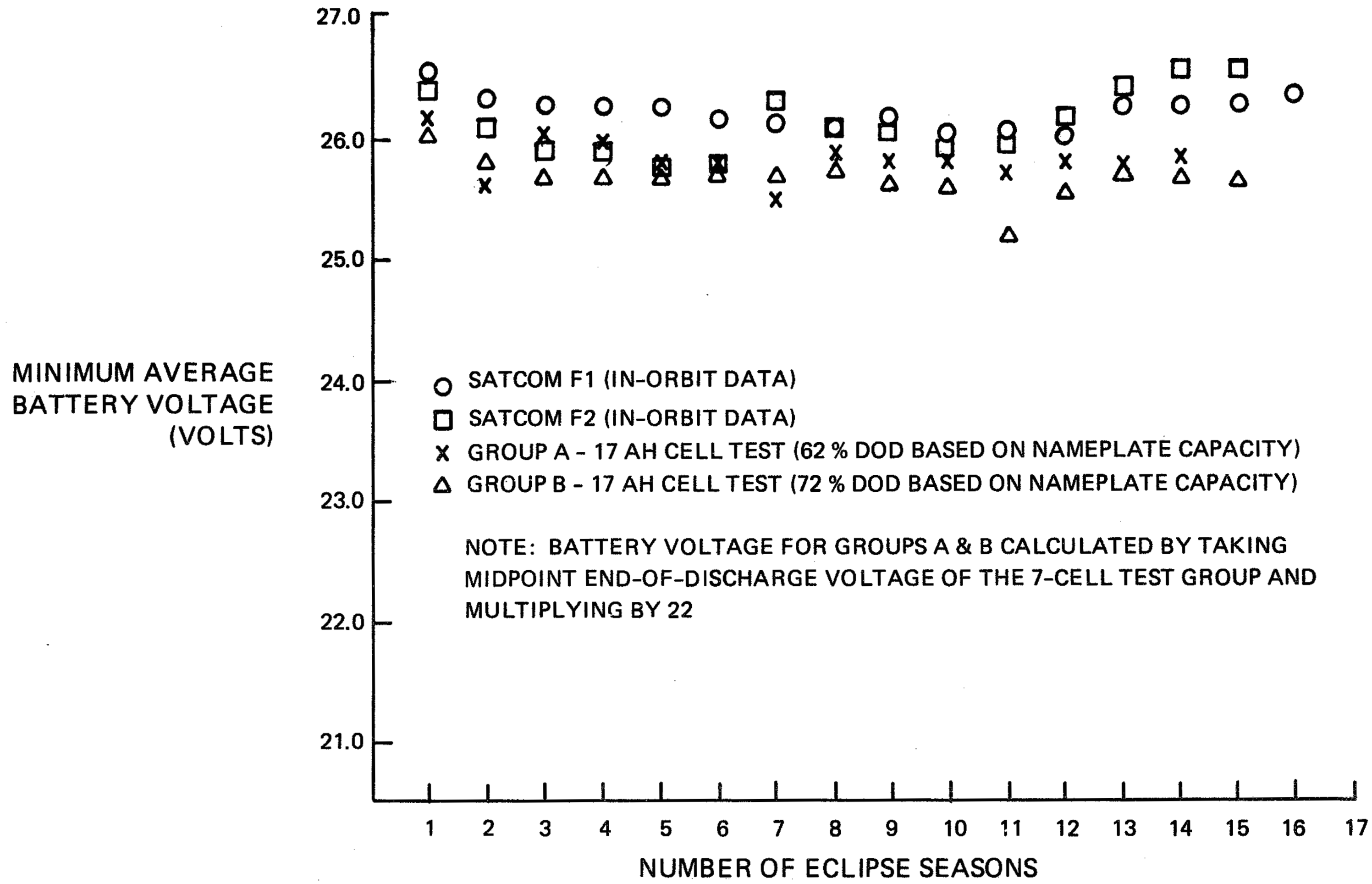

Figure 5. Minimum average battery voltage vs. number of eclipse seasons.

Q. Kunigahalli, Bowie State College: Could you tell me what is the unique procedure that is different from other procedures?

A. Gaston, RCA-Astro: We have a series of wheel outs in each battery and each relay leads to a reconditioning which actually needs two relay contacts to get the resistor on, ground command all the relays click on and all the relays close to have these crystals draining all in the same time so all are separate. Each cell has its own resistor. So it is different from the others. So you can drain it and not worry about any reversal.

Q. George, NASA/Marshall Space Flight Center: You said that you applied this unique reconditioning method prior to each eclipse season?

A. Gaston, RCA-Astro: Yes.

Q. George, NASA/Marshall Space Flight Center: How long prior to each, immediately prior?

A. Gaston, RCA-Astro: There are always some operation problems. The operation problems as follows you got three batteries and you have a fixed time you want to be sure you cannot you don't want to recondition all three at the same time you always want to have some batteries on. So it's about two to three weeks prior. Is that the correct date Stewart? We start about 2 to 3 weeks prior to start the eclipse so we can recondition the first battery - battery 1, battery 2 or battery 3 or whichever way you like to.

Q. George, NASA/Marshall Space Flight Center: So it takes approximately a week to recondition the battery - run it down and recharge it.

A. Gaston, RCA-Astro: Well giving yourself, it shouldn't take quite that long but just give yourself a little time extra - time in case you want to try it longer or in case you just want to make sure you are ready in time.

A. George, NASA/Marshall Space Flight Center: Thank you.

Q. Armantrout, Lockheed: Steve would you comment on what the plateau looks like when you do this reconditioning and is it changing with time?

A. Gaston, RCA-Astro: Well I don't have it here to show, you're talking about the discharge voltage profile. Right? Is that what you are referring to? Right?

A. Armantrout, Lockheed: Yes.

A. Gaston, RCA-Astro: I don't have it here but when I get chance some day we will discuss it over the phone. I think there are some slight differences but not very significant. I haven't seen them yet.

COMMENT

Hendee, Telesat Canada: Really there is negligible being of course now this is a resistive discharge not a constant current or anything it's a resistive discharge and we see a negligible plateau perhaps barely perceptible plateau if you were to go ahead and correct that back to say some kind of a constant current discharge. Like to say one other thing. We abuse those cells tremendously and we have been mistreating them on the Anik B discharging several times everyday and quite a few things have been running out quite well. The original cells which were allocated to Anik B were retrofitted just prior to launch. I can see at this point where all our abuse we're just starting to see a slight spread in the cell of voltages at the end of discharge whereas the flight simulation, they are locked in tight as can be.

Gaston, RCA-Astro: Interesting.

Hendee, Telesat Canada: One other thing you didn't mention is your charge sequence Steve, and that is a major difference to other people as well and I've been getting a lot of questions at Telesat. Well what do you think about the sequential charge and as far as I can tell actually the sequential charge which we do five minutes fast charge and ten minutes off. Actually, it seems to be beneficial or I won't say it's beneficial let me say that I see certainly no degrading affects due to that.

Gaston, RCA-Astro: Let me just add, Anik B was launched I mentioned before that's the table I was missing was launched November 1978 so it's five years, ten eclipse seasons.

Q. Bell, Hughes Aircraft: Steve, do you have individual cell voltage data on the battery?

A. Gaston, RCA-Astro: No we do not. We felt at that time we don't need it. It's usually when you have a common charging system you are concerned about reversing some cells so you like to go to some threshold value then you would need cell voltages, individual ones. No we don't.

Q. Bell, Hughes Aircraft: Just one other question, because in some laboratory testing that we've done depending on the length of the lead wire on the resistor with a series string of batteries sometimes the individual cell resistors act like a 22 resistor string across a 22 cell battery. That was the reason why I asked about the individual cell voltages.

A. Gaston, RCA-Astro: We don't have it on this spacecraft and in the whole series.

A. Bell, Hughes Aircraft: Thank you.