

## ATMOSPHERIC EXPLORER

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### INTRODUCTION

(Figure 8)

OBENSCHAIN: AE is a 1971 power system design, but again using the heritage of the ITOS system. We have two rings of solar arrays. We again have the nine shunts to control a 38 voltage from the high end. We have three batteries now, each one with its own individual battery charger. The battery charger has been modified to present a high temperature cut-off, to present a little bit different V/T curve to the batteries, and again the discharge in parallel to an unregulated bus. Now we have gone to pulse with modulated switching regulators as opposed to series dissipative. And we also now have an undervoltage system on the spacecraft to try to protect the battery should the large loads be presented to the batteries, greater than what they could really support.

(Figure 9)

Again, RCA/AED came up with the spacecraft design, G.E. Gainesville cell. They are on three batteries. There are 24 cells per battery, of which two of them are third electrode cells. The nameplate capacity of the cells, as in the case of ITOS, is 6 ampere hours. The weight is a little bit down, 8.9 kilograms per battery, although we put an additional cell in. We have again taper charge and voltage control. We have signal electrode control of the batteries. From a systems standpoint it was never used as anything but a telemetry function. We had some operational problems when we tried to use it -- actually put the batteries into a trickle charge.

We also now have a high temperature cut-off of 37 1/2 degrees C. The nominal operating temperature of the batteries was 0 to 30 degrees C. In fact it was designed to work at 11 degrees, a controlled baseplate. During the first year of the mission the batteries normally work there, but after that the orbit had changed enough and things had degraded enough inside the spacecraft that the battery temperature range sort of widened up a little bit.

We have a nominal C/4, an amp and a half taper charge, charge to a taper charge. We have a C/40 trickle charge rate, again when it was effected by one of the two third electrode cells. Again, as I mentioned, we do not use that operationally except as telemetry. And we have a nominal 18 percent depth of discharge, although we do get 40 percent on occasion. As Phil Brandt will discuss, we run the thing at undervoltage periodically just to get the maximum out of it.

(Figure 10)

There were three spacecraft in the series. Two of them are still operating. One will be four years old in December, and another one will be two years old a couple of days ago I guess or in a couple of days. So, the birds have operated very well.

The interesting thing here is, as Floyd brought up, this is the previous V/T curve on the AE-C, which is the first of the two birds that is now operating. We took this V/T curve, which is essentially just an extrapolation for 24 instead of 23 cells in the ITOS curve. You notice we are in a little bit of excess of 36 volts, 24 cells. That is a little bit over 1.5 volts per cell at 0 and then down to 30 we are a little bit over 34 volts.

Two other hard lines, solid lines, are what we call the standard, Goddard NASA standard, whatever they are, levels 5 and 6. For AE-D and AE-E (the only spacecraft that is presently operating) we took a V/T curve and just simply laid it in the middle there. You will notice a difference between the two. When Phil talks he will explain the difference in the performance and you will see again the first bird, the V/T curve was high. We have had difficulties with the battery overcharging and the battery performance. Where the V/T curve is lower and more in line with the overcharge characteristics of the cells we are getting nowadays, the performance has been excellent.

## OPERATIONS

BRANDT: This just shows the kind of eclipse we have, typically 1971, 1972.

(Figure 11)

Roughly there is 30 minutes of eclipse, and it is a 90 minute orbit. So, there is 30 minutes eclipse, 60 minutes charging.

(Figure 12)

This is a typical experiment sequence, one in which we had trouble, if I can explain a little bit.

At the bottom I am showing experiments operating, the tape recorder coming along in the experiment, in cycles like that. During this time, no operation, just basically the receiver is running and that is about it.

Some more experiments, more experiments. These dark things are eclipses. Here I am showing ground contact. What happened in this particular sequence is we were operating for actually two, operating it and charging the batteries during sunlight, but also operating the bird at the time, 6 amps coming out of the battery during eclipse. Here is a time like that. Here is one.

And what happened is that batteries were just decaying and not getting charged, just running down in essence. And at the end we had what we call an undervoltage, and that is when the bird essentially shuts itself off.

Up at the top these numbers are showing the third electrode signal voltages. Normally they run I think it is about five-tenths of a volt when the battery is fully charged. Oh, these points are all just real time contacts that I had a chance to get the data from. Notice you are going from .36, three one, two three, two one. Here is the last one out here, .19. And that is about when the bird went to undervoltage.

The point of this is that when battery designers design batteries you think that you are going to charge for so much and discharge for so much. But actually here is a place where we are operating the thing not in the way you people thought that we should operate it.

(Figure 13)

The other problem we are having now is the batteries on C are getting old. They are heating up, and we are having the same problems Rick discussed on ITOS. We have got to take the batteries off charge.

But another problem that I have noticed on one of the batteries on the old bird (the bird that has been in orbit for four years) is we took it off charge and one here the circles are voltage and the triangles are for battery temperature. I don't know if you are interested in numbers. But we took it off charge, which means essentially the battery is not being charged and is not supplying any of the load that I know of. So it is sitting there all by itself, and look how it decays from one o'clock in the morning to one, two, three o'clock in the afternoon. It decayed from 32 volts. Well, that is misleading because that is being charged. Here 30 volts to 28.5 all by itself, self-discharging.

The other interesting point is that when we put it back on charge, which is over here, of course the voltage jumped up, but the temperature started rising like crazy too. This surprised me, so what I thought I would do is on the newer bird I would disconnect the battery and watch it the same way. And that is this line. Obviously the battery holds its charge and holds its voltage on a good battery. This other battery that is much older falls down.

#### DISCUSSION

RITTERMAN: TRW. Do you have any idea as to the extent of self-discharge of the cell battery as far as ampere hours go? How much per hour?

BRANDT: Well, roughly this was decaying at 0.1 volt per hour.

RITTERMAN: What is the ampere rate?

BRANDT: I can't tell that. I just don't know. Just judging by telemetry from the spacecraft I can't tell. The whole exercise I went through doing this was to try to determine that, but I just can't tell what the current is.

NAPOLI: RCA. I gather from all this overcharging problem that we have here that we are overcharging as the battery gets older for a specific V/T curve? Is that correct? Are you inferring that maybe the design, the future design, should have a selectable curve that give you a charge rate --

BRANDT: I don't know.

BAER: I think we really aren't inferring anything. That is just what happened.

NAPOLI: The second question is if you do go to a lower charge rate with this type, do you have the ability to recharge the battery when you come back into sunlight with that lower charge rate?

BRANDT: Yes, we could by turning off the experiments, in other words, shutting down the bird.

NAPOLI: A compromise.

BRANDT: That is what we do in operations. We are constantly juggling between running experiments, charging the batteries, and watching the temperatures.

OBENSCHAIN: Goddard. I think I can answer your question. Your second question, is there a compromise along the V/T curve? The answer is no. What Phil was talking about is the fact that we have not enough solar array power to really run the bird and charge the batteries at the same time. You have to turn off the experiments. He charges the battery, runs the experiments and runs the battery. There are two different things. This is a lack of array capability. What you were referring to was the V/T curve. This V/T curve right here when you have 100 percent sun and there is sufficient array energy does permit full recharging the battery.

NAPOLI: It also allows overcharging.

OBENSCHAIN: No. It limits overcharging. The AE-E, the flight curve across there, that bird right there, as I showed you, at a lower V/T curve, when that bird is less than 100 percent sun it operates beautifully. It tapers right down to C/20. It does not overheat. It does not overcharge significantly enough so that you start raising up the temperature. On AE-C, which is most of the data presented along the curve here, you do get overcharge. So I am not saying we ought to have a multiple V/T curve. I think you can select the V/T curve which is a very good compromise. I think we did on AE-E. I think we have demonstrated it now. It is over two years old or in a couple of days it will be two years old. We have never had a battery temperature problem. We never had any kind of a fading problem or anything. It is working nicely. It is the same cell as we flew in AE-C. They are both G.E. 6 ampere hour cells from the same lot.

NAPOLI: What is the final charge rate when you get down to the lower end of that?

BRANDT: About 150 mils.

OBENSCHAIN: That is the C/40.

FORD: Goddard. I guess the point that I would like you to go back to is after you have had the batteries in the older bird on open circuit you said you put them back on charge and you immediately had a temperature rise.

BRANDT: Yes.

FORD: I think that may be the part that we are getting confused about. Do you ever feel or do you have any insight as to what caused that? Or do you just hold it up as something you observed?

BRANDT: It is something we observed. Why, I don't know.

To contradict Rick a little bit, we have begun to notice on E one of the batteries is starting to behave the same way, starting to get a little hot when you go to charge.

FORD: GSFC. I would like to address your first question. But I would like to defer that until later on in the morning because one of the characteristics we have seen on old spacecraft of old batteries is apparent softening of the V/T way down after the cells begin to wear out, meaning that for a given design it may be adequate for two year life, but if you are really going to push that operation into like four or five years that V/T curve for the early life may not suffice for later life. So I think we might get into that a little later.

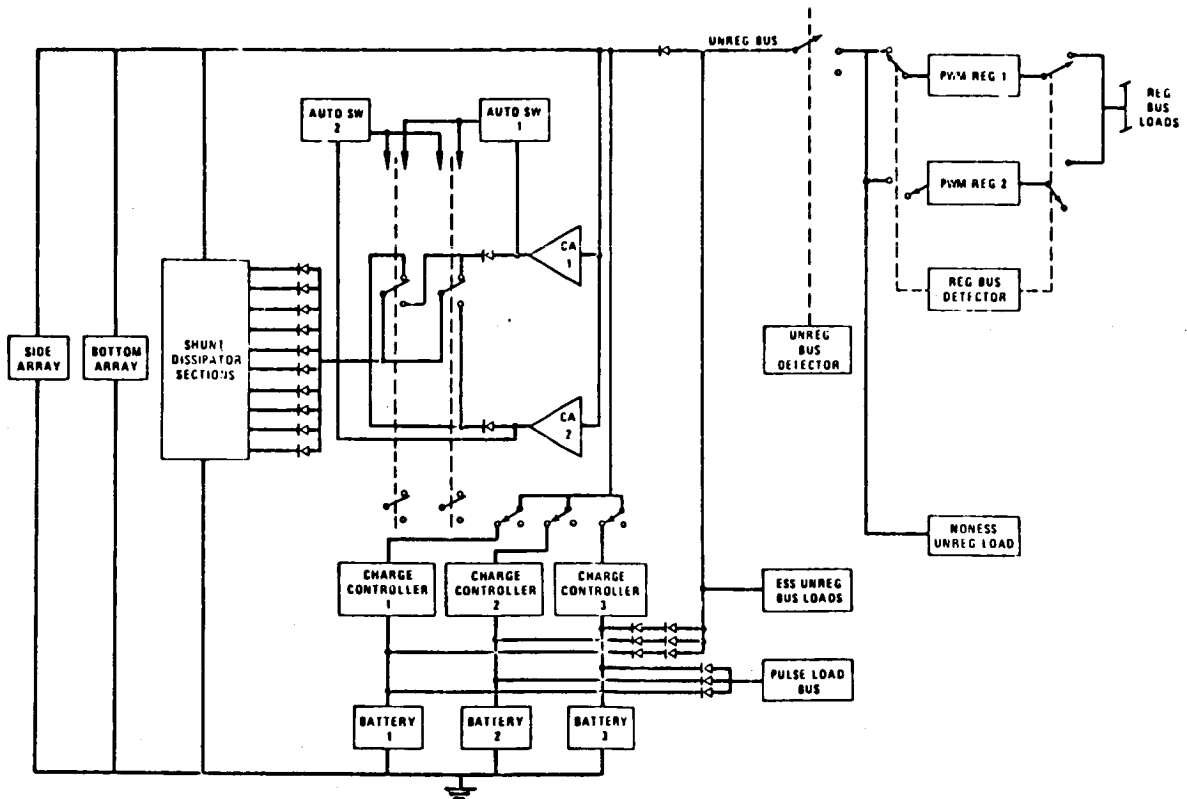


Figure 8. Power Supply Electronics Block Diagram

CONTRACTORS	SPACECRAFT: RCA/AED
BATTERIES PER SPACECRAFT	CELL: GE
CELLS PER BATTERY	3
STORAGE CAPACITY	24 (TWO SIGNAL-ELECTRODE)
WEIGHT (PER BATTERY)	6 AMPERE-HOURS (NAMEPLATES)
CHARGE CONTROL METHOD	8.90Kg
	TAPER CHARGING WITH VOLTAGE AND TEMPERATURE CONTROL
	SIGNAL-ELECTRODE CONTROL OF BATTERY OVERCHARGE
	TERMINATION OF ALL CHARGE AT BATTERY TEMPERATURE OF 37.5° C
OPERATING TEMPERATURE	0° TO 30° C
CHARGE RATE	C/4 (1/5A) PER BATTERY (MAXIMUM)
	TAPER CHARGE RATE DETERMINED BY BATTERY VOLTAGE AND TEMPERATURE
	C/40 TRICKLE CHARGE WHEN FULL RECHARGE, AS DETECTED BY ONE OF TWO SIGNAL ELECTRODE CELLS, IS ACCOMPLISHED
DEPTH OF DISCHARGE	40 PERCENT MAXIMUM
	18 PERCENT NOMINAL

Figure 9. AE Battery Design

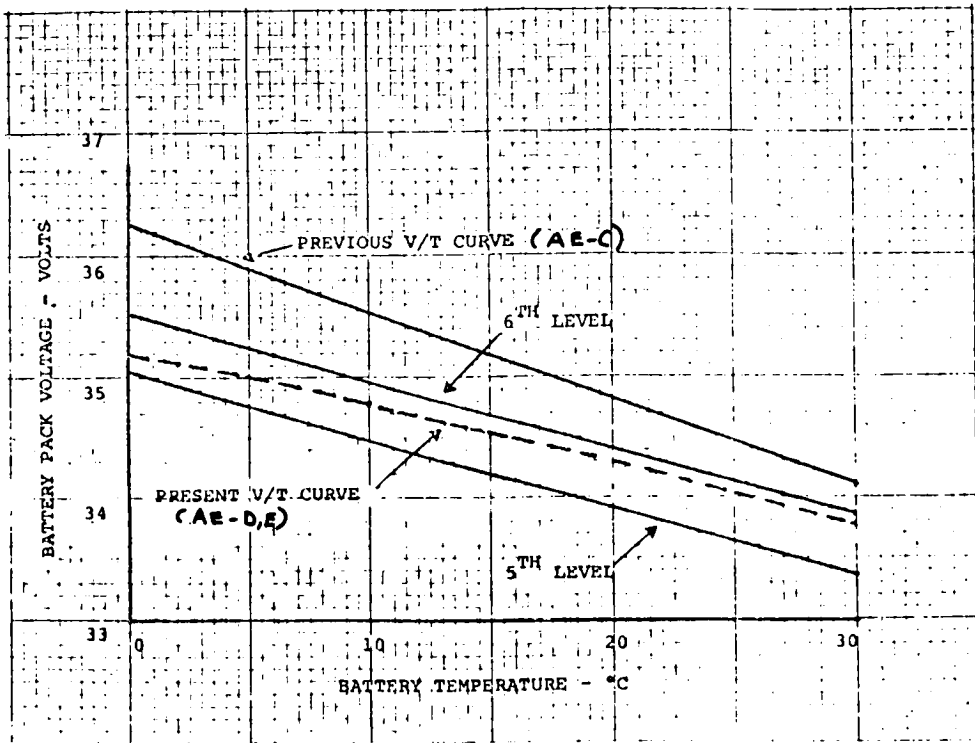


Figure 10. Battery Voltage/Temperature Limiting

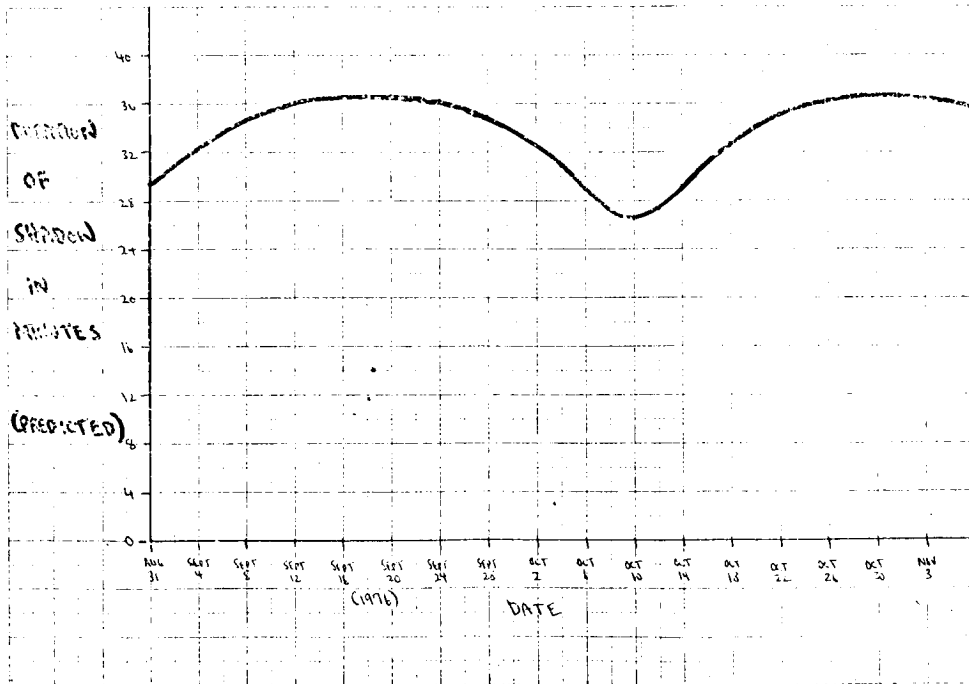


Figure 11. Prediction of Duration of Shadow for 21st and 22nd S/C Turnarounds for AE-C

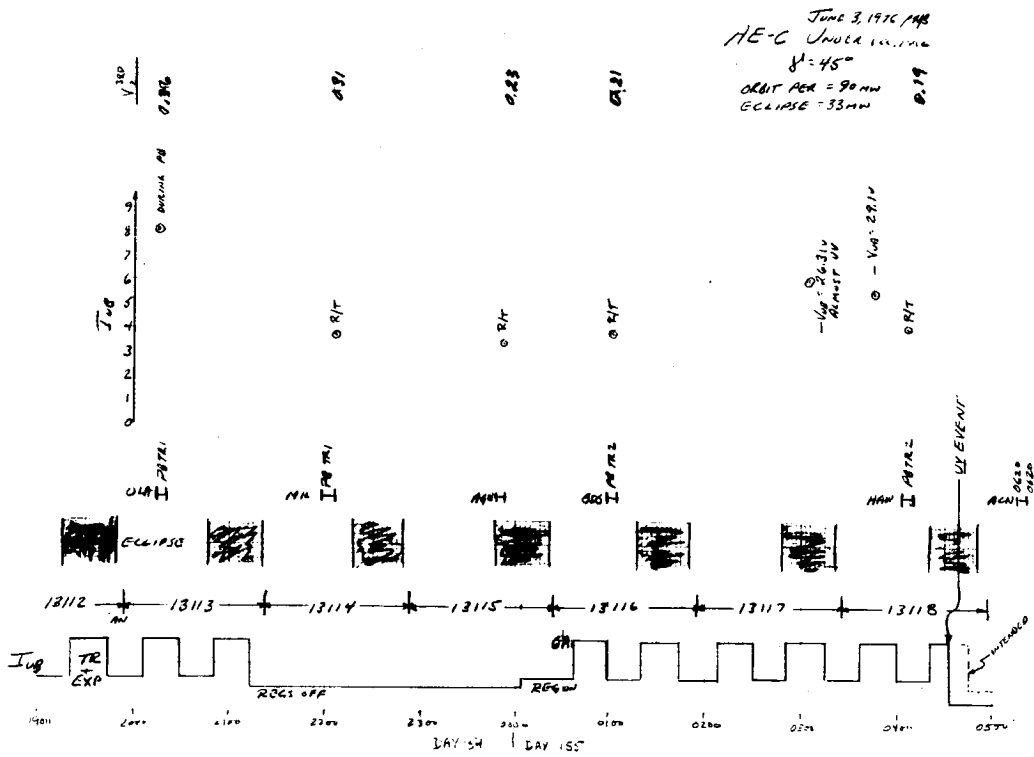


Figure 12. AE-C, Under Voltage (6-3-76)

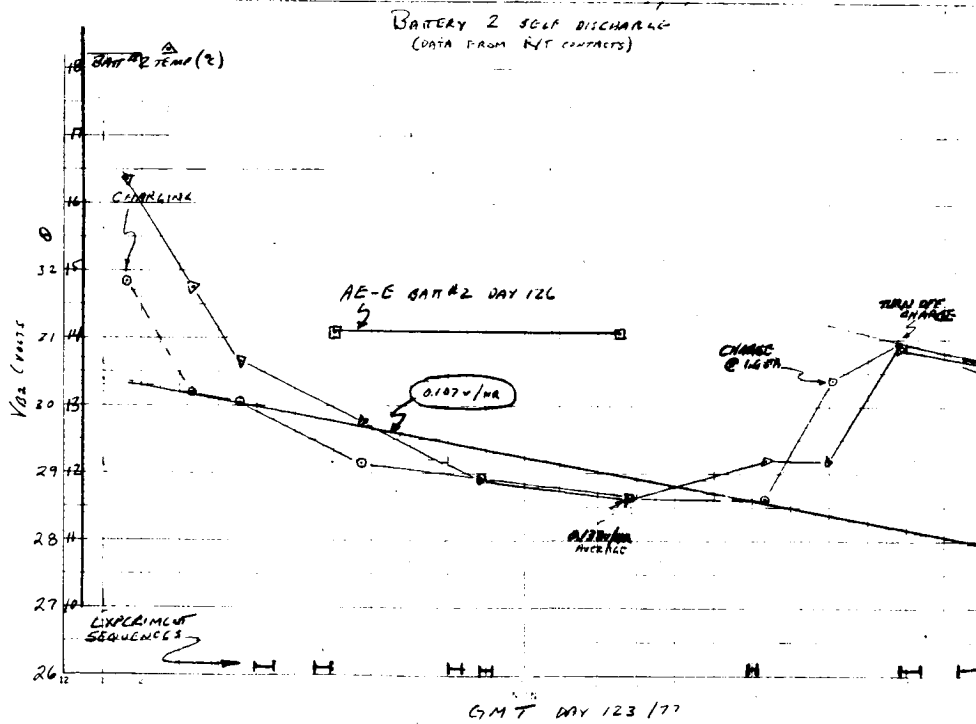


Figure 13. AE-C, Day 123 (5-3-77)