

NIMBUS AND LANDSAT

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INTRODUCTION

BAER: The next satellite to be discussed is the Landsat, which was formerly the Earth Resources Technology satellite, and Nimbus. Here again we have an early 1960 design, and it is still being used mainly from the viewpoint of not redesigning the system and has been relatively successful even with its faults.

They are both very similar, almost the same satellite at least functionally. There are some subtle differences in it, so we are kind of lumping the presentations together.

(Figure 14)

G.E. was the prime contractor. RCA did the storage module, and the cell was manufactured by General Electric. The cell is a 4 1/2 ampere hour nickel cadmium cylindrical cell, 23 cells connected in series formed the battery. The storage module weight was 7,020 grams, about 15 1/2 pounds. The reason it is called a storage module is there is also electronics in the same box as the battery. And the electronics in this case weighs on the order of about one and three-quarters pounds. There are eight batteries on the spacecraft.

(Figure 15)

As far as charge control goes, there is a current limit of 1.1 amps. There is a temperature compensated voltage limit. However, most of the charge control is by use of auxilliary loads, switching off and on. Because the voltage limits are so high it is used more for safety than anything. There is also a temperature cut-off at 43°C, and that cuts the current back to .15 amps. And these batteries can be removed from the main bus by ground command.

(Figure 16)

Okay, here is the V/T curve. You can see it is a little higher than what is normally used in practice today. The curve falls somewhere in between these two tolerances.

On the cell level at 0 degrees C it is about 1.50 to 1.52. At 20 degrees C it is about one four six to one four eight. At 40 it is about one four two to one four four. I said that is a little higher than most designs used today.

(Figure 17)

Okay, the power system, here again we have a negative bus system with the shunt dissipate driver through this transistor that is located over in the storage module, and there are eight storage modules. That clamps the solar array bus at about a minus 40.

One difference on this diagram between Landsat and Nimbus is you have this extra payload regulator. That is on Landsat, and it is not on Nimbus. Here are the aux loads that are coupled in by ground command, five of them, and depending on what the loads are it depends on how many aux loads are on. So, essentially what he has to do is he has to know how much he is going to take out during the night and what the loads are going to be on during the sun. And then he selects his aux loads to limit the current to the batteries to get a C to D of about 1.10 to 1.15. The battery is coupled to the solar array bus through the charge controller, and that is where your voltage and current and temperature limits are -- in the charge controller.

During the night the battery is coupled, diode coupled, to the unregulated bus, and there are also these relays which allows you to remove any one battery off the line.

Here are the regulators which regulate at about minus 24.5, the regulator bus. And about the only other thing of interest is there is a fuse tap. That is used to blow the fuses if your loads get too heavy. The regulators don't have enough to blow the fuses in all cases.

Okay, that is about it as far as design constriction goes.

NIMBUS OPERATIONS

WISE: The Nimbus spacecraft initial design life was six months to one year.

(Figure 18)

As you can see from the chart here we had good luck with them. Nimbus 3 was launched April 14, 1969, and it was eventually turned off in January of 1972, with two and three-quarters years of operation. Nimbus 4 went from April 8, and then in October of this year, seven and a half years of operation. Nimbus 5 is still operational. It had five years of operation. Nimbus 6 is still operational.

There were batteries turned off on 3 and 4. Batteries 5 and 6 have had no batteries turned off to date. None of the battery problems that occurred have effected mission operation.

(Figure 19)

The orbital period is 107 minutes, which is 34 minutes a night, 73 minutes a day. During the first year the battery temperatures averaged 20 to 24 degrees. The system battery capacity, 4 1/2 ampere hours, is 20 on the 160 ampere minutes. The depth of discharge was typically 14 to 15 percent and dropped to 4 to 5 percent after seven and a half years of operation. This is primarily because at the beginning of the spacecraft life you have all the experiments operating. As each experiment drops out, of course the load reduces. Then as you have problems with the batteries, the remaining good ones can still carry the load without effecting the mission.

The maximum charge voltage was 32.7 to 33 volts. The discharges were approximately 28.2 to 28.7. On the Nimbus type spacecraft for a period of time the loads were always relatively constant. In other words, they would go into a mode of operation with a set of experiments and they would last for three or four or five months or until they were through with that experiment or it had failed. So, it set at a relatively constant load on the bus throughout its life.

With the method of charge that Dave Baer has described, we typically would have 25 to 26 amps at charge and about 1.1 amps at discharge respectively.

(Figure 20)

Okay, with the method of charge that we are using the match of the batteries is very important. If the electrical characteristics were mismatched, the charge and load sharing would tend to spread. Or if the temperature would spread it would also force the battery to start spreading and charging, load sharing.

They have had C to D ratios as high as 4.8 to 1. And the temperatures have been as high as 43 degrees among individual batteries. As mentioned, the warm batteries are the ones that are the more susceptible to the runaway.

Nimbus both 3 and 4, were okay for seven years. The other six batteries had various problems where they were turned off and on. At the present time the spacecraft is -- They have an attitude control problem when the spacecraft goes like into deep orbit and then turns around. This presents a special problem in the fact that the batteries that were in the sun going forward, suddenly turned around, are still facing the sun and they don't get their proper cooling. So they have a very hotspot on that spacecraft.

Battery spread went up to 18 degrees from a nominal of 9 to 10. And then batteries 3 and 4 eventually became mismatched.

(Figure 21)

Okay, these are two examples of the batteries that became mismatched. By mismatched, what we really mean is that generally the charge here starts to increase and the load share decreases and then the temperature starts rising. The C to D ratio.

At night, in battery number 5 there, 28.93 ampere minutes of discharge, load share about 12.8, this 28.2, battery temperature around 21. Charge share went up to 37, so that means C to D ratio about 1.281. I guess that would be an example of a good battery pack.

The mismatch there is shown on the right with battery 7. The discharge amp minutes is 20. Go down to the charge, there is 5.8. You have a 2.781 charge/discharge ratio. And the temperature is up five degrees. That is nominal.

(Figure 22)

This shows that on the left is the night and on the right is the charge. This left scale on discharge is as you can see the numbers there, 1.1 and .63. That shows you typically how a discharge is done. As the voltage goes down, the current goes up. You have a constant power and voltage.

Over here in the daytime now this shows typically the way the charge current would go. You can see the scale right over here. This would be a normal.

(Figure 23)

This is sort of a very vivid graph that I will just show you basically. In this area here is the C/D ratio varying all over. The voltages are up here. The temperature is this dashed line. They have various charge sharing, load sharing.

This is when the problem started occurring on battery 7. They tried various things, such as lowering the voltages and attempting to see if the battery recovered, trying to overcharge, and cycling it, and almost everything. Nothing would finally work, so eventually they shut the battery off. And on this particular system we have approximately a 25 milliampere telemetry circuit which will discharge the battery. So, if you turn it off at some convenient time in the day-time, then if you wait approximately two months the battery will discharge down to 1.1 volt per cell, or about 25 1/2 volts. At that time we turn it back on. Now when they turned it back on you can see dramatic change here. You can see that everything just straightened out immediately. The C to D ratio was great. The charge, load sharing completely got together. The temperature was steady, and the voltages were steady.

So, this is typical. We call this a restoration cycle, not a conditioning. But we call it a restoration cycle in our nomenclature. This is typically what we do on Nimbus and also on Landsat. It seems to help very much.

(Figure 24)

This is just what I have mentioned before. We can turn the battery off and wait until it gets down to 26 or 25 1/2 volts and then turn it back on, and you have seen the results on the previous graph. It was successful with batteries 4, 6, and 7 on Nimbus 3 -- 3, 4, 6, and 7 on Nimbus 4. It did not work, however, on battery 2 of Nimbus 4.

Another technique that sometimes works is that if you operate the system -- Well, if you see this starting to creep up and you know it is going to run away soon, if you operate the system deliberately at lower voltages and lower C to D ratios, sometimes then when you go back to normal the battery will return to normal. If that does not work, then the second recourse is to turn it off.

LANDSAT OPERATIONS

(Figure 25)

WISE: Now turning to Landsat, we are on a 910 kilometer circular orbit. It is ground synchronous and initially sun synchronous. The orbit period is 103 minutes, 72 minutes day, 31 minutes night. On Nimbus the sun comes directly to the front of the spacecraft. It is in the plane of the orbit because it is a high ending orbit. In our spacecraft, though, the sun is over 33 degrees to the left nominally. It is actually about a plus or minus 7 degree variation throughout the year because of the sun's being directed to the earth.

We launched Landsat 1 in July, 1972. Today it is going through orbit 27,060, which is approximately two, five, years of very good operation. Landsat 2 was launched in January of 1975 for over 14,330, and not 14,330 years. It is only 2.7 years. The batteries have not limited mission operation.

(Figure 26)

This is just a rehash in a more simplified form of the block diagram system. We have the solar array and the shunt aux loads. We have a charge regulator. We have two with modulated regulators. And on this particular spacecraft the smooth loads come off the service regulator. Pulse loads where they have a lot of inverters and so forth come off the payload regulator. And we have a special series of loads that are solenoids and very heavy loads, pulsed loads, that come off it, shuttered and so forth, that come off the pulse load bus, which connect it directly to the battery.

This particular technique, using the battery to buffer those heavy loads, works very well.

(Figure 27)

Nimbus, as we mentioned, had a very steady load. On Landsat we have a highly variable load. So the depth of discharge, 9 to 16 percent. When we reach 16 percent it would be necessary to turn off the payloads because if we operated it any lower we may drop out of regulation.

At the present time now we are 8.2 to 10.3, and we also only have four batteries on at this time. I will explain why that is working well. The temperature was initially 20.4 to 25.7. We are now 18.7 to 26.6. We have hit peaks up to 40.2. And the main reason is that the spacecraft is drifting. The initial 33 degrees sun angle has moved over to around 48 as you can see down below here. As we go to that higher sun angle though, the day-night changes. Where we started out with a 73-minute day and 30-minute night, we now have an 83-minute day and 20-minute night. The short night prevents us from cooling the spacecraft properly. In addition as we get towards five here we get some degradation of the thermal surface which helped contribute to warmer temperatures. The temperature at present is 18.7 to 26.6. We are going to be winding though toward the higher temperatures. Temperatures on the sunny side of the spacecraft are about 32, but they are presently off. Those temperatures there reflect the four working batteries which are opposite the sun.

The C to D ratio was .06 to 1.17. We are now about 1.15 to 1.33. The reason the C to D ratio has to increase is that initially we had very good --

mismatch. With eight batteries they should be 12 1/2 percent, the charge and load sharing. That will run typically from 12 to maybe 12.8 on both of them at initial conditions. At end of life, like they are now, it will run from 11.5 to 14. The batteries that are taking more than their share on charge prevent us then from getting the correct account of the other batteries because we have to work on it as a total system and not as an individual battery when we control the charge. So this means the C/D ratio has to slightly increase. This means then that some batteries are getting larger than desired C to D ratio. Others are getting just a correct amount.

Landsat 2, 10.5, 11 percent. We have 16 percent peaks. Let us talk a little about these peaks now. 16 percent of both cases are when we have a night playback, and so therefore we will go into night and we will discharge maybe down to 10 percent. The next 6 percent of discharge will be at a rate of C over 2, C over 4, in other words 1 amp to about 2.2 amps. So this makes a voltage problem because at those high discharge currents we get pretty large high arc offs. If we held the same depth of discharge throughout the two years here, 2.7 years, the temperature ranging to 23 initially. They are now 17 to 26. We have hit peaks of about 30. The C to D ratio at 0 is 1.05, 1.08. But even on this spacecraft we have the D to D ratio up now, 1.17 to 1.25. Sun angle has changed from 36 to 42. We have a slightly increased day and a slightly shorter night. That is the reason we have those higher temperatures.

(Figure 28)

Now, here is a little history of the restoration cycles that we described earlier on Landsat. Okay, let us go to battery 6 on Landsat 1. The first restoration cycle was at 3.7 years, and the second at 4 years. And you can see that when we turn it off we recovered, operated normally for a while, but then it reverted back to its old characteristics and ran away at the end. We turned it off at four years.

You find that battery 5, 6, 7 and 8 were off respective at 4.5, 4.7, 5.2, and 3.1 years. I think that is supposed to be 3.7, that battery. I made an error there. We had a switching anomaly which prevented us from turning the batteries back on. So when we got to the place that those batteries were required, the restoration cycle, we had to turn them off. But once they were off they could not be returned to service because of another switching problem on the spacecraft. It turned out, though, as you noted earlier, that we went to a longer day, shorter night. This meant that I could get by with less battery because the night discharge, you know, was smaller. Even though I had only four batteries, I am still holding only 10 percent depth of discharge. This is a case where the orbital drift parameters and the battery characteristics all worked out so we were able to keep the mission going.

On Landsat 2, battery 1 had four cycles, 1.7, 2.3, 2.7, 2.8 years. Battery 2 we had one cycle at 2.5. Battery 5 one cycle at 2.1. Battery 6, which has been our trouble battery, meaning to operate it is taking the most care, required -- well, you can see all the numbers there.

There is one, you know, trend that I can mention on this. If we had turned the battery off and let it discharge down to that 26 1/2 and then turn it on at about 25 1/2 volts, then we turn it back on, the battery operates very normally. And then eventually it will start creeping, where the charge share will go up gradually, the load share goes down, and the temperature stays relatively constant. Then, suddenly, at about the 14 to 30 orbit period, which is one to two days the charge share will go up dramatically, the load share will go down, the temperature will rise. At that point we shut it off.

Now if I turn that battery off the first time it will last maybe two to three months. The next time it will be 2 1/2 months, the next time two months, the next time one and three-quarters. What I have is the time of good performance after restoration cycle is decreasing, and now it is getting so that if I turn it off now I can only expect about two weeks of good operation before I know I will have to turn it off again.

We are still trying to keep it on because though we can operate the mission without it it makes the mission a little easier as far as scheduling. So we do go through the trouble of restoring the thing, getting back on line as much as we can.

As you can see, we have had quite a history. And those other batteries, like battery 2, it was only two and a half, battery 5 -- 2.1 years. They are working normally. We have had no need to turn them off the second time. So that is the end of my presentation.

DISCUSSION

GROSS: Boeing. What is the typical restoration duration?

WISE: Well, we don't control the point where we turn it off, in other words, the depth of discharge or the percent of charge at the time we turn it off. We just do it randomly and when it is convenient to us. But with the 25 milliamps to when we discharge it typically takes about two months.

GROSS: Two months?

WISE: Two months, yes. Now there have been intervals where for some reason where we needed that battery on line where we turned it on in less than a week. It had not gone through the full restoration cycle. When it comes back on it acts as if it had. But let us suppose I had it turned off only for a week and the battery voltage only dropped maybe to 27 1/2 volts, it will act normally but maybe only for a week. If I had done that at 25 1/2 volts it would have lasted for months.

GROSS: And do you start your restoration at the end of a charge or a discharge?

WISE: It is in the middle of a charge. We are into the daytime. We have a daytime contact, and I will just turn it off at some point. Now it has not fully recharged. It has been down to 10 percent depth of discharge. I maybe added another 2 percent. So I may be sitting at 92 percent state of charge. And I turn it off and then let it go down to the 1.1 volts per cell.

SCOTT: TRW. To what degree do you attribute the unbalance problems between an inherent change in the IUE characteristics of the battery and differences in the thermal environment of the different batteries?

WISE: I am not sure we can really distinguish the differences, but I would say that if the thermal conditions had remained about constant that if suddenly the battery should fall it would have to be internal characteristics. That is about the only way. We have no way of really distinguishing.

SCOTT: How you do characterize the uniformity of thermal dissipation between all those different eight batteries as far as the design is concerned, physically where they are placed and all that?

WISE: Because of the complexity of the thermal problem I am not sure how to answer you. We have 18 compartments, and the batteries are spread around these 18 compartments in a circle. On 16 of these compartments we have active thermal shutters that if the night is long enough they will open, close, and tend to cool the battery and keep it at within let us say 23 plus or minus 2. It is possible that the battery gets a high C/D ratio that we can force the battery to put more heat than the shutters can handle. Also we have other equipment in those, and with the wide reverting modes we have and the self-generated heat from the battery itself we have such a wild combination of circuit, you know, conditions that I can't answer your question directly.

FORD: Goddard. Would you comment on the restoration cycle and what problem you are trying to solve? Load sharing on charge and discharge, or either?

WISE: Yes, we start the restoration cycle, and we key it to the fact that we have a sudden rise in charge share, a sudden decrease in load share, and a sudden temperature rise of that battery pack above its normal operating conditions. At that time we will then switch into restoration cycle. We tend to try to catch it early for the reason that we felt that if you do go into this high C to D ratio you are not doing the battery any good. We could still operate with high C to D ratio and it wouldn't hurt the spacecraft, or we would still be getting some use out of it. But we felt if we turned it off early it may salvage the battery and allow a little more useful life in the long run.

UCHIYAMA: JPL. When you say you turned off your batteries you said you turned off everything, no load, no direct load?

WISE: Yes, there is no direct load on it. It is disconnected. The only direct load is the voltage telemetry circuit, which operates directly off the battery. And it is around 25 milliamps.

UCHIYAMA: So there is a slight load.

WISE: There is a slight load, yes.

PARK: Battery Development. I was just wondering if somebody in the meeting would comment on whether it would be better to have more discharge during this restoration period.

WISE: That would be an interesting question. On our spacecraft we could not do it. We have no way of doing it, but it might be an interesting thing. If you could explain the phenomena that is occurring, you might be able to figure out a better way of accomplishing it.

PARK: If anybody around here has tried that, testing it on the ground and found this sort of thing in ground testing. I could imagine that possibly it wouldn't take you -- maybe a week, you know, to make it behave or something like that, a matter of days even.

SCOTT: TRW. I would like to ask whether you know how much different the behavior of the battery is on that 25 milliamp load compared to just leaving it on open circuit on real open circuit?

WISE: I don't know because we have no way of going to open circuit. We are fixed to that mode. Helm Thierfelder was at G.E. and had tested some earlier ones. Do you have any idea? Have there been any tests that we compared self-discharge by the telemetry to the open circuit?

THIERFELDER: G.E. Well, if you just left them open circuit, it would take a lot longer than two months. It would take probably well over a year to get them all the way down. So that 25 milliamp load has a big advantage --

NAPOLI: RCA. Do you notice that when you are charging the batteries that there is a difference in voltage? Can you measure the voltage individually in each battery?

WISE: Yes. Each voltage is measured individually, but during charge and discharge they track very close together, within 10 millibels to one another.

NAPOLI: But when you are tapering off to the final charge are they within the --

WISE: Well, with the system that we use we just barely approach the taper curve, and they very seldom go into taper. In other words, the taper charge curve is set so that you get a 1.3 or something like that C to D ratio. And we don't normally shoot for that. We shoot for lower, so we don't quite reach the taper curve on most.

NAPOLI: What about on discharge? Do you see any difference between them on discharge?

WISE: Yes, on the way down they will vary a little bit. But they all end up, you know -- one will come down. Well, there are small differences. I would say they are insignificant though. They track very close both going up and coming down.

NAPOLI: It is only with currents that you really have a problem.

WISE: Yeah, the current vary a little bit. When the batteries are what I call normal they track fairly well also. It is only when they start getting this runaway condition that it starts creeping and then finally goes very suddenly that we have a problem.

BAER: I might add usually when you are running a system like this with batteries in parallel usually your voltages are going to track very closely unless you have unusual IR drop across a diode or something. So the voltages are usually going to track. But what happens is you see the difference in the current, on discharge current that it delivers, or else in the current it will accept on charge.

NAPOLI: On discharge it could be depth of discharge.

BAER: Not usually, no. You know, they will try to seek the same voltage level. But the difference is going to be in your current usually.

LANDSAT/NIMBUS BATTERY DESIGN

- CONTRACTORS: SPACECRAFT - GENERAL ELECTRIC
STORAGE MODULE - RCA
CELL - GENERAL ELECTRIC
- CELL SIZE & TYPE: 4.5 AH NICKEL-CADMIUM (CYLINDRICAL)
- CELLS/BATTERY: 23 CELLS CONNECTED IN SERIES
- STORAGE MODULE: 7020 GMS (15.5 LBS) MAXIMUM
- BATTERIES/SPACECRAFT: 8

Figure 14

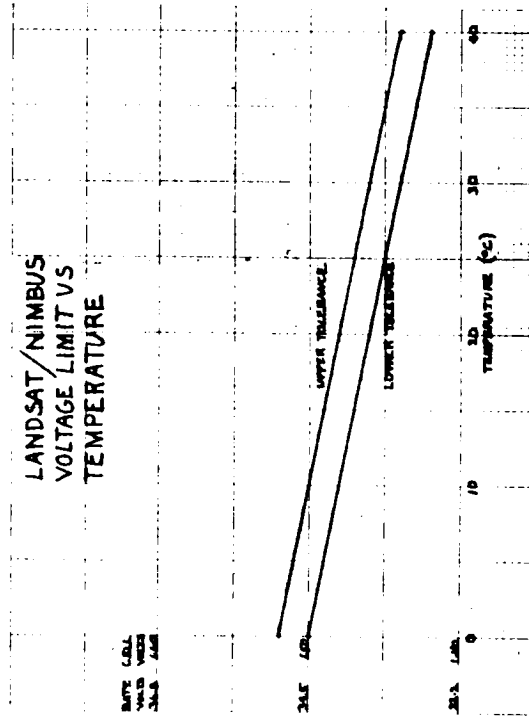


Figure 16

LANDSAT/NIMBUS CHARGE CONTROL & BATTERY PROTECTION

- CURRENT LIMIT: 1.1 AMPS EACH BATTERY
- CHARGE CONTROL: TEMPERATURE COMPENSATED VOLTAGE LIMIT AND USE OF AUXILIARY LOADS BY GROUND COMMAND
- TEMPERATURE CUT-OFF: TEMPERATURE OF 40°C SWITCHES BATTERY TO A .15 AMP TRICKLE CHARGE
- EACH BATTERY CAN BE REMOVED FROM MAIN BUS BY GROUND COMMAND

Figure 15

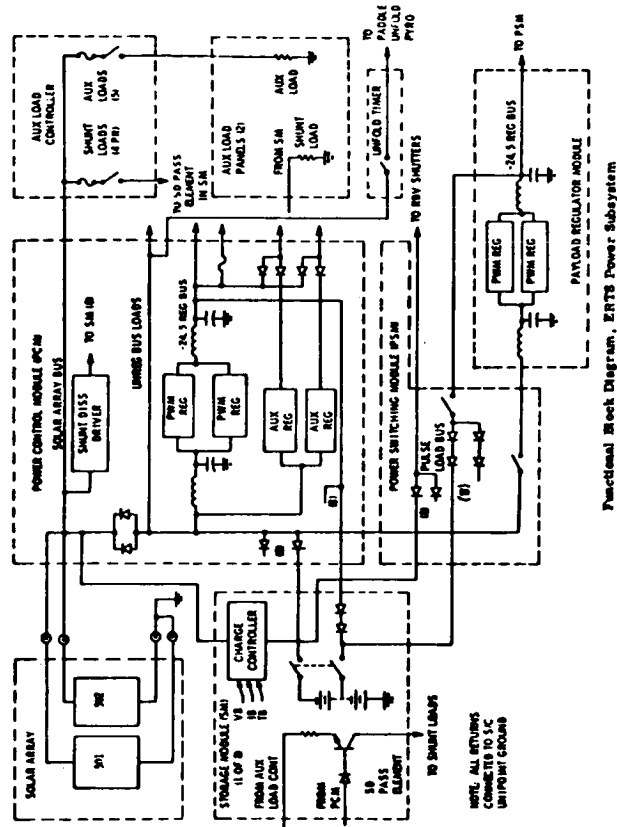


Figure 17

NIMBUS OPERATIONAL BATTERY

PROBLEMS AND SOLUTIONS

- o THE NIMBUS SERIES OF SPACECRAFT WERE DESIGNED TO CARRY HIGHLY ADVANCED OCEANOGRAPHIC, METEOROLOGICAL AND EARTH-SENSING EXPERIMENTAL PAYLOADS TO INCREASE THE KNOWLEDGE OF EARTH'S ENVIRONMENT.
- o DESIGN LIFE OF NIMBUS SPACECRAFT RANGED FROM 6 MOS TO 1 YEAR.
- o CURRENT VERSION OF BATTERY MODULE DEVELOPED FOR USE ON NIMBUS 3.
- o USED ON FOLLOWING NIMBUS SPACECRAFT

SPACECRAFT	LAUNCH DATA	CURRENT STATUS	YEARS OF OPERATION
NIMBUS 3	APRIL 14, 1969	TURNED OFF JAN. 22, 1972	2 3/4
NIMBUS 4	APRIL 8, 1970	PLACED IN HYBERNATION MODE 10/17/77	7 1/2
NIMBUS 5	DECEMBER 11, 1972	OPERATIONAL	5
NIMBUS 6	JUNE 12, 1975	OPERATIONAL	2 1/3

- o NO BATTERIES ON NIMBUS 5 OR 6 TURNED OFF TO DATE
- o NO BATTERY PROBLEM HAS AFFECTED MISSION OPERATIONS.

Figure 18

BATTERY PROBLEM

- o BATTERY "MISMATCH" PROBLEM
- o DIVERGENCE OF LOAD AND CHARGE SHARING PERCENTAGES.
- o RISE IN C/D RATIO (AS HIGH AS 4:8:1)
- o HIGHER TEMPERATURES (AS HIGH AS 43°C)
- o WARM BATTERIES MORE SUSCEPTIBLE
 - o NIMBUS 4 - BATTERIES 3 AND 4 OK FOR 7 YRS. S/C BEGAN PIROUQUETTING TWICE AN ORBIT.
 - o EXPOSED TO SUNLIGHT ENTIRE SAT DAY.
 - o BATTERY SPREAD INCREASED TO 18°C FROM 9-10°C.
 - o BATTERIES 3 AND 4 (28°C) BECAME MISMATCHED.

Figure 20

TYPICAL BATTERY OPERATIONS

- o ORBITAL PERIOD = 107 MINUTES (34 NIGHT - 73 DAY)
- o BATTERY TEMPERATURES DURING FIRST YEAR AVERAGED 20 - 24°C.
- o SYSTEM BATTERY CAPACITY (RATED) = 2160 AMP. MIN. (8 BATS)
- o DEPTH OF DISCHARGE WAS TYPICALLY 14-15 % (320 AM) INITIALLY AND DROPPED TO 4 TO 5 % AFTER 7 1/2 YEARS OF OPERATIONS (NIMBUS 4), - DEPLETED SEVERAL TIMES.
- o MAXIMUM CHARGE VOLTAGES GENERALLY WERE -32.7 TO -33.0 VDC,
- o END OF DISCHARGE VOLTAGES WERE GENERALLY CONSTANT THROUGHOUT FLIGHT DUE TO DECREASING DEPTHS OF DISCHARGE (-28.2 TO -28.7 VDC)
- o EXPERIMENT LOADING MAXIMIZED TO S/C CAPABILITY.
- o REGULATED BUS LOAD RELATIVELY CONSTANT THROUGHOUT ORBIT.
- o THEREFORE CHARGE AND DISCHARGE CURRENTS WERE REASONABLY CONSTANT AT .5-.6 AMPS AND 1.1 AMPS PER BATTERY, RESPECTIVELY, DURING FIRST YEAR.

Figure 19

EXAMPLES OF NORMAL AND MISMATCHED BATTERIES

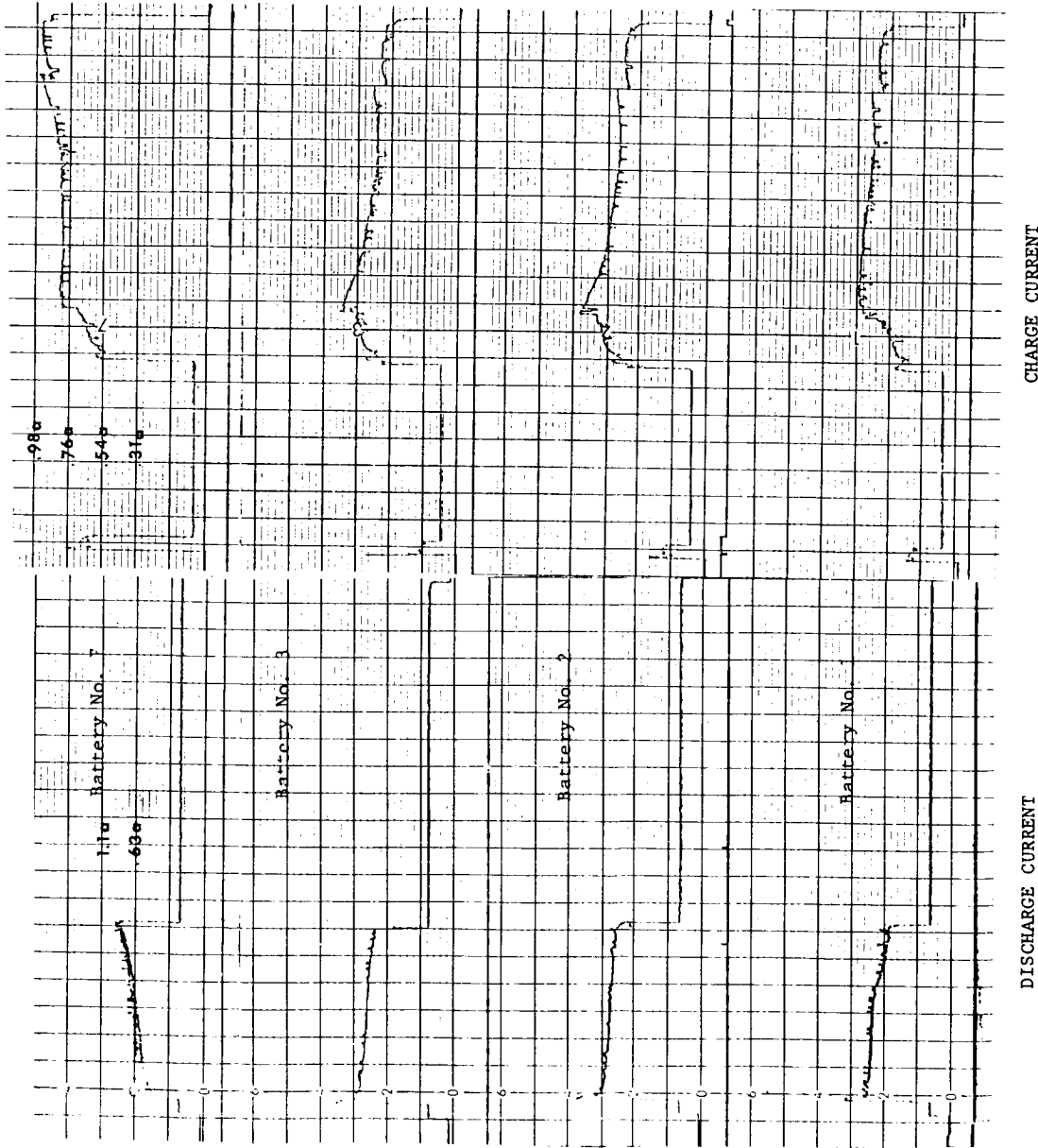
BATTERY NO.	SAT. NIGHT (35 MIN)	(NORMAL)	(MISMATCHED)
5	DISCHARGE IN AMP-MIN.	28.93	20.05
	LOAD SHARING %	12.80	8.87
	END OF NIGHT VOLTAGE	-28.23	-28.13
	BATTERY TEMP IN °C	21.06	25.97
SAT. DAY (73 MIN)			
	CHARGE IN AMP-MIN.	37.00	55.83
	CHARGE SHARING %	11.64	17.57
	MAX. CHARGE VOLTAGE	-32.26	-32.07
	BATTERY TEMP	19.75	24.65
	CHARGE/DISCHARGE RATIO	1.28:1	2.78:1

30 AM WASTED.

Figure 21

THE CHARGE CURRENT FOR BATTERY NO. 7 IS MUCH HIGHER THAN THE OTHER BATTERIES AND ACCOUNTS FOR THE HIGHER BATTERY TEMPERATURE AND WASTE OF OVER 30 AMP-MINUTES.

NOTE: THE DISCHARGE TLM IS SCALED ABOUT TWICE THE CHARGE TLM AND THE SATELLITE DAY PERIOD IS TWICE THE NIGHT PERIOD. THEREFORE, THE CURRENT SHOULD READ ABOUT THE SAME TLM READING.



CHARGE CURRENT

NIMBUS 5

DISCHARGE CURRENT

Figure 22

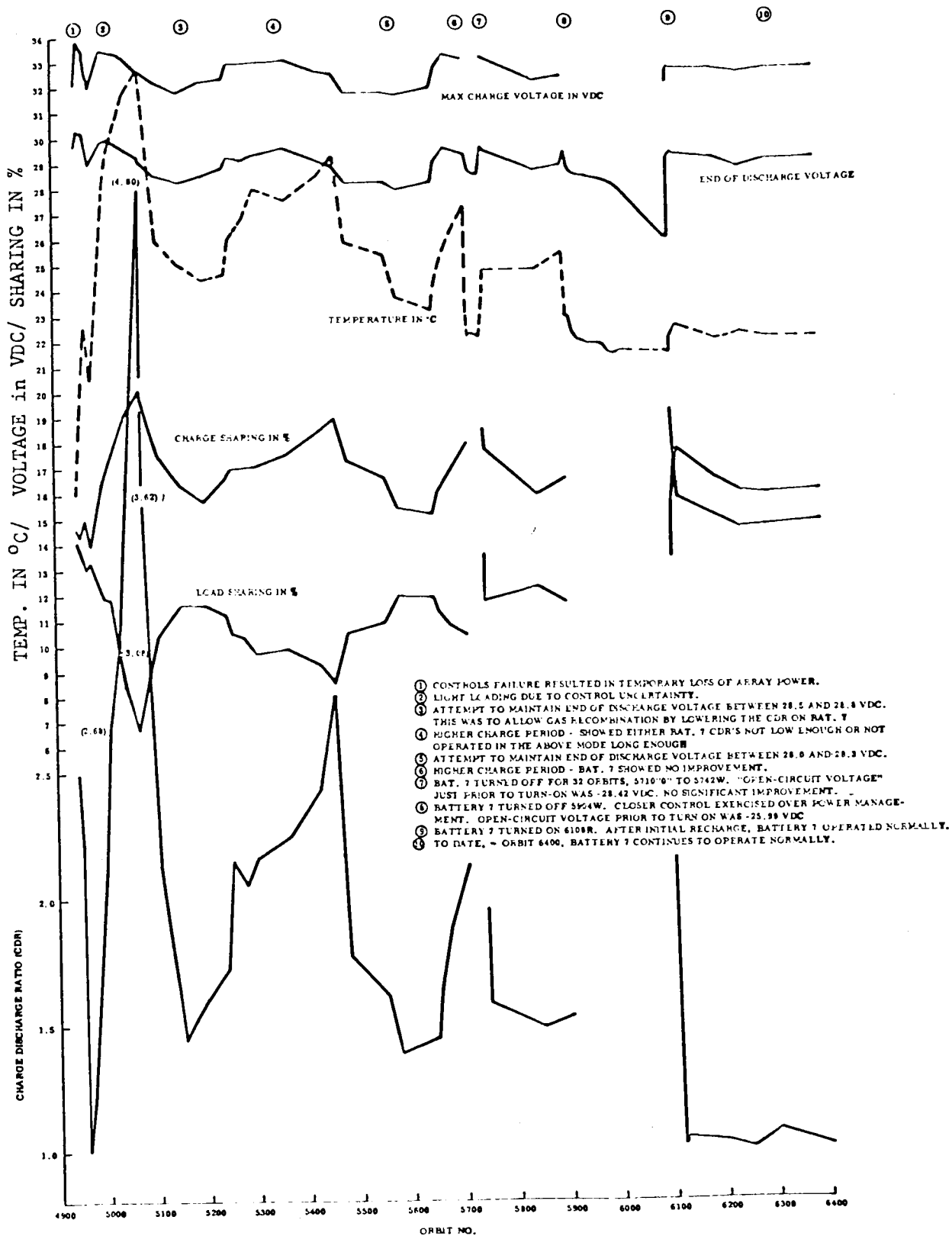


Figure 23. Battery No. 7 Performance

SOLUTIONS

- 0 TURN THE BATTERY OFF.
 - 0 WAIT UNTIL OPEN CIRCUIT VOLTAGE DROPS TO -26. VDC.
 - 0 SUCCESSFUL ON BATTERIES; 4,6, AND 7 ON NIMBUS 3.
3,4,6 AND 7 ON NIMBUS 4
 - 0 NEVER WORKED ON BATTERY 2 OF NIMBUS 4.

- 0 OPERATE SYSTEM AT LESS THAN FULL CHARGE
 - 0 SUCCESSFUL ON NIMBUS 5 AND 6, BUT REQUIRES MORE TIME.

Figure 24

LANDSAT	
ALTITUDE	910 KM CIRCULAR
GROUND SYNCHRONOUS - INITIALLY SUN SYNCHRONOUS	
ORBIT PERIOD	103 MINUTES
72 MIN DAY	31 MIN NIGHT
SUN ANGLE - NOMINALLY 33° TO ORBIT PLANE	
LANDSAT-1 LAUNCHED 7/23/72	ORBIT 27060 TODAY (5.25 YEARS)
LANDSAT-2 LAUNCHED 1/22/75	ORBIT 14330 TODAY (14330 YEARS)
BATTERIES HAVE NOT LIMITED MISSION OPERATION	

Figure 25

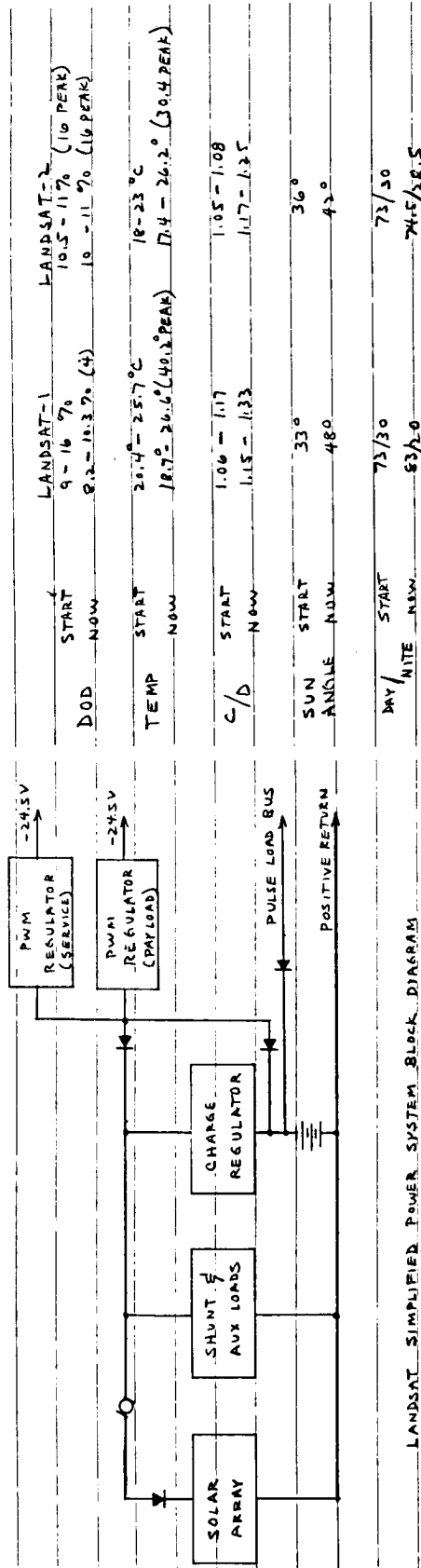


Figure 26

Figure 27

LANDSAT RESTORATION EXPERIENCE	LANDSAT-2
BATT 5 OFF 4.5 YRS	BATT 1 4 CYCLES 1.7, 2.3, 2.7, 2.8 YRS
BATT 6 2 CYCLES 3.7, 4.0 YRS	BATT 2 1 CYCLE 2.5 YRS
OFF 4.7 YRS	BATT 5 1 CYCLE 2.1 YRS
BATT 7 OFF 5.2 YRS	BATT 6 10 CYCLES 1.0, 1.9, 2.0, 2.2, 2.5, 2.6, 2.7, 2.75, 2.8, 2.9 YRS
BATT 8 OFF 3.1 YRS	BATT 7 2 CYCLES 2.7, 2.8 YRS
* TURN ON ANOMALY	BATT 8 1 CYCLE 2.7 YRS

Figure 28