

# **FAST Spacecraft Battery Design and Performance**

**by  
David S. Jung  
Gopalakrishna Rao  
Anisa Ahmad**

**NASA/Goddard Space Flight Center  
Greenbelt, Maryland 20771**

## **Abstract**

The Fast Auroral Snapshot (FAST) Explorer spacecraft is to study the physical processes that produce the aurora borealis and aurora australis. It is a unique plasma physics experiment that will take fundamental measurements of the magnetic and electrical fields. This investigation will add significantly to our understanding of the near-earth space environments and its effects. The FAST has a 1 year requirement and 3-year goal for its mission life in low earth orbit. The FAST power system topology is a Direct Energy Transfer (DET) system based on the SAMPEX design. The FAST flight battery supplies power to the satellite during pre-launch operations, the launch phase, the eclipse periods for all mission phases, and when the load requirements exceed solar array for all mission phases. The nominal orbital average load is about 50 watts. The FAST battery, 9 Ah Super nickel-cadmium (SNIcD), was designed by Hughes Aircraft Company (HAC) in Torrance, California. The cells were manufactured by Eagle Picher Industries (EPI) in Colorado Springs, Colorado. The battery assembly contains twenty-two series-connected prismatic hermetically sealed cells with dual ceramic seals. The battery weighs 11.3 Kg. The size of battery is 12.70 in x 7.26 in x 4.95 in. The cell and battery designs are presented together with the ATP data, life cycle test results, I&T operations, and in flight performance data.

## **OUTLINE**

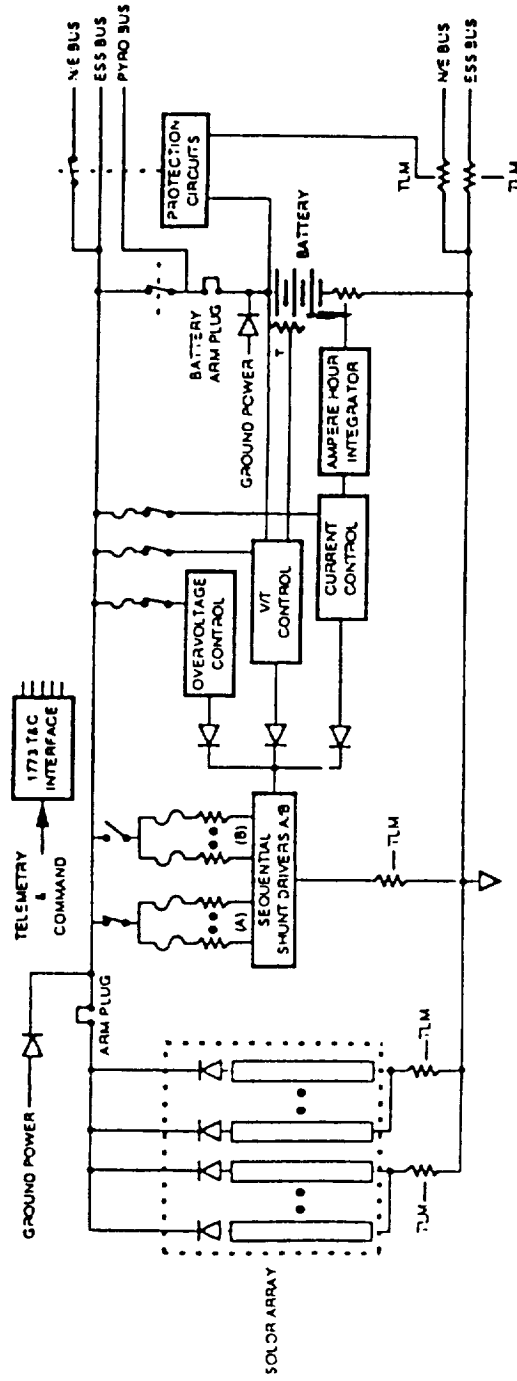
- **MISSION OVERVIEW**
- **POWER SUBSYSTEM ELECTRONICS**
- **BATTERY DESIGN**
- **CELL DESIGN**
- **CELL ATP DATA SUMMARY**
- **LIFE CYCLE TEST DATA**
- **BATTERY BACKGROUND**
- **DPA SUMMARY AND RESULTS**
- **HANDLING AND STORAGE**
- **IN-FLIGHT PERFORMANCE**
- **SUMMARY**

## **FAST MISSION OVERVIEW**

- **The second of the small-class explorer (SMEX) missions**
- **Investigate plasma physics of the auroral phenomena which occurs around both poles of the earth**
- **S/C will orbit in a near-polar, highly elliptical orbit**
- **One year mission duration**
- **Launched in August 1996**

# POWER SUBSYSTEM ELECTRONICS

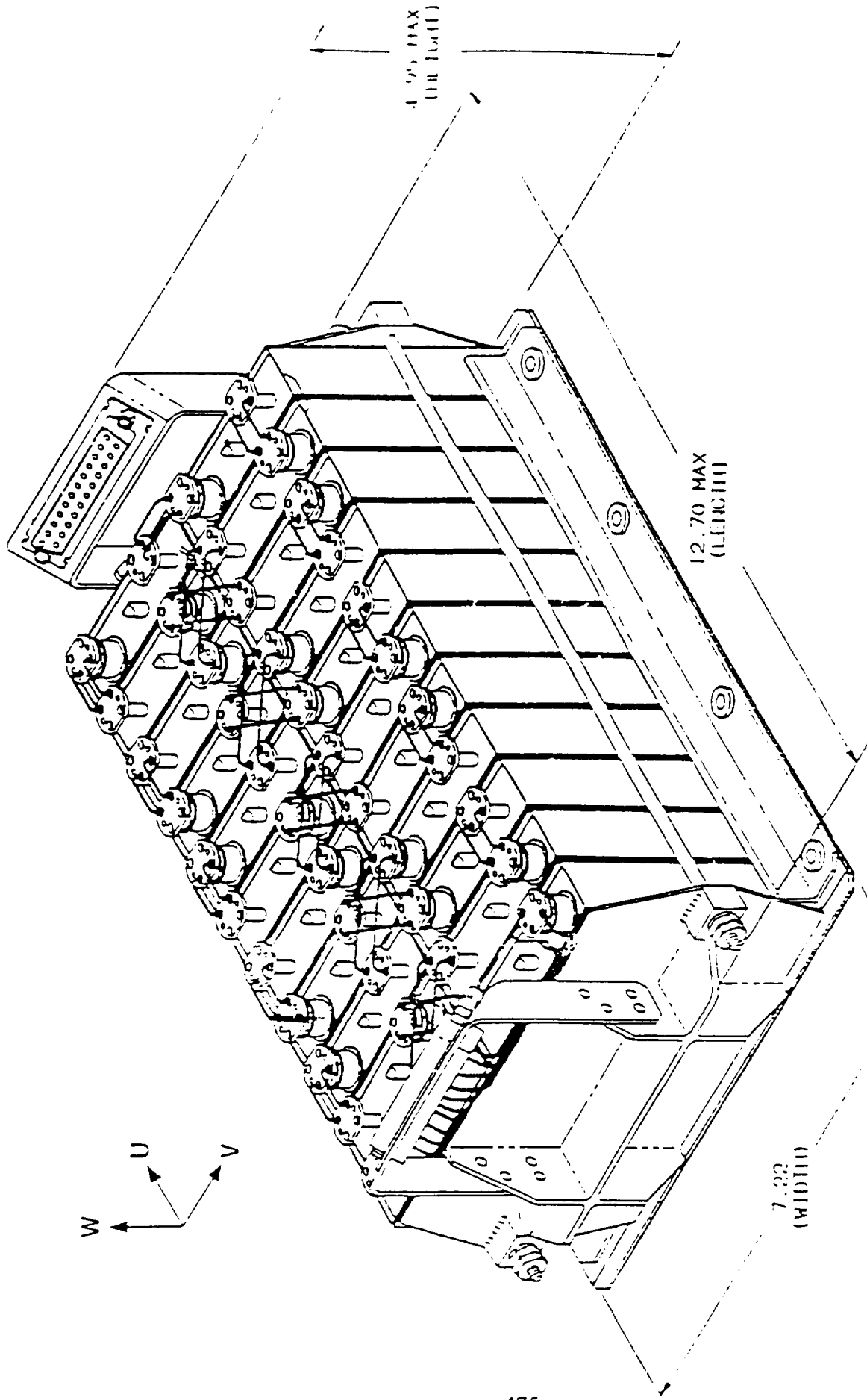
- VT Controller
- Number of VT levels changed from 8 to 16
- Amp hour Integrator included as a key part of charge control



Small Explorer Power System Block Diagram

## **BATTERY DESIGN**

- **9AH Super NiCd (S/N 002)**
- **22 cells connected in series using crossed intercell connections**
- **22 - 34 Volt**
- **Dimension: 18.3 x 32.3 x 12.6 Cm**
- **Mass: 10.96 Kg**
- **Operate in a 0 to 25 deg. C (Baseplate)**
- **The SAMPEX Battery connectors re-oriented to meet FAST mechanical footprint**
  - **Minimum of harness re-routing**
  - **No re-wiring**
- **Capability to monitor battery & cell voltages and battery temperature**
- **Capability for external charging, reconditioning, and cooling of battery**



**9 Amp-Hour FAST Battery Configuration**

## **CELL DESIGN**

- **11.5 AH Capacity at 10 deg. C**
- **Specific energy at 10 deg. C: 31Wh/Kg**
- **Sinter void volume for both neg. and pos. electrodes: 80%**
- **11 positive, 12 negative electrochemically impregnated plates**
- **Zircar separator**
- **31% KOH electrolyte concentration**
- **35 to 40% precharge ratio**



## CELL ATP DATA SUMMARY

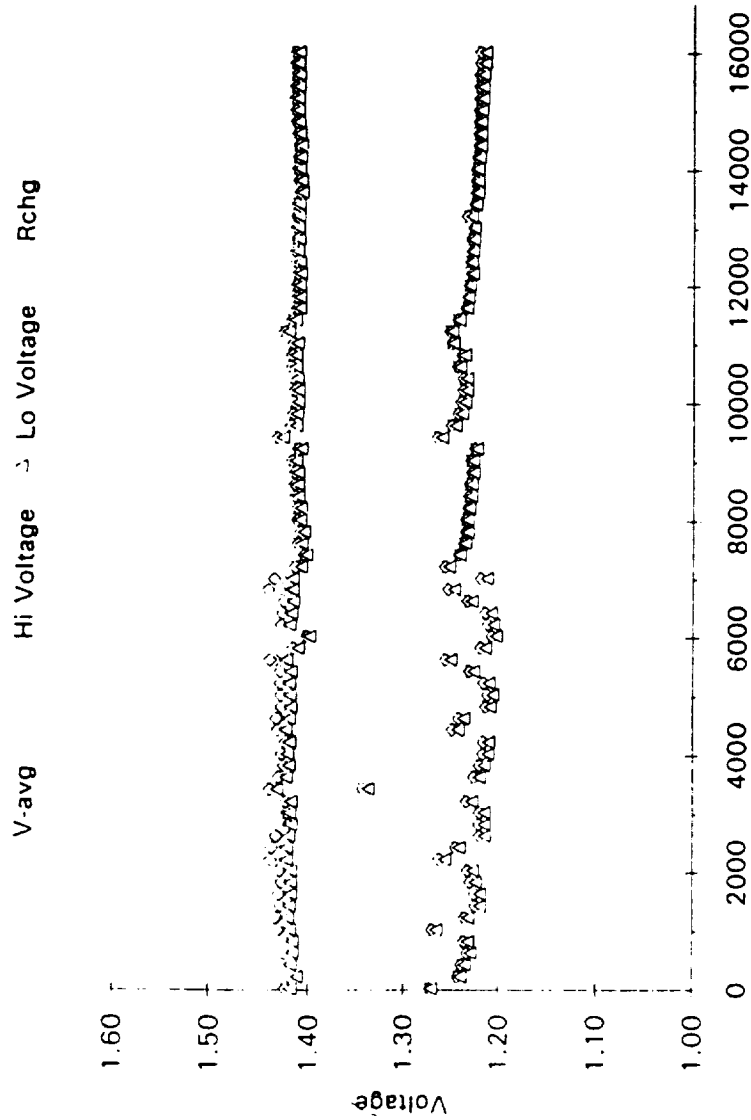
### Flight Battery (S/N 002)

<u>Cell S/N</u>	<u>Capacity Ah</u>	<u>Cell S/N</u>	<u>Capacity Ah</u>
13	12.07	16	12.17
22	12.03	23	12.03
26	12.03	28	12.06
29	12.07	36	12.04
39	12.06	48	12.03
64	12.06	66	12.05
71	12.07	73	12.14
74	12.08	75	12.10
81	12.05	83	12.03
84	12.04	85	12.04
88	12.04	89	12.06

Avg. = 12.06  
Avg. Cell Wt. = 442 grams  
Total Cell Wt. = 21.44 LB

# LIFE CYCLE TEST DATA

Voltage/Pressure/Recharge EOC /EOD Trend Plot      08/31/92 - 10/30/96  
SAMPEX Mfg.. HUGHES Temp(C): 5 DOD(%): Varied MISSION ORBIT



**Nominal SAMPEX mission profile (7137 cycles) and nominal FAST mission profile (>9000 cycles at 12% DoD and 5 deg. C) for the FAST flight battery cell pack**

## **BATTERY BACKGROUND**

- **9 Ampere-Hour Super NiCd developed as flight Battery for SAMPEX**
- **Cells activated in May 1991**
- **Received from Hughes in January 1992**
- **Shipped to Hughes for rework (bent base plate) and retest in January 1992**
- **Hughes shipped battery back to GSFC in June 1993**
- **Performed magnetic testing in September 1993**
- **DPA one cell (LOT 1, S/N79) to extend the wet life after 3 years of storage in April, 1994**
- **Mechanical and electrical integration to spacecraft were performed in May 1994**
- **Performed thermal vac test in June 1994**
- **Battery moved to mag. test site for mag. testing in June 1994**
- **Spacecraft packed for shipment to Wallops for spin balance in July 1994**
- **Launch scrubbed due to Pegasus failure on August 1994**
- **Removed battery from S/C for storage in battery lab in September 1994**

## **BATTERY BACKGROUND (CON'T)**

- **DPA another cell (LOT 1, S/N108) to extend the wet life after 4 years of storage in Mar., 1995**
- **Integrated battery to S/C in April 1995**
- **Performed T/U and S/C functional test in April 1995**
- **Moved battery to Battery Lab due to another Pegasus failure in August 1995**
- **Battery has been topped-off every 3 or 4 days intervals at Battery Lab**
- **Started re-integration activities in March in preparation for August, 1996**
- **DPA another cell (LOT 1, S/N 86) to extend the wet life after 5 years of storage in April, 1996**
- **Flight battery was re-integrated to S/C on April 20, 1996**

## **DPA SUMMARY AND RESULTS**

- **DPA was performed on Lot 1 S/N 86 in April 1996**
- **The cell was removed after 5 years of open circuit and trickle charge storage to evaluate it for flight worthiness**
- **Nominal capacity (>10 Ah)**
- **Slightly lower charge and discharge voltages were observed when compared to a previous FASTcell from 3.5 years of trickle charge storage**
- **The same amount of electrolyte was observed for both cells (4.20 cc/Ah)**
- **The separators looked well wetted and the cell experienced minimal cadmium migration as evident in the separators**

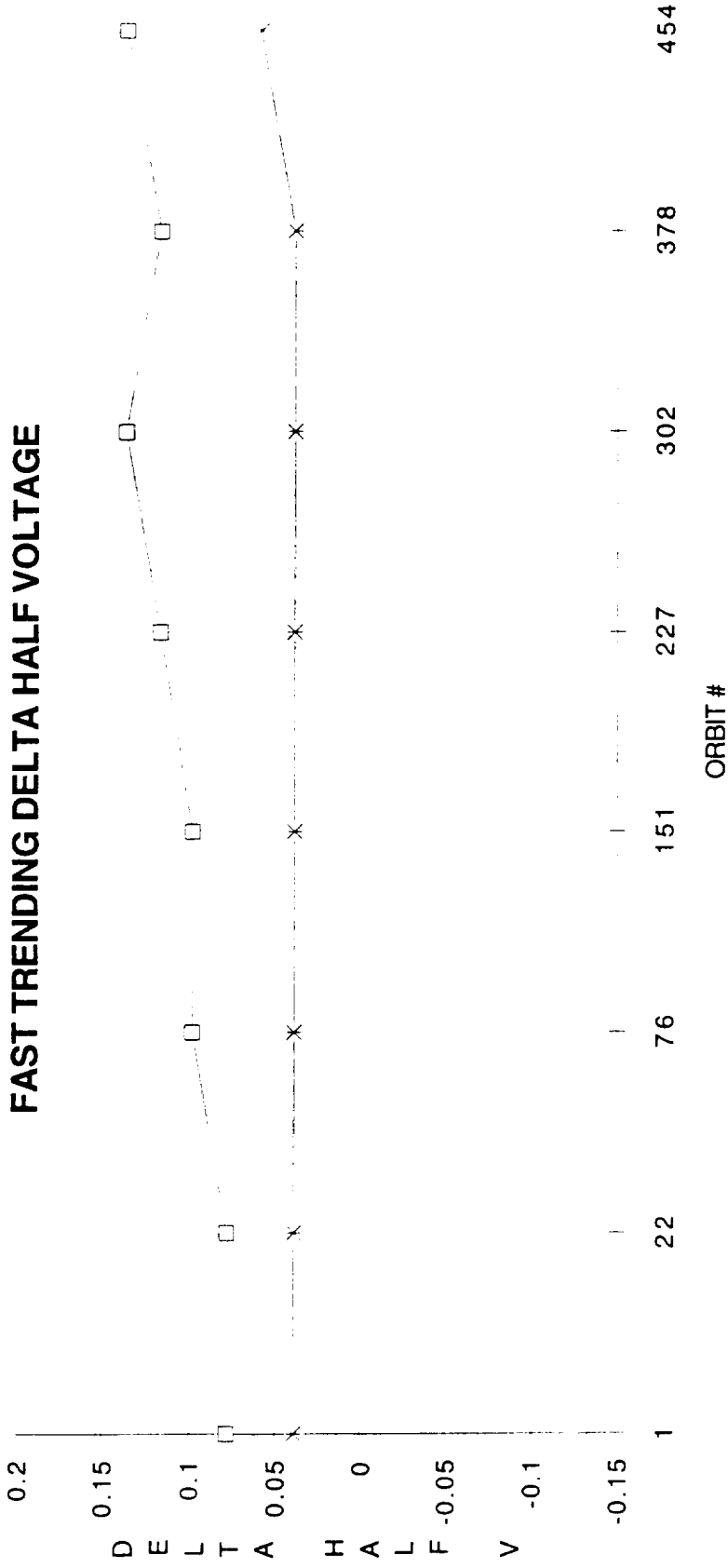
## **HANDLING AND STORAGE**

- **Maintained charged open circuit condition with a periodic top-off charge or trickle charged continually**
- **Battery was stored on trickle charge mode (C/100, 6 deg. C) at Battery Lab after receiving it from the vendor in Jan. 92**
- **Performed top-off charge (C/20, 0.45A, 15 deg.C, 140 min or rollover + 30 min) after 5 min. discharge at 1 Amp. every 3 or 4 days at Battery Lab when not on trickle charge**
- **At the launch site, performed top-off charge and battery was trickle charged continuously after the final reconditioning before launch; Battery temperature was maintained at ~18 deg. C**

## **IN-FLIGHT PERFORMANCE**

- **Changed VT level from 5 to 4 to achieve c/d ratio at ~110%**
- **Battery temperature has been stabilized and is running around 5 deg. C**
- **The following trend plots summarize in-flight performance since the launch:**
  - 1. Trending delta half voltage**
  - 2. Battery voltage**
  - 3. Battery discharge volt and minimum state of charge**
  - 4. Volt and temp trending**
  - 5. Max discharge current**
  - 6. Max charge current**
  - 7. Total c/d ratio**
  - 8. C/D ratio and eclipse duration**

CHART FAST DELTA



*	DELTA HLF V MIN	()	DELTA HLF V MAX
---	-----------------	----	-----------------



Chart FAST BAT V

### BATTERY VOLTAGE FOR FAST

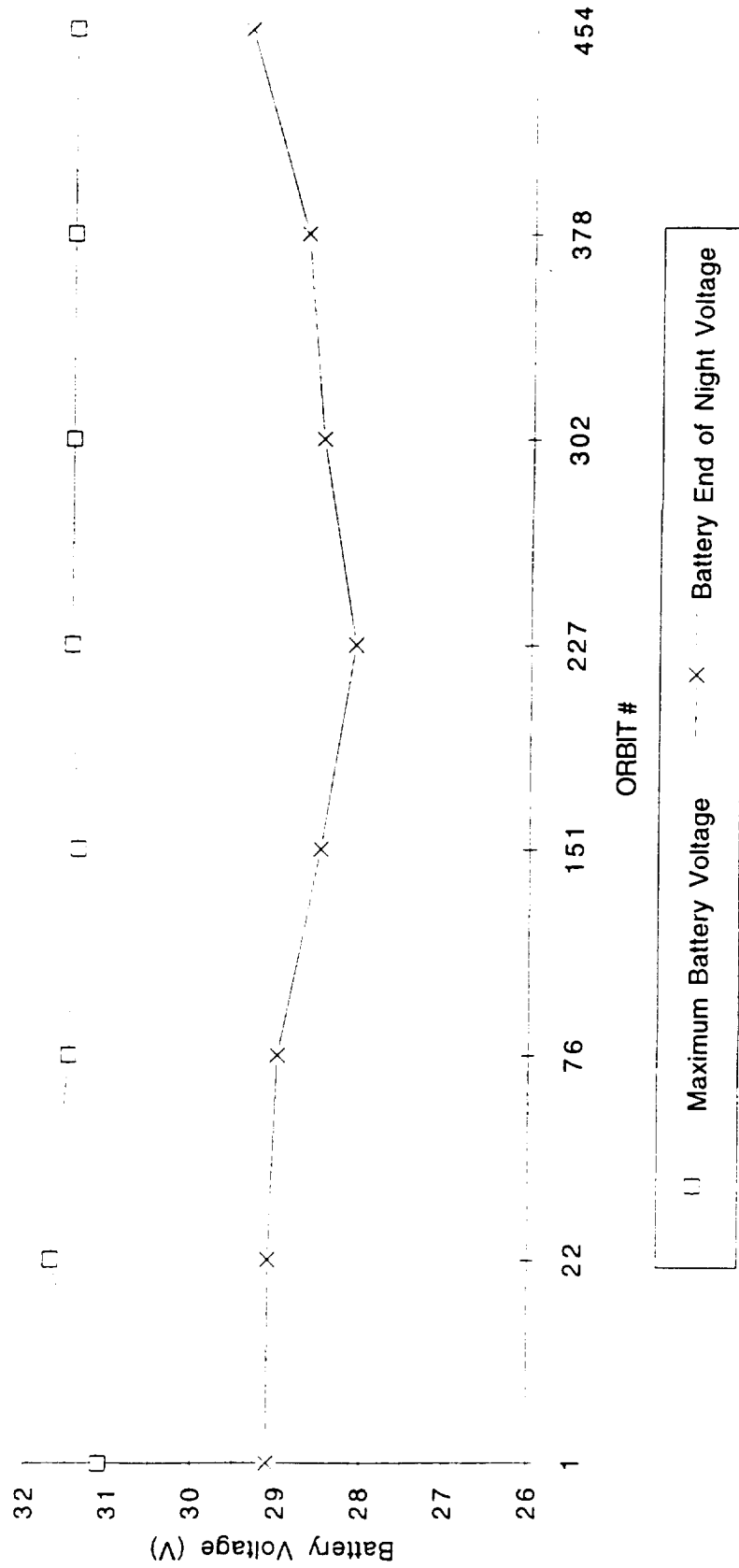
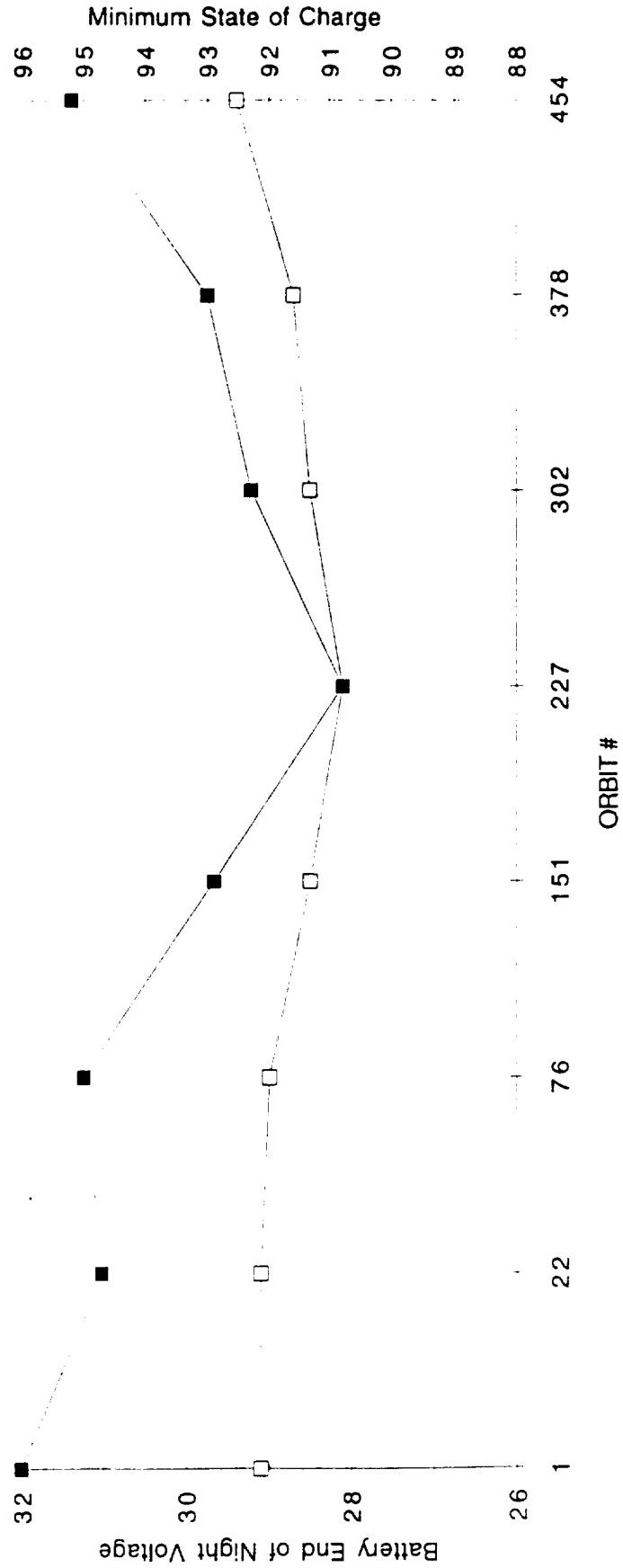


Chart FAST BAT V & SOC

FAST BATTERY DISCHARGE VOLTAGE AND MINIMUM STATE OF CHARGE



( ) Battery End of Night Voltage    ■ Minimum State of Charge

**BATTERY VOLTAGE AND TEMPERATURE TRENDING FOR FAST**

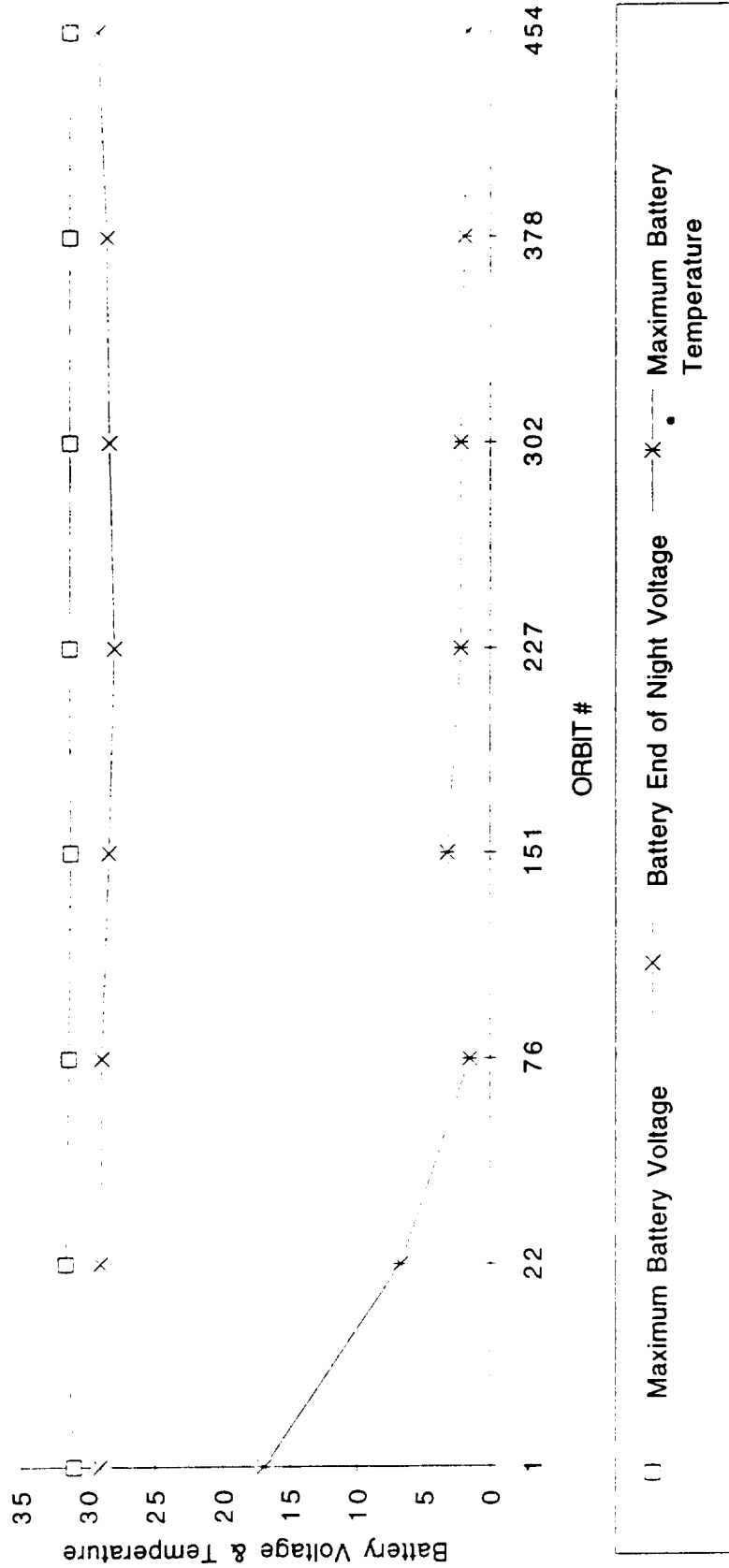


Chart FAST BAT DIS I

**MAXIMUM BATTERY DISCHARGE CURRENT FOR FAST**

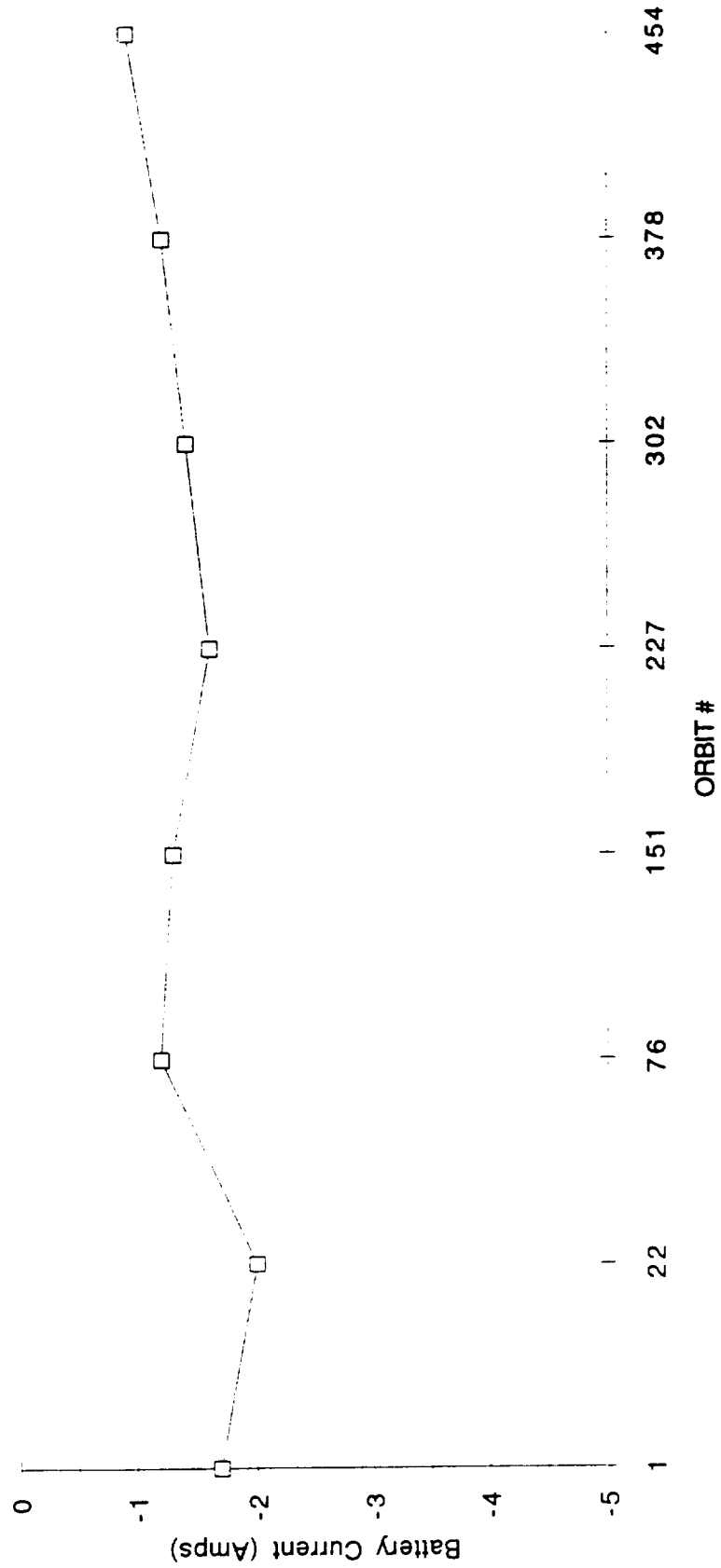


Chart FAST BAT I

MAXIMUM BATTERY CHARGE CURRENT FOR FAST

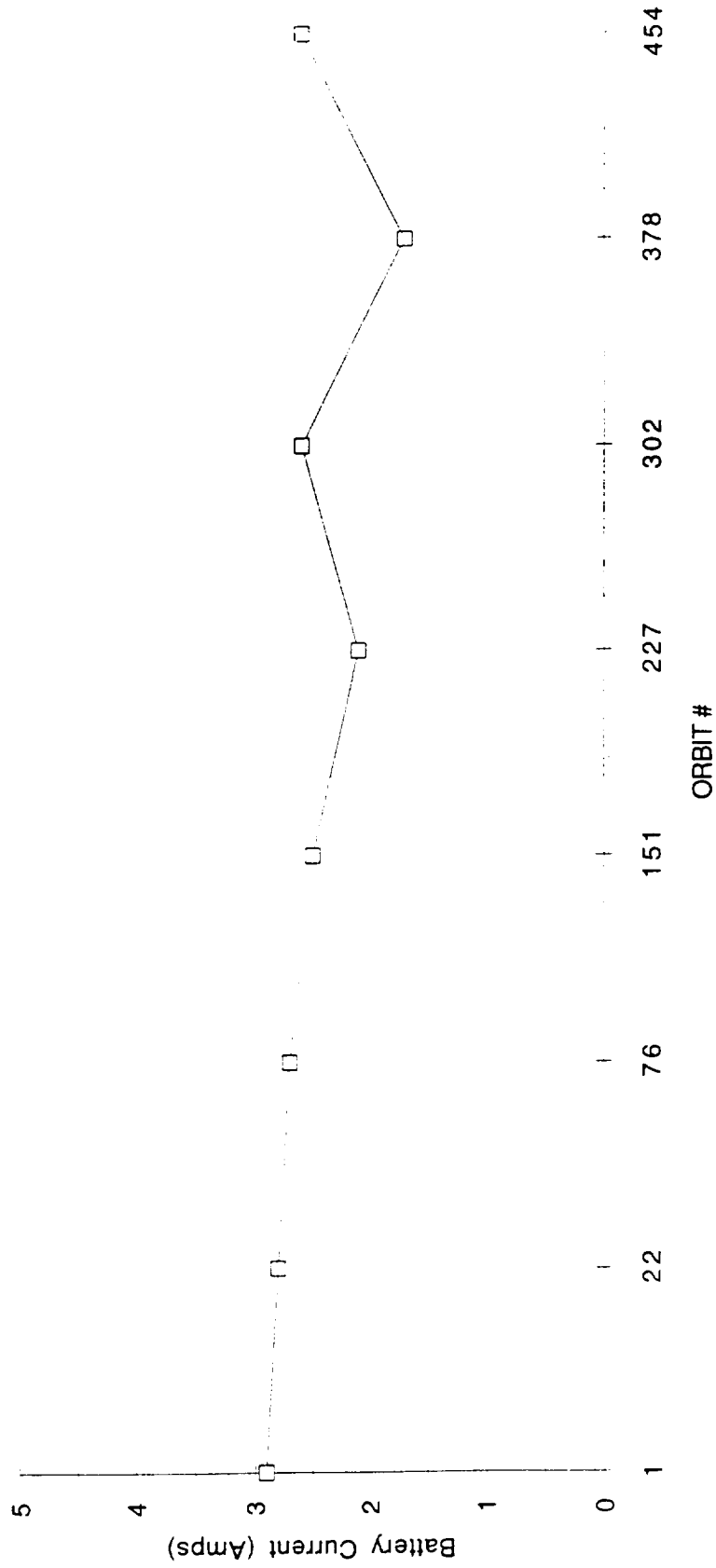


CHART FAST C/D RATIO

TOTAL CHARGE/DISCHARGE (C/D) RATIO FOR FAST

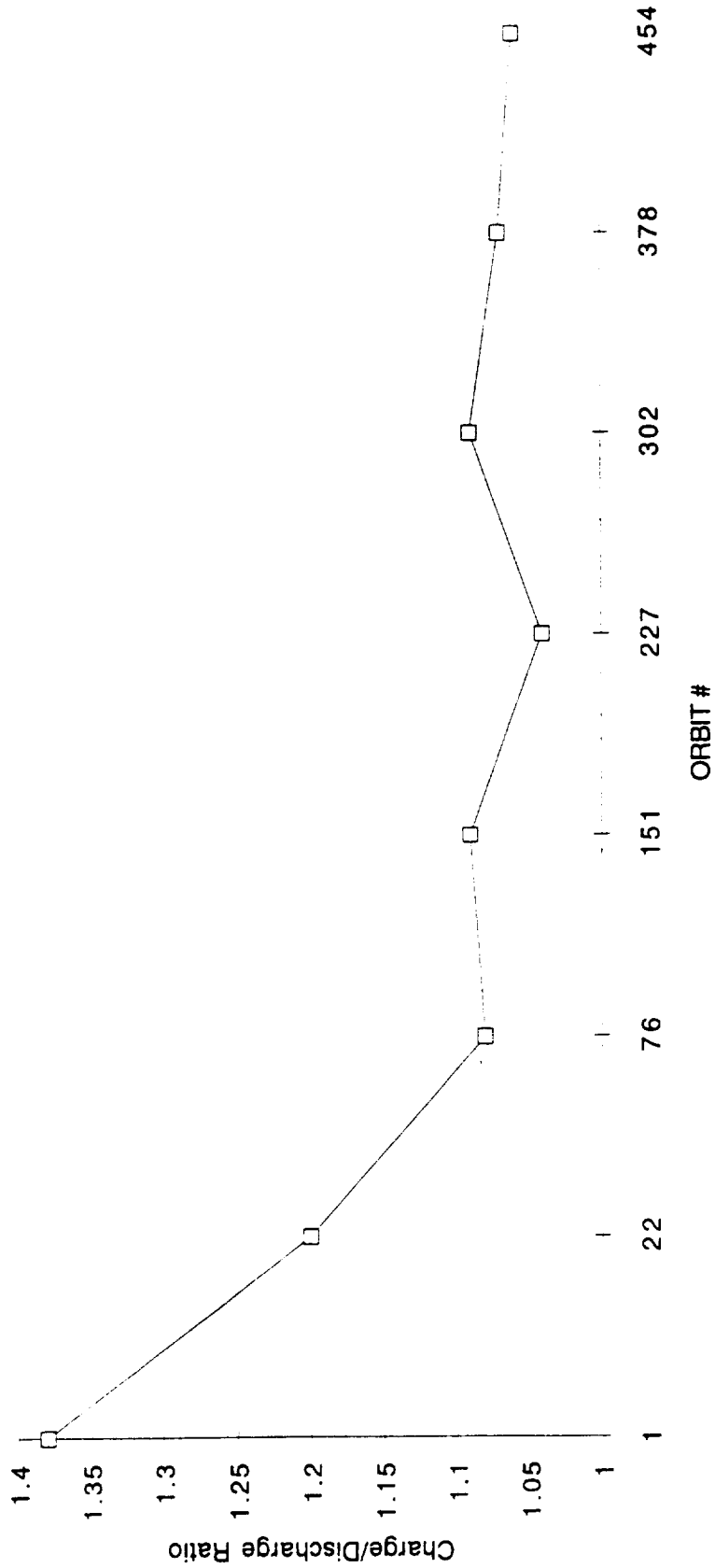
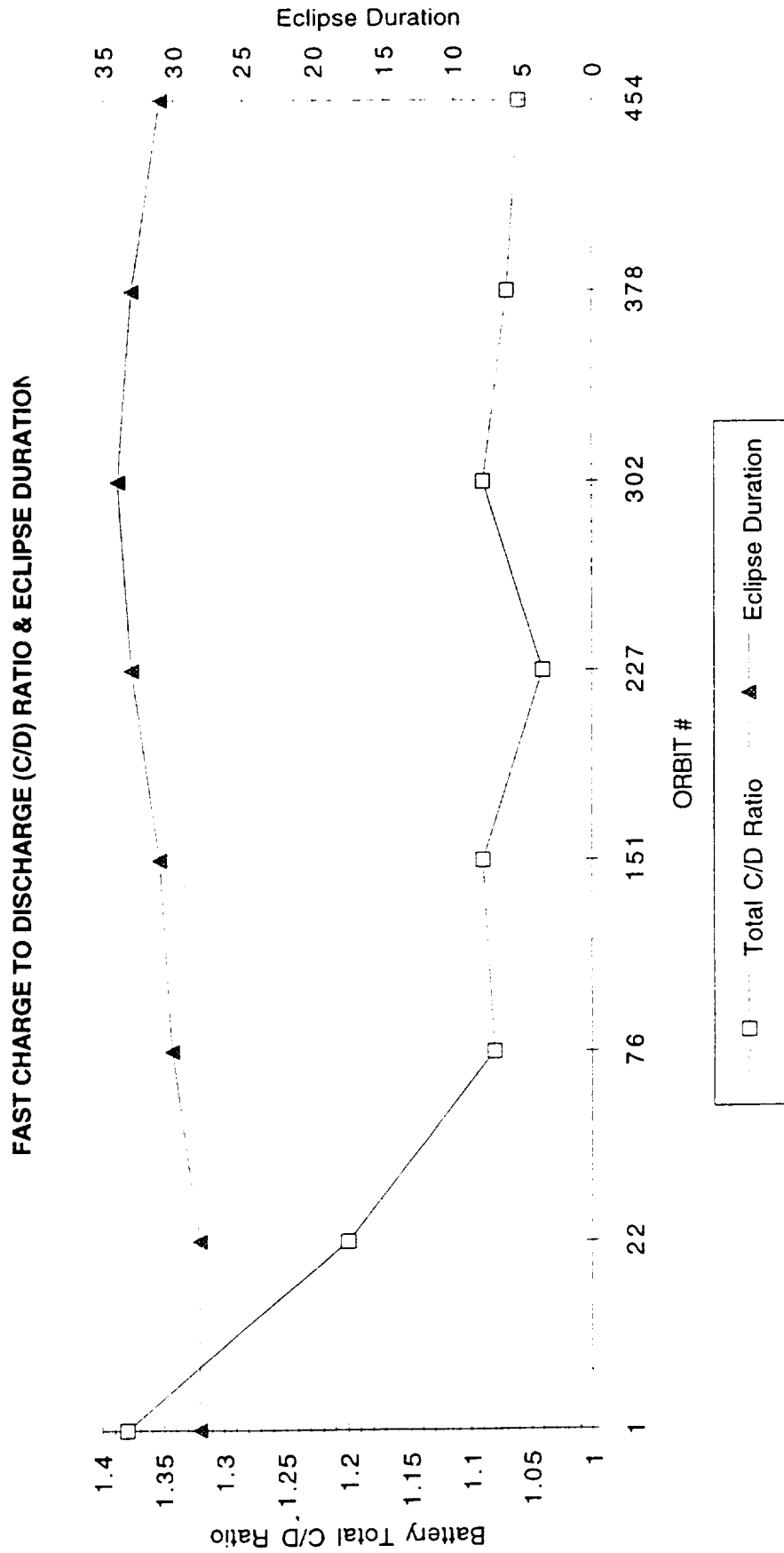


Chart FAST C/D & Eclipse



## **SUMMARY**

- **FAST S/C with 9 Ah SNIcd was launched in August 1996**
- **This was the fourth SNIcd mission in LEO application**
- **The cells were activated for 63 months prior to launch and maintained on trickle charged at 5 deg. C whenever possible**
- **The flight data indicates that the FAST S/C is performing nominally since Aug '96 launch**