Power Team
Mission Day Instructions

Overview

Every 90 minutes the space station orbits the earth, passing into and out of the sun's direct light. The solar arrays and batteries work together to provide constant power to life support equipment and invaluable scientific experiments. The PV arrays convert solar energy into electricity for about 60 minutes of every orbit. They also recharge the nickel-hydrogen batteries. While in the earth's shadow for the remaining 30 minutes of the orbit, the batteries use about 35% of their available power. Any interruption in the charging process could leave the station without enough electricity during this "eclipse" period. The Power Systems Calculator allows the Power Team to monitor and experiment with the distribution of electricity throughout the space station.

As a member of the Power Team, you will be responsible for monitoring the power of the space station, determine the power load on the systems, and make recommendations to Mission Control. Battery power levels necessary for life support should not fall below 50% capacity while the station is in the earth's shadow.

Your Task

- Learn to analyze real-time data , record and graph it, and make calculations.
- Monitor all power fluctuations, report the effects that they may have on station operations, and recommend adjustments to avoid a dangerous situation
- Review the information you studied during specialist training. Study your notes on electricity, battery power, solar cells, and PV arrays. (see http://clc.wju.edu/ssa)
- Familiarize yourself with the station's power systems, the Power System Calculator, and the way in which power is allocated on the space station.

To do its job effectively, the Power Team should be able to:

1. Identify the primary and secondary source of power on the station.
2. Calculate the percentage of the power designated for the environmental control & life support systems, the thermal control system, communication & tracking, and the electrical power system.
3. Relate the production of electrical energy to the orbit of the space station.

Mission Day Materials

On mission day, it will be critical to be prepared to assist the Space Station crew if it becomes necessary. To do this effectively your team will need the following:

- 2 computers: One to receive real-time data from the Space Station and the other to load the Power Systems Calculator. If necessary, both the data and the Calculator may be loaded on only one computer instead, but this is not ideal.
- One or more copies of the Space Station Reference guide (see http://clc.wju.edu/ssa/ssrefguide.htm)
- Mission Day Materials packet (one per team member):
    - Mission Day Instructions
    - Power Team Data Tracking Tables
    - Power Team Data Graphs

- 15 Blank Report Forms (see Mission Day Materials packet) on colored paper to deliver to the Communications Team
- Calculators for each team member
- Rulers for plotting data on graphs
- Ballpoint pens or pencils of various colors (optional)

Job Assignments
The following tasks must be completed during the mission. Next to each task, assign a team member.

Team Member(s) Assigned To This Task	Task
_____	**Data Recording**: Monitors real-time data for new readings and bulletins from mission control. The URL for the real-time data will be given by Mission Control at the start of the mission. This may be combined with other tasks.
_____	**Data Analysis (Battery Reserve)**: Records real-time data in data tracking tables. Conducts analyses using data tracking worksheet. Completes Report Forms every five to six minutes or as needed.
_____	**Data Analysis (Solar Array)**: Records real-time data in data tracking tables. Conducts analyses using data tracking worksheet. Completes Report Forms every five to six minutes or as needed.
_____	**Managing the Power Systems Calculator**: Makes adjustments and communicate with all team members regarding all power assignments and reallocation. This may be assigned to two team members.
_____	**Data Graphing**: Records real time data and projections on graphs. Uses ruler to make predictions. This may be combined with Data Analysis tasks.
_____	**Crisis Management**: Makes sure all data is analyzed every five to six minutes. Determines priority level, whether there are any concerns, and helps team decide on any recommendations. Takes this information to the Crisis Management Team for further discussion.
_____	**Data Runner**: Gathers report forms every five to six minutes. Prioritizes any urgent recommendations. May be combined with Crisis Management Tasks.
_____	**Research and Reference**: Assists team in finding necessary information to make recommendations to Mission Control. Reads and understands information provided in the Reference Guide. May be combined with other tasks above.
_____	**Reporter**: Assists team in recording the situation as the mission progresses. Tracks emergencies, options, choices, successes, and areas for improvement.

Power Team— Data Tracking Instructions

You will be receiving readings every five to six minutes from the Power Systems Status Monitor (PSSM). The data will have information on the reserve battery capacity and solar array efficiency. It is imperative that your team is familiar with the data and that you are able to analyze it quickly and efficiently.

Please note: Total Battery Capacity: The space station is constantly undergoing construction. On any given day, the battery capacity is dependent on the number of solar arrays connected to the main frame. The value on February 14, 2001, is 24.50 kilowatts.

Critical Battery Capacity: The station will be in a critical stage if power levels drop below 50% of the total battery capacity. This number is 50% of the Total Battery Capacity, or 12.25 KW.

Using the instructions below and the attached spreadsheet, you should be able to conduct all the necessary calculations. Round all decimals to **2 decimal places**.

Battery Reserve Data Tracking Instructions

First, find the spreadsheet labeled "Battery Reserve Data Tracking Table"

Column A: Coordinated Universal Time (UTC)
The time will be included in the data from the PSSM. Record the time in UTC units in Column A.

Time is given in Coordinated Universal Time (UTC), a universal standard. To eliminate any errors, we use a 24-hour clock with no "am" or "pm". On a 24-hour clock, 00:00 or 24:00 is midnight and 12:00 is noon. One o'clock in the morning is 01:00. Four-twenty in the afternoon is 16:20, etc.

Column B: Reserve Battery Data
Record the real-time data in the Reserve Battery column. This is how much battery power you have in reserve, given as a percentage of the total battery capacity.

Column C: Reserve Battery Capacity in Kilowatts
To calculate the Reserve Battery capacity in kilowatts, use the number you recorded in Column B, divide it by 100, then multiply this new number by the total battery capacity (24.50 KW).

For example: Your battery has a reserve of 65%. Divide 65 by 100, and then multiply it by the total battery capacity (24.50 KW) = 15.93 KW.

Column D: Change
To calculate the Change in the Reserve Battery Capacity, use the number that you recorded in Column C and subtract the previous reading from Column C.

Column D = Current reading from Column C minus the Previous reading from Column C.

Column E: Rate of Change
To determine how fast things are changing, you will need to find the rate of change. To do this, you need to take the current reading from Column D and divide this answer by the amount of time that has elapsed between the two readings. This gives a rate of change in kilowatts. Record this number in Column E.

Column E = $\frac{\text{Column D}}{\text{Time elapsed (20 min)}}$

Column F: Time to Criticality

In this column, you must record the time to criticality. In order to find this number, take the critical value (12.25) and subtract from it the current reading from Column C. Divide this answer by the rate of change you calculated in Column E. Now take the absolute value of the result. This is the amount of time the station has before power is at dangerous levels.

Note: If the Battery Reserve is above 12.25 and the Rate of Change is positive, then Time to Criticality does not apply. Also, if the Battery Reserve is below 12.25 and the Rate of Change is negative, then Time to Criticality does not apply.

Column F = (Abs Value of) $\frac{\text{Column C} - 12.25}{\text{Column E}}$

Note, this equation comes to us from the general equation for the slope of a line: $y = mx + b$
If we convert this equation to solve for x, we get this $x = \frac{y - b}{m}$

Solar Array Data Tracking Instructions

Find the spreadsheet labeled Power Team - Solar Array Data Tracking Table

Column A: Coordinated Universal Time (UTC)

The time will be included in the data from the PSSM. Record the time in Column A for every entry.

Time is given in Coordinated Universal Time (UTC), a universal standard. To eliminate any errors, we use a 24-hour clock with no "am" or "pm". On a 24-hour clock, 00:00 or 24:00 is midnight and 12:00 is noon. One o'clock in the morning is 01:00. Four-twenty in the afternoon is 16:20, etc.

Column B: Solar Array Efficiency Data

Record the real-time data in the Solar Array Efficiency column. As the station's solar arrays (photovoltaic cells) are bombarded with solar radiation, they will produce at less than 100% efficiency.

NOTE: If the array efficiency drops quickly, check first to see if the station is in the Earth's shadow.

Column C: Power Generation

To calculate how many kilowatts per hour are currently being generated by the solar arrays, start with the number you recorded in Column D, divide it by 100, and multiply it by the total battery capacity value at the top of the sheet.

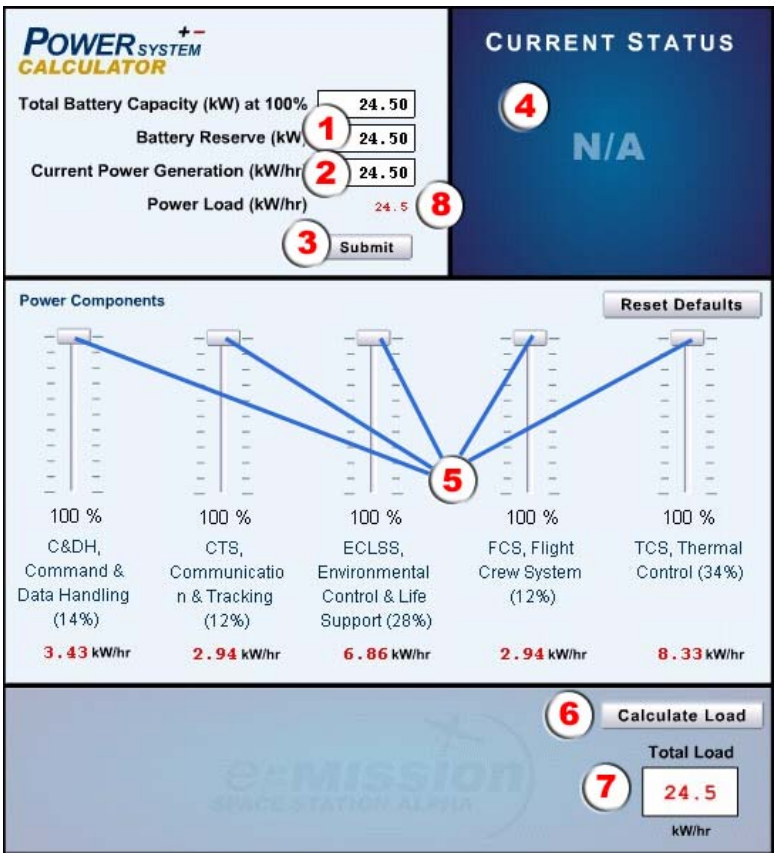
For example: Your solar arrays are 95% efficient. Divide 95 by 100, and then multiply it by the battery capacity start value (24.50 for instance) = 23.28 KW/hr.

Column D: Current Power Load

This column shows the power load in kilowatts/hour that the ISS is currently using. Calculate this number using the Power Systems Calculator. YOU CANNOT WRITE ANYTHING HERE WITHOUT USING THE CALCULATOR FIRST.

See Power Systems Calculator Below

Power System Calculator Instructions



Note: The Power Systems Calculator may be found online. A link may be found on the Space Station Alpha website under “Pre-Mission Preparation”—Power Team.

Before beginning, make sure that all slider bars are at 100%. Click on "Reset Defaults" to set all slider bars at 100%.

1. Enter the most recent Battery Reserve (kW) data from Column C of the Battery Reserve Data Tracking Table into the calculator.
2. Enter the most recent Power Generation (kW/hr) data from Column C of the Solar Array Data Tracking Table into the calculator.
3. Press "Submit".
4. Once data is submitted into the system, you will see an indication of whether the system is “charging” or “draining.”
5. Slide the bar for each Power Component to adjust the amount of power being used by that segment. A digital readout of the amount of power being consumed by each component appears underneath the sliders. Put your mouse over the title of each component to view a description.
6. Press “Calculate Load”.
7. Your Total Load (kW/hr) will appear in a box above the “Calculate Load” button. Write this number in Column D.
8. Note that this number also appears at the top -- next to “Power Load (kW/hr)”.

Column E: Rate of Charging or Draining
To calculate the "Rate of Charging and Draining", subtract Column D (Power Load) from Column C (Power Generation).

Note: If the solar arrays are creating MORE power than the station is using (the load from Column G) then it is producing power (**charging**). If the solar arrays are creating LESS power than the station is using (the load from Column G) then it is consuming power (**draining**). Remember that power drain should be shown by a negative number.

For example:

Power generation in kW/hr (23.27) - Power Load in kW/hr (24.50) = -1.23 kW/hr. This is a negative number and indicates a state of draining.

Column G: New Time to Criticality
The station will be in a critical stage if power levels drop below 50% of the total battery capacity. Take the number from Column C on the **Battery Reserve** Data Tracking Table and subtract the critical battery capacity value of 12.25 kW. Take the resulting number and divide by the Rate of Charging or Draining from Column E on the Solar Array Data Tracking Table. Finally, take the absolute value of the resulting number.

Note: If the Battery Reserve is above 12.25 and the Rate of Change is positive, then Time to Criticality does not apply. Also if the Battery Reserve is below 12.25 and the Rate of Change is negative then Time to Criticality does not apply. To understand this idea, plot the original data from Column B on a graph, and examine the slope of the line. When the slope is in the direction of the critical value, then Time to Criticality applies.

$$G = \frac{\text{(Abs Value of) Col C from } \textbf{Battery Reserve (kW)} - 12.25 \text{ (kW)}}{\text{Column E (kW/hr)}}$$

Note, this equation comes to us from the general equation for the slope of a line: $y = mx + b$
If we convert this equation to solve for x, we get this $x = \frac{y - b}{m}$

Instructions for Graphing the Data

You will be creating two graphs.

- Battery Reserve Power in kW as a Function of Time

Use the data from Column C from the Battery Reserve Data Tracking Table for the y-axis values and plot them along the x-axis according to the correct UTC time. The scale for the y-axis values is 0 to 30 kW.

Next, draw a heavy line across from left to right at 12.25 kW to represent the "danger zone" and label it.

- Power Load as a Function of Time

Use the data from Column D from the Solar Array Data Tracking Table for the y-axis and plot along the x-axis according to the correct UTC time. The scale for the y-axis is 0 to 30 kW.

Power Team - Battery Reserve Data Tracking Table

Column	A	B	C*	D	E	F
Table Headings	UTC	Reserve Battery Capacity	Battery Reserve	Change	Rate of Change	Time to Criticality***
Units	24 Hour Clock	%	Kilowatts	Kilowatts	Kilowatts/ Min	Minutes
Calculations	From Data	From Data	C= B/100 X 24.50**	D= C -previous C	E= D/20 (min)	F= (Abs Value of) (C- 12.25****)/E
Example	19:00	83	20.34	2.94	0.15	53.93 (N/A)
	15:00			n/a	n/a	n/a
	15:20					
	15:40					
	16:00					
	16:20					
	16:40					
	17:00					
	17:20					
	17:40					
	18:00					
	18:20					
	18:40					
	19:00					
	19:20					
	19:40					

Note that this value may be used in the Power Systems Calculator

* Graph this column.

** Total Battery Capacity – On any given day, the battery capacity is dependent on the number of solar arrays connected to the main frame. The value on February 14, 2001 is 24.50 kilowatts.

*** Remember, if the Battery Reserve is above 12.25 and the Rate of Change is positive, then Time to Crit does not apply. Also if the Battery Reserve is below 12.25 and the Rate of Change is negative then Time to Crit does not apply.

**** Critical Battery Capacity – The station will be in a critical stage if power levels drop below 50% of the total battery capacity. The number is 50% of the Battery Capacity Start Value, or 12.25 kilowatts.

Power Team - Solar Array Data Tracking Table

Column	A	B	C	D*	E	F	G
Table Headings	UTC	Solar Array Efficiency	Power Generation	Current Power Load	Rate of Charging or Draining	Charging or Draining	New Time to Criticality***
Units	24 Hour Clock	%	Kilowatts/ Hour	Kilowatts/ Hour	Kilowatts/ Hour		Hours
Calculations	From Data	From Data	C=B/100 X 24.50**	See Power Systems Calculator	E = C-D	Pos # = Charging Neg # =Draining	G= (Abs Value of) Col C from **Battery Reserve** – 12.25**** Column E
Example	19:00	65	15.93	19.00	-3.07	Draining	2.64
	15:00						
	15:20						
	15:40						
	16:00						
	16:20						
	16:40						
	17:00						
	17:20						
	17:40						
	18:00						
	18:20						
	18:40						
	19:00						
	19:20						
	19:40						

Note that this value may be used in the Power Systems Calculator

Note that this value is determined by using the Power Systems Calculator

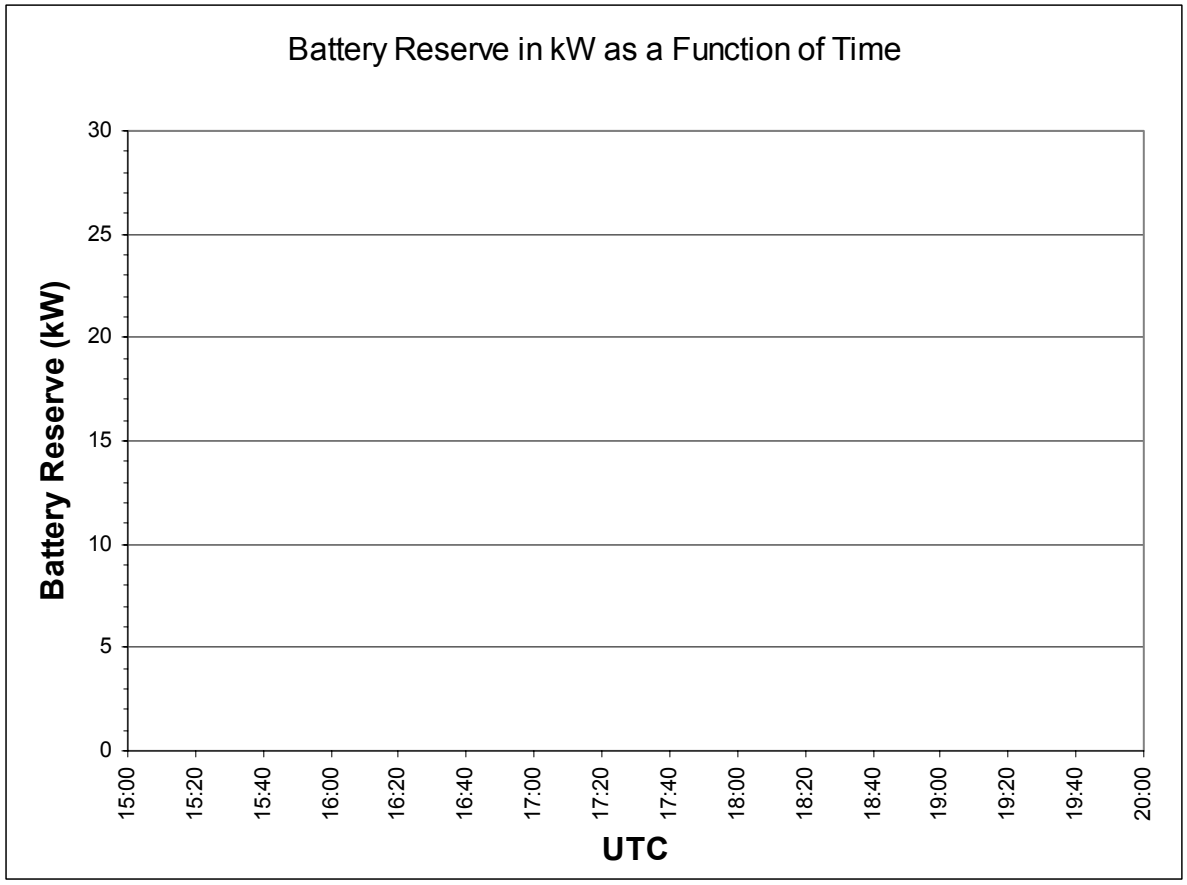
* Graph this column.

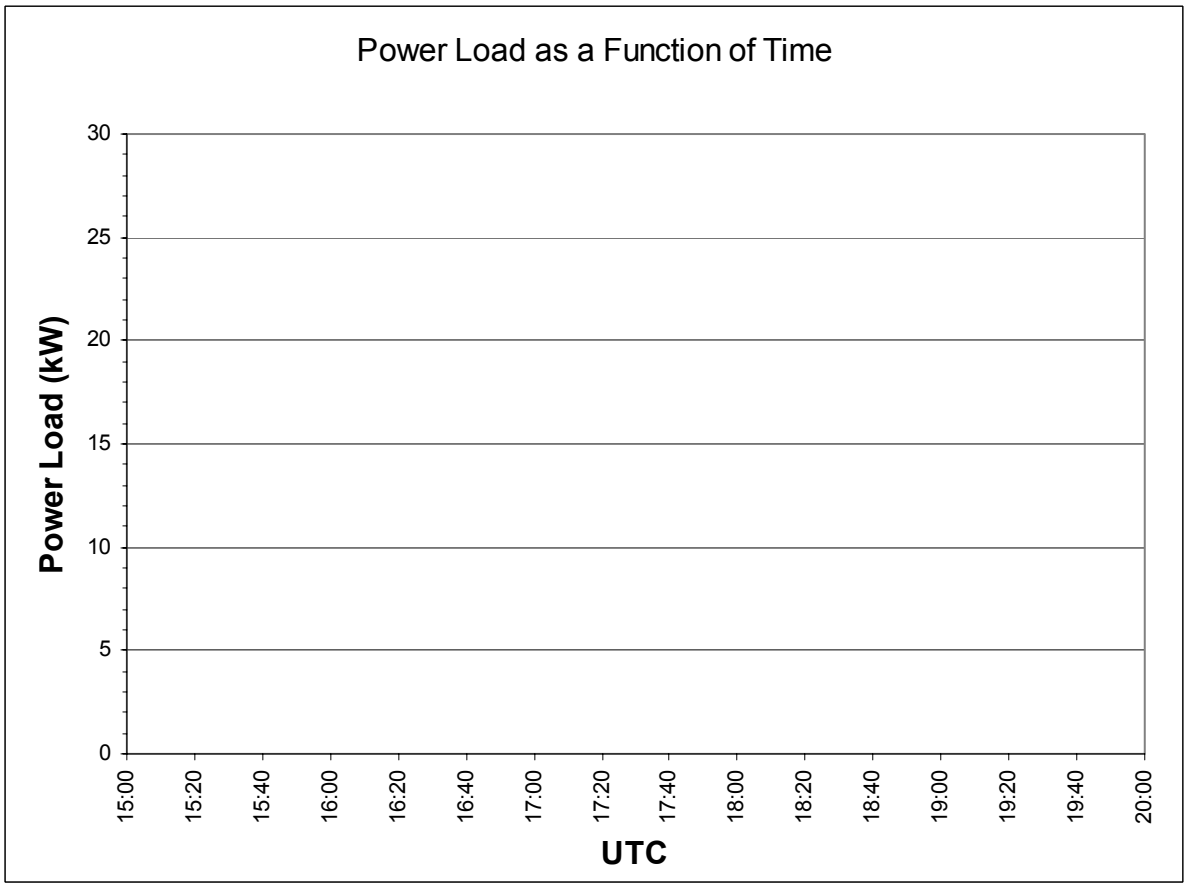
**Total Battery Capacity – On any given day, the battery capacity is dependent on the number of solar arrays connected to the main frame. The value on February 14, 2001 is 24.50 kilowatts.

***If Column F is "Charging" there is no need to find time to criticality. Put "n/a" in the blank. Remember, if the Battery Reserve is above 12.25 and the Rate of Change is positive, then Time to Crit does not apply. Also if the Battery Reserve is below 12.25 and the Rate of Change is negative then Time to Crit does not apply.

**** Critical Battery Capacity – The station will be in a critical stage if power levels drop below 50% of the total battery capacity. The number is 50% of the Battery Capacity Start Value, or 12.25 kilowatts.

Note: Use the Power Systems Calculator to balance the Power Load (Column D) against the Time to Criticality (Column G). As the load goes down, the time to criticality will go up and vice versa. In general, you should try to adjust the Power Load to stay above 15 kilowatts/hour of consumption. Likewise, you should try to keep the new Time to Criticality to above 0.5 hours (and anything above 1.0 hours is unnecessary).


Battery Reserve in kW as a Function of Time
Battery Reserve (kW)
30
25
20
15
10
5
0
15:00
15:20
15:40
16:00
16:20
16:40
17:00
17:20
17:40
18:00
18:20
18:40
19:00
19:20
19:40
20:00
UTC


Power Load as a Function of Time
Power Load (kW)
30
25
20
15
10
5
0
15:00
15:20
15:40
16:00
16:20
16:40
17:00
17:20
17:40
18:00
18:20
18:40
19:00
19:20
19:40
20:00
UTC

Power Team – Practice Data

Data from the Space Station Power Systems
Status Monitor

UTC	Reserve Battery (%)	Solar Array Efficiency (%)
15:00	94	100
15:20	88	99
15:40	78	82
16:00	85	0*
16:20	63	0*
16:40	66	30
17:00	59	18

*Note that during these times, the space station is orbiting in the Earth's shadow and the solar arrays are generating no power. The space station is in the Earth's shadow (also called "eclipse") for one-third of every 90-minute orbit.

Power Team Report Form

Priority Level (circle one): **1** Urgent – Inform Mission Control Immediately **2** Potential Danger—Monitor Closely **3** Maintaining Normal Levels

Please fill in ALL blanks in case Mission Control needs the information.

	A	B	C	D	E	F
Battery Reserve	UTC	**Battery Reserve Capacity (%)**	**Battery Reserve (kilowatts)**	**Change (kilowatts)**	Rate of Change (kilowatts)	**Time to Criticality (minutes)**

	A	B	C	D	E	F	G
Solar Arrays	**UTC**	**Solar Array Efficiency (%)**	**Power Generation (kilowatts/hour)**	Current Power Load (kilowatts/hour)	**Rate of Charging or Draining (kW/hour)**	Charging or Draining	New Time to Criticality (hours)

Communication Team: Please do NOT report the shaded areas to Mission Control.

Recommendations:

Reduce power load:

Adjust to _____% C&DH: Command and Data Handling
Adjust to _____% C&TS: Communication and Tracking System
Adjust to _____% EC&LS: Environmental Control and Life Support
Adjust to _____% FCS: Flight Crew System
Adjust to _____% TCS: Thermal Control System

Other Recommendations:

Power Team Report Form

Priority Level (circle one): **1** Urgent – Inform Mission Control Immediately **2** Potential Danger—Monitor Closely **3** Maintaining Normal Levels

Please fill in ALL blanks in case Mission Control needs the information.

	A	B	C	D	E	F
Battery Reserve	UTC	**Battery Reserve Capacity (%)**	**Battery Reserve (kilowatts)**	**Change (kilowatts)**	Rate of Change (kilowatts)	**Time to Criticality (minutes)**

	A	B	C	D	E	F	G
Solar Arrays	**UTC**	**Solar Array Efficiency (%)**	**Power Generation (kilowatts/hour)**	Current Power Load (kilowatts/hour)	**Rate of Charging or Draining (kW/hour)**	Charging or Draining	New Time to Criticality (hours)

Communication Team: Please do NOT report the shaded areas to Mission Control.

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Other Recommendations: