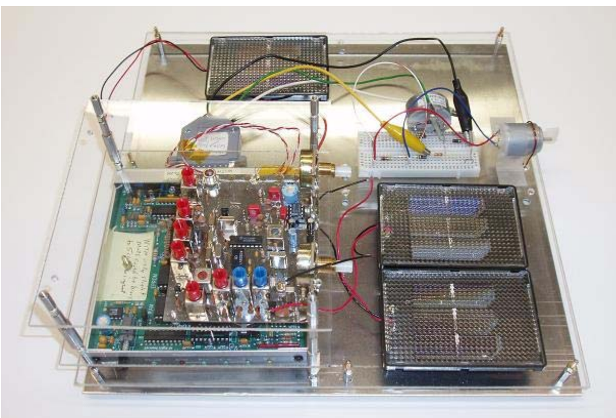
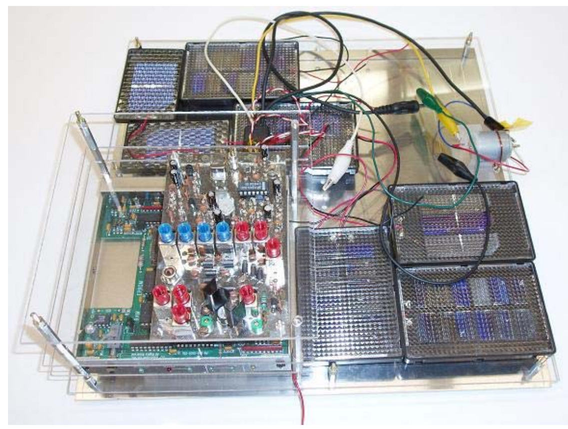
EA-467 LABsat Power System <u>Design</u> (draft) **Fall 2006**

To demonstrate your knowledge of Electrical Power Systems you are to design an electrical power system for your LABsat spacecraft. We have at least 8 different solar panel assemblies of various voltages and currents which you may use. You will be scored on how closely you are able to meet the mission objectives. You will have to design, select, and engineer your components to fit our 6" cube LABsat and a set of given loads as shown below.

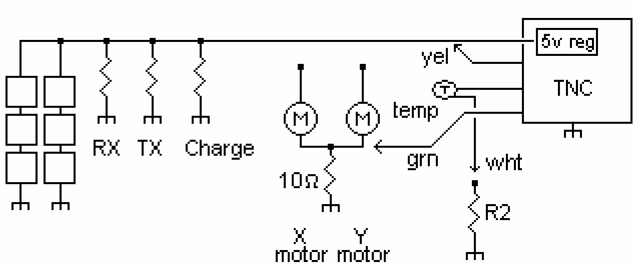
✓	Receiver	7v-10v	40 mA	continuous
✓	Transmitter	7v-10v	400 mA	1 telemetry packet every 10 seconds
✓	Telemetry TNC	7v-18v	15 mA	continuous
✓	Battery Charging	tbd	tbd mA	assume 35% eclipse & 90% charge efficiency
✓	Momentum wheel 1	3v-9v	75 mA	continuous
✓	Momentum wheel 2	3v-9v	20 mA	continuous

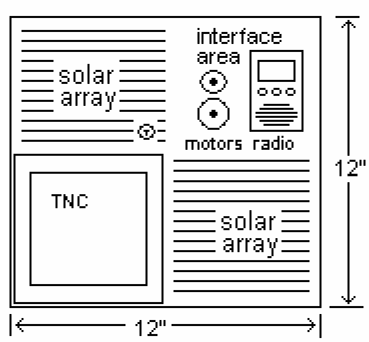




Design Power Budget:

First, calculate the average current for your transmitter _______. Determine how to wire your momentum wheels to save current and then add up all the load currents to find your average design load ______. This total would be the solar power requirement if your mission was always in full sun. But your mission is in a 35% dark, 65% sun orbit which requires additional current while in sun to account for the time in eclipse. Also let's say that charging is only 90% efficient. Add that charge current to your previous total and the result is the total required average solar current while you are in the sun______.





Solar panels: The surface area available for solar panels for this mission is two 7" square panel areas as shown above. There are eight different solar panel modules from Solarworld.com that come in multiple sizes, voltages and currents and price: (http://www.solarworld.com/SolarMini-Panels&Motors.htm)

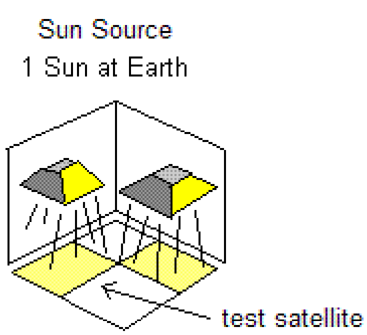
Number	1-3.0-20	1-1.5-50	3-500	3-1.5-100	4-1.5-200	4-4.0-100	4-6.0-50	Pcsat
Size	1 x 1.75	1 x 1.75	1.75 x 3	1.75 x 3	2.5 x 3.75	2.5 x 3.75	2.5 x 3.75	5.3 x 4.5
Current	20 mA	50 mA	500 mA	100 mA	200 mA	100 mA	50 mA	60 mA
Voltage	3 Volts	1.5 Volts	0.5 Volts	1.5 Volts	1.5 Volts	4.0 Volts	6 Volts	18 Volts
Cost $	$11	$9	$8	$10	$13.50	$17	$18	$32
Mass	5g	5g	13g	13g	24g	24g	24g	76g
Quantity	12	24	18	24	22	32	24	12
Peak Pwr								
W/sq-in								

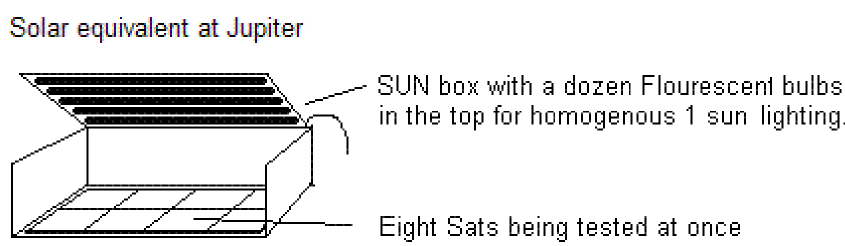
Panels produce peak power at less than the given open circuit voltage and short circuit current shown. You must look at their peak-power curve to determine their optimum voltage and current for your design. These plots are in the box lids. Observe and compute the peak power and and optimum power density and add to the chart above. Also note the optimum useable voltage and currents at that point.

Design Solar Panel System:

You are constrained by available surface area for your body mounted panels, and by cost and mass. Also, you must series modules to get sufficient bus voltage to meet the minimum requirements of all loads on the spacecraft and you must parallel modules to get enough current. Your design must balance all of these constraints. Each box of solar modules has its own I-V and power plot. Once you have selected your solar panel design and laid it out on your FLATsat model with all loads, you will then set it in the solar simulator to evaluate its performance.

WARNING!!! You must not keep your satellite in the SUN BOX for more than 30 seconds or your will MELT it! You will be penalized if you melt your solar panels.





Your spacecraft's abilty to remain running with a positive power budget while also scoring high on its mission objectives with a minimum of mass is your measure of success. Your excess voltage above the minimum will give a good indication of your design margin. The following paragraphs give you some basic design basis for each of the components of your design:

System Battery: Batteries are used for power in eclipse and to provide peak power for intermittent loads. To simplify this exercise, your spacecraft is assumed to have constant average loads so no eclipse battery system is required. Besides it takes hours and multiple eclipse cycles to see the long term net gain or loss of your power budget.

Charge and Bus regulators: The TNC has an internal voltage regulator to provide 5.0 volts for the electronics. The other loads will all run on the unregulated solar array bus.

Heater: For this exercise, we do not need spacecraft heaters, but your spacecraft temperature limit is 60 deg C. You must not allow your solar panel to get above that temperature (too close to the lamp).

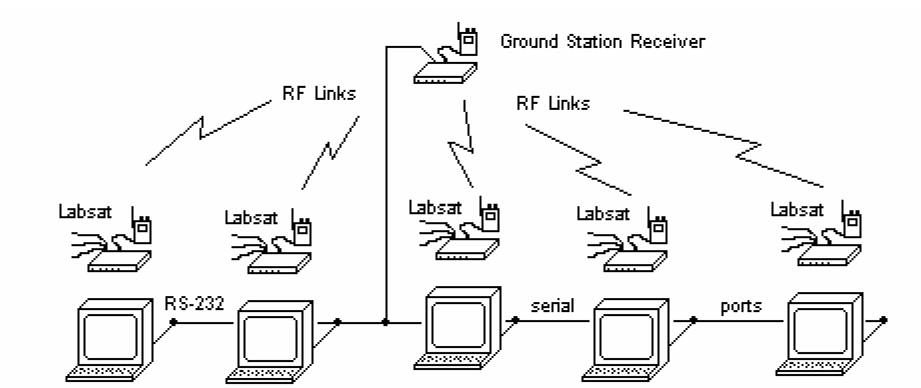
Receiver/Transmitter: You will use the transceiver system used in the Telemetry Lab. To avoid the high peak-to-average transmitter currents and need for a spacecraft battery, the transceiver will use its own internal battery for its peak currents but you must connect the receiver and transmitter simulator resistors that are equivalent to their average load current. (18 ohms each)

TNC Telemetry System: The TNC requires 15 mA at 7 to 18 volts

Momentum Wheels: We have two motors available. You must provide enough current to run them both. Motor characteristics are as shown in the following table:

Motor	Volts	Current	Starting Current	RPM	Mass
MC-05/07	3	20 mA	40 mA	300	
MRE-260	3	80 mA	100 mA	300	

Telemetry System: You will be using the same telemetry system you used in the telemetry lab. It will be connected to a your solar bus voltage, motor current and panel temperature. As in the telemetry lab, telemetry will be transmitted to the central ground station for distribution to your workstation.



Configure your LABsat A/D inputs to read the following parameters:

Channel 2 – (yellow) Solar array bus voltage
Channel 3 – (white) Temperature (R2 selected for a half scale count of 128 at room temperature)
Channel 4 – (green) Motor current as the voltage across a 10 ohm resistor

SCORING: *Unfortunately, this simple spacecraft design laboratory cannot give you all the range of options nor often conflicting requirements to fully simulate all of the design drivers in a real spacecraft, but at least you get the idea of the challenges involved. Teams will be ranked on these quantities::*

- Open circuit voltage, short circuit current, peak design power , and peak measured power.
- Array arrangement efficiency (packing density. Array areas divided by 100 sq inches)
- Array electrical efficiency assuming 100W per square foot illumination
- Solar Bus voltage (motors are almost constant current (no load). Voltage will tell available power)
- Mass of solar panels used

EARTH ORBIT: When your system design is finished, place the solar array in the SUNbox to fully illuminate your panel to one-sun illumination. Connect it to the Satellite Simulator and measure each of the electrical and mechanical parameters above. Verify system performance by the presence of telemetry and use the voltage and current telemetry to measure motor power.

JUPITER ORBIT: The solar power available at Jupiter is about 4% of what it is in Earth orbit. Assume we can reduce the transmit dutycycle down by a factor of 6 and we can reduce the RX power by a factor of 6 and we can turn off the momentum wheels and operate in a gravity gradient stabilized mode. (Disconnect the motors and change the RX and TX resistors to 110 ohms each). Place your labsat now in the Jupiter solar simulator and see if your spacecraft will operate.

Post Lab:

Sketch your solar array design and give its overall specifications. Compare actual measured values with design values and comment. Discuss your results under the simulated full sun. Score your project with these scoring rules:

Open circuit voltage times short circuit current (in mA)

Divide by solar module total area in square inches. Multiply by 100

Add motor power in milliwatts. Subtract mass in grams.

Subtract temperature in Kelvin. Subtract solar module cost.

The result is your score. Highest count wins.

Laboratory Report:

Prepare a team laboratory report with your partner. Tabulate the key parameters in your design such as:

TX average current _________
Average load current (less battery charge) _________
Battery charge current _________
Wheel currents ________
Total average current _________
Solar panel choice ______________ Design Operating voltage ___________
Number of modules in each string _________ Number of strings __________
Total solar panel area _________ Total spacecraft mass ___________
Actual operating voltage ___________ Total solar module cost ___________
Note the results of your design under Mars illumination and Jupiter.

Be sure your report includes the following elements:

- Use a standard report cover page
- Describe the laboratory's purpose, apparatus, procedures, results and conclusions.
- Discuss circuit functions, and include a circuit diagram.
- Include a sketch of your solar panel design and include other data as necessary to describe it.
- Summarize your conclusions and discuss how well the theory supports the observations.
- Make specific comments concerning knowledge gained, and the laboratory's value as a learning tool. Recommend any improvements to the laboratory.