Astro 331 Prelab 1: Electrical Power

Report Instructions

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2023-01-12

Documentation:

- DFAS writing guide (I used to write these instructions—you should read it but don't need to list it in your documentation statement)
- Cite references as necessary, but don't include course notes, course text (SMAD), or these instructions as documentation
- Don't forget to update your own documentation statement when you write your prelab report!

Overview

FlatSAT's solar array, shown in Figure 1, consists of four silicon photovoltaic cells. The cells can be connected in series or in parallel. You will predict array performance for each configuration using the provided specifications to determine if the solar array will satisfy mission requirements in FlatSAT's 500 km orbit.

You have already measured the solar array's short-circuit current and open-circuit voltage. Include these experimental measurements in your prelab and discuss whether they match your predictions.

You will illuminate FlatSat's solar array to validate your prelab predictions and create an empirical I-V plot. By adjusting a potentiometer in the circuit, the array will generate different voltages. At each point, you will measure both voltage and current with Adafruit's INA219 current sensor breakout board. Use these data to create your plot.

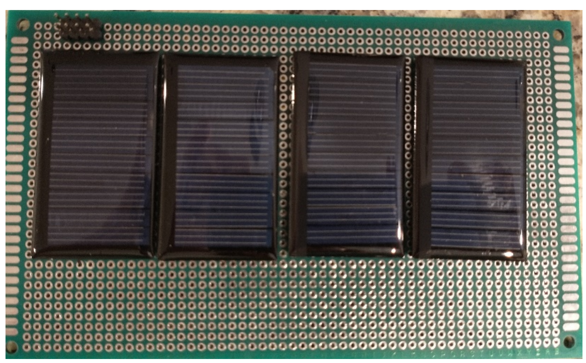

Fig. 1 FlatSAT's solar array

Format

Include the sections required in a Short Summary Report from the USAFA/DFAS writing guide, with the addition of a Nomenclature section. Do not include a cover sheet for prelabs.

- Objectives
- Nomenclature
- Approach
- Assumptions
- Math Technique
- Theoretical Predictions
- Experimental Setup
- (Preliminary Results)
- (Experimental Results)

- Discussion
- Conclusions and Recommendations
- Appendices

Include preliminary results in an Experimental Results section only if you have performed preliminary testing—you did perform preliminary solar array testing for this prelab. Collect additional data during this lab for inclusion in your end-of-semester lab report.

This assignment will be no more than five typed pages. This assignment is individual effort, but you may use websites and textbooks provided that you cite all sources used (see the References section in the DFAS Writing Guide). A documentation statement is required.

Prelab Content

Calculate array performance if FlatSat were launched into a circular orbit with a 500 km altitude. Use the performance parameters in Tables 3 and 4 (in Appendix A).

Create an I-V plot for the solar panel, assuming BOL conditions. Reference Fig 11-9 in SMAD (I-V Plot for a Planar Array). Identify the open-circuit voltage, short-circuit current, and peak power point on your plot. Be sure that you have a title and axis labels with units.

Summarize your theoretical predictions in a table like Table 1.

Table 1 Predicted array output

	V_{oc} (V)	I_{sc} (mA)	P (mW)
series	xx	yy	zz
parallel	x	y	z

Solve for the number of solar cells that FlatSat would need to meet its power requirements. Comment on your results and what changes you would suggest to the design to improve its performance.

Explain each equation, define all variables including units, and state any assumptions you made in order to use those equations. You must show all work to arrive at your answers. Work may be hand-written or performed on a computer so long as it is clear to the reader how you arrived at your answers. This prelab should be a stand-alone document that any engineer without prior exposure to this course could read and understand.

At a minimum, you will need the following equations:

Earth's angular radius:

$$\sin\rho = \frac{R_e}{R_e + h} \tag{1}$$

Eclipse fraction:

$$\cos\Phi = 2\frac{\cos\rho}{\cos\beta} \tag{2}$$

Period, Eclipse time, and Daylight time are found using Equations 3–5.

$$Per = 2\pi\sqrt{\frac{a^3}{\mu}} \tag{3}$$

$$T_e = Per\frac{\Phi}{360^\circ} \tag{4}$$

$$T_d = Per - T_e \tag{5}$$

Power required from solar arrays to generate adequate power to spacecraft:

$$P_{req} = \frac{P_e T_e}{\eta_e T_d} + \frac{P_d}{\eta_d} \tag{6}$$

Power generated by solar array at BOL:

$$P_{BOL} = S\eta I_d \cos\theta A \tag{7}$$

Power generated by solar array at EOL:

$$P = P_{BOL}\,(1 - annual\ degradation)^{elapsed\ years} \tag{8}$$

Solar array efficiency:

$$\eta = \frac{P_{\text{panel}}}{A_{\text{panel}} E_e} \tag{9}$$

A luxmeter measures illuminance, E_v, in lux. 1 lx = 1 lm/m^2. The lumen is the SI unit of brightness, which weights light by wavelength according to the standard luminosity function of human visual perception. Illuminance can be converted to irradiance, E_e, with Equation 10.

$$E_e = \frac{E_v}{K} \tag{10}$$

For unfiltered sunlight, luminous efficacy, K, is 122 lm/W [1]. For incandescent halogen worklight bulbs, it is 19.3 lm/W [2].

Postlab Data Analysis

Produce an IV plot using the data you collected during the lab.

Using your measured peak power (remember, $P - IV$) and measured incident illuminance collected with the luxmeter, calculate the efficiency of your solar array.

Summarize your results in a table like Table 2.

Table 2 Predicted array output

	V_{oc} (V)	I_{sc} (mA)	P (mW)	efficiency (%)
series	xx	yy	zz	aa
parallel	x	y	z	a

Update your Discussion. Compare your results to the predicted results. Discuss and explain any differences. Discuss the difference between serial and parallel array performance. Do the observed results match your predictions? How does the measured efficiency compare to the manufacturer's stated efficiency?

Update your Conclusion and Recommendations. You may find that you need a different number of cells.

References

[1] Michael, P. R., Johnston, D. E., and Moreno, W., "A conversion guide: Solar irradiance and lux illuminance," *Journal of Measurements in Engineering*, Vol. 8, No. 4, 2020, pp. 153–166.

[2] Philips Lighting, *Plusline Small*, 9 2022, `https://www.lighting.philips.com/api/assets/v1/file/PhilipsLighting/content/fp924735544280-pss-global/924735544280_EU.en_AA.PROF.FP.pdf` retrieved 2022-02-11.

Appendix A: Key parameters

Table 3 Mission, orbit, and spacecraft parameters

Mission life	3 years
Power in eclipse	2 W
Power in sunlight	4 W
Power regulation	direct energy transfer*
Worst sun incidence angle	25°
Worst beta angle	0°

*See paragraph after Eqn 11-5 in SMAD

Table 4 Cell & panel parameters (*single cell)

Dimensions*	53 mm × 33 mm
Short-circuit current*	30 mA
Open-circuit voltage*	5 V
Efficiency	14.8%
Inherent degradation	46.78%
Cells	4
connection	series & parallel