PACE 2012

Electrical Power System

14 – 18 May, 2012

Subsystem Agenda

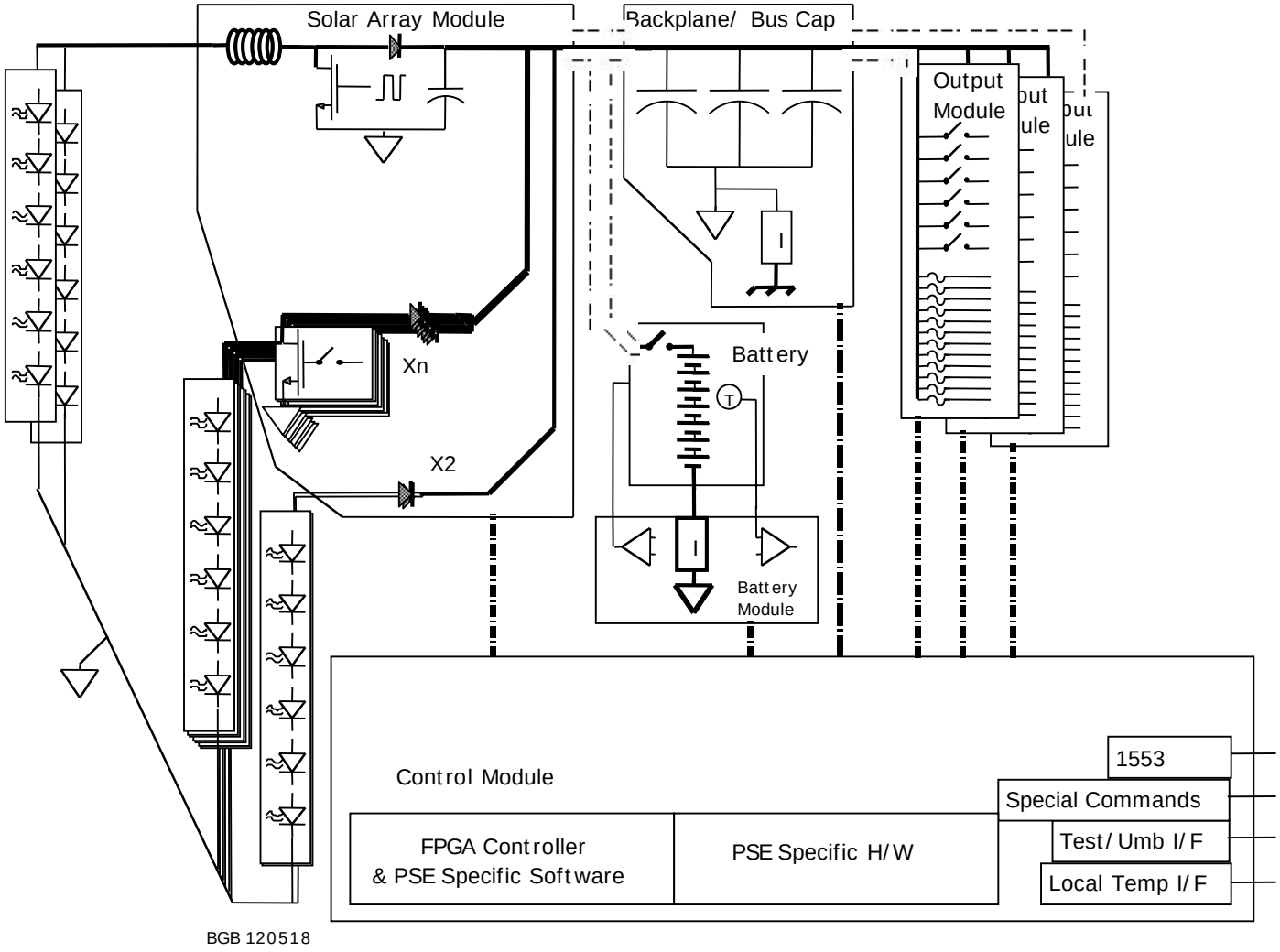
- System Description
- Block Diagram
- Load Analysis
- EPS Curve
- ACS and Comm Power Events
- EPS Summary
- Issues / Potential Risks / Future work
- Acronym List
- Backup Material

Subsystem Overview

- **Electrical Power System Summary**
  - **Solar Array**. TjGaAs at 28% efficiency, in a 98.2 deg polar orbit at 700 km circular. Spenvis Pmax 3.98E+13 used for the solar array degradation at the 5 year point. The Solar array will have one extra strings at the 3 year point to meet the power requirement at 5 years. Solar array temp assumed to be 70 deg C.
  - **Battery**. Is made from 140 ah Lithium Ion, GSYUASA (formally JSB) cells. The battery is sized to provide power during the eclipsed and for the communications and spacecraft slew modes near the five year life point. For the 3 year requirement there will be about 16,000 discharge cycles. For the 5 year case there will be 26,600 discharge cycles. The nominal battery depth of discharge (DOD) will be 18.85 %. The Launch DOD is expected to be under 10%. The Battery is internally redundant. To meet the 26,600 cycle life for a LiIon chemistry, the DOD must be kept to below 20% and the operating temperature is assumed to be 10 deg C. The thermal system has a 5kg impact on maintaining the 10 deg battery temp requirement. A trade is provided in the back up slides to show the mass impacts to go to a NiH2 battery.
  - **Power System Electronics (PSE)**. A independent PSE is assumed.
  - **Harness**. Harness is calculated based on a newly updated Cable Harness tool.

Electrical Power Block Diagram

Mission Design Laboratory

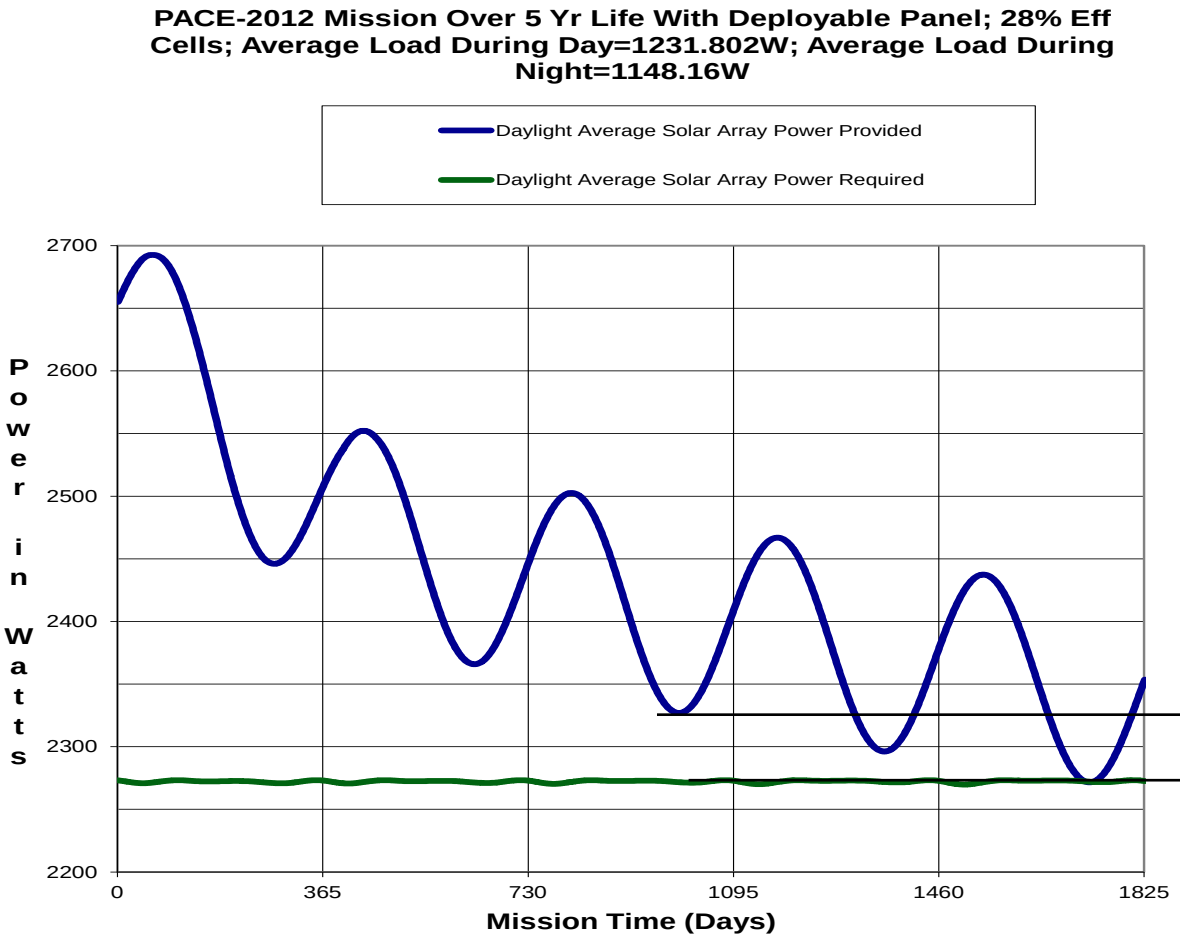


Load Analysis

Mission Design Laboratory

PACE-2012										
5.0	Mission Life in Years									
EPS Load Item Description				Launch Power	Sun Avg. Power Watts	Eclipse Avg. Power Watts	Safehold Power in Watts	Peak Power	Comm Downlink	Slew Maneuver
Total Power				**66.9**	**1,231.8**	**1,148.2**	**977.5**	**2,851.8**	**1,289.8**	**1,260.84**
Time Period Over Which Averaging Is Done For Each Mode (min.)		Contingency								
	Inst Global Contingency	30								
Instruments with Contingency				**0.0**	**764.1**	**708.5**	**591.2**	**1426.1**	**708.5**	**764.1**
Ocean Color Experiment 2 (OCE)				0.0	515.0	515.0	214.0	648.0	515.0	515.0
	Contingency	30		0.0	154.5	154.5	64.2	194.4	154.5	154.5
Polarimeter				0.0	72.8	30.0	30.0	100.0	30.0	72.8
	Contingency	30		0.0	21.8	9.0	9.0	30.0	9.0	21.8
OCE Survival Heater				0.0	0.0	0.0	244.0	349.0	0.0	0.0
	Contingency	30		0.0	0.0	0.0	30.0	104.7	0.0	0.0
Spacecraft Loads with Contingency				**66.9**	**467.7**	**439.7**	**386.3**	**1425.7**	**581.3**	**496.7**
	Spcft Global Contingency	30								
PSE	MAP like (95.4% eff)	56.66		3.1	56.7	50.4	41.7	121.2	55.6	55.4
	Contingency	30		0.9	17.0	15.1	12.5	36.4	16.7	16.6
Electrical - Harness Losses	BGB			0.2	4.2	3.9	3.3	9.7	4.4	4.3
	Contingency	30		0.1	1.3	1.2	1.0	2.9	1.3	1.3
Command & Data Handling	Porfi B.			0.0	83.0	38.0	46.0	92.0	83.0	54.0
	Contingency	30		0.0	24.9	11.4	13.8	27.6	24.9	16.2
Solar Array Drive Motor	BGB			1.1	5.7	5.7	1.1	17.2	8.5	5.7
	Contingency	30		0.3	1.7	1.7	0.3	5.1	2.5	1.7
Solar Array Drive Electronics	BGB			2.2	10.9	10.9	2.2	13.8	10.9	10.9
	Contingency	30		0.7	3.3	3.3	0.7	4.2	3.3	3.3
Attitude Control	Eric S.			22.8	140.2	140.2	123.2	653.2	140.2	202.2
	Contingency	30		6.8	42.1	42.1	37.0	196.0	42.1	60.7
Thermal	Kim B.			20.0	30.0	60.0	60.0	75.0	30.0	30.0
	Contingency	30		6.0	9.0	18.0	18.0	22.5	9.0	9.0
Propulsion	Bob E.			2.0	2.0	2.0	2.0	2.0	2.0	2.0
	Contingency	30		0.6	0.6	0.6	0.6	0.6	0.6	0.6
Data Systems	Blake L.			0.0	27.1	27.1	17.6	112.6	112.6	17.6
	Contingency	30		0.0	8.1	8.1	5.3	33.8	33.8	5.3

EPS Curve



One extra solar array string for reliability at the 3 year point.

ACS Lunar Slew & Communication Power

- **To cover the ACS lunar calibration slew, an additional 0.966 ah will be needed from the battery. (The power difference is 32.49 watts. The current needed is 32.49/28v = 1.16 amps additional for ½ a orbit (50min). The max discharge at would be 1.16a x 50/60= 0.966ah.) This will change the battery DOD from 18.85% to 20.22% DOD. This will be ok.**

- **To cover the Communication, power may be needed from the battery. Load Analysis Comm Mode requires 1289.8 watts. The solar array will need to deliver 2337 watts with current EPS losses* from the normal 2273 watts. The difference will needs to come from the battery. This will be 64/28v = 2.28 amps additional. The max com downlink will be 10 min. During the sun 2.28a x 10 Min/60 = 0.38 ah. DOD = (0.38)/145 x 100= 0.26%DOD during the Sun at near end of life (EOL). This will be ok.**

*this calculation is bases on EOL solar array power. During earlier times, depending on the season, the solar array may have ample power and no battery discharge is needed.

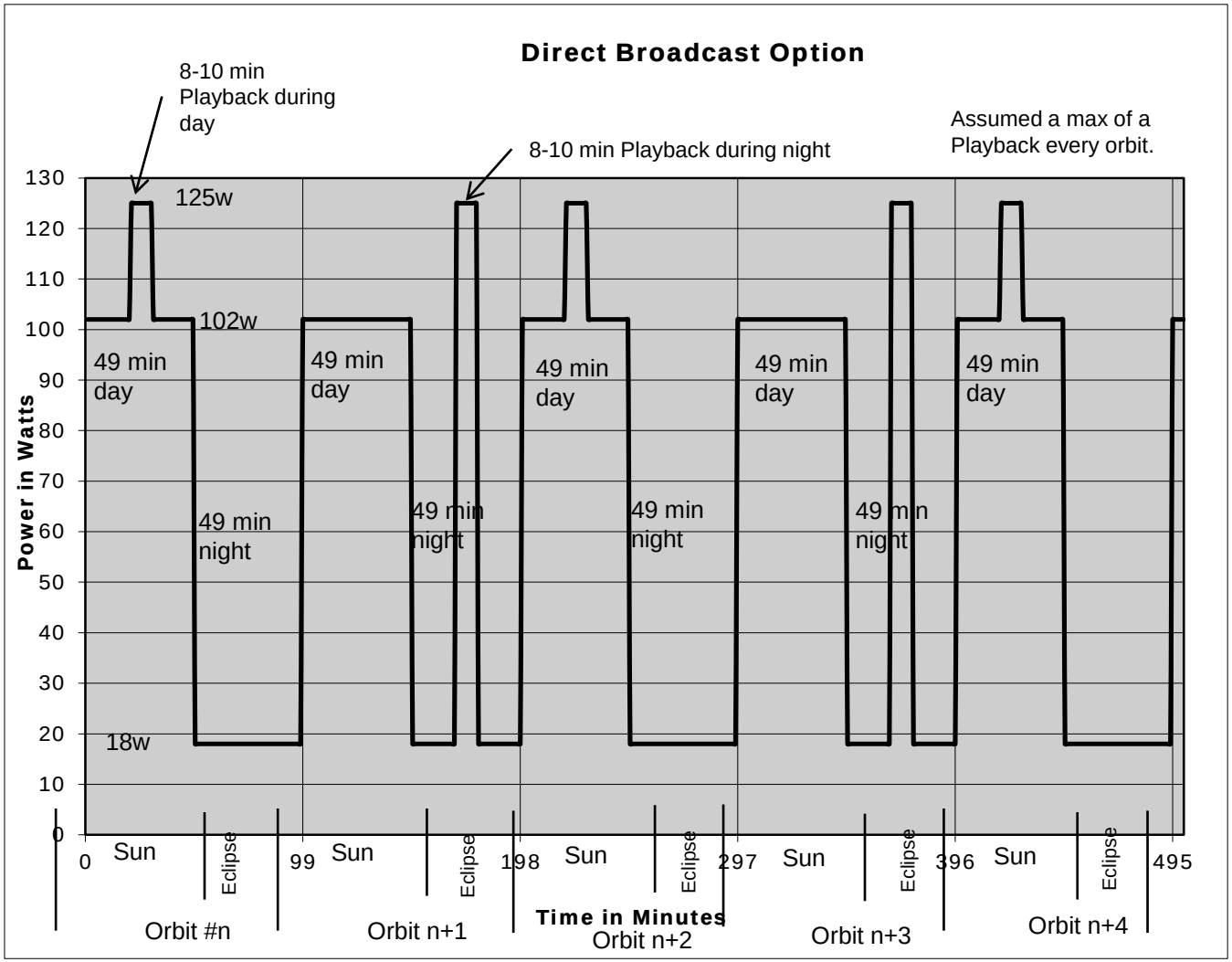
EPS Summary

Mission Design Laboratory

PACE-2012		Dimensions (M)		#	Area M^2 or Vol M^3	Total Mass(Kg)
Solar Array TJGaAs		1.00	9.14	1	9.14	95.66
Lith Ion, Battery 145 A 19.98% DOD	0.28	0.26	0.20	1	0.01	38.06
PSE	0.22	0.28	0.65	1	0.04	27.72
Solar Array Drive				1		6.25
Harness spacecraft & solar array				1		22.38
			Total Materials			190.1

Broadcast mode Load Profile

Mission Design Laboratory



Broadcast mode impact to power

- To cover this Communication Option:
- Sun Power. Will require 51.24 watts more than the baseline average power. The 27.1 watts average needs to be replaced with 78.34 watts average. To cover this, The solar array area will need to go from 9.14 m^2 to 9.67 m^2. Power may again be needed from the battery for the day play back. The com Load Analysis 1289.8 watts + 15 watts. The solar array will need to deliver 2354 watts with current EPS losses* from the normal 2273 watts. The difference will needs to come from the battery. This will be 81/28v = 2.89 amps additional. The max com downlink will be 10 min. During the sun 2.89a x 10 Min/60 = 0.48 ah. DOD = (0.48)/145 x 100= 0.33%DOD. This will be ok.

PACE-2012, Direct Broad cast option		Dimensions (M)		#	Area M^2 or Vol M^3	Total Mass(Kg)
Solar Array TJGaAs		1.00	9.66	1	9.66	101.09
Lith Ion, Battery 145 A 19.98% DOD	0.28	0.26	0.20	1	0.01	38.06
PSE	0.22	0.28	0.67	1	0.04	28.48
Solar Array Drive				1		6.25
Harness spacecraft & solar array				1		22.55
			Total Materials			196.42

- Eclipse Power. Will require 0.637ah additional from the battery. (125-18)w/28v=3.82a, 3.82ax10min/60min/hr= 0.637ah. This changed the battery DOD for that orbit from 18.85% to 19.98% DOD.
- This will increase Power System mass by 6.36 KG.

Issues / Potential Risks / Future work

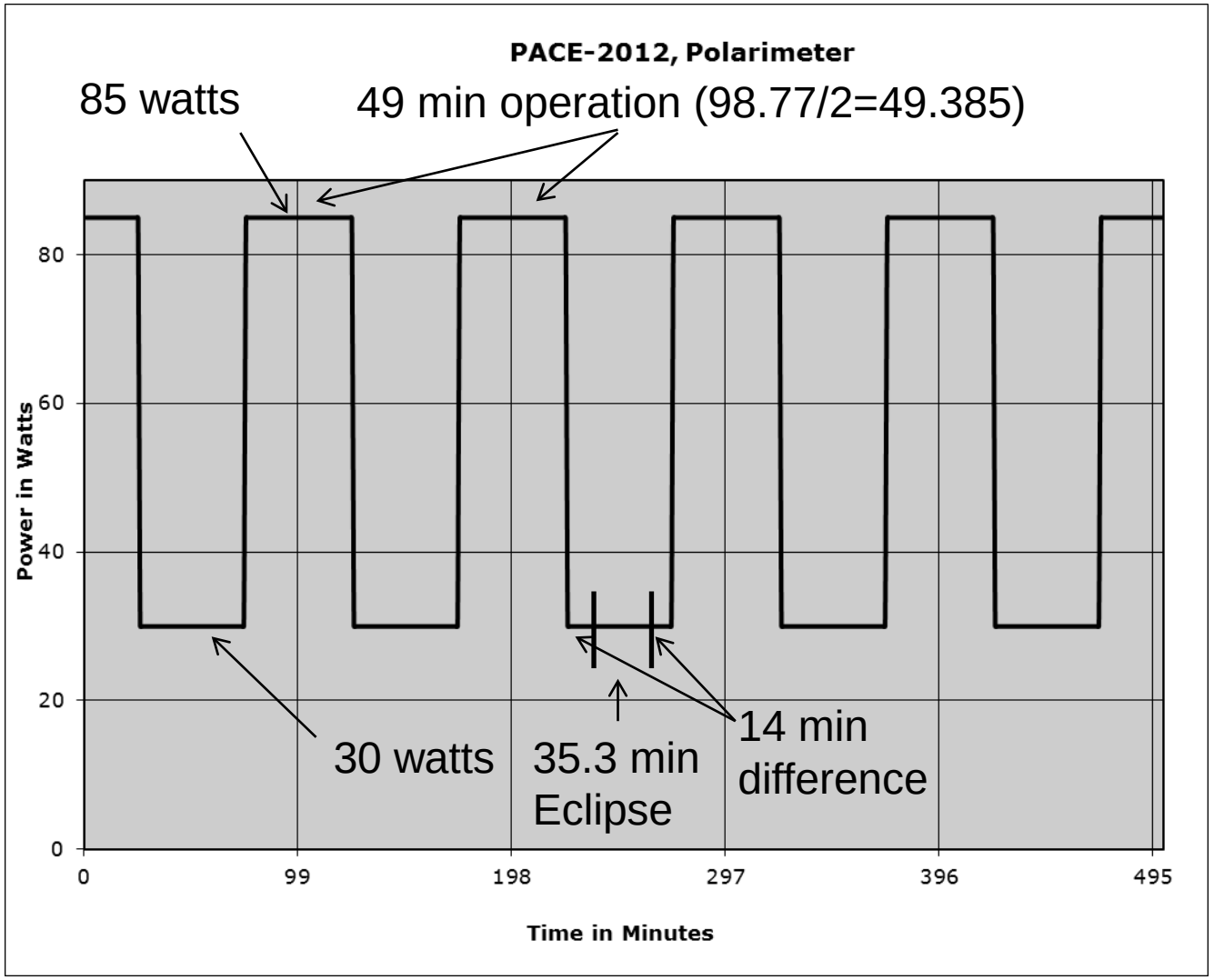
- **Issues**
- **Risk**
- **Future Work.**

Acronym List

PSE	Power System Electronics
DOD	Battery Depth of Discharge
SA	Solar Array
SAD	Solar Array Drive
EOL	End of Life
Ah	Ampere hours
TjGaAs	Triple Junction Gallium Arsenide
M	Meters
M^2	Meters Squared
Kg	Kilograms
deg	Degree, Temp or angle depending on use
LiIon	Lithium Ion Battery

Backup Material

Polarimeter Load Profile



Day Average Power = (85*49+30*14)/63 = 72.77 watts

Battery Chemistry Trade

Mission Design Laboratory

Item	Size, estimate	Volume cm^3	Mass, Kg	Depth of Discharge %
Base Line, LiIon Battery, LSE 145	28.3cmH*26.0cmW*20.0cmL	14,716	28.4	20.0
Option, NiH2 Battery 80 ah, SAR-10121,	33.17cm dia*64.01cmL	55,313	36.3	34.2
Delta		40,597	7.9	

The history of the NiH2 battery chemistry has been known for longer cycle life than LiIon. Current LiIon spacecraft batteries show cycle life that exceeds the 26,600 cycle requirement for 5 years, however some heritage buses may be configured for NiH2 and cost to change could be expensive.

Cable Harness Tool for Power

Mission Design Laboratory

Cable #	From	To	Peak Power Power in Watts	Contingency Inst Bus	Contingency 30%	Conductor Length feet	Conductor Length meters	28 volts DC Cable Gage	# of Conductors	Power loss Watts	Cable mass, Kg	Connector Mass, Kg	Shelding Mass, Kg	Total Mass, Kg
1	PSE or IAU	Ocean Color Experiment 2 (OCE)	648.00		194.40	7	2.134	4	2	0.79	1.664	0.04	0.02	1.72
2	PSE or IAU	Polarimeter	100.00		30.00	7	2.134	18	2	0.48	0.085	0.04	0.02	0.14
3	PSE or IAU	OCE Survival Heater	349.00		104.70	7	2.134	10	2	0.92	0.415	0.04	0.02	0.47
								SubTotal		**2.18 Watts**	**2.16 KG**	**0.12 KG**	**0.05 KG**	**2.33 KG**
110	Solar Array	PSE, Max S/A Power from EPS Curve	2692.67		807.80	6	1.829	Ot	4	2.30	7.22	0.10	0.03	7.35
120	Battery	PSE, Peak Power from Load Analysis	2852.50		855.75	5	1.524	Ot	4	2.15	6.02	0.10	0.03	6.14
200	PSE	Command & Data Handling	92.00		27.60	5	1.524	19	2	0.37	0.05	0.10	0.03	0.18
210	PSE or IAU	N/A, Solid State Data Recorder	0.00		0.00	0	0.000	0	0	0.00	0.00	0.00	0.00	0.00
111	PSE or IAU	N/A, Solar Array Drive Motor	17.20		5.16	5	1.524	29	2	0.13	0.01	0.04	0.01	0.06
112	PSE or IAU	N/A, Solar Array Drive Electronics	13.80		4.14	5	1.524	30	2	0.11	0.01	0.04	0.01	0.06
300	PSE	Attitude Control	653.23		195.97	7	2.134	4	2	0.80	1.66	0.04	0.02	1.72
410	PSE	Com,	112.60		33.78	7	2.134	17	2	0.48	0.10	0.04	0.02	0.16
600	PSE or IAU	Propulsion	2.00		0.60	5	1.524	40	2	0.02	0.00	0.04	0.01	0.05
700	PSE or IAU	Thermal, Instrument 4 ckts	30.00		9.00	5	1.524	26	2	0.20	0.01	0.04	0.01	0.26
700	PSE or IAU	Therm, Tankes, 8 ckts	30.00		9.00	5	1.524	26	2	0.20	0.01	0.04	0.01	0.52
700	PSE or IAU	Therm, Trusters, 8 ckts	12.00		3.60	5	1.524	30	2	0.08	0.01	0.04	0.01	0.47
700	PSE or IAU	Therm, Fuel Lines, 16 ckts	6.00		1.80	5	1.524	34	2	0.05	0.00	0.04	0.01	0.90
700	PSE or IAU	Therm, ST, Gyro, 2 ckt	10.00		3.00	5	1.524	31	2	0.07	0.01	0.04	0.01	0.12
700	PSE or IAU	Therm, Reaction Wheels, 8 ckts	20.00		6.00	5	1.524	28	2	0.14	0.01	0.04	0.01	0.49
700	PSE or IAU	Therm, Battery, 2 ckts	10.00		3.00	5	1.524	31	2	0.07	0.01	0.04	0.01	0.12
700	PSE or IAU	Therm, C&DH, 2 ckts	10.00		3.00	5	1.524	31	2	0.07	0.01	0.04	0.01	0.12
700	PSE or IAU	Therm, S/A Drive, 2 ckts	3.00		0.90	5	1.524	38	2	0.03	0.00	0.04	0.01	0.11
700	PSE or IAU	Umbilical, launch Harness	10.00		3.00	10	3.048	31	2	0.14	0.01	0.04	0.03	0.08
700	PSE or IAU	Analoge, Prop, Pyro,Acs Sensors &Mech	10.00		3.00	5	1.524	31	2	0.07	0.01	0.04	0.01	0.06
700	PSE or IAU	End	0.00		0.00	0	0.000	0	0	0.00	0.00	0.00	0.00	0.00
								Subtotals		**7.49 Watts**	**15.15 KG**	**0.94 KG**	**0.3 KG**	**18.95 KG**

Cable Harness Tool for Data

Mission Design Laboratory

Data Harness						SubTotal			0.061	0.760	0.278	1.099
				feet	meters	Cable Guage	#of Conductors		Cable Kg	Conn Kg	Shelding Kg	Total, Kg
Ocean Color Experiment 2 (OCE)				7	2.1	24	2		0.004	0.04	0.018	0.061
Polarimeter				7	2.1	24	2		0.004	0.04	0.018	0.061
OCE Survival Heater				7	2.1	24	2		0.004	0.04	0.018	0.061
PSE, Max S/A Power from EPS Curve				6	1.8	24	2		0.003	0.04	0.015	0.058
PSE, Peak Power from Load Analysis				5	1.5	24	2		0.003	0.04	0.013	0.055
Command & Data Handling				5	1.5	24	2		0.003	0.04	0.013	0.055
N/A, Solar Array Drive Motor				5	1.5	24	2		0.003	0.04	0.013	0.055
N/A, Solar Array Drive Electronics				5	1.5	24	2		0.003	0.04	0.013	0.055
Attitude Control				7	2.1	24	2		0.004	0.04	0.018	0.061
Com,				7	2.1	24	2		0.004	0.04	0.018	0.061
Propulsion				5	1.5	24	2		0.003	0.04	0.013	0.055
Thermal, Instrument 4 ckts				5	1.5	24	2		0.003	0.04	0.013	0.055
Therm, Tankes, 8 ckts				5	1.5	24	2		0.003	0.04	0.013	0.055
Therm, Trusters, 8 ckts				5	1.5	24	2		0.003	0.04	0.013	0.055
Therm, Fuel Lines, 16 ckts				5	1.5	24	2		0.003	0.04	0.013	0.055
Therm, ST, Gyro, 2 ckt				5	1.5	24	2		0.003	0.04	0.013	0.055
Therm, Reaction Wheels, 8 ckts				5	1.5	24	2		0.003	0.04	0.013	0.055
Umbilical, launch Harness				10	3.0	24	2		0.006	0.04	0.025	0.071
Analoge, Prop, Pyro,Acs Sensors &Mech				5	1.5	24	2		0.003	0.04	0.013	0.055

Total	9.67W atts	17.37 KG	1.82 KG	0.63 KG	22.38 KG