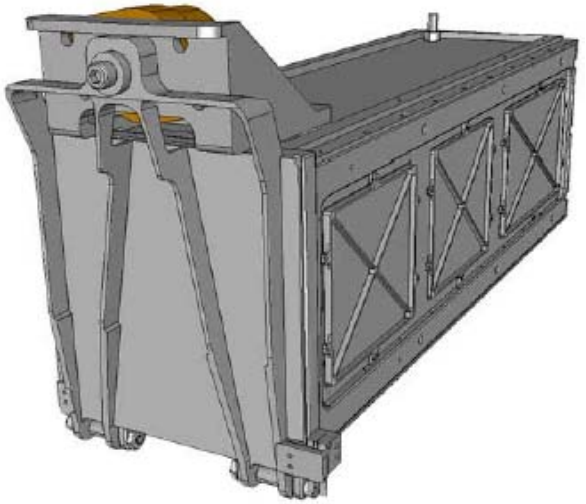
Fox 1 Mechanical Design

Robert Davis

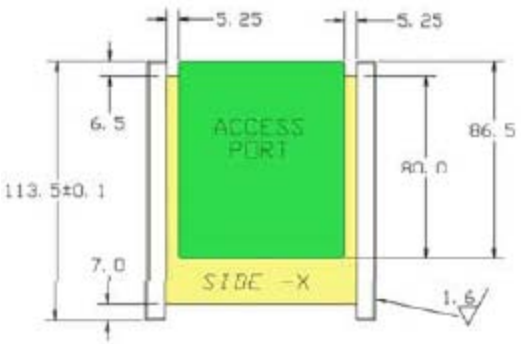
KF4KSS

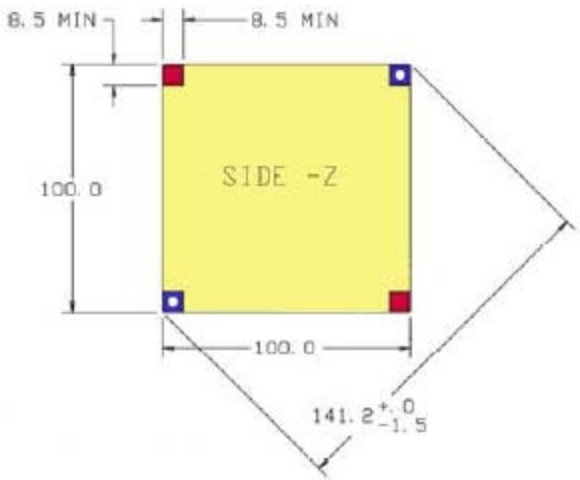
2011 AMSAT Space Symposium

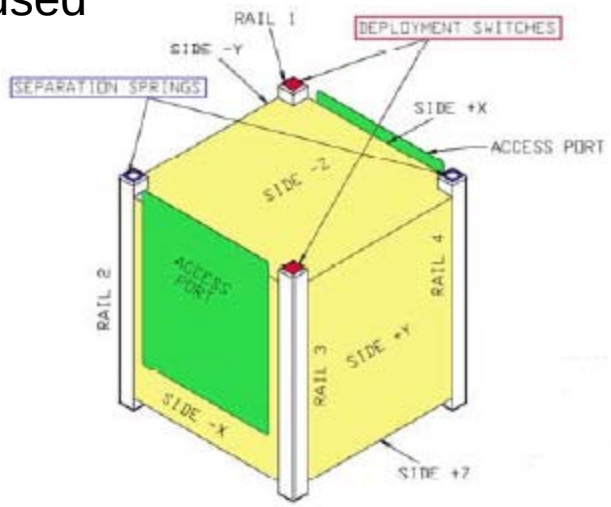
Requirements from Cal Poly



- CubeSat Design Specification, Rev 12
  - Base dimensions/tolerances/material
  - Rail width/length/plating
  - Envelope for protrusions (solar panels, antennas, etc)
  - Mass and location of center of mass
  - Contact switch(es) to turn CubeSat off inside PPOD
  - Springs to separate CubeSats when released from PPOD
  - Access Port location if Umbilical or Safe Plug is used







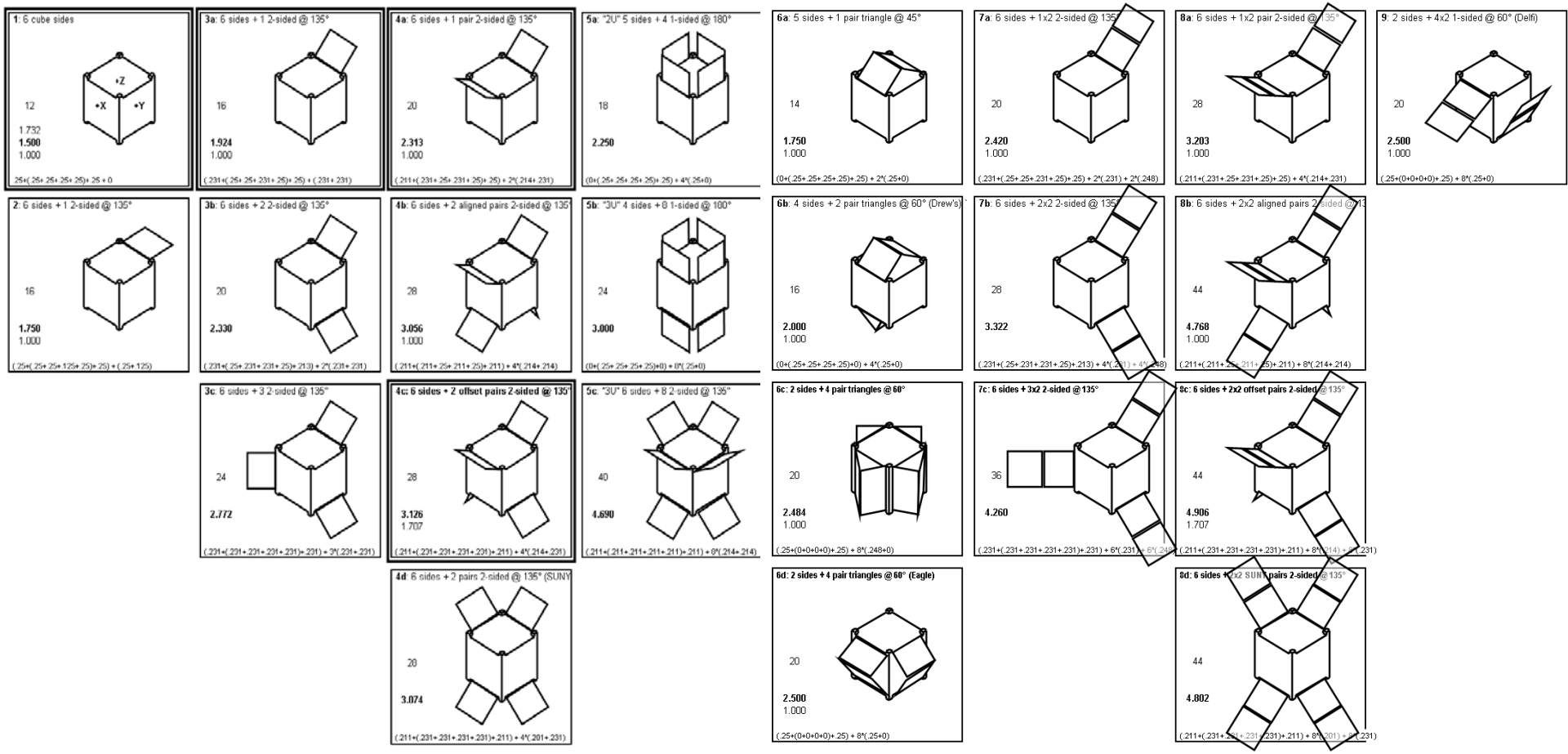
Requirements from NASA

- LSP-Req-317.01, for ELaNa opportunity
  - Selection of Factors of Safety based on verification method
  - Ventable volume/area <2,000
  - Definition of tiers of environmental testing
  - Selection of materials
    - Dissimilar metals
    - Stress corrosion cracking
    - Fracture control
    - Strengths used in analysis
  - No pressure vessels
  - No propulsion
  - 45 minute timer before deployments/transmissions
  - Vacuum bakeout minimum temp 70° C (or 60° C if hardship)

Requirements from Project

- Maximize solar cells, avionics & experiments
- Antenna deployment is mission critical
- Umbilical & Safe Plug without giving up a solar cell
- Passive magnetic attitude & spinning
  - Magnet aligned with Z axis
  - Hysteresis rods perpendicular to Z axis
  - Izz > Ixx and Izz > Iyy, for spin stability
  - OSR surface strips, for differential solar pressure
- Commonality Fox 1 & 2 (deployable solar panels)

Early Panel Trade



Solar ☑ XYZ

flux	1367	W/m²

Structure

WxH	100	100	mm

Rails

WxH	8.5	6.5	mm

P-POD Access Panel

☐ No -Z cell on −X

Panels

WxH	80	95	mm
thick	0		mm
shift	0		mm

Cell BOL/End-Of-Life

degr/yr	0.50	%
Lifetime	0	yrs, 0 for BOL
BOL	100.0	%

Cells of X and Y Panels

"Best" Spectrolab CIC			
2	at	28.3	%
WxH	68.9	39.5	mm
crop	8.0		mm
thick	0		mm
gap	10		mm
Cell Xarea		26.62	cm²
Panel Power		2.060	W
Rotate Cells		☐	

Cells of Z Panels

"Best" Spectrolab CIC			
2	at	28.3	%
WxH	68.9	39.5	mm
crop	8.0		mm
thick	0		mm
gap	10		mm
Cell Xarea		26.62	cm²
Panel Power		2.060	W
Rotate Cells		☐	

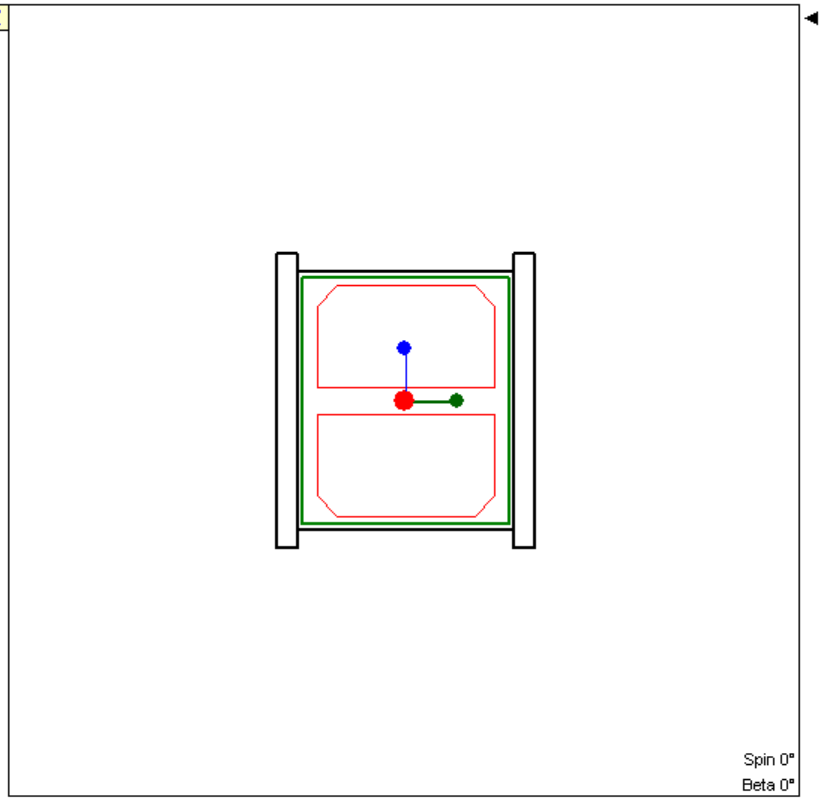
Cells of Deploy Panels

"Best" Spectrolab CIC			
2	at	28.3	%
WxH	68.9	39.5	mm
crop	8		mm
gap	10		mm
Cell Xarea		26.62	cm²
Panel Power		2.060	W
Rotate Cells		☐	

Deploy at	135°
Shadowing	☑

Shadowing brings down whole panel.

bxP_2011Mar04 for color symp pres.x
2011 Oct 19, 10:06 AM



This View's Incident Power (W)

☐	+Z+Y	0.00
☐	+Z−Y	0.00
	+X	2.06
	Y	0.00
	Z	0.00
☐	−Z+X	0.00
☐	−Z−X	0.00
	Sum	**2.06**

Methods for whole orbit Incident Power (W)

Random Orientation	Max	3.57
	Ave	**3.09**
	Min	2.06
Smallest IP Beta 90° Spin	Max	2.06
	Ave	**2.06**
	Min	2.06
Manual Beta +80° Spin	Max	2.53
	Ave	**2.48**
	Min	2.39
Magnetic & Spin, Polar	Max	3.57
	Ave	**2.99**
	Min	2.06

IP →

Energy Balance superseded by simulation

*IP*Eppt*Td=Le*Tel(Ebat*Epsu)+Ld*Td/Epsu*

Sun (neglects albedo)
↓ Cell efficiencies & orientations
Ave Incident Power as Magnetic & Spin
↓ PPT efficiency *Eppt* 90%
Bus Power
PSU efficiency *Epsu* 90%
+ Daylight Load *Ld*
Battery
Battery efficiency *Ebat* 90%
Eclipse Load *Le*

Orbital Parameters

Altitude	500	km	
Period	94.62	min	
Eclipse	35.8	min	*Te*
Sun	58.9	min	*Td*

Power Budget during Max Eclipse

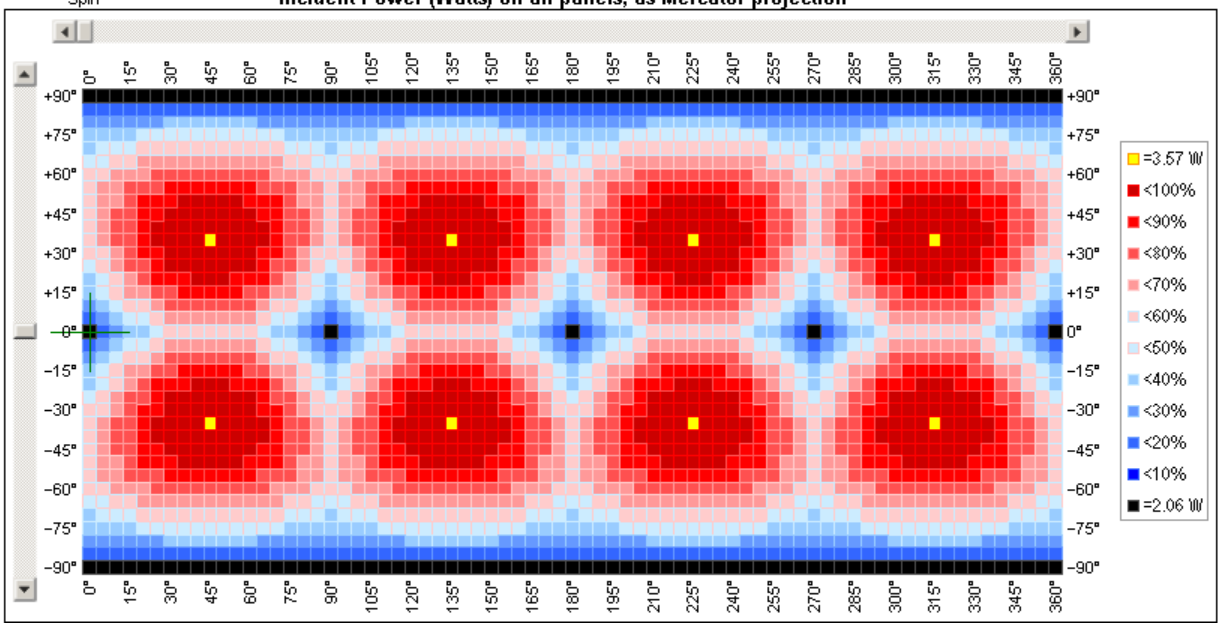
IF Eclipse Load is 100% Daylight Load, then
Le = Ld 1.45 W

IF Eclipse Load is 75% Daylight Load, then
Le 1.21 W
Ld 1.61 W
0.40 W load was shed

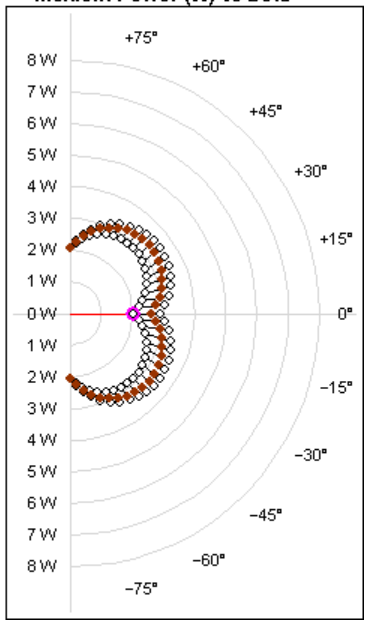
Power Budget in Full Sun (no eclipse)

Ld #N/A W

Incident Power (Watts) on all panels, as Mercator projection



Incident Power (W) vs Beta



Solar ☑ XYZ

flux	1367	W/m²

Structure

WxH	100	100	mm

Rails

WxH	8.5	6.5	mm

P-POD Access Panel

☐ No -Z cell on −X

Panels

WxH	80	95	mm
thick	0		mm
shift	0		mm

Cell BOL/End-Of-Life

degr/yr	0.50	%
Lifetime	0	yrs, 0 for BOL
BOL	100.0	%

Cells of X and Y Panels

"Best" Spectrolab CIC			
2	at	28.3	%
WxH	68.9	39.5	mm
crop	8.0		mm
thick	0		mm
gap	10		mm
Cell Xarea		26.62	cm²
Panel Power		2.060	W
Rotate Cells		☐	

Cells of Z Panels

"Best" Spectrolab CIC			
2	at	28.3	%
WxH	68.9	39.5	mm
crop	8.0		mm
thick	0		mm
gap	10		mm
Cell Xarea		26.62	cm²
Panel Power		2.060	W
Rotate Cells		☐	

Cells of Deploy Panels

"Best" Spectrolab CIC			
2	at	28.3	%
WxH	68.9	39.5	mm
crop	8		mm
gap	10		mm
Cell Xarea		26.62	cm²
Panel Power		2.060	W
Rotate Cells		☐	

Deploy at	135°
Shadowing	☑

Shadowing brings down whole panel.

bxP_2011Mar04 for color symp pres.x
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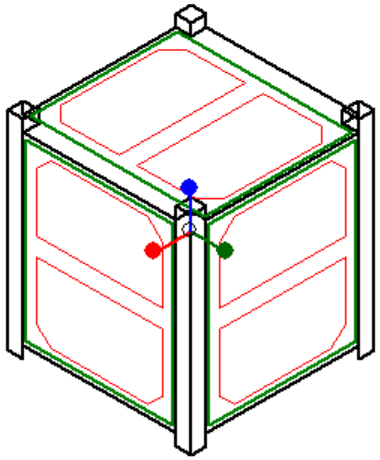


Spin 45°
Beta +35°

This View's Incident Power (W)

☐	+Z+Y	0.00
☐	+Z−Y	0.00
	+X	1.19
	+Y	1.19
	+Z	1.18
☐	−Z+X	0.00
☐	−Z−X	0.00
	Sum	**3.57**

Methods for whole orbit Incident Power (W)

Random Orientation	Max	3.57
	Ave	**3.09**
	Min	2.06
Smallest IP	Max	2.06
Beta 90°	**Ave**	**2.06**
Spin	Min	2.06
Manual	Max	2.53
Beta +80°	**Ave**	**2.48**
Spin	Min	2.39
Magnetic & Spin,	Max	3.57
	Ave	**2.99**
Polar	Min	2.06

IP

Energy Balance superseded by simulation

*IP*Eppt*Td=Le*Te/(Ebat*Epsu)+Ld*Td/Epsu*

Sun (neglects albedo)
Cell efficiencies & orientations
Ave Incident Power as Magnetic & Spin
PPT efficiency *Eppt* 90%
Bus Power
PSU efficiency *Epsu* 90%
\+ **Daylight Load** *Ld*
Battery
Battery efficiency *Ebat* 90%
Eclipse Load *Le*

Orbital Parameters

Altitude	500	km	
Period	94.62	min	
Eclipse	35.8	min	*Te*
Sun	58.9	min	*Td*

Power Budget during Max Eclipse

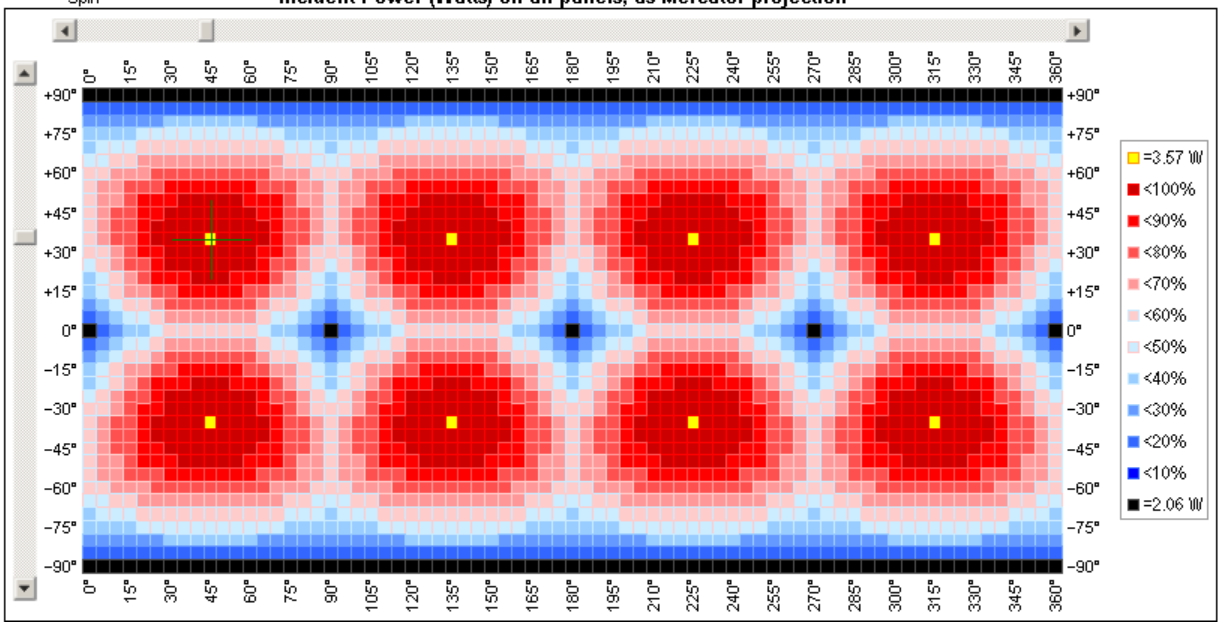
IF Eclipse Load is 100% Daylight Load, then
Le = Ld 1.45 W

IF Eclipse Load is 75% Daylight Load, then
Le 1.21 W
Ld 1.61 W
0.40 W load was shed

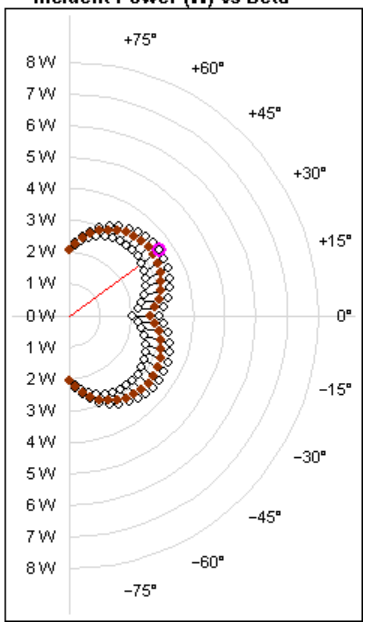
Power Budget in Full Sun (no eclipse)

Ld #N/A W

Incident Power (Watts) on all panels, as Mercator projection



Incident Power (W) vs Beta



Solar ☑ XYZ

flux	1367	W/m²

Structure

WxH	100	100	mm

Rails

WxH	8.5	6.5	mm

P-POD Access Panel

☐ No -Z cell on −X

Panels

WxH	80	95	mm
thick	0		mm
shift	0		mm

Cell BOL/End-Of-Life

degr/yr	0.50	%
Lifetime	0	yrs, 0 for BOL
BOL	100.0	%

Cells of X and Y Panels

"Best" Spectrolab CIC		
2	at	28.3 %
WxH	68.9	39.5 mm
crop	8.0	mm
thick	0	mm
gap	10	mm
Cell Xarea	26.62	cm²
Panel Power	2.060	W
Rotate Cells	☐	

Cells of Z Panels

"Best" Spectrolab CIC		
2	at	28.3 %
WxH	68.9	39.5 mm
crop	8.0	mm
thick	0	mm
gap	10	mm
Cell Xarea	26.62	cm²
Panel Power	2.060	W
Rotate Cells	☐	

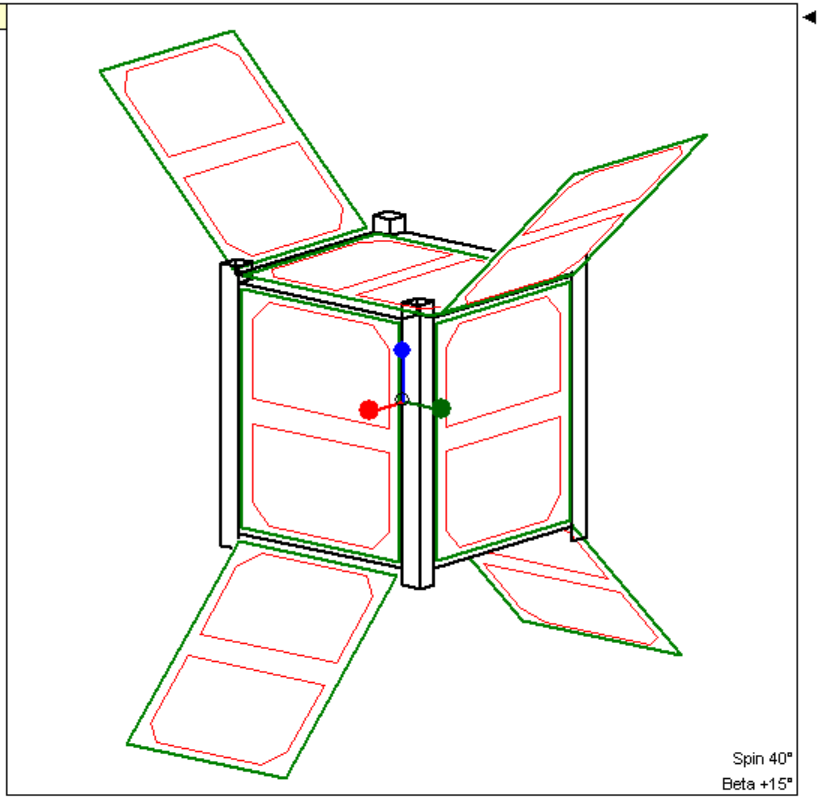
Cells of Deploy Panels

"Best" Spectrolab CIC		
2	at	28.3 %
WxH	68.9	39.5 mm
crop	8	mm
gap	10	mm
Cell Xarea	26.62	cm²
Panel Power	2.060	W
Rotate Cells	☐	

Deploy at	135°
Shadowing	☑

Shadowing brings down whole panel.

bxP_2011Mar04 for color symp pres.x
2011 Oct 19, 10:10 AM



This View's Incident Power (W)

☑	+Z+Y	0.53
☑	+Z−Y	1.28
	+X	1.52
	+Y	1.28
	+Z	0.00
☑	−Z+X	1.45
☑	−Z−X	0.00
	Sum	**6.07**

Methods for whole orbit Incident Power (W)

Random Orientation	Max	7.89
	Ave	**5.87**
	Min	3.52
Smallest IP **Beta** -5° Spin	Max	6.19
	Ave	**4.98**
	Min	3.63
Manual **Beta** +80° Spin	Max	7.77
	Ave	**6.76**
	Min	6.38
Magnetic & Spin, Polar	Max	7.89
	Ave	**6.09**
	Min	3.52

IP →

Energy Balance superseded by simulation

*IP*Eppt*Td=Le*Te\|(Ebat*Epsu)+Ld*Td\|Epsu*

Sun (neglects albedo)
Cell efficiencies & orientations
Ave Incident Power as Magnetic & Spin
PPT efficiency *Eppt* 90%
Bus Power
PSU efficiency *Epsu* 90%
+ Daylight Load *Ld*
Battery
Battery efficiency *Ebat* 90%
Eclipse Load *Le*

Orbital Parameters

Altitude	500	km	
Period	94.62	min	
Eclipse	35.8	min	*Te*
Sun	58.9	min	*Td*

Power Budget during Max Eclipse

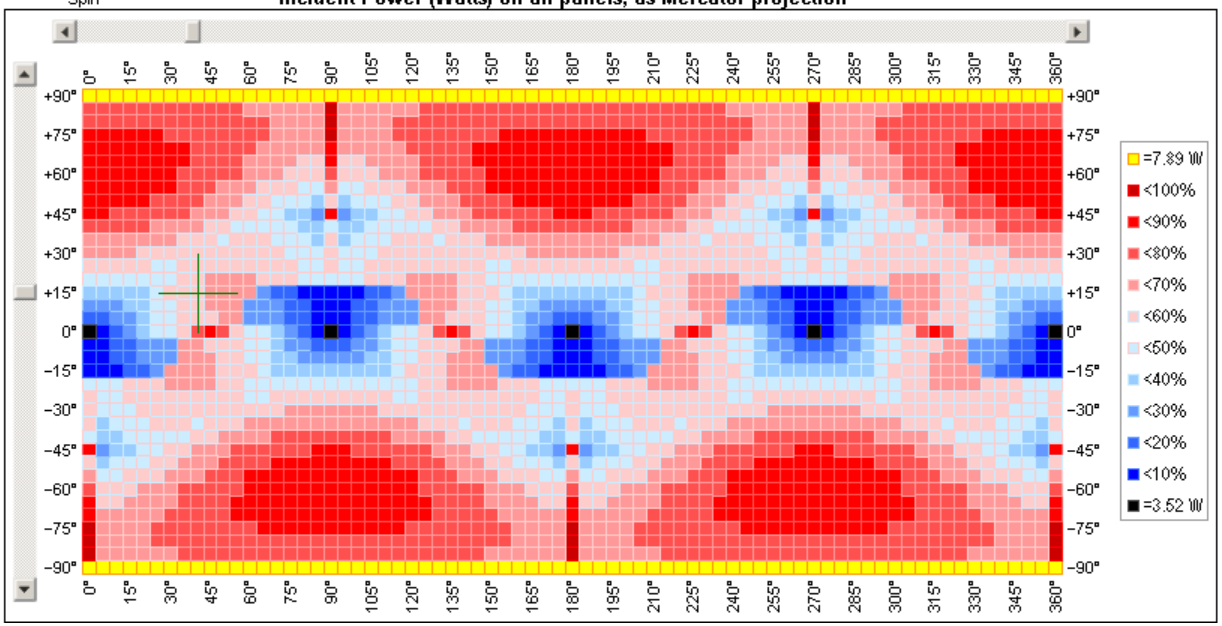
IF Eclipse Load is 100% Daylight Load, then
Le = Ld 2.95 W

IF Eclipse Load is 75% Daylight Load, then
Le 2.46 W
Ld 3.28 W
0.82 W load was shed

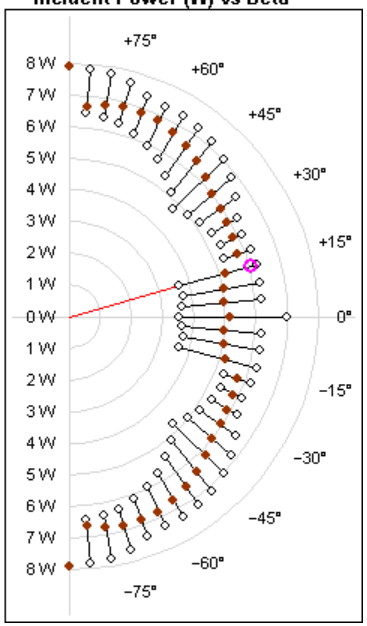
Power Budget in Full Sun (no eclipse)

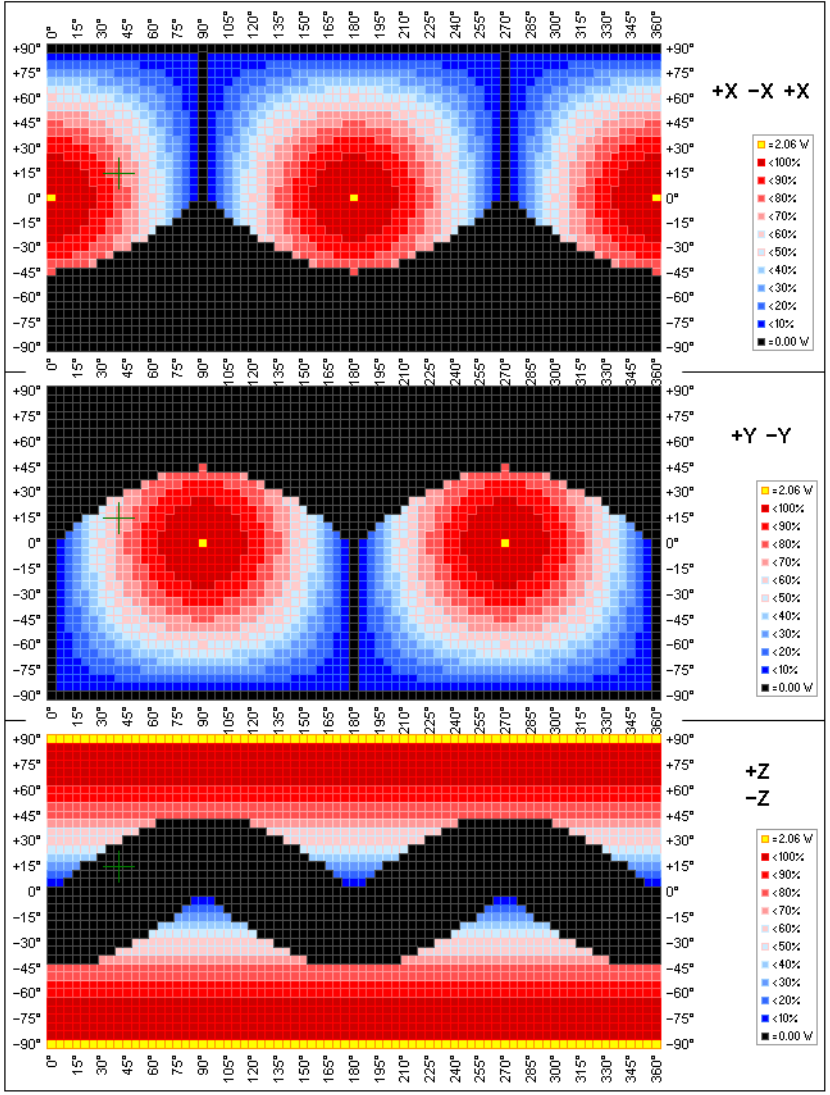
Ld #N/A W

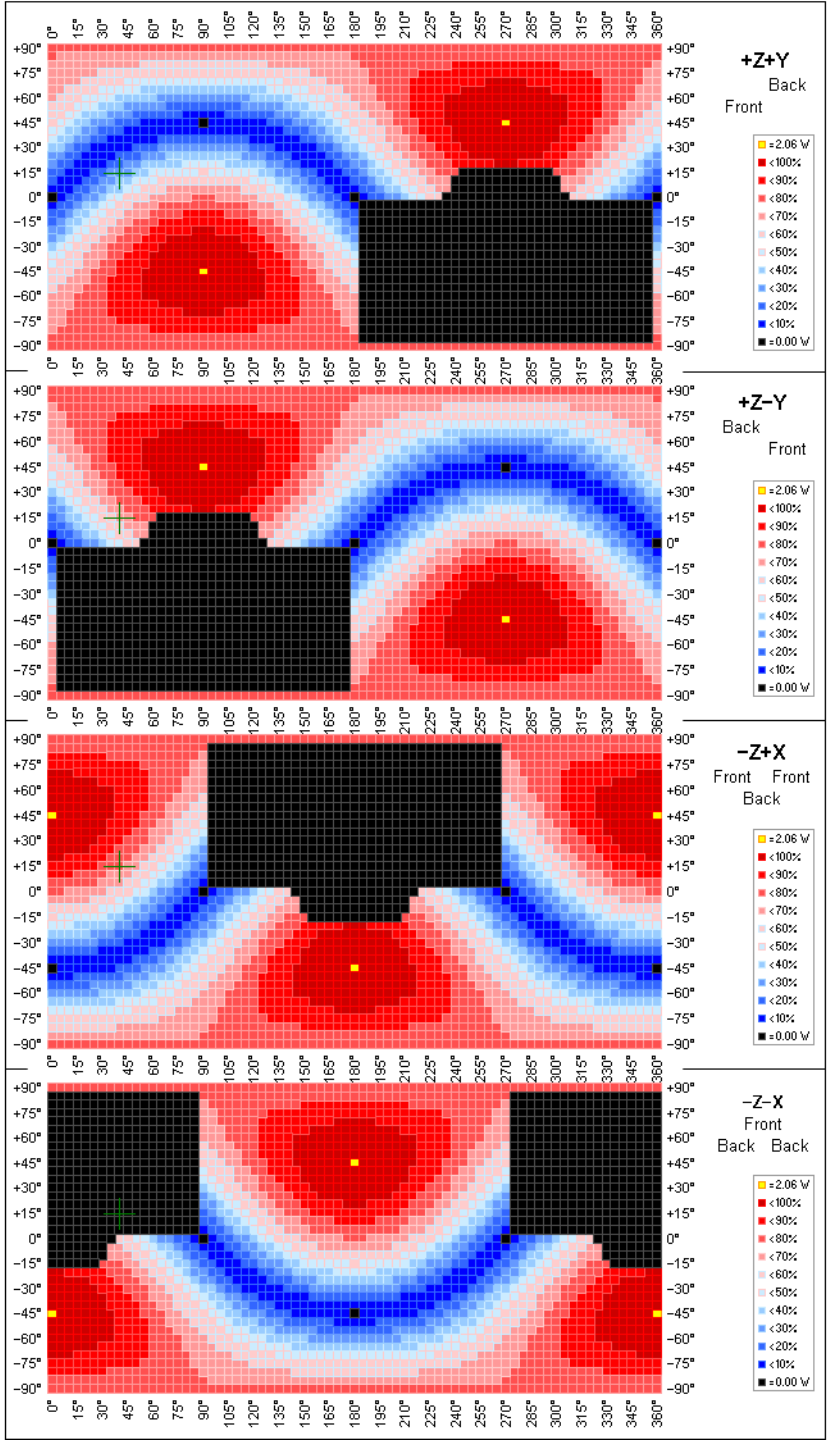
Incident Power (Watts) on all panels, as Mercator projection



Incident Power (W) vs Beta







Normalized IP, Sum = 2.85		
+Z+Y	0.205	Ave front & back
+Z−Y	0.205	Ave front & back
X	0.209	Ave + & −
Y	0.209	Ave + & −
Z	0.185	Ave + & −
−Z+X	0.205	Ave front & back
−Z−X	0.205	Ave front & back
Ref	0.250	No shadowing

Solar flux 1367 W/m²

Structure WxH 100 100 mm

Rails WxH 8.5 6.5 mm

P-POD Access Panel ☐ No -Z cell on −X

Panels WxH 80 95 mm; thick 0 mm; shift 0 mm

Cell BOL/End-Of-Life degr/yr 0.50 %; Lifetime 0 yrs, 0 for BOL; **BOL** 100.0 %

Cells of X and Y Panels

"Best" Spectrolab CIC			
2	at	28.3	%
WxH	68.9	39.5	mm
crop	8.0		mm
thick	0		mm
gap	10		mm
Cell Xarea		26.62	cm²
Panel Power		2.060	W
Rotate Cells		☐	

Cells of Z Panels

"Best" Spectrolab CIC			
2	at	28.3	%
WxH	68.9	39.5	mm
crop	8.0		mm
thick	0		mm
gap	10		mm
Cell Xarea		26.62	cm²
Panel Power		2.060	W
Rotate Cells		☐	

Cells of Deploy Panels

"Best" Spectrolab CIC			
2	at	28.3	%
WxH	68.9	39.5	mm
crop	8		mm
gap	10		mm
Cell Xarea		26.62	cm²
Panel Power		2.060	W
Rotate Cells		☐	

Deploy at 135°

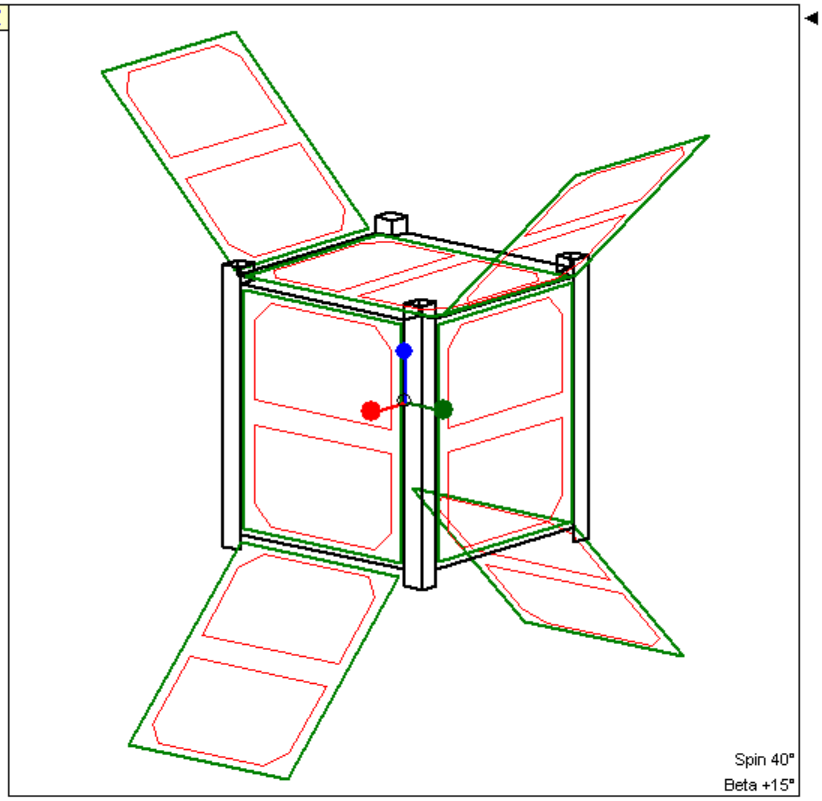
Shadowing ☐

Shadowing brings down whole panel.

bxP_2011Mar04 for color symp pres.x

2011 Oct 19, 10:11 AM

☑ XYZ



This View's Incident Power (W)

☑	+Z+Y	0.53
☑	+Z−Y	1.28
	+X	1.52
	+Y	1.28
	+Z	0.53
☑	−Z+X	1.45
☑	−Z−X	0.70
	Sum	**7.30**

Methods for whole orbit Incident Power (W)

Random Orientation	Max	8.41
	Ave	**7.21**
	Min	4.97
Smallest IP	Max	7.03
Beta 0°	**Ave**	**6.33**
Spin	Min	4.97
Manual	Max	8.27
Beta +80°	**Ave**	**8.22**
Spin	Min	8.12
Magnetic & Spin,	Max	8.41
	Ave	**7.38**
Polar	Min	4.97

IP →

$$\frac{6.09 + 7.38}{2} = 6.7 \text{ Watts}$$

Energy Balance superseded by simulation

$IP*Eppt*Td=Le*Te|(Ebat*Epsu)+Ld*Td|Epsu$

Sun (neglects albedo)

Cell efficiencies & orientations

Ave Incident Power as Magnetic & Spin

PPT efficiency *Eppt* 90%

Bus Power

PSU efficiency *Epsu* 90%

\+ Daylight Load *Ld*

Battery

Battery efficiency *Ebat* 90%

Eclipse Load *Le*

Orbital Parameters

Altitude	500	km
Period	94.62	min
Eclipse	35.8	min *Te*
Sun	58.9	min *Td*

Power Budget during Max Eclipse

IF Eclipse Load is 100% Daylight Load, then

Le = Ld 3.57 W

IF Eclipse Load is 75% Daylight Load, then

Le 2.98 W

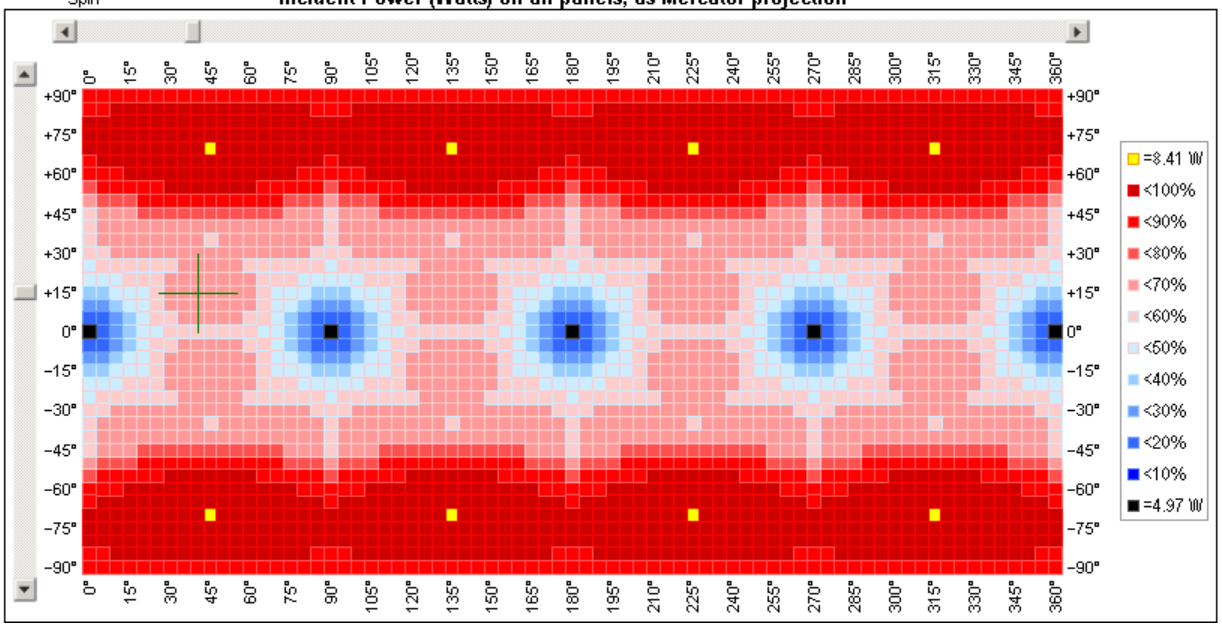
Ld 3.97 W

0.99 W load was shed

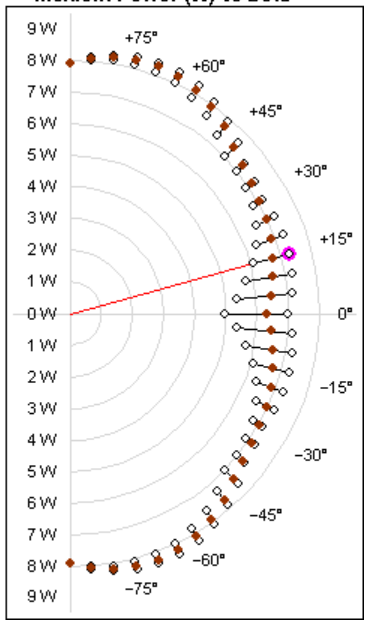
Power Budget in Full Sun (no eclipse)

Ld #N/A W

Incident Power (Watts) on all panels, as Mercator projection

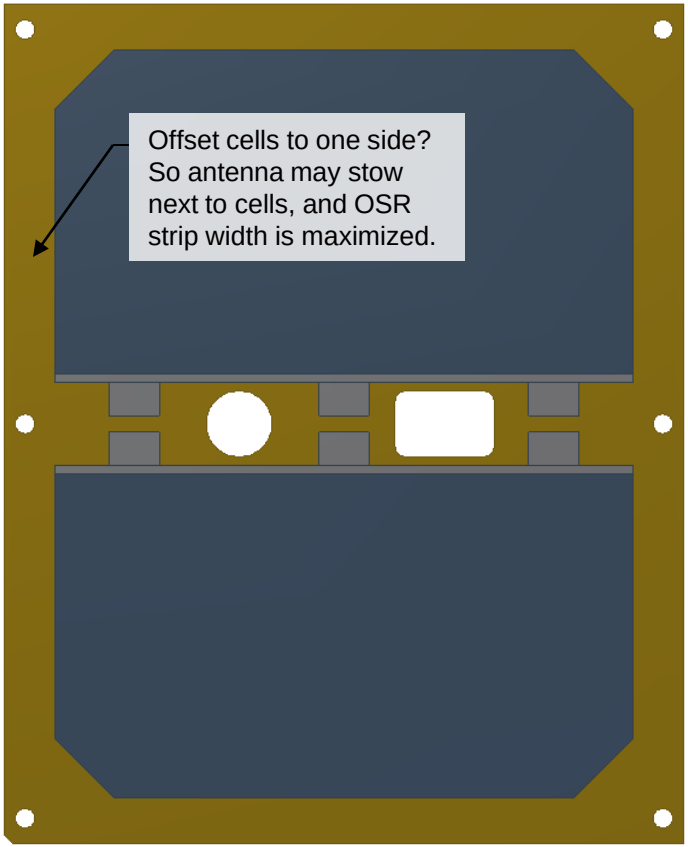


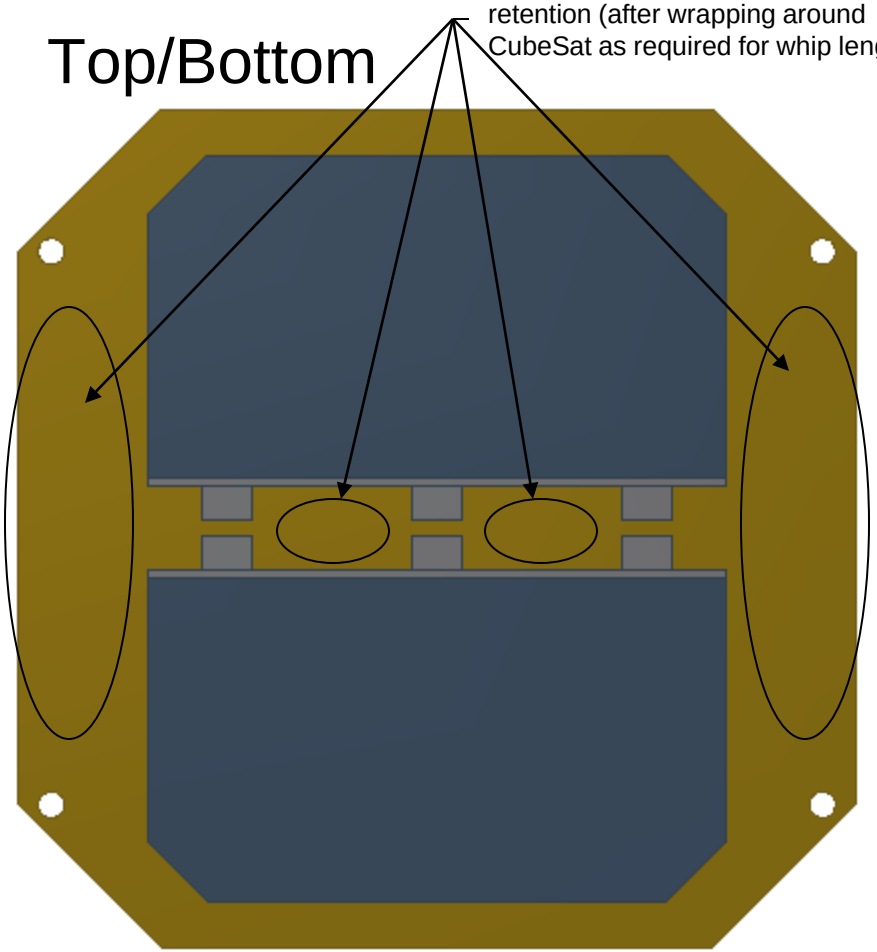
Incident Power (W) vs Beta



CICs on Panels

- Two PCBs: Sides and Top/Bottom

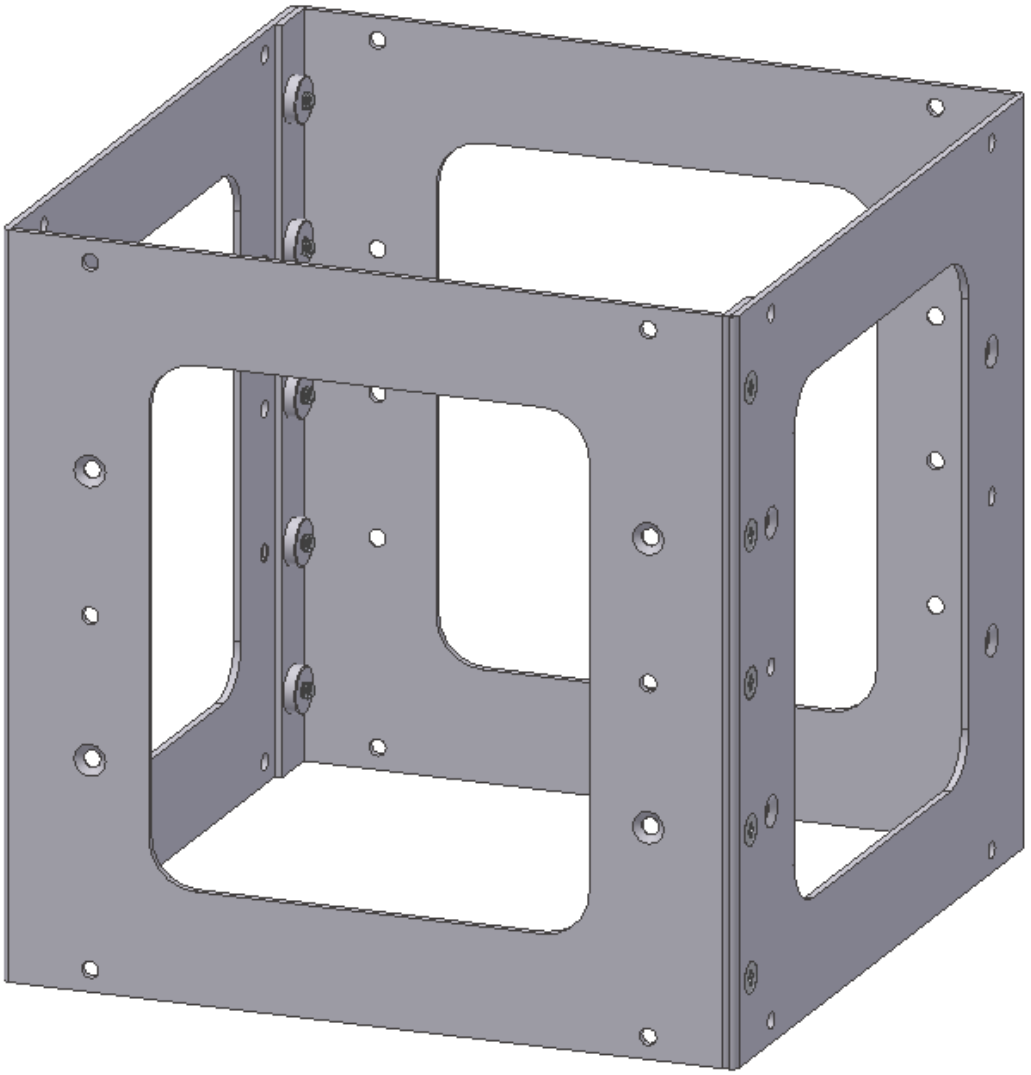




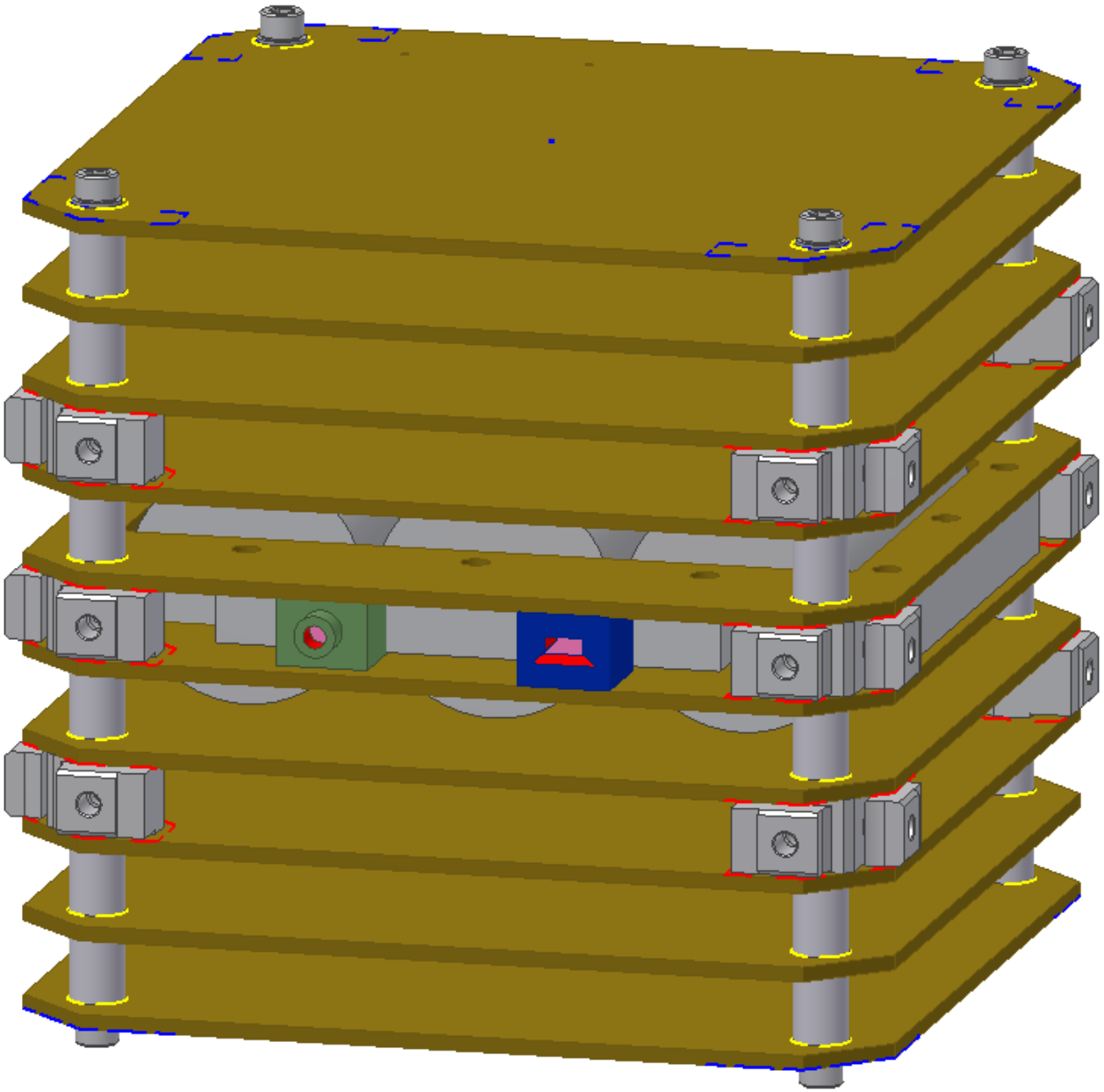
- Shown with Spectrolab's 26.62 cm^2 28.3% UTJ.
- 29.85 cm^2 appear to fit until other details are considered.

Sheetmetal Walls

- 2-piece bent sheetmetal
- Fewer joints/fasteners
- Maximizes PCB volume
- 5052-H32 bendable with no radius
- Material waiver required with Cal Poly's CDS Rev 12
- No waiver required with KSC's LSP-REQ-317.01
- Need a professional bender due to tight tolerances of widths between PPOD Rails



PCB Stack – Tentative Assignments



Rx & GPS Antenna Card

Experiment #3

Experiment #2

Experiment #1

Battery #2

Battery #1

PSU

IHU

RF

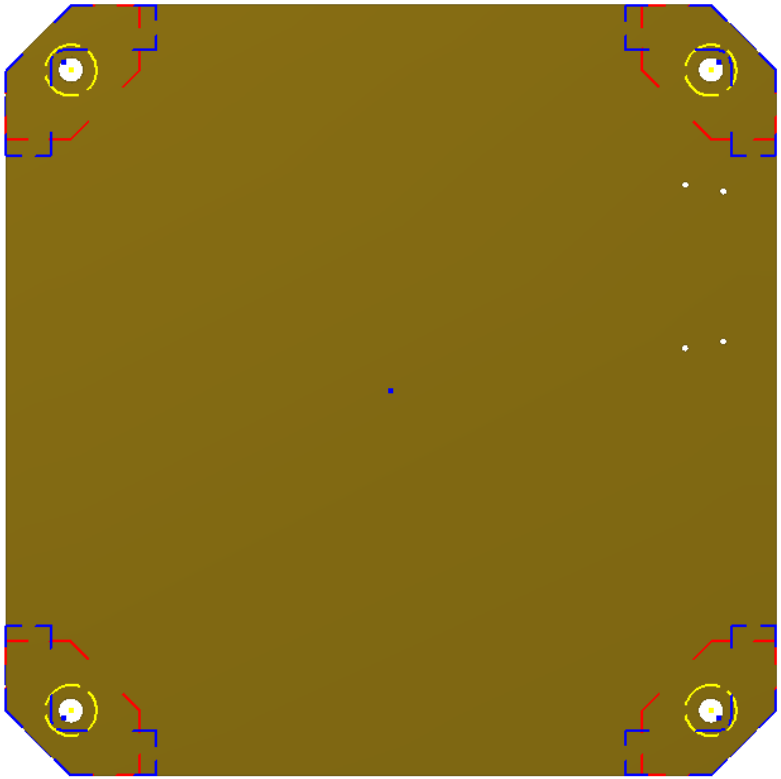
Tx Antenna Card

Notable Items on PCBs

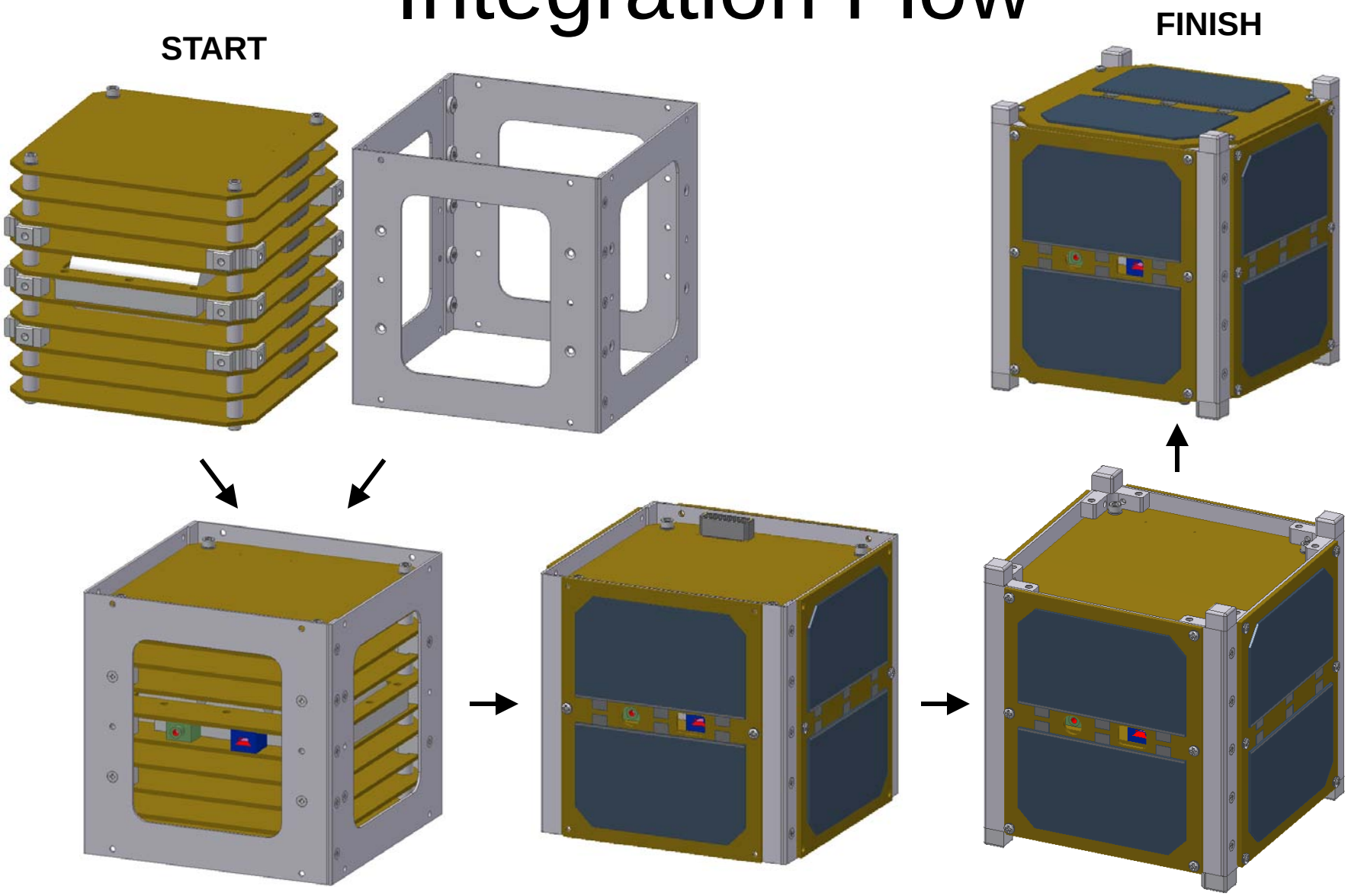
- **RX and GPS Antenna Card**
  - **70cm antenna**
  - **Diplexer (to 70cm and GPS receivers)**
  - **GPS receiver**
  - **connector to +Z Top Solar Panel**
- **Experiment #1 - #3**
  - **If experiment is less than 3 PCBs, then it will be “padded” to total 3 PCBs**
- **Battery #1 and #2 (division is TBD)**
  - **3 “C” cells**
  - **Micro/Mini USB**
  - **Stereo jack RBF safe plug**
  - **4 connectors to 4 Side Solar Panels**
  - **Magnet(s)**
  - **Hysteresis rods**
- **PSU (Power Supply Unit)**
  - **MPPTs**
  - **Battery protect**
- **IHU (Internal Housekeeping Unit)**
- **RF**
  - **Receiver**
  - **Transmitter**
- **TX Antenna Card**
  - **2m antenna**
  - **Connector to –Z Bottom Solar Panel**

PCBs

- 10 PCBs “fill” the interior
- 95x95mm, standard 1/16” thick
- 8mm tall spacers between based on choice of connector
- Clearances:
  - 1.5 mm to side Aluminum
  - 2.5 mm to side solar panels
  - About 1 mm to rail extensions
  - About 6 mm to top/bottom solar panels
- Stayout zones have been identified for
  - aluminum spacers
  - Delrin blocks
  - Rail extensions top/bottom



Integration Flow



Thermal details

- Provided CAD physical model for creation of thermal analytical model
- No meaningful opportunities for thermal to dictate materials, areas, or coatings of exterior
- Good bonding of side solar panels to structure
  - 6 screws and wide overlap of ground plane to aluminum
- Good bonding of PCBs with each other
  - Ground planes conduct to aluminum spacers
- Isolation of PCBs from structure
  - Conduction: Delrin with “long path” from PCBs to structure
  - Radiation: One-layer insulation on backside of +/-Z solar panels
- Assist documenting of thermal inputs and results

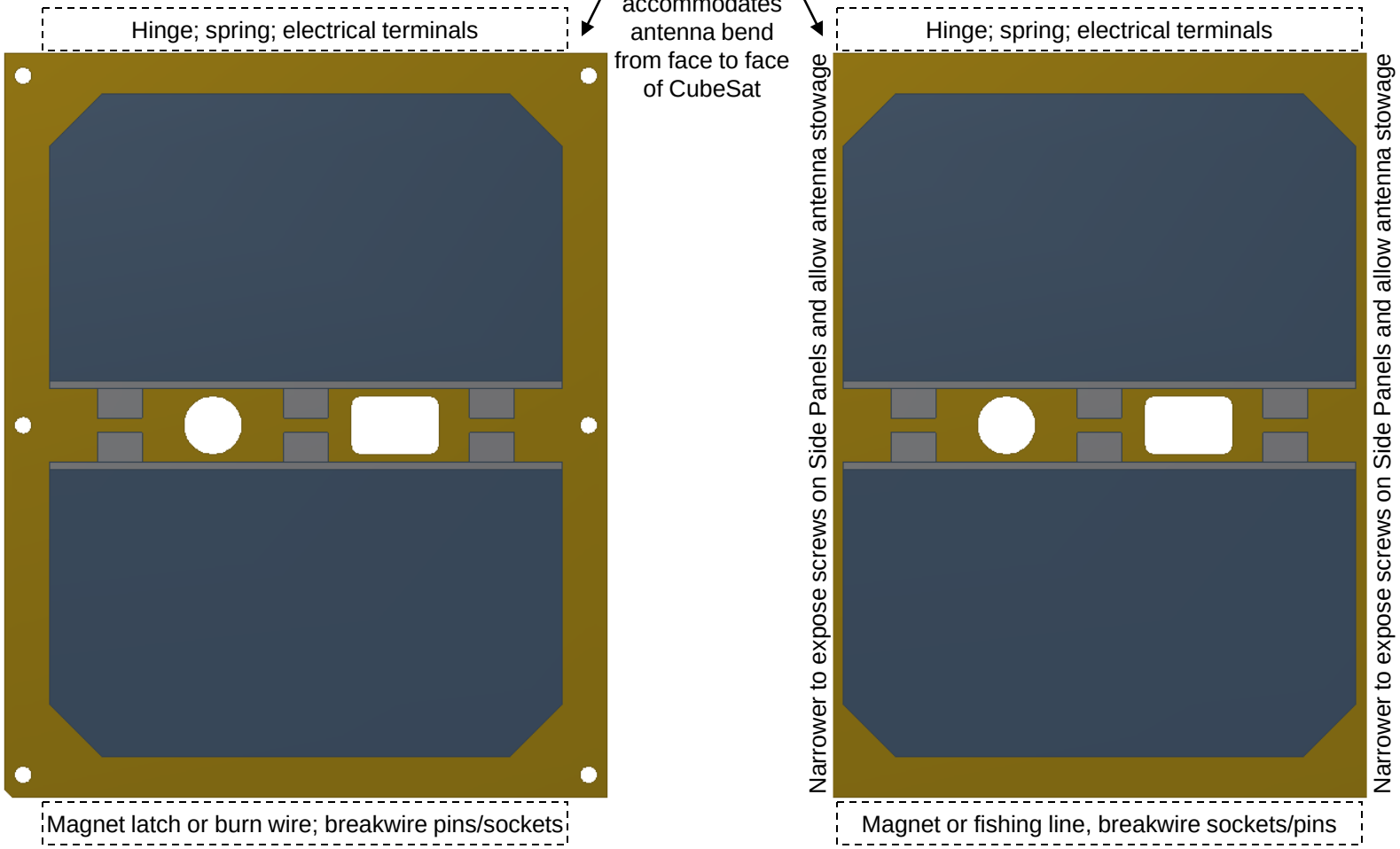
Antennas

- Whips from +/-Z faces (// spin axis)
- Possible torsion spring hinges
- Magnetic capture, or burn wire
- Possible breakwire stow status

Fox 2 Deployable Solar Panels

Side Panel mods should be incorporated in Fox 1

Deployable Panels have cells both sides



Prelim checks with Cal Poly

- Provided drawing of interpretation of envelope
  - Cal Poly agreed proper interpretation
  - Recommended backing away from envelope on faces toward other CubeSats. Built-in gap is only 0.5 mm.

    "*How much do you trust your neighbor?*"
- Discussed sheetmetal plan
  - Not using 7075 or 6061 requires Waiver
  - Precedence for 5052-H32 (Pumpkin's CubeSat Kit)
  - Waiver approval likely
- Provided CAD model screen capture of bent walls
  - Further discussion on tolerances and Rail contact area
  - Some suggestions but current plan OK

Prelim checks with NASA

- Conversation about sheetmetal plan
  - Will not impose 7075 or 6061 requirement from CDS
  - Will impose NASA requirements for materials
    - Dissimilar metals
    - Stress corrosion cracking
    - Fracture control
    - Strengths used in analysis
  - Mr. Skrobot will ask materials group to comment on our compliance
    - I provided statement on 5052-H32 concerning each NASA requirements doc

Plans for 2012

- Early retirement of risk items
  - Sheetmetal bend tolerance
  - Stowed antenna within envelope
- Prototype as necessary
  - Bent sheetmetal walls
  - Delrin blocks for PCB Stack
  - Antenna stowage/deployment
- Complete design of Fox 1
- At least preliminary design of Fox 2 addition of deployable solar panels (to maximize commonality between Side Solar Panels between Fox 1 & 2)
- Build four Fox 1
  - but initially only two receive expensive solar cells