AMSAT-NA FOX-1 Satellite

BURNS FISHER, W2BFJ

AMSAT FOX FLIGHT SOFTWARE CO-LEADER

BEFORE WE START:

The Elephant In The Room -- ITAR

International Traffic in Arms Regulations

- Complex – Here is the short version
  - Satellites are "armaments"
  - Satellite makers can only talk to "US Persons" about details which have not been openly published.
  - "Published" means literally printed and distributed on paper
- No desire to keep things secret!
  - Penalties!
  - Please understand why I'm careful

Getting into Orbit

ALWAYS LOOKING FOR A FREE RIDE

In The Beginning

- Extra space/weight available on an LV (Oscar-1)
- First launch of a new LV (P3A – Obvious problem here)
- Government help (VO-52; maybe future Qatar GEO comsat)
- Collaboration to fill a need (ARISSat)
  - These generally involve cutting a deal of some sort and ALL require friends in high places
- Hosted Payloads (future Qatar comsat)
  - $$$

Small Satellites “too successful”

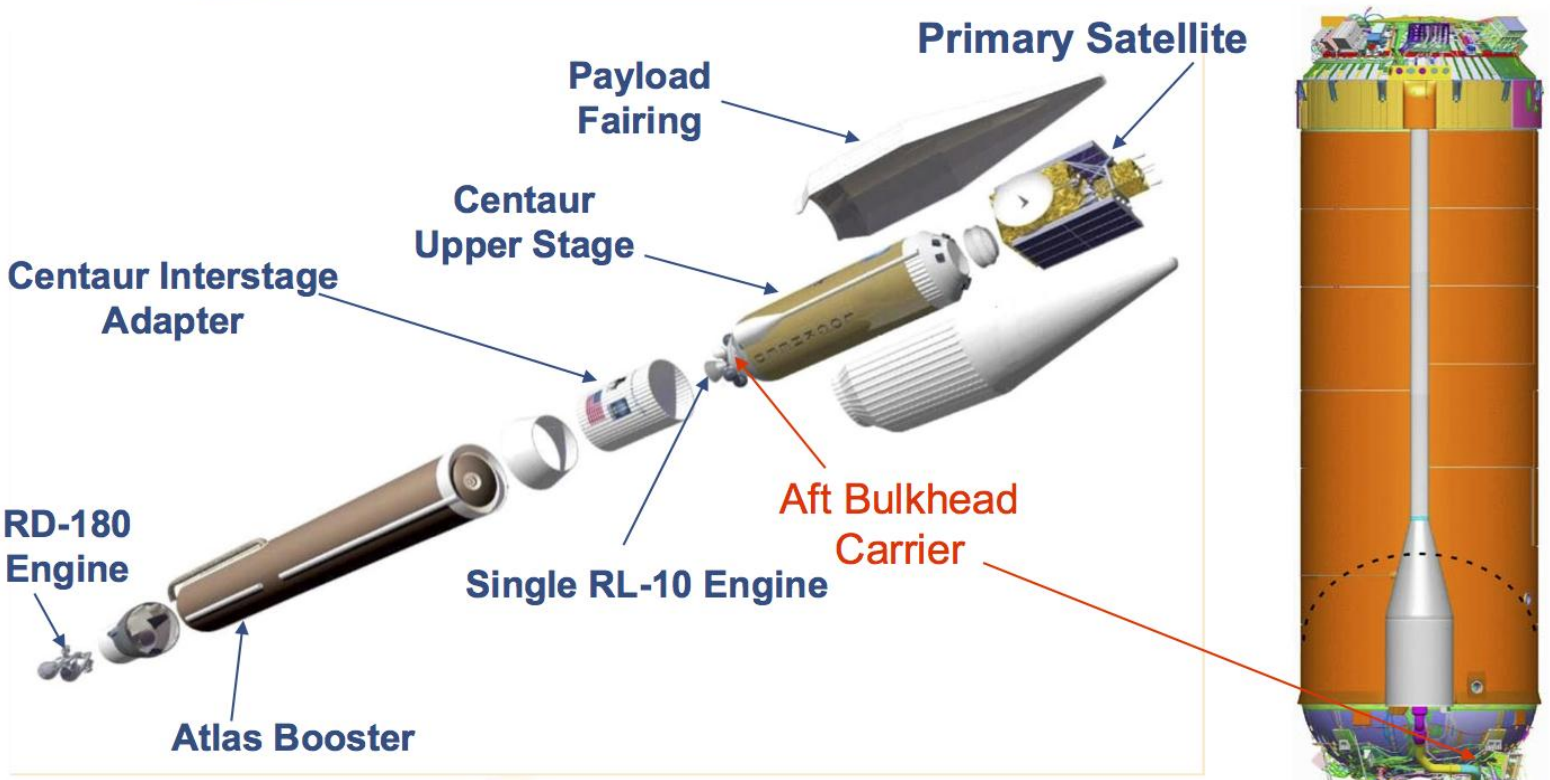
- Lots of competition for “extra space” rides
- Even new LV launches can be sold
- ARISSat and payload opportunities infrequent
- Hosted payload new concept and probably expensive

Cubesats

- Cubesats are a standard way to get extra-space rides
- Most LVs have a place to attach “P-PODS”
- Little burden on launch partner
- Inexpensive (as launches go)

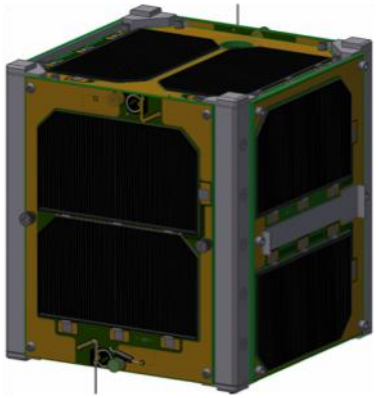
Where do they go?

Atlas V with Aft Bulkhead Carrier



Fox Development Strategy

- Take advantage of large and growing interest in CubeSats
- Develop family of CubeSats with ham radio transponders that are attractive for hosting science experiments
- Partner with universities to develop joint science and education missions
- Get grants for free launch
  - Based on carrying science and STEM payloads
  - Example: NASA ELaNa program



The Fox Satellite Series

Let's Bend Metal!

General Satellite Difficulties

- Radiation
  - “Hardened” parts are expensive
  - COTS parts can be sensitive
- Vacuum
  - Everything you know about heat is wrong
  - We only have conduction and radiation! No convection.
    - Home freezer testing does not work
- Power
  - Small area for solar panels
  - Eclipse every orbit
  - Small size and mass for batteries

Cubesat Difficulties

- Popular – Universities, NASA, even military
  - Price goes up!
- AMSAT-NA has no previous experience
- Tiny – Tight design
- Tiny – Little power (1 W or so)
- Tiny – Less tweaking for temperature control

Fox-1: AMSAT-NA's First CubeSat

- Smallest satellite previously built by AMSAT-NA was a 25 cm (approximately 10 inch) cube
- Fox-1 is10 cm (approximately 4 inches) per side
  - Miniaturization level not attempted before by AMSAT-NA
  - Coaxing maximum power from limited solar panel area
  - New heat challenges
- Success gives us CubeSat design heritage and puts AMSAT-NA back in space
  - Success proves our worth to additional experiment and grant partners

Fox -1 CubeSat

Size: 1U

Mass: 1.33 kg

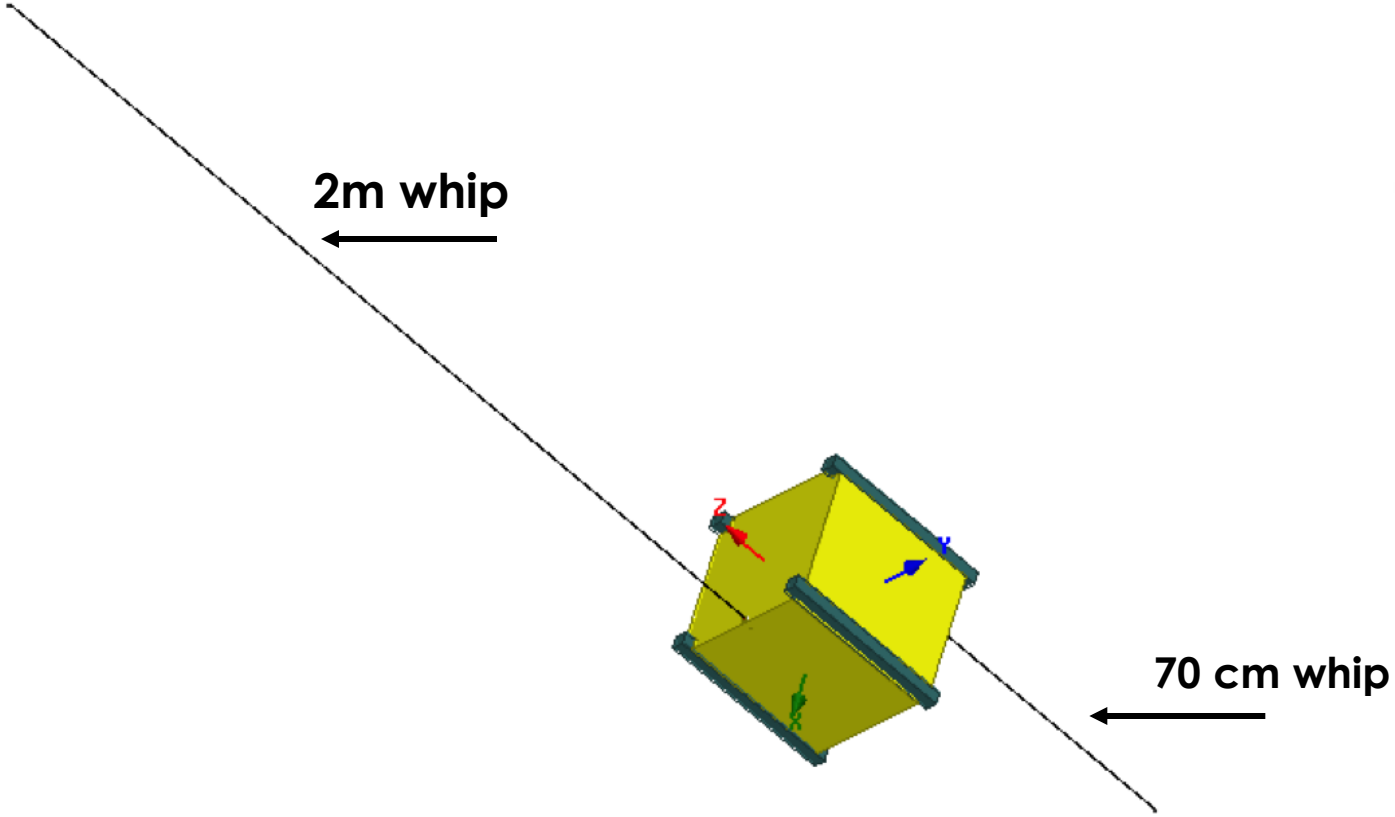
RF Power: 800 mW max

- **Mission Description: *To inspire, engage and educate the next generation***
- Two-way FM communications transponder
- MEMS Gyro Experiment (Penn State)
- Low Energy Proton Experiment (Vanderbilt)
- JPEG Camera (Virginia Tech)

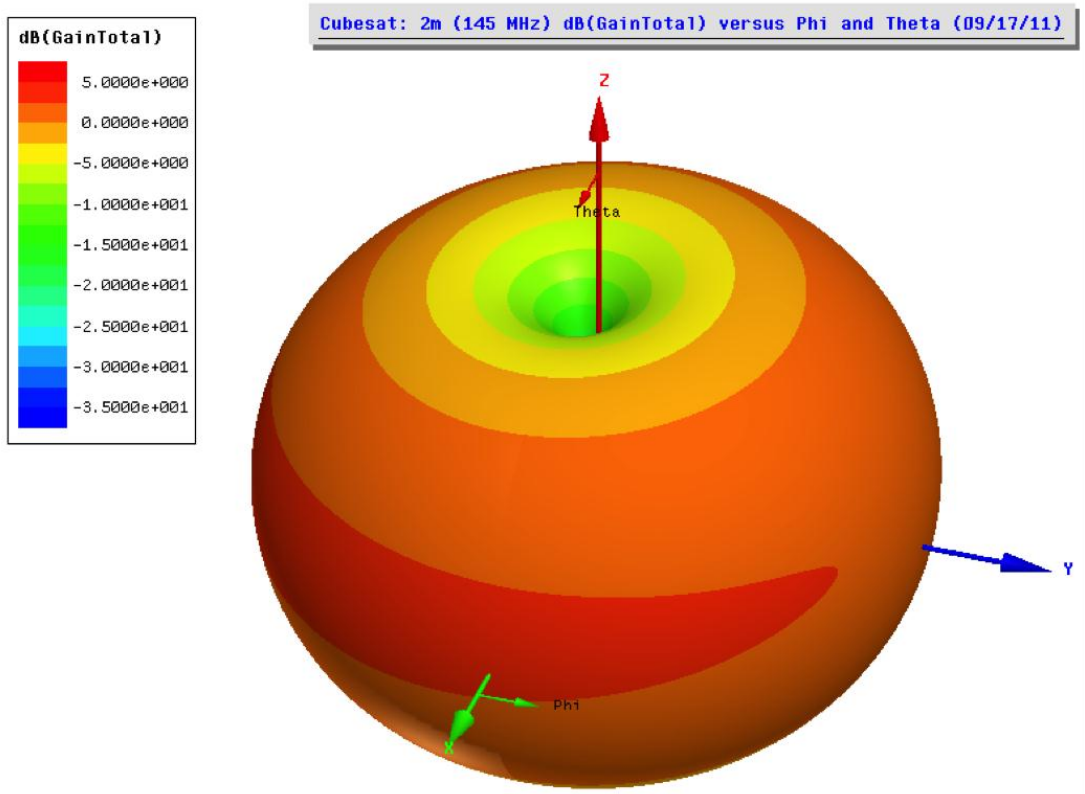
Fox-1 Dates!

- **Launch 2015 on ELaNa XII**
  - **NRO "GRACE" mission – our original manifest**
  - Planned orbit is 470 km x 780 km @ 64 degrees inclination
  - Expected orbit lifetime is 11 years
- But that means---
  - Complete by November 2014!
  - That means build, test, shake, test, heat, test etc etc.

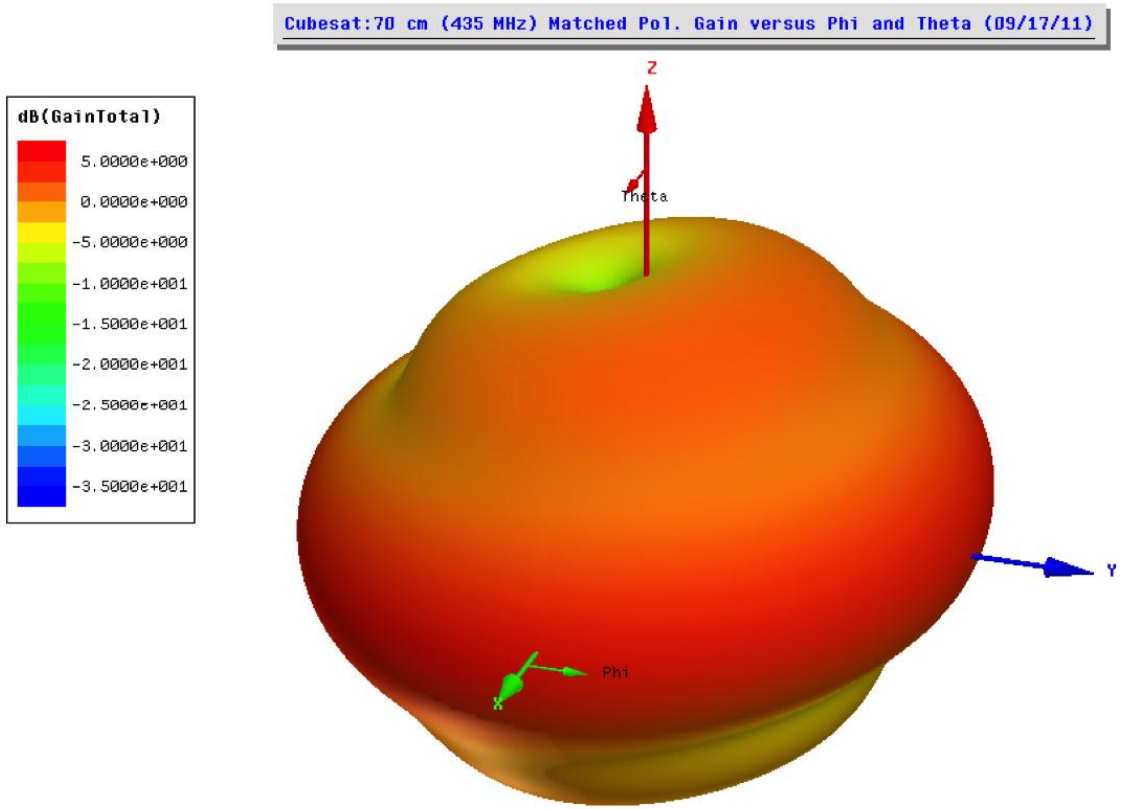
Antennas



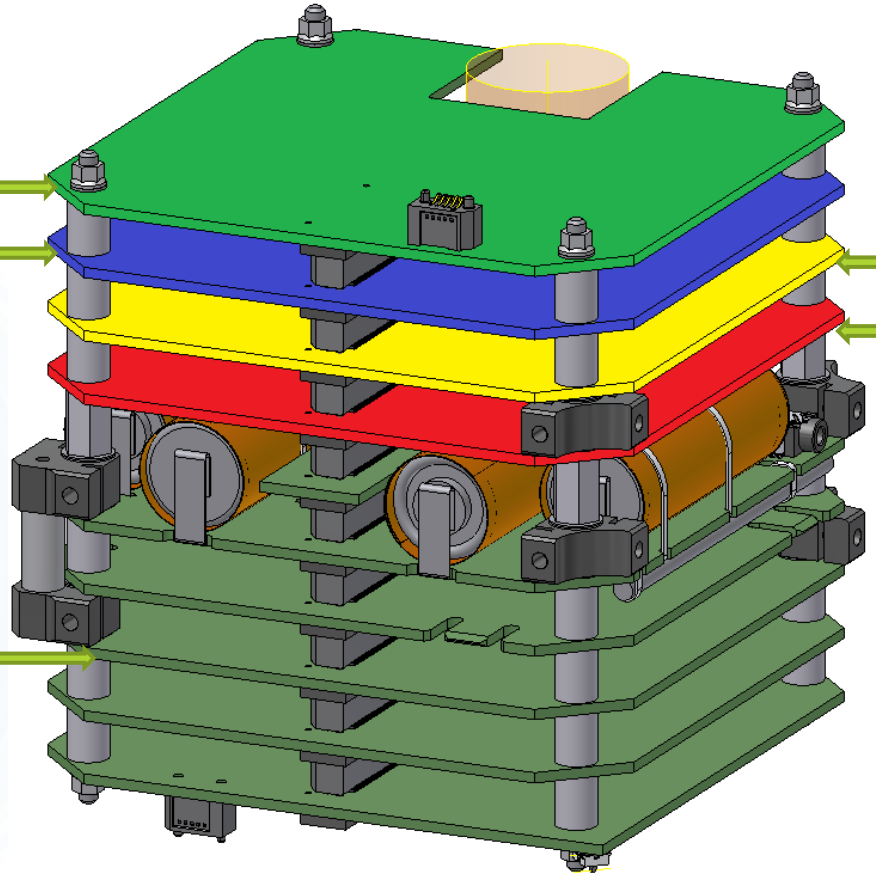
2M (Downlink) Antenna Pattern



70cm (Uplink) Antenna Pattern



University Experiment Payloads on Fox-1

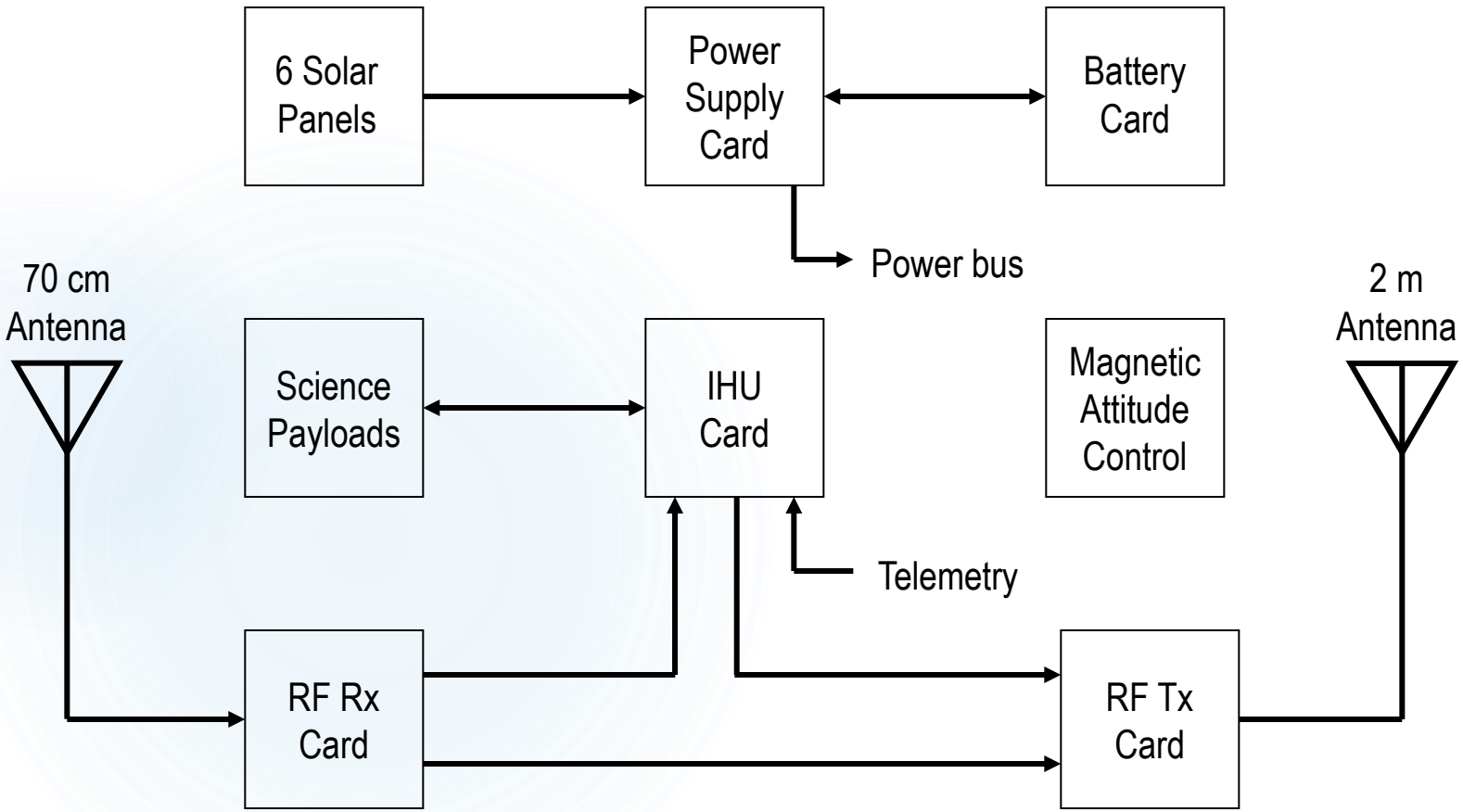


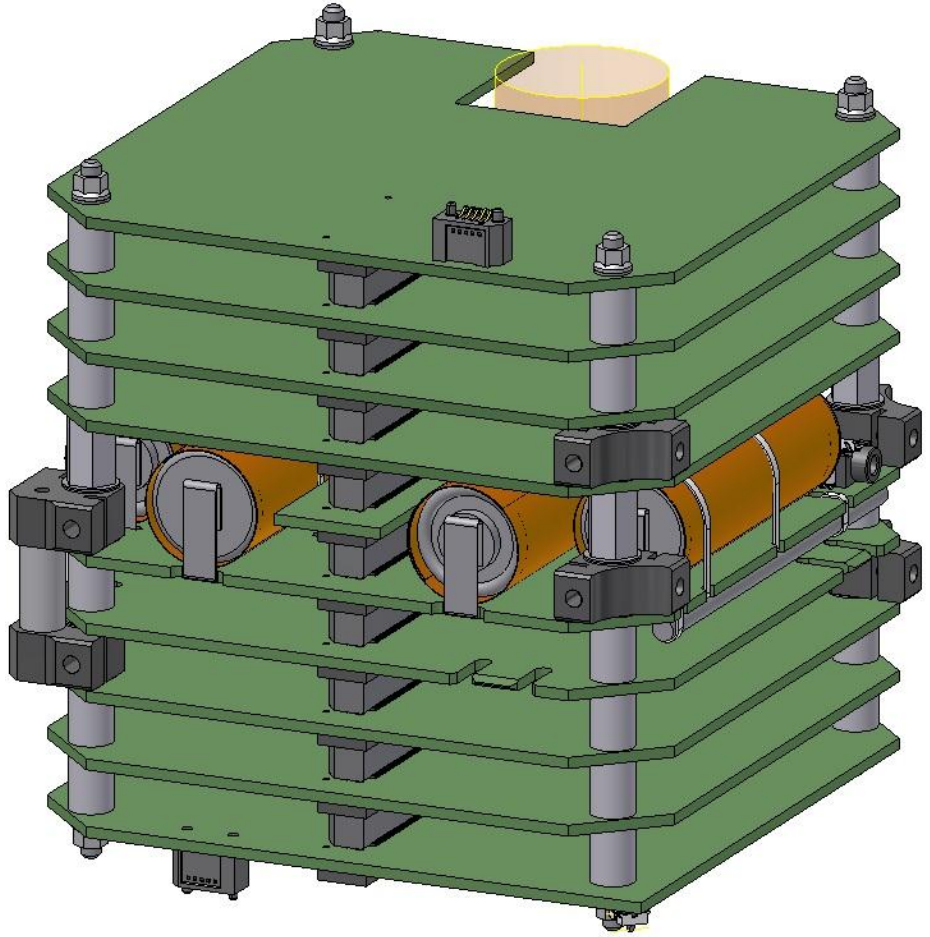
Virginia Tech "EXP4"
Filler/Lens Hole
VT Camera

Penn State - Erie
MEMS Gyros
(on IHU board)

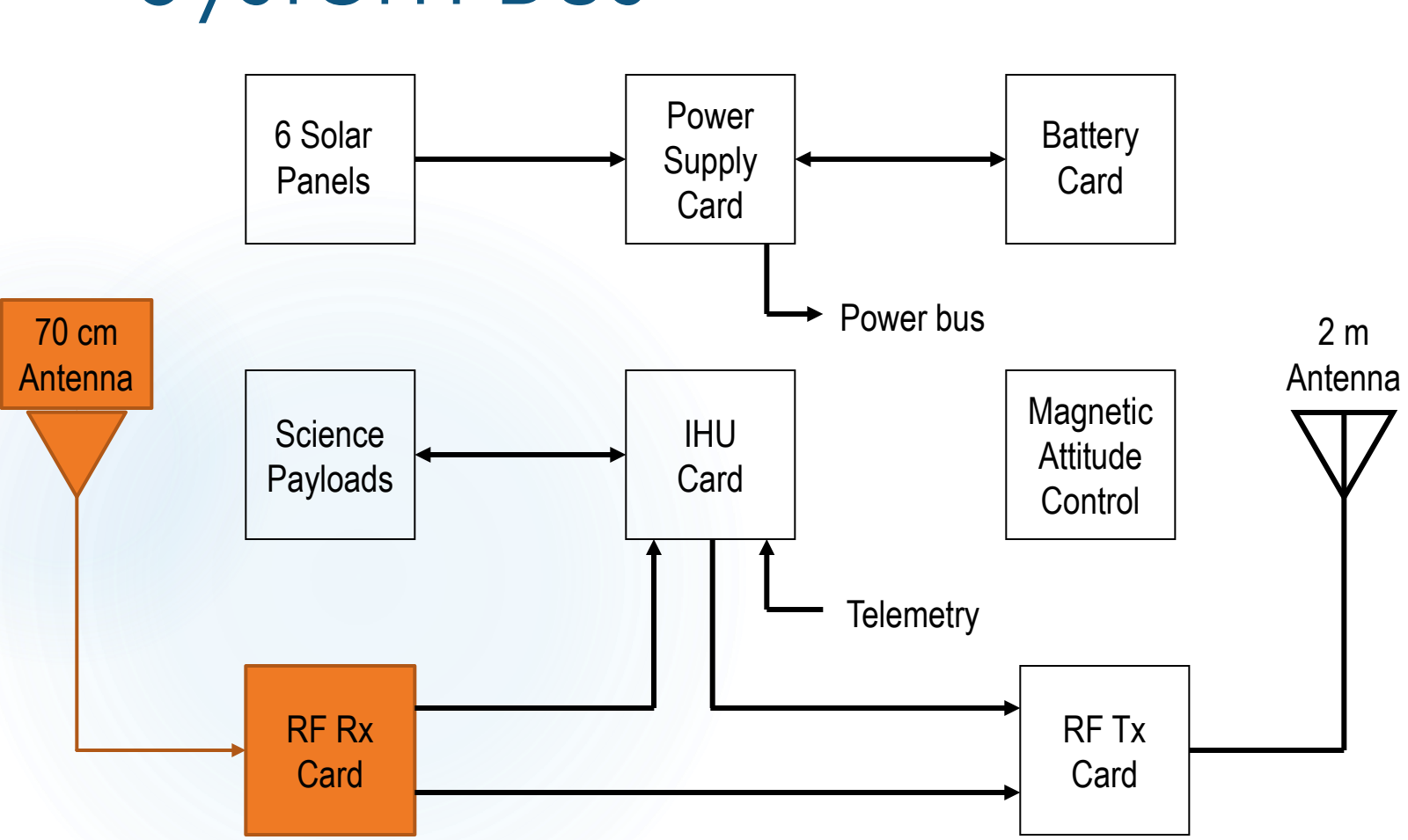
Vanderbilt "EXP1"
Vanderbilt Sensors
Vanderbilt Controller

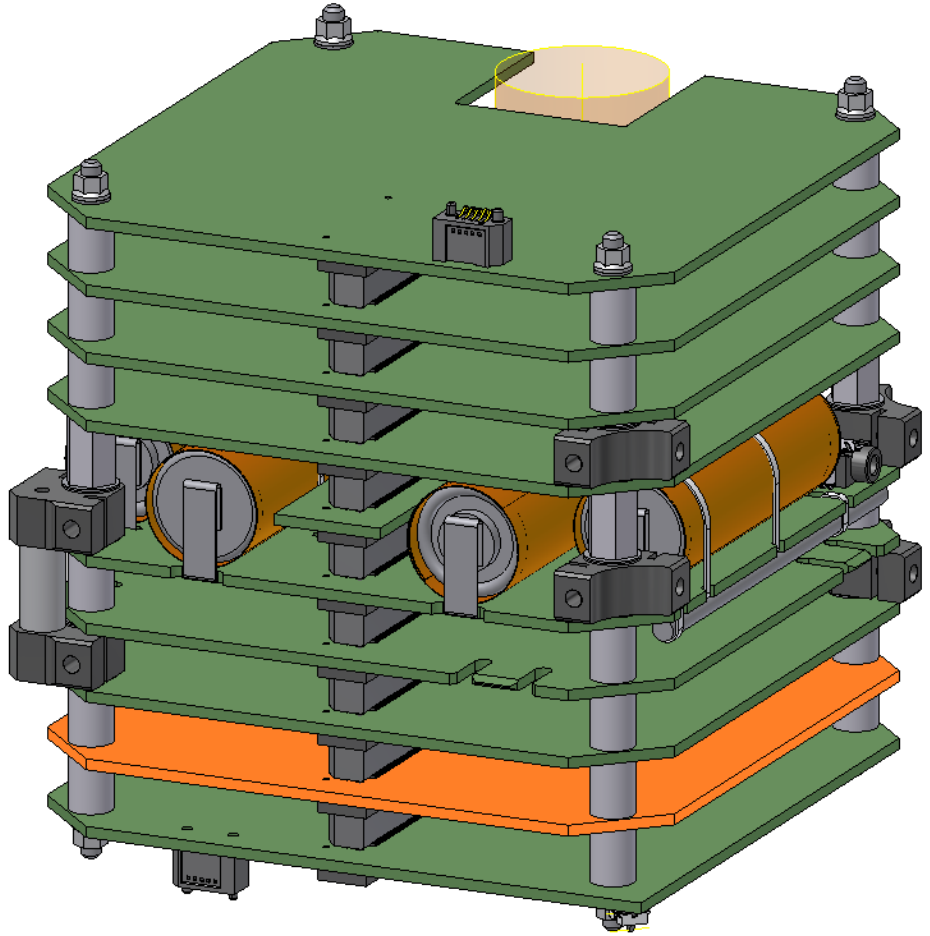
Fox-1 Block Diagram and Avionics System Bus





Fox-1 Block Diagram and Avionics System Bus





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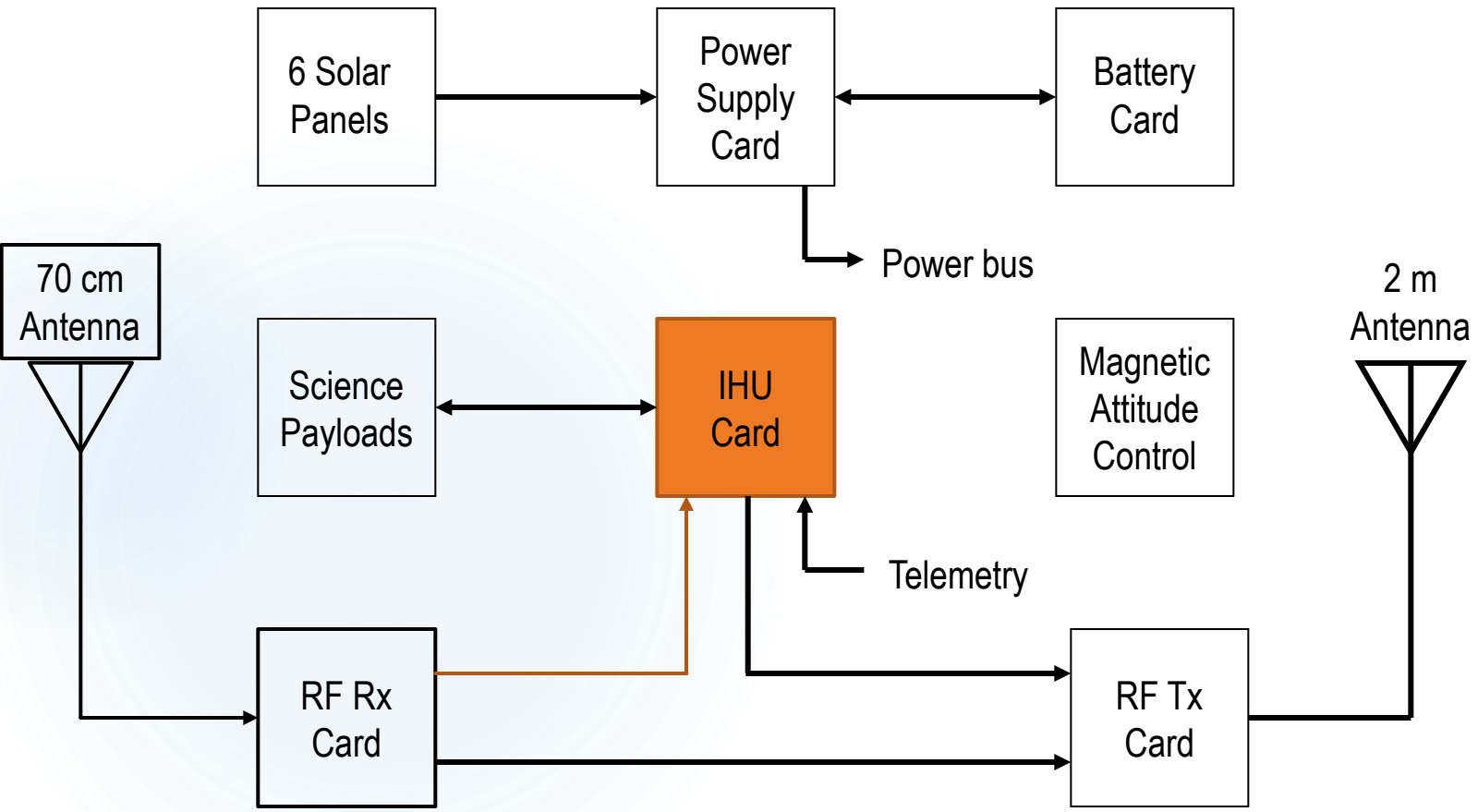

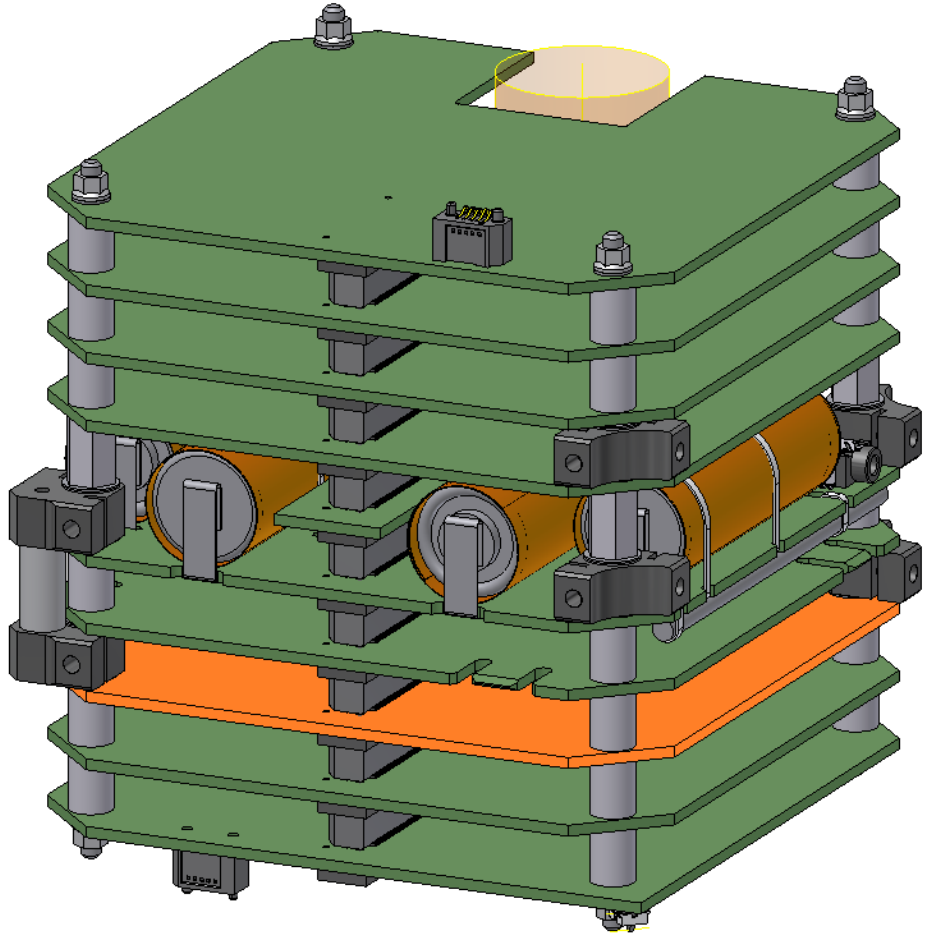

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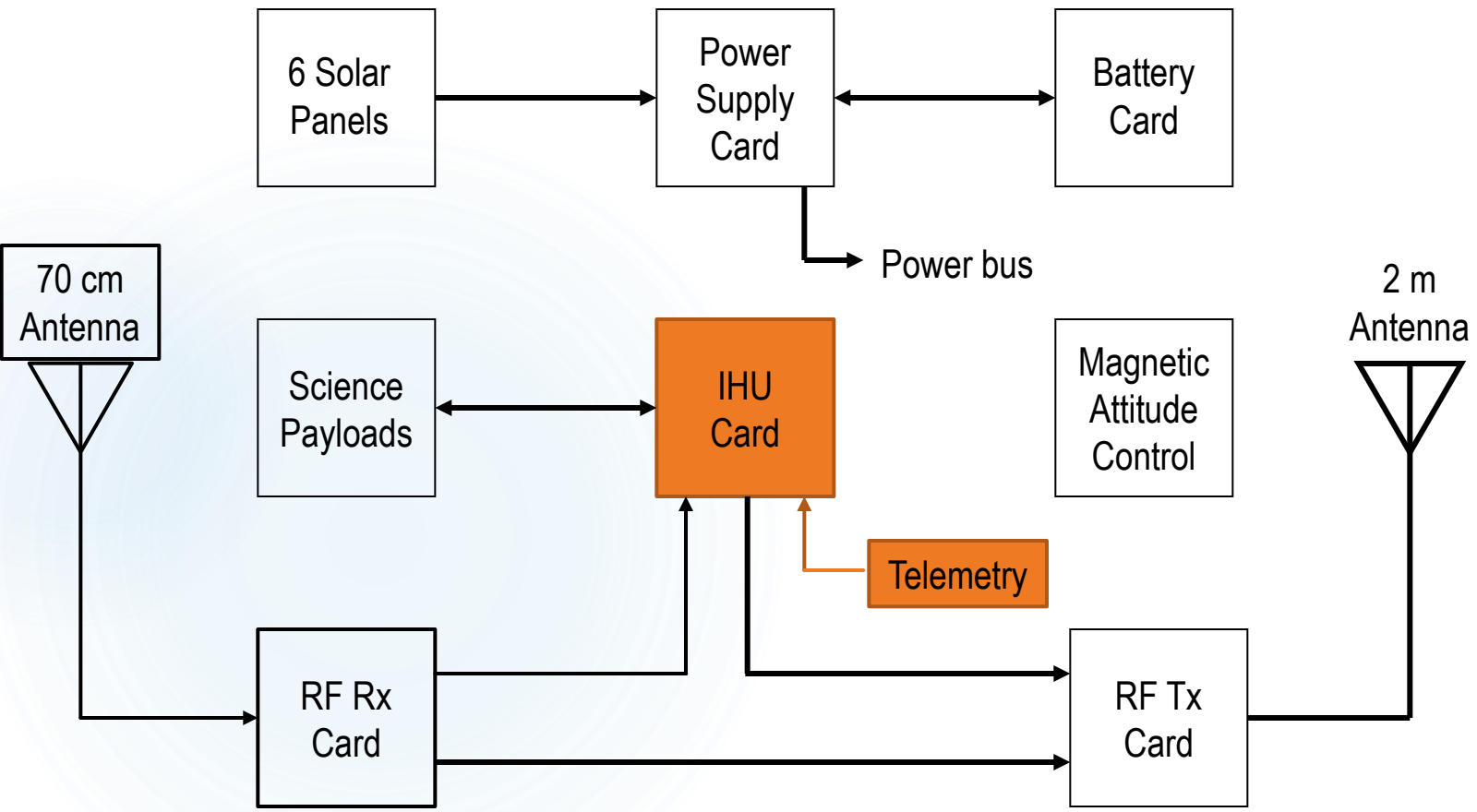

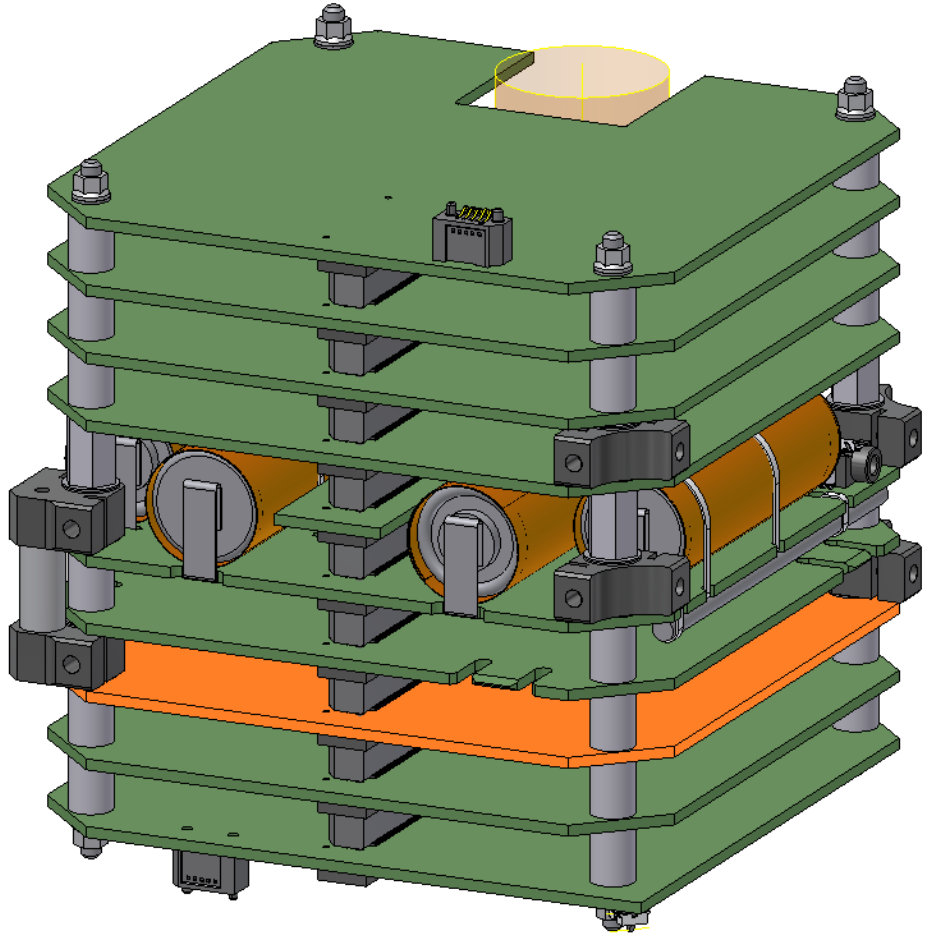

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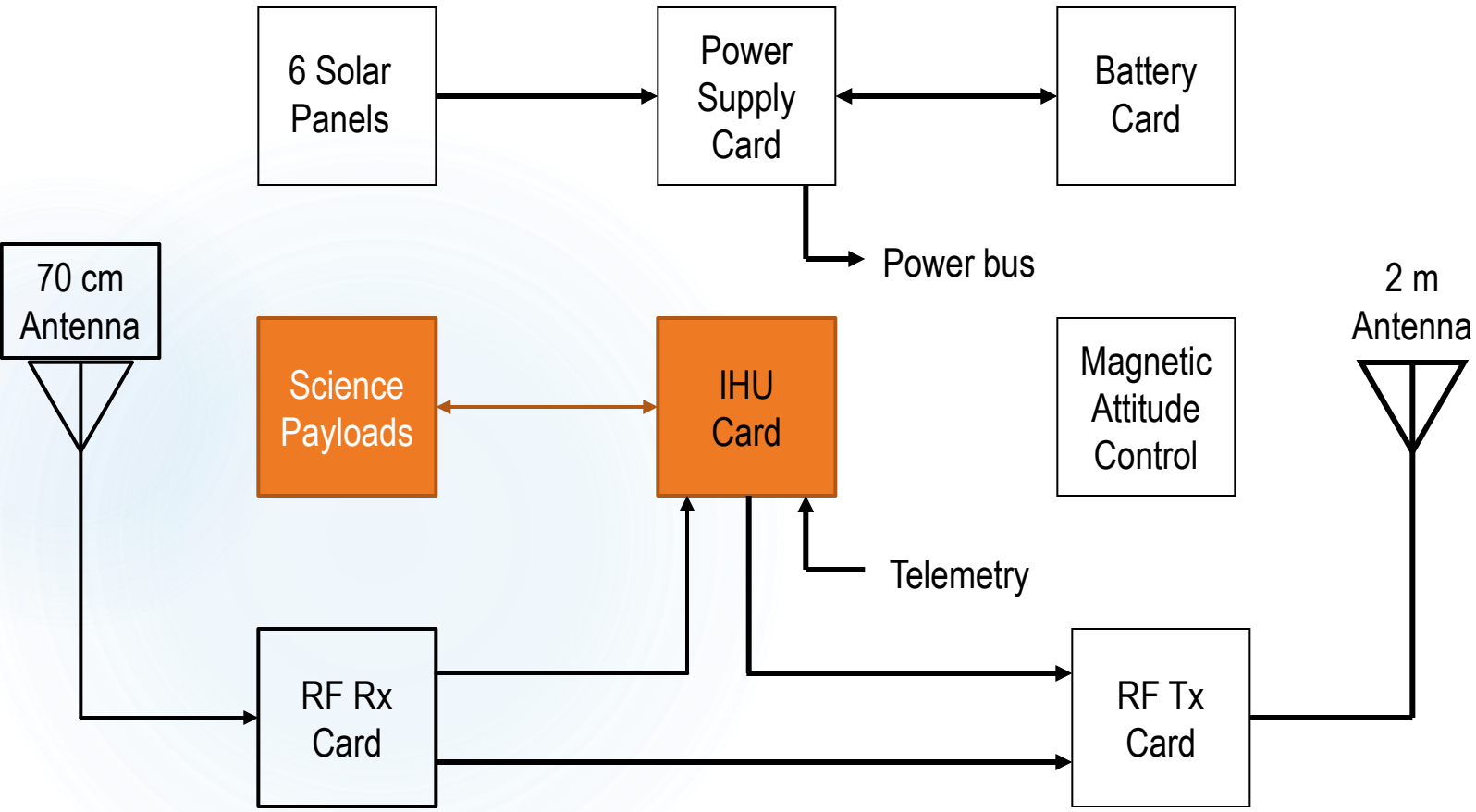

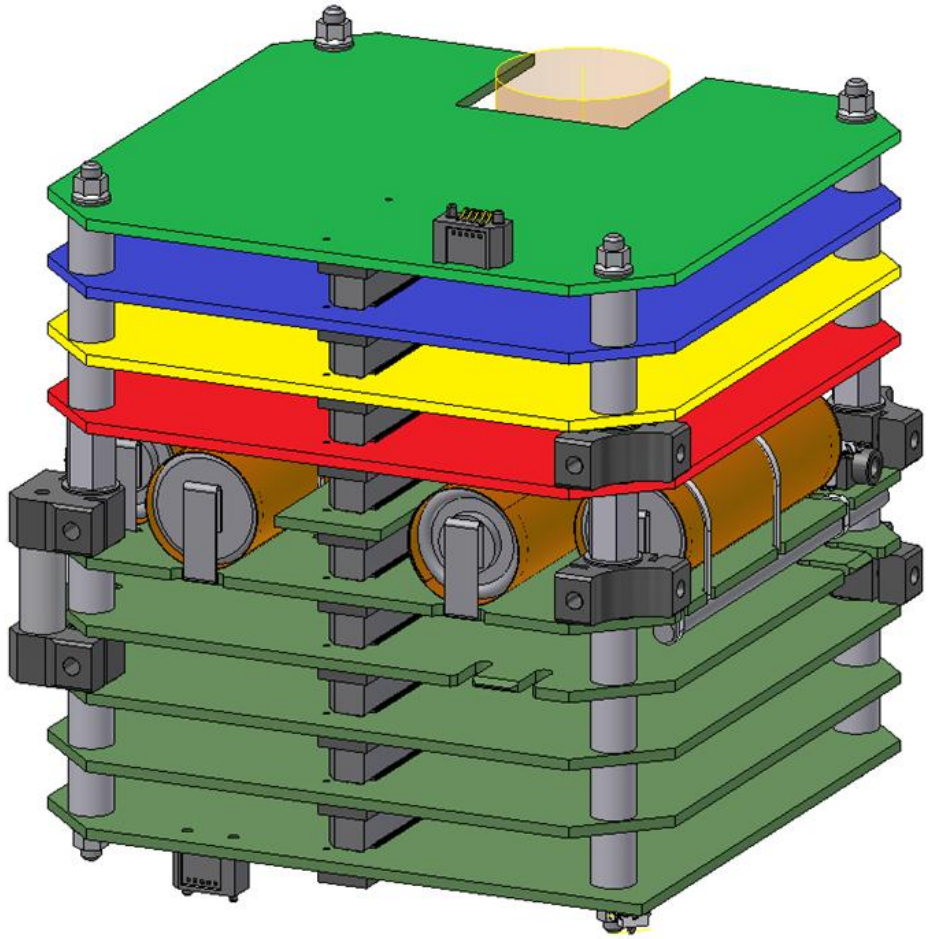

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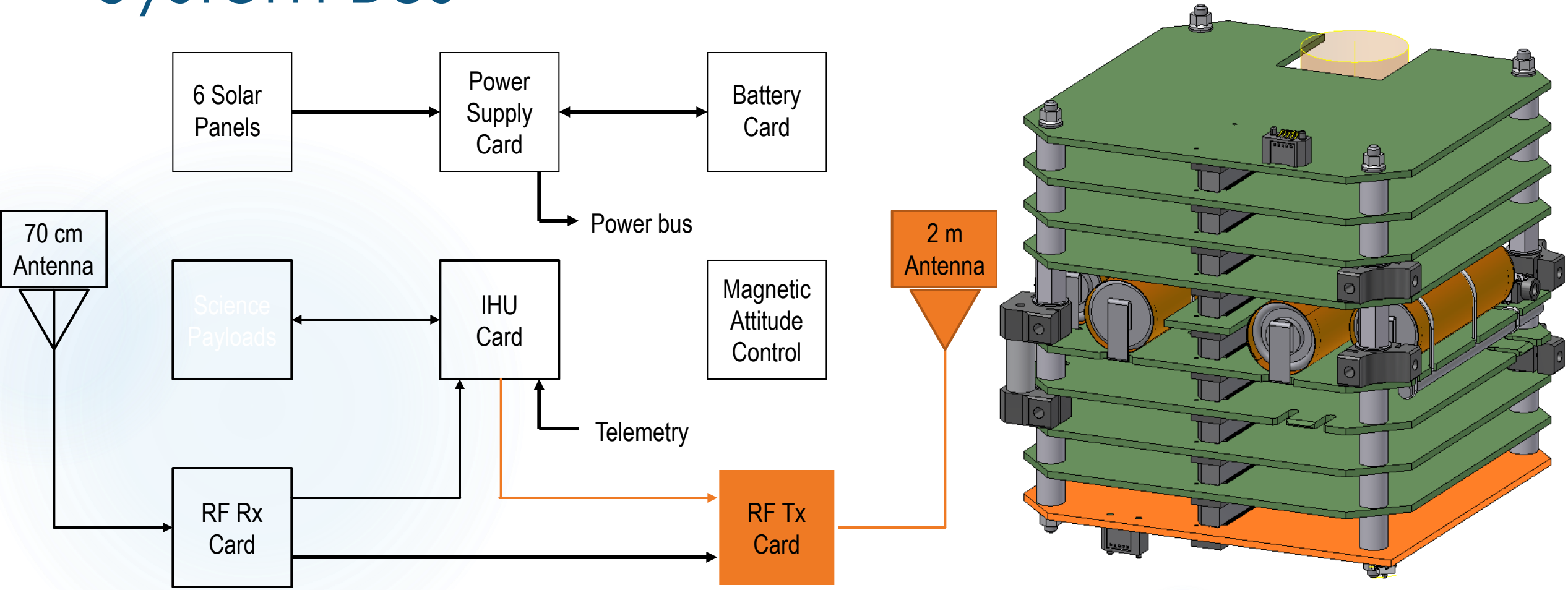
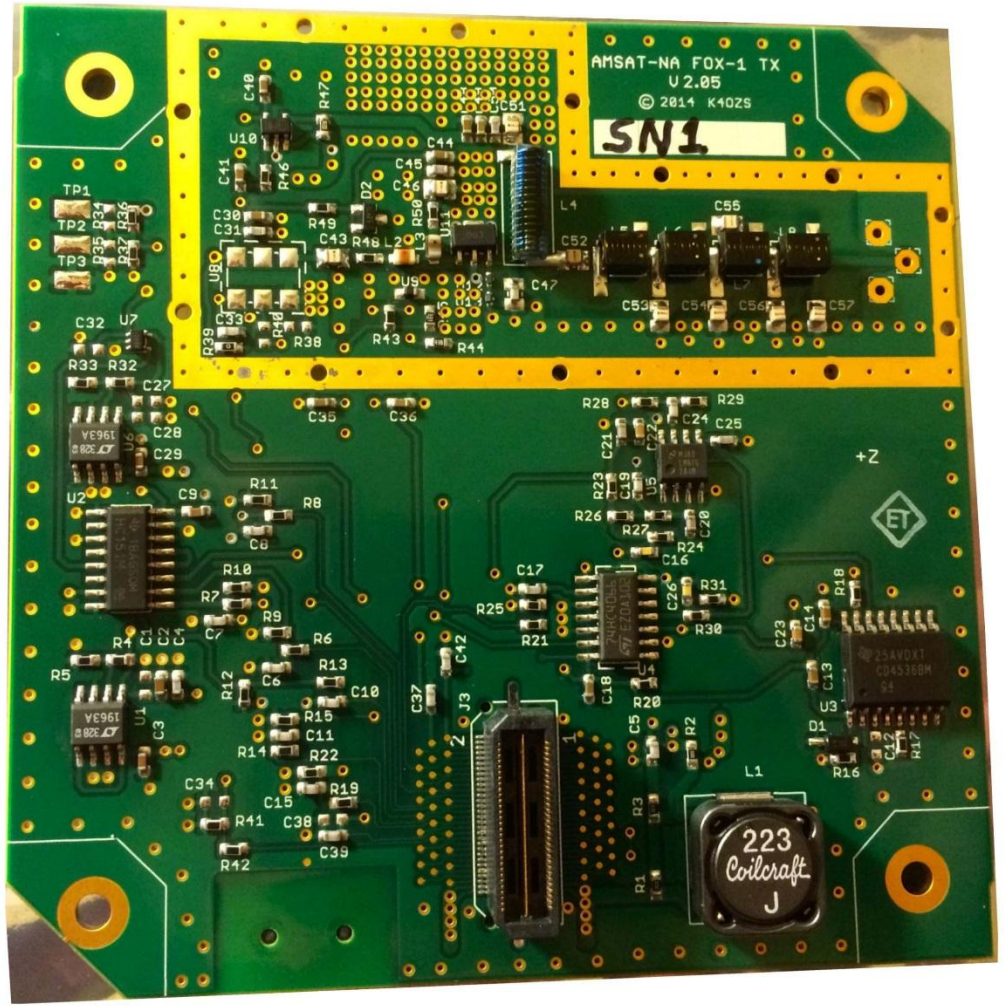


RF Transmitter System

Engineering Model shown w/o shield



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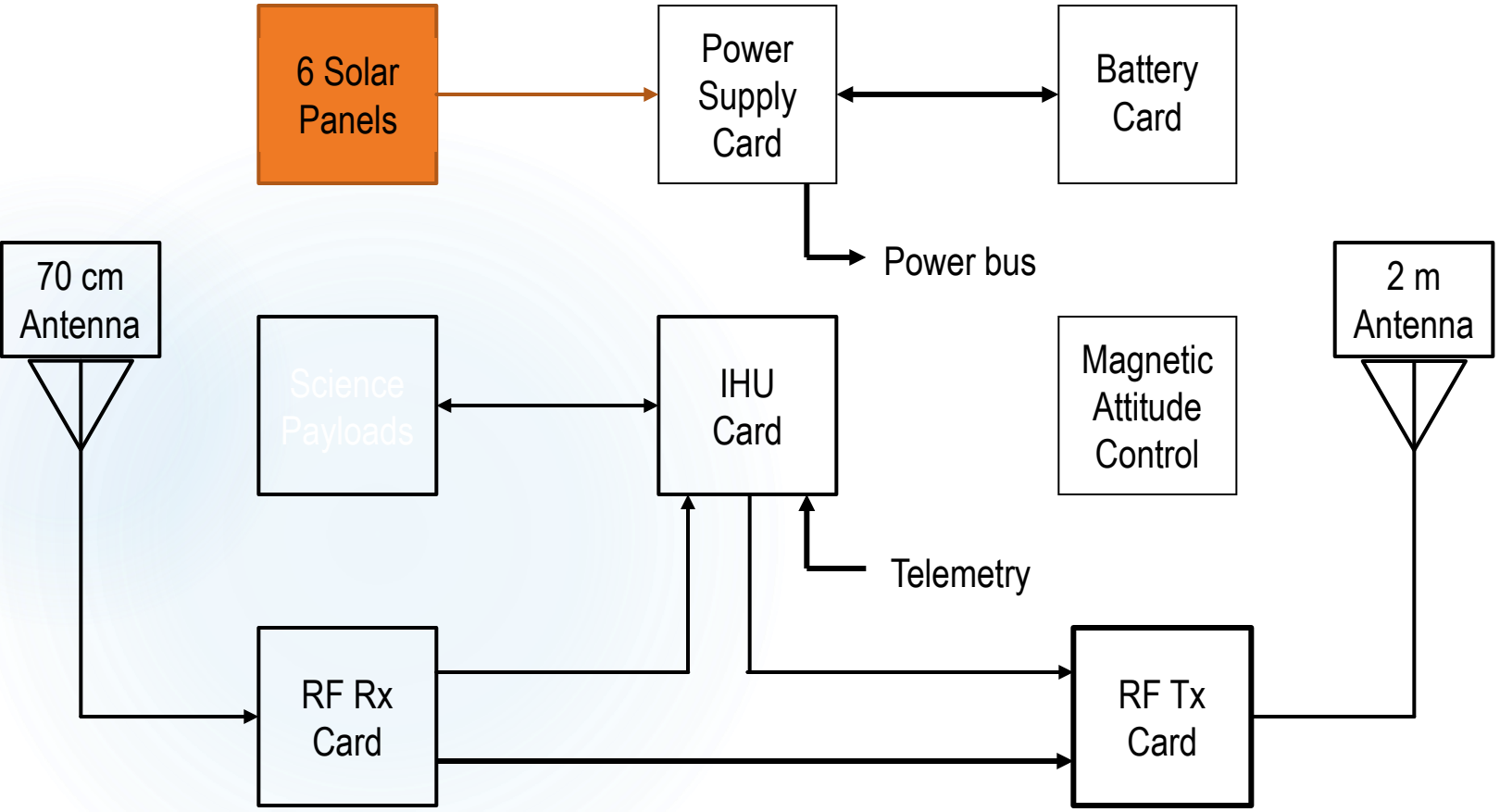

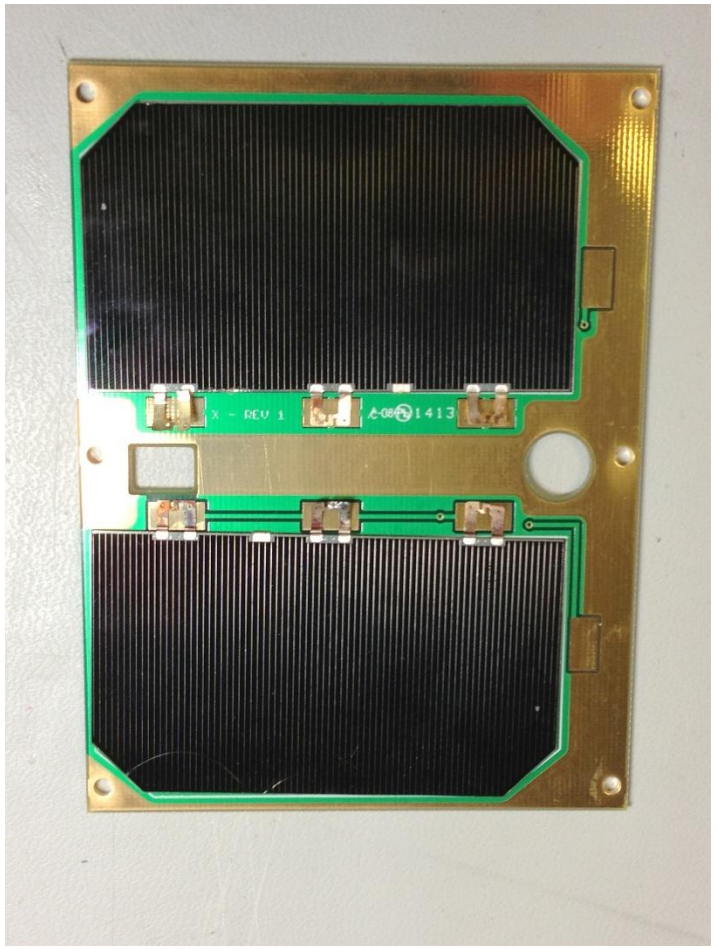

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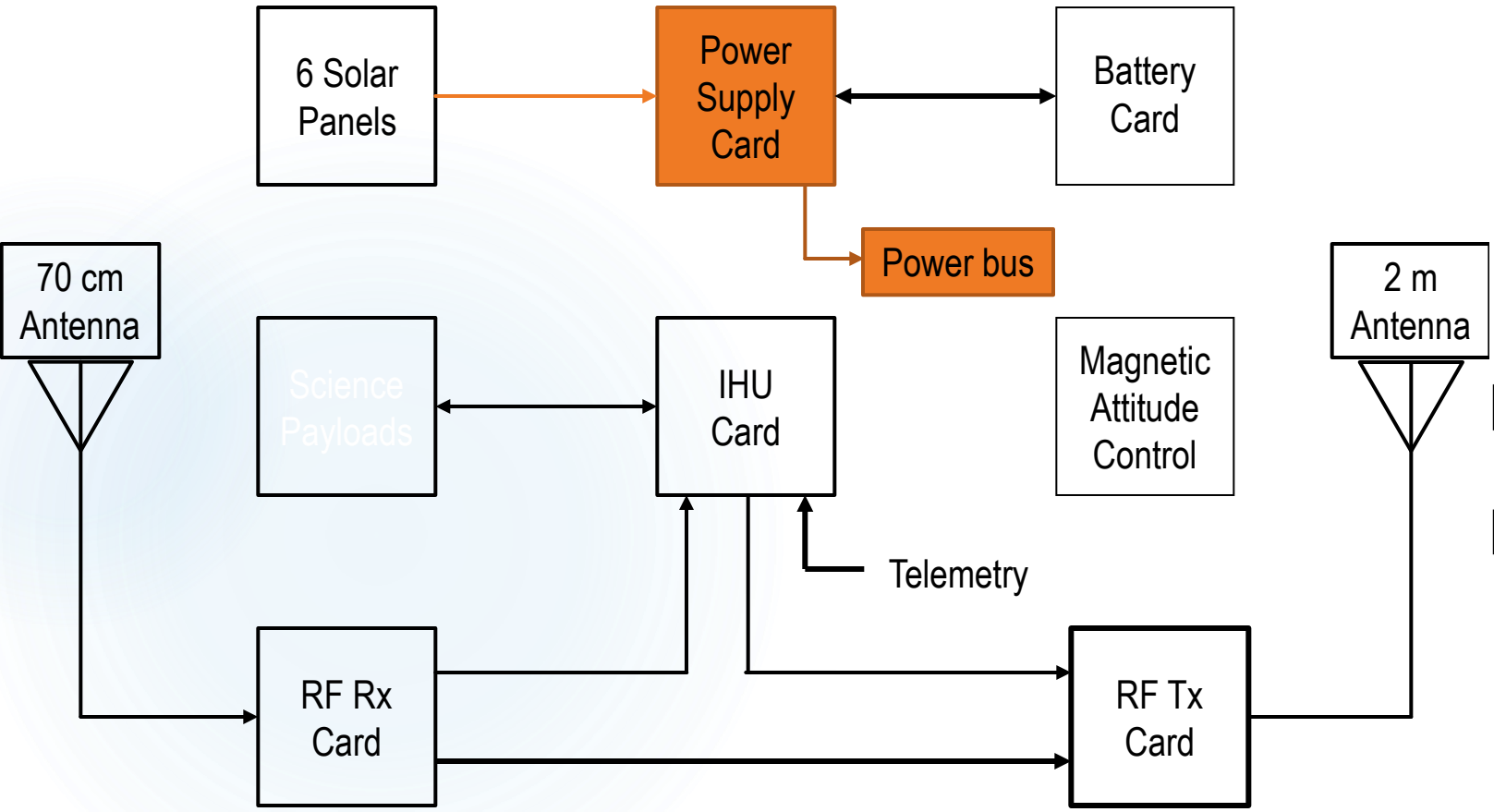
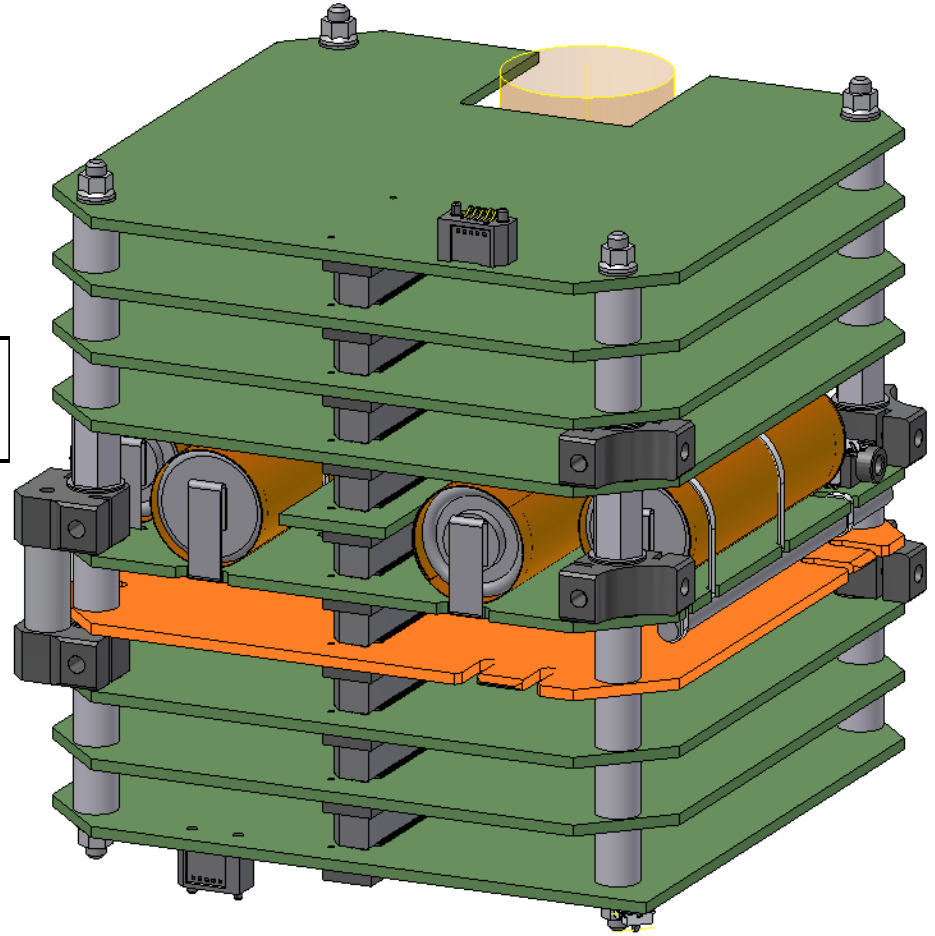
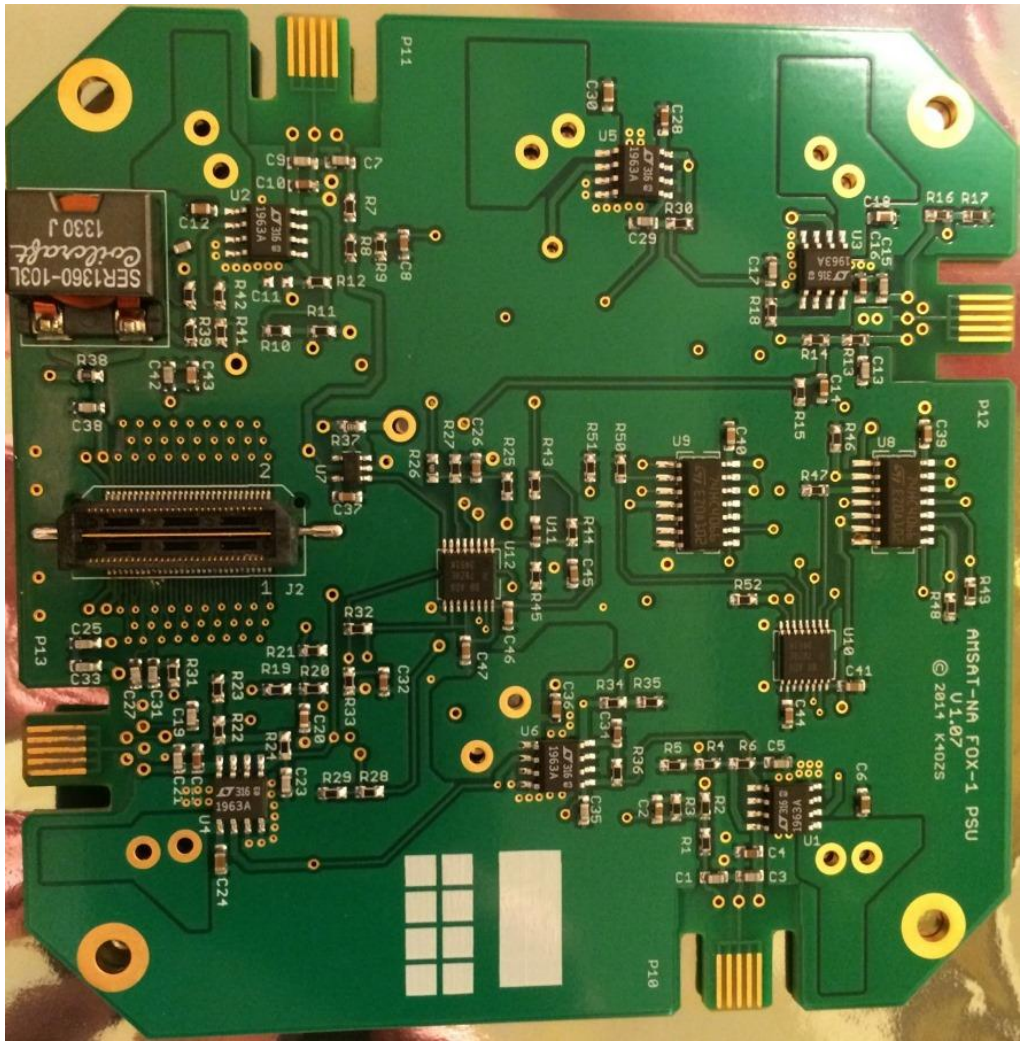




Power Supply System

Engineering Model



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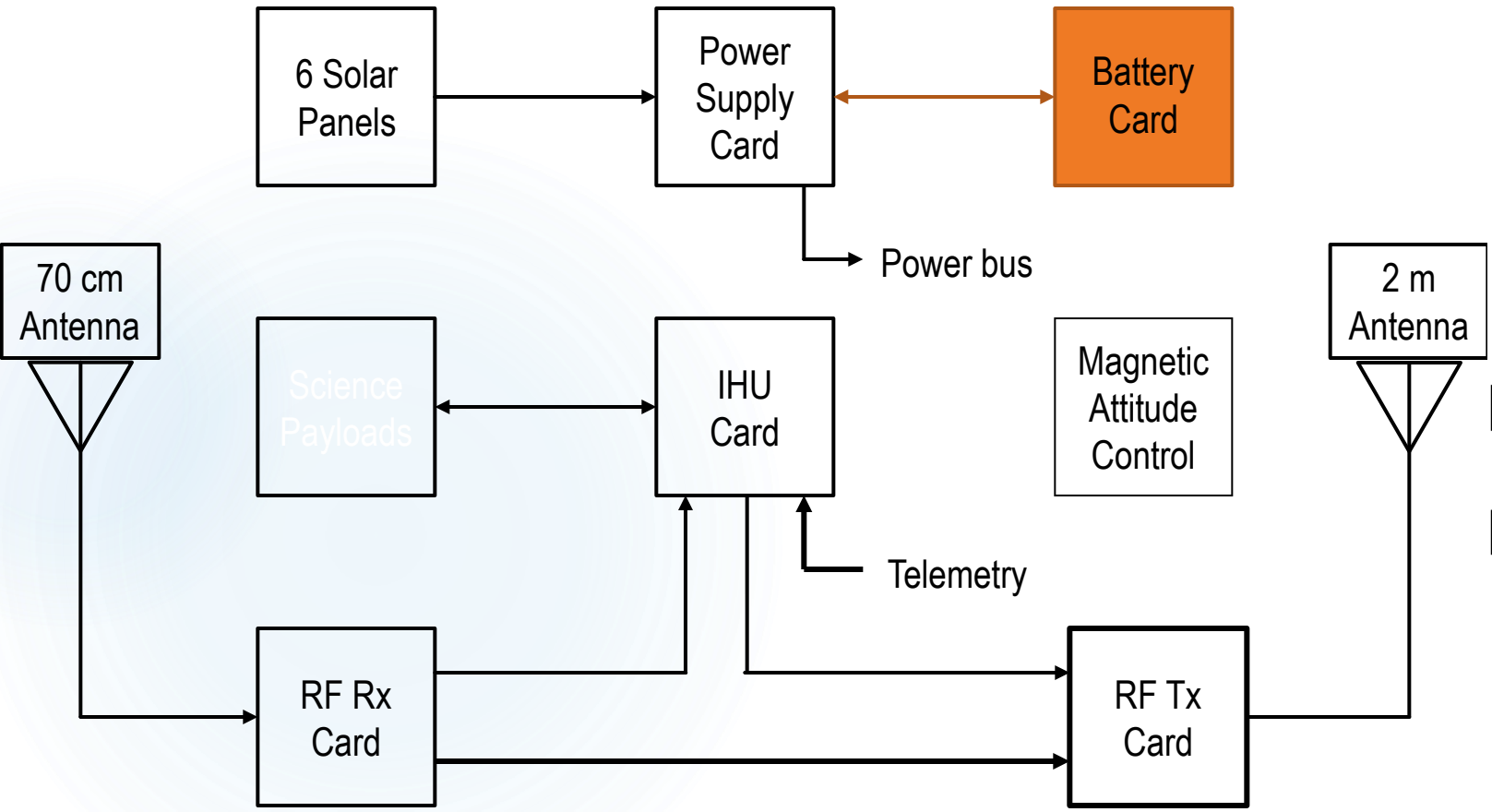
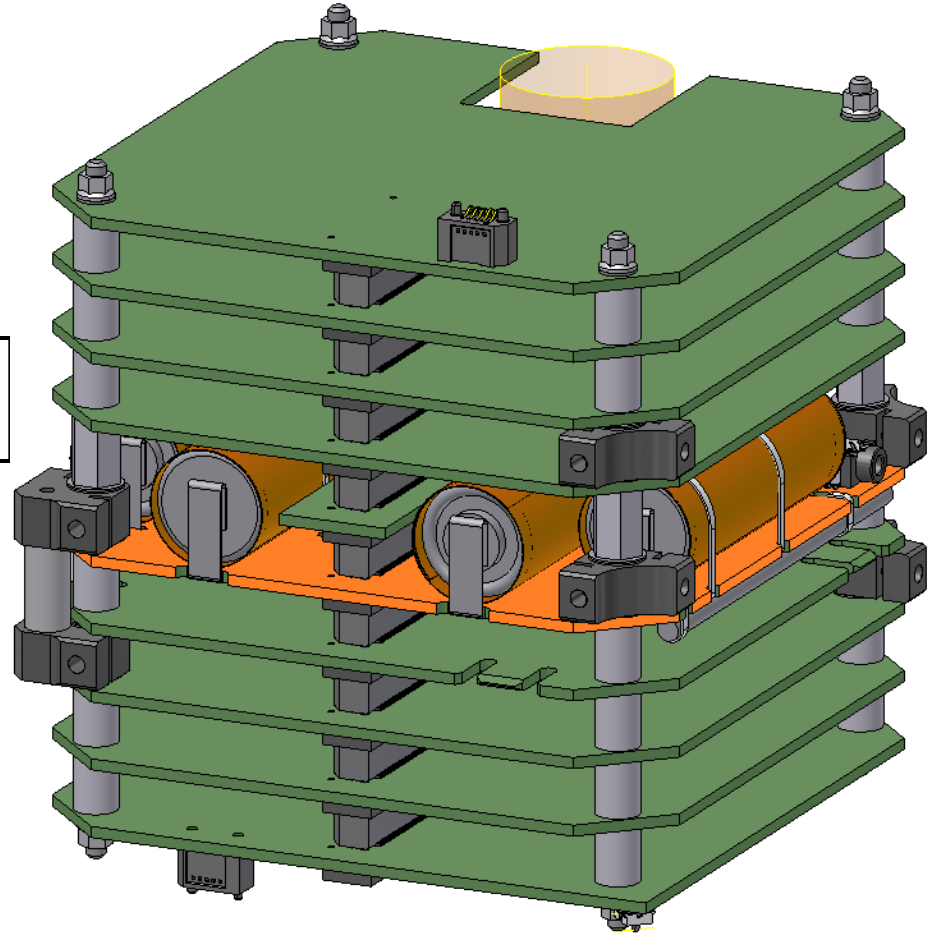
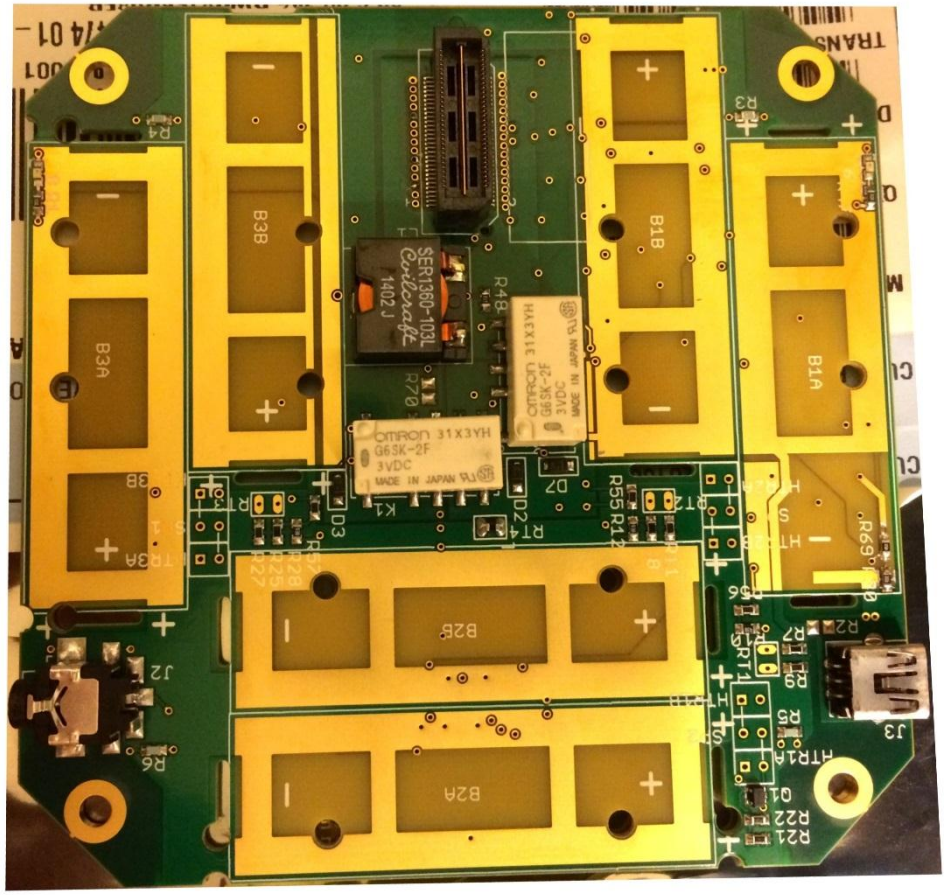




Battery System

Engineering Model w/o batteries



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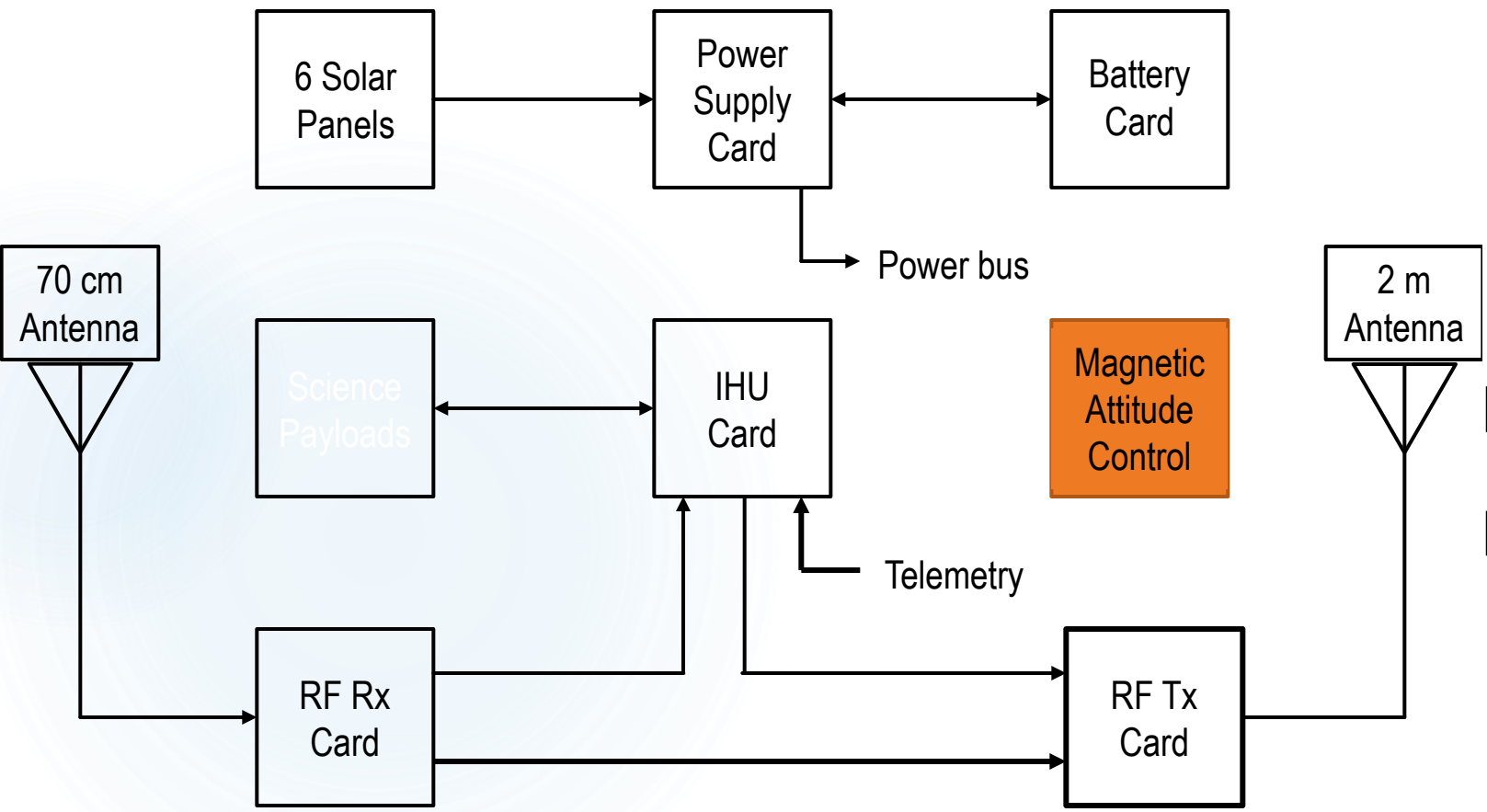

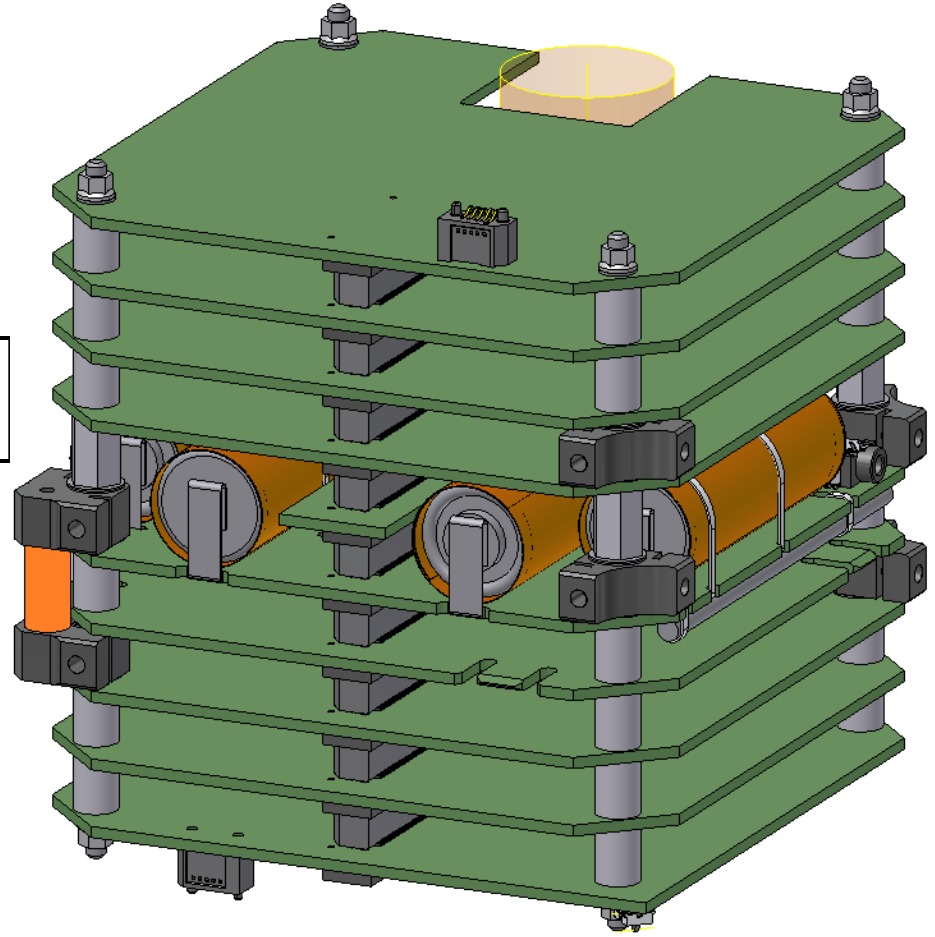

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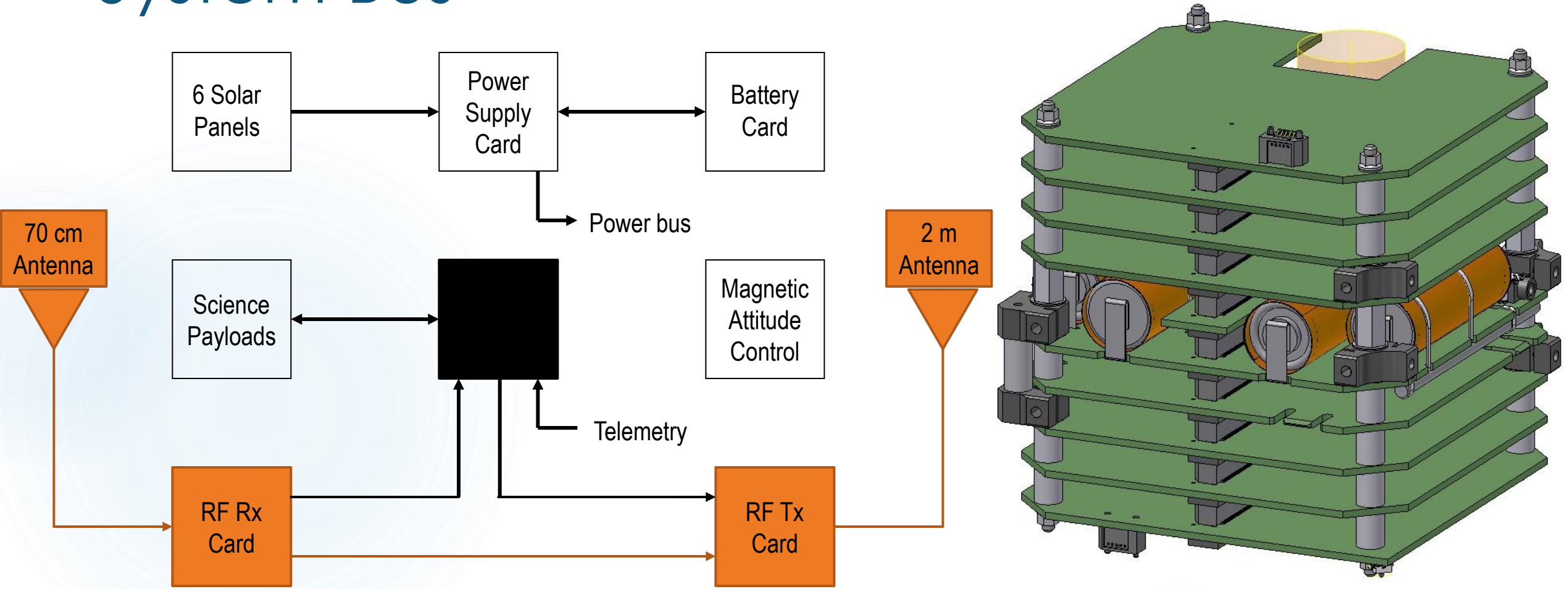
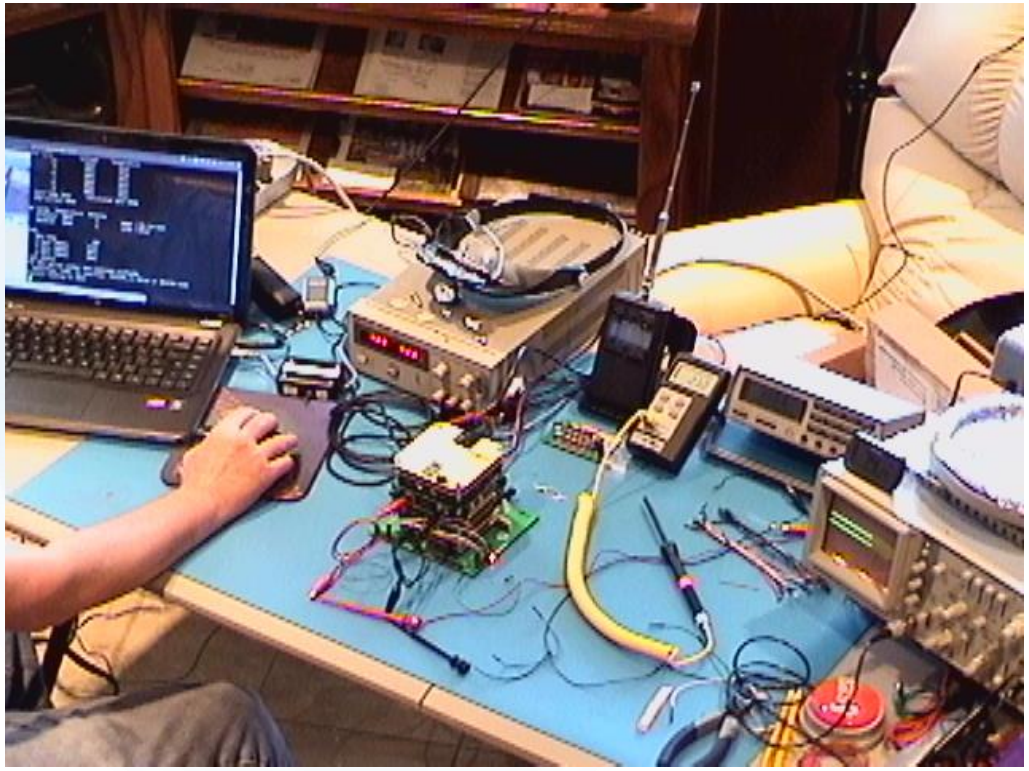
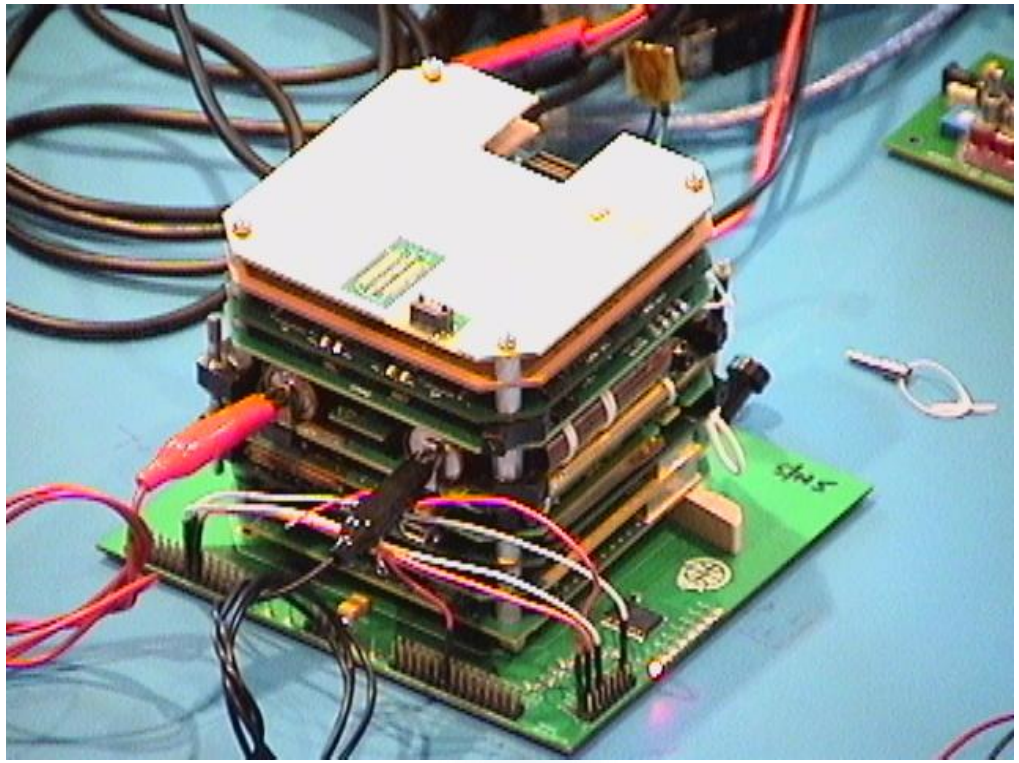


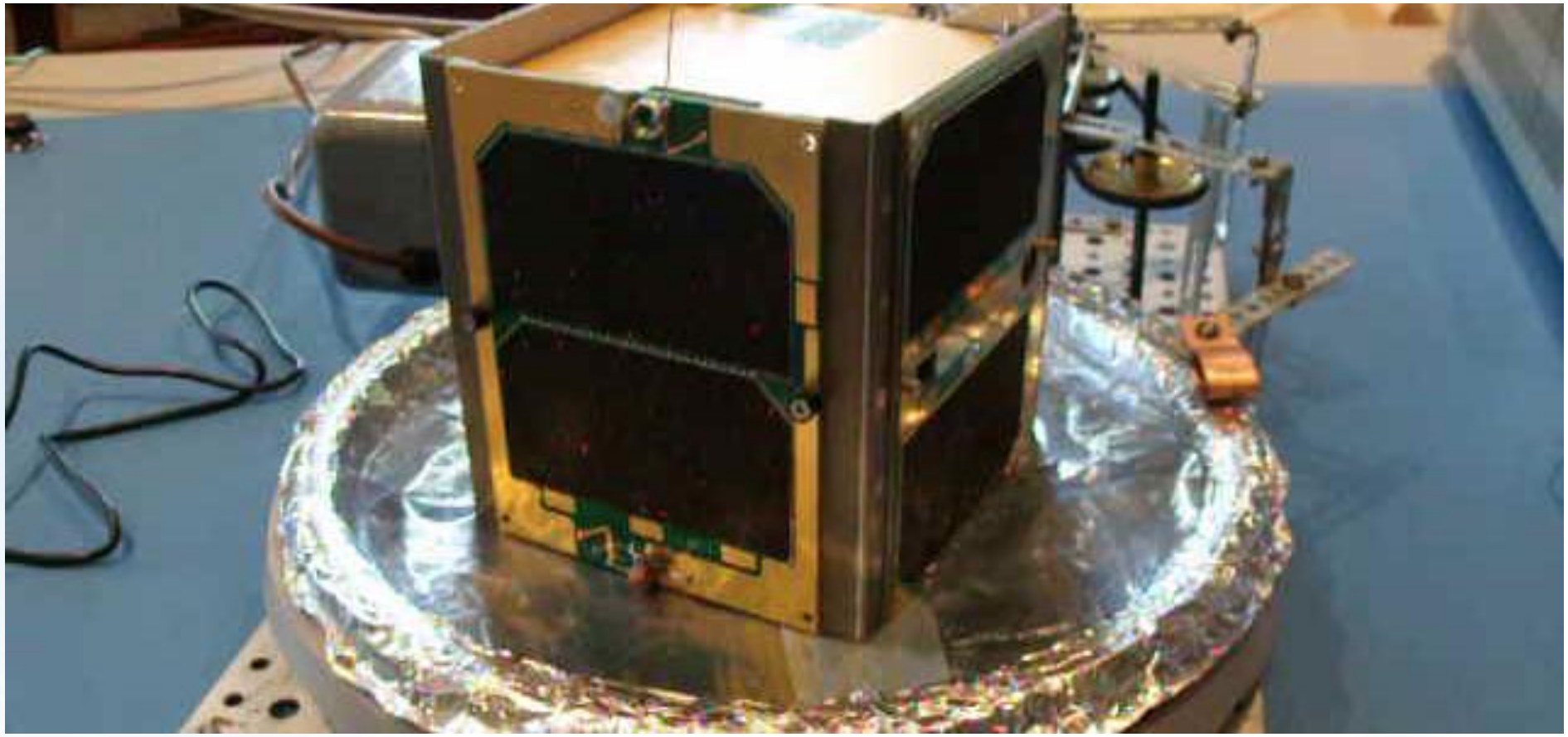
Fox-1 Status

- Engineering model testing ongoing





Fox-1 Status – Engineering Model Testing



Fox-1 Status

- Coming up--
  - Critical Design Review
  - Flight model build and test
  - “Day in the life” testing
  - Vibration Testing and Thermal Vacuum (bakeout)
  - Mission Readiness Review then hands off (by November)

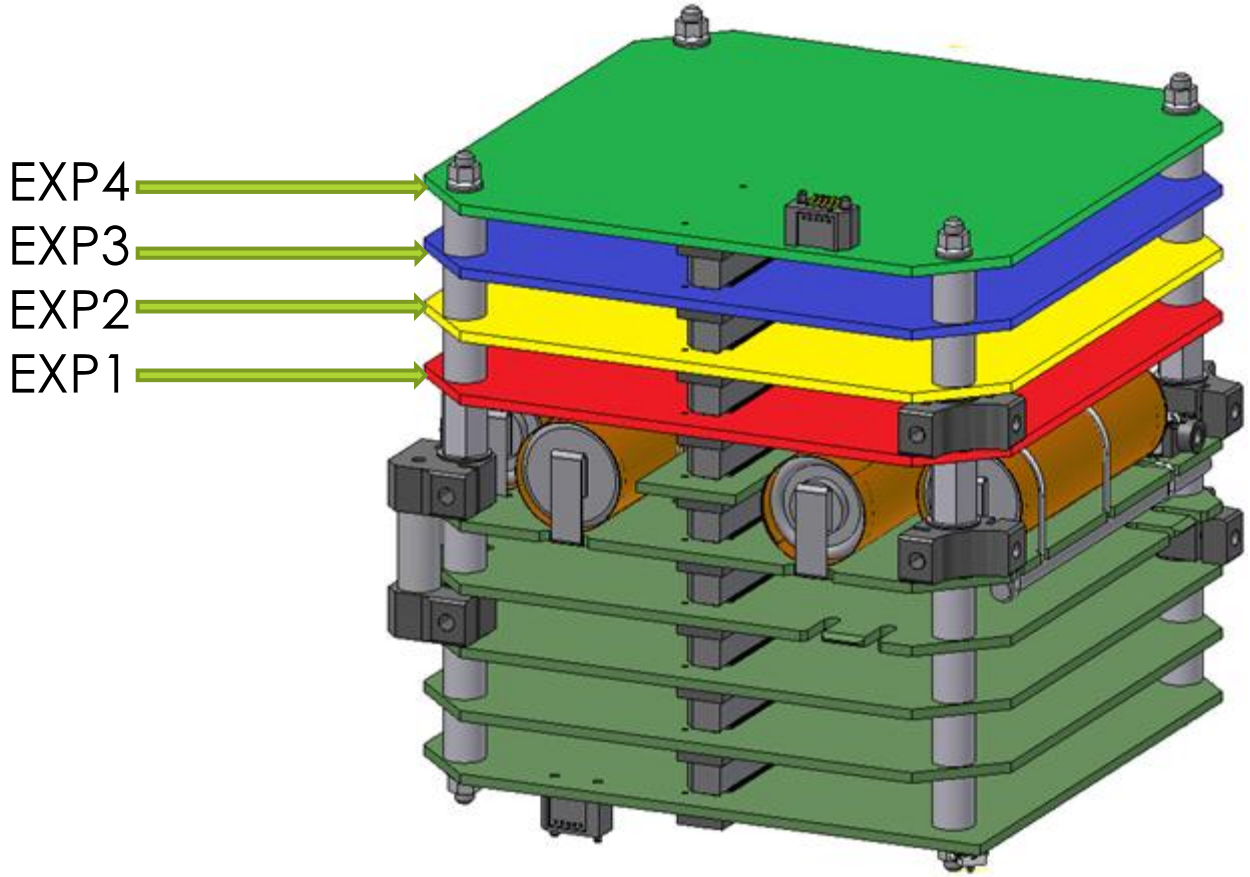
Fox-1 Status

Fox-1B "RadFXSat" (CSLI 4 Feb 2013)

- Use Flight Spare hardware from Fox-1
  - Flight Spare experiments from Fox-1 returned to partners
- Vanderbilt RadFXSat experiment installed
  - Operates simultaneously with Transponder
- Reset and start again
  - CDR, Flight Model and Flight Spare integration and testing, Launch provider required testing, Deliver to launch provider

Fox-1 Status
Fox-1C and Fox-1D

- On the shelf and ready to fly, requiring only solar cells
  - (Of course, all of the other integration and testing is still required!)
- Looking for university partners
- You provide the experiments, we provide the communications for your data
- Partner for launch opportunities
- Amateur radio transponder during or after experiment phase



Fox-1 Ground Segment

Modulation

- Fox-1 series will be FM
  - Relatively easy to use
  - Only one user at a time

Power

- Transmitter will be ~750mw (depending on bus voltage)
  - Comparison: ARRISat-1 FM Beacon: 500mw
  - AO-73 high-power beacon: 350mw
  - (Both ARRISat-1 and AO-73 easily heard with a rubber ducky)
  - Collect telemetry from both ARRISat-1 and AO-73 easily with omni antenna (eggbeater)

Working Fox-1

- Essentially no difference expected from previous class on working FM satellites
  - Power much higher than the current FM satellite, SO-50, so it should be easier
- 67Hz tone required to "open" the transponder for 90 sec. You might as well just leave the tone turned on.
- When transponder is not open, a 10-second beacon is sent periodically: unmodulated carrier, then voice ID and a couple frames of telemetry

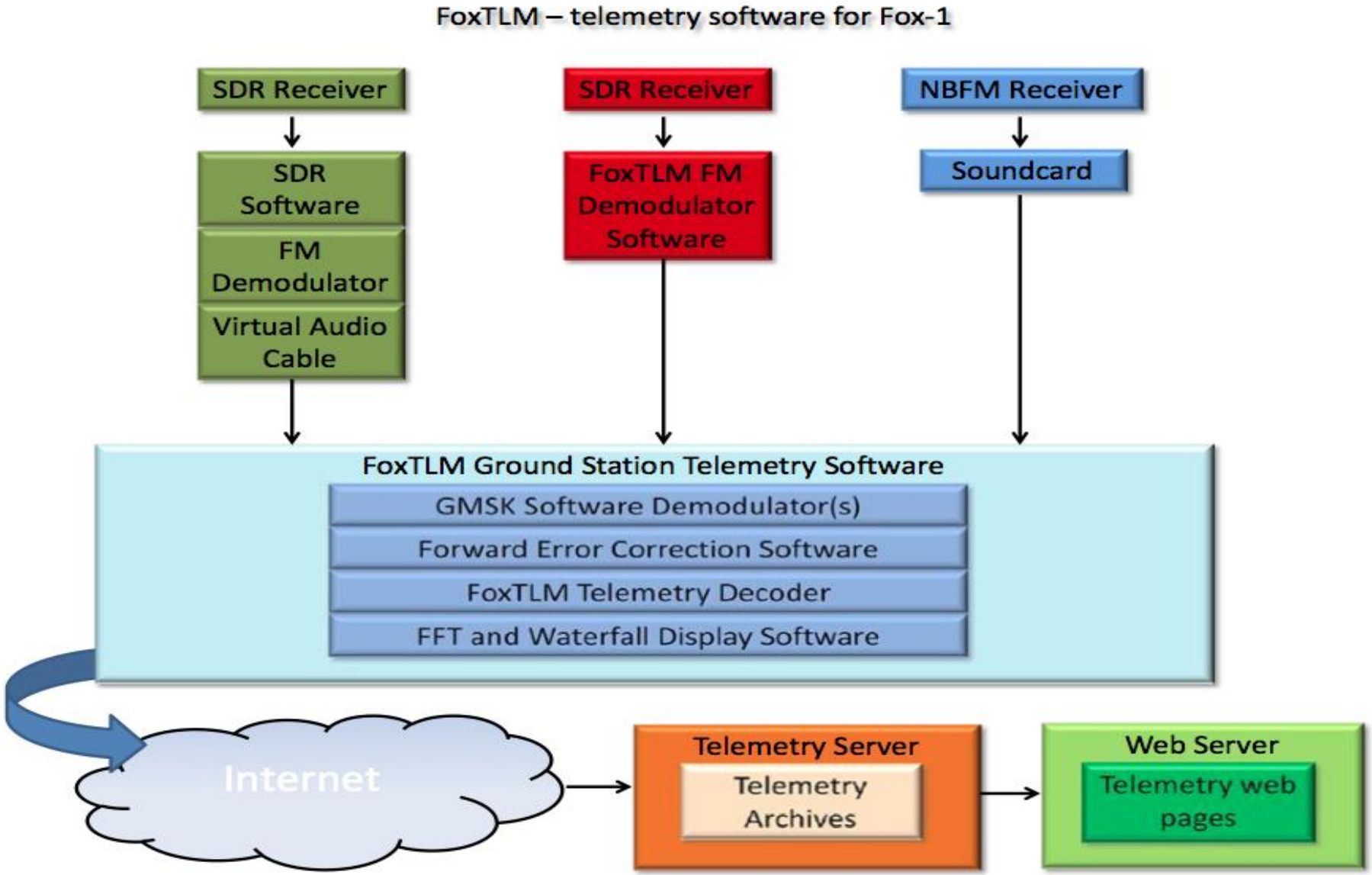
Fox-1 Telemetry

- For Details, see Proceedings of the AMSAT-NA 31st Space Symposium and AMSAT-NA Annual Meeting, 2013 Houston TX.
- Types of data (Current, Min, and Max when it makes sense):
  - Time (seconds since last reset, and resets since launch)
  - Battery voltages and temperatures
  - Solar Panel voltages and temperatures
  - Temperatures at other point in the spacecraft
  - Transmitter PA Current
  - Error and Diagnostic Data
  - Angular velocity in X, Y, Z (MEMS experiment)
  - Experiment Data (radiation and pictures)

Telemetry Frames

- Five types of frames: Current, Min, Max, Radiation, and Picture
- Current, Min, Max, and Radiation
  - Alternate during beacon or transponder operation.
  - 200bps
  - FEC should recover from a 200ms fade (out of 5 sec)
- Picture frame
  - Satellite must be commanded into this mode (by Fox ops team)
  - Runs for about 20 minutes at a time
  - No beacon or transponder while downlinking pictures
  - 9600bps with FEC

Ground Software



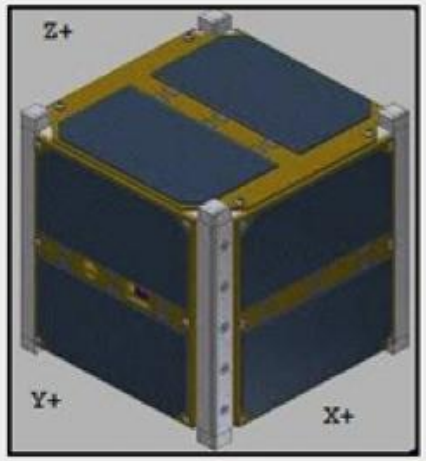
FoxTLM Dayton Demo Version 0.3 Registered to AMSAT

File Edit Tools Help

Fox-1 Uptime 0 days 4 hours 23 min

Reset Count	4	Commands Received	4
Frames Sent by Fox-1	247	Experiment Status	ON

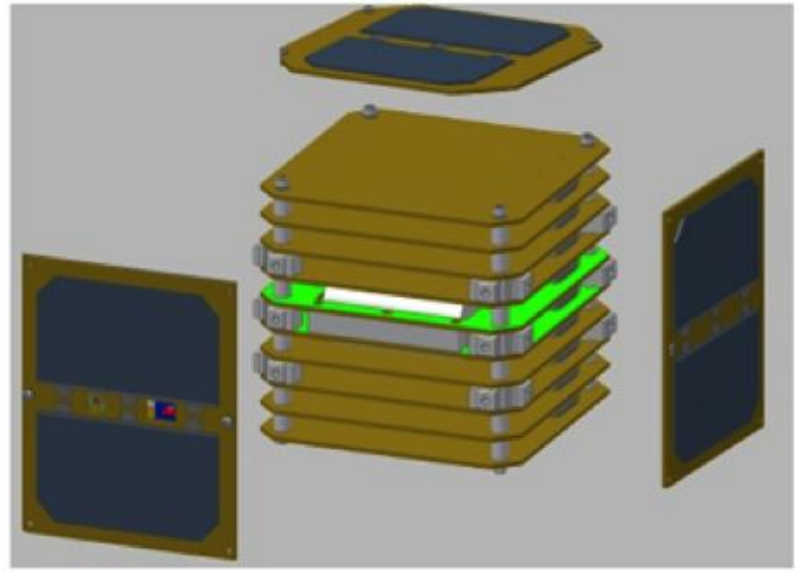
Ground Station:	KA2UPW	Frames Received	42	Until next AOS:	00 h 00 m 00 s	Azimuth:	42 degrees
Location:	EM13oa	Frames Forwarded	42	Until next LOS:	00 h 05 m 17 s	Elevation:	45 degrees
Audio buffers	656	Forwarding is	ON				



	Volts	mA	C
X+	0.000	0.000	28.8
X-	2.400	0.666	25.5
Y+	0.000	0.000	29.9
Y-	0.000	0.000	26.6
Z+	2.300	0.555	24.4
Z-	0.000	0.000	27.7

00: xx xx xx xx xx xx xx xx - xx xx xx xx xx xx xx xx THi, this is Fox
10: xx xx xx xx xx xx xx xx - xx xx xx xx xx xx xx xx -1.kj"hj8b%$g3jh
20: xx xx xx xx xx xx xx xx - xx xx xx xx xx xx xx xx $g8s%!~twg%6aadA

IHU | BCR | Battery | Receiver | Experiment | Transmitter



Battery Cell 1	1.20 V
Battery Cell 2	1.24 V
Battery Cell 3	1.28 V
Battery Cell 4	1.32 V
Battery Cell 5	1.36 V
Battery Cell 6	1.40 V
Cell 1 Temp	9.10 °C
Cell 2 Temp	9.20 °C
Cell 3 Temp	9.30 °C
Cell 4 Temp	9.40 °C
Cell 5 Temp	9.50 °C
Cell 6 Temp	9.60 °C
Battery 1	3.72 V
Battery 2	4.08 V

Future

FOX-2 AND BEYOND

Fox-2

- ***Flight heritage and track record from Fox-1 series***
- 3U CubeSat
- Software Defined Transponder
- Higher power, more bands/modes
- Attitude Determination and Control
- Higher orbits
- Development underway

And Beyond…

- CubeSat market has not yet reached a plateau
- Larger sizes are becoming more common
  - 3U, 6U, even 12U
- Exploration and research leading to expanded possibilities
  - Propulsion (higher orbits, HEO - but not allowed on ELaNa)
  - Satellites in formation
  - Constellations of satellites
- Several possibilities and partnerships being explored
- We are ALWAYS looking for new opportunities!

Any Questions?