SHADE

Spacial HEO Autonomous Detector & Evaluator

Manufacturing Status Review

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Project Overview

Project Goal

Higher risks now posed by Earth-orbiting objects
- Attributed to cheaper launches and limited space junk removal

Large Space Situational Awareness Systems
- Highly capable, very expensive, currently overwhelmed

Need to reduce 'trivial' tracking requests
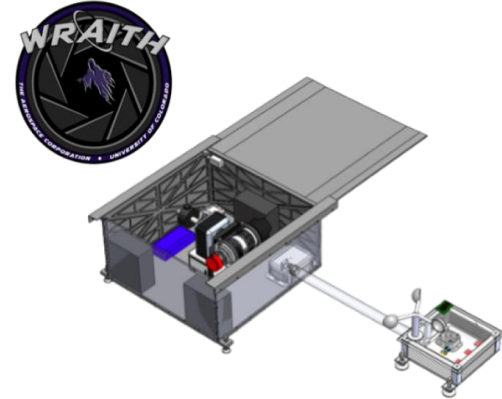- Producing inexpensive smaller systems will free up operational bandwidth for more capable systems

Courtesy: NASA Goddard Space Flight Center

Project History

Ground-Based **H**ardware for **O**rbital **S**pace **T**esting

Foundation systems for autonomous imaging of circular LEO and MEO objects

Validated with ISS tracking tests

Weather **R**esistant **A**utonomous **I**maging for **T**racking **HE**Os

Added HEO tracking capabilities & weather protection

Systems operate autonomously for 12 hours

Project cut short in March 2020 due to COVID-19 pandemic

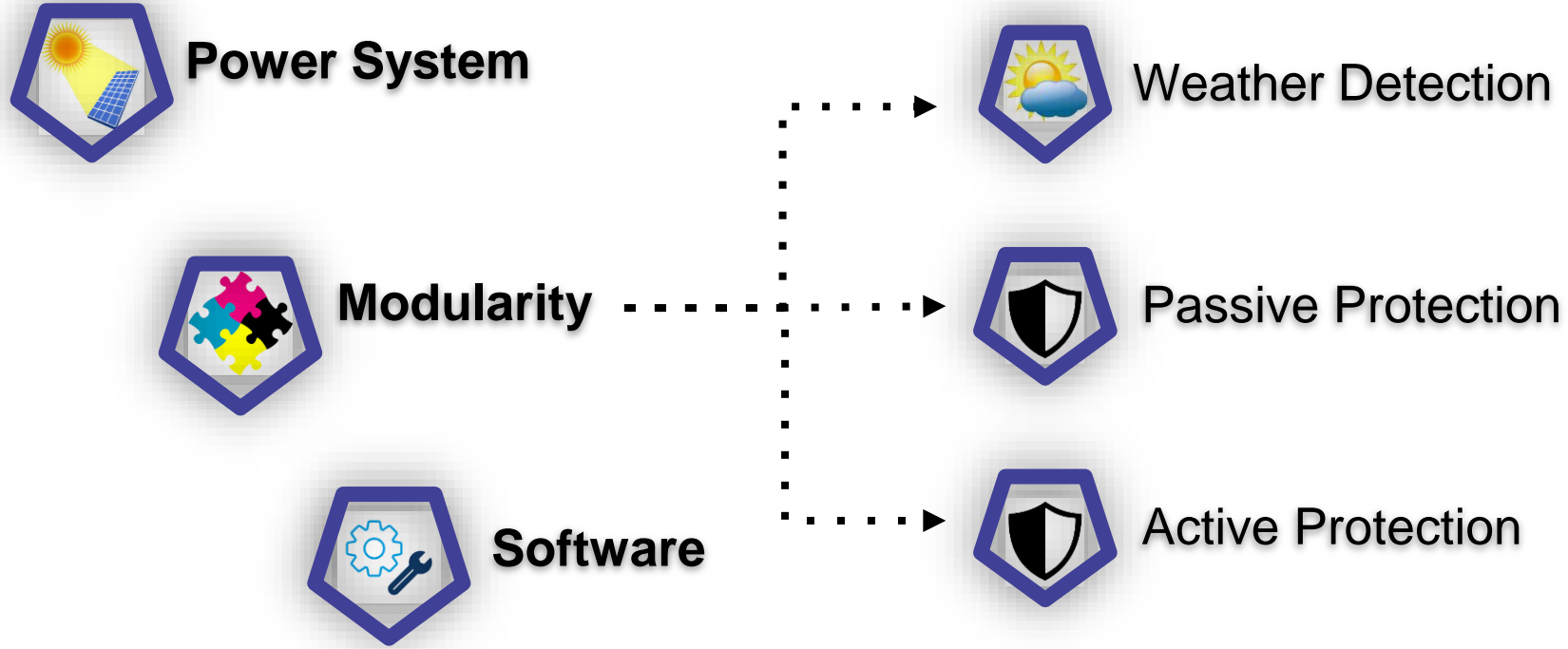**Timeline** Project Overview Schedule Manufacturing Budget

Spacial HEO Autonomous Detector & Evaluator 2020/21

Mission Statement

To provide an easily accessible, multi-night orbit tracker, specializing in the evaluation of highly elliptical orbits. SHADE will be a low-cost capable tracking system, able to withstand adverse weather conditions.

Timeline | Project Overview | Schedule | Manufacturing | Budget

Critical Project Elements

Power System

Modularity

Software

Weather Detection

Passive Protection

Active Protection

Levels of Success

| Category	Level 1	Level 2	Level 3
Scheduling [WRAITH]	● Accept NORAD Satellite IDs ● Sort based on time, visibility, field of view ● 6 objects per hour	● Prioritize scheduling by image capture probability or human override	● Search for missing objects and send alert
Image Processing [WRAITH]	● Extract endpoints of streaks ● Signal to noise ratio of 30 or less	● Identifies when a target object is missed	● Camera maneuvers to find missing object
Orbital Determination [WRAITH]	● Accurate orbit determination using Batch filter	● Level 1	● Predict possible orbits for missing objects
Pointing [WRAITH]	● Track HEO orbits near apogee (GEO)	● Track HEO orbits near perigee (LEO)	● Search for missing objects using possible locations

Levels of Success

| Category	Level 1	Level 2	Level 3
Environmental Control [WRAITH]	● Initiate protection from on-board sensors. ● Protection from light rain/wind.	● Level 1	● Initiate protection in accordance with remote override. ● Update weather & system status to ground station
Modularity	● Module weight under 50 lbs ● On-site system assembly is required	● Level 1	● Module weight under 35 lbs ● Minimal required on-site system assembly
Power Efficiency	● Operates autonomously for two nights	● Operates autonomously for three nights	● Operates autonomously for five nights

Design Changes

Power System
Solar panel stand design
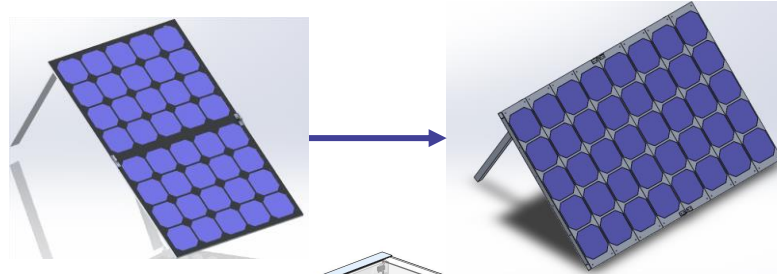
Active Protection
Addition of corner guards
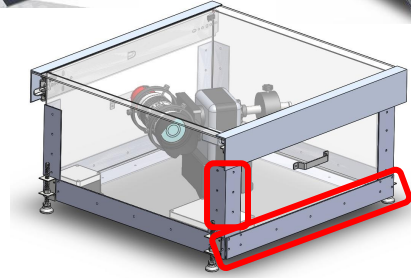
Software
Search algorithm replaced by a new dynamic scheduler
More adaptive runtime software structure

Timeline | Project Overview | Schedule | Manufacturing | Budget

CONOPS

STORMY/CLOUDY NIGHT

4 Bad weather?

SAFE MODE ON

CLEAR NIGHT

HEO, LEO, GEO, MEO

5 Object present?

4 Imaging

NO

6 Update Scheduler

YES

6 Analyze & Predict

Individual system modules <50 lbs

Distance to deployment <100 ft

3 Assembly & Deployment

Continue Condition
Break Condition

1 Transport

2 Single operator carriage

5 5 trips to deployment site

7 Cycle continues each night

8 Recovery & Disassembly

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(24" x 43" x 21")
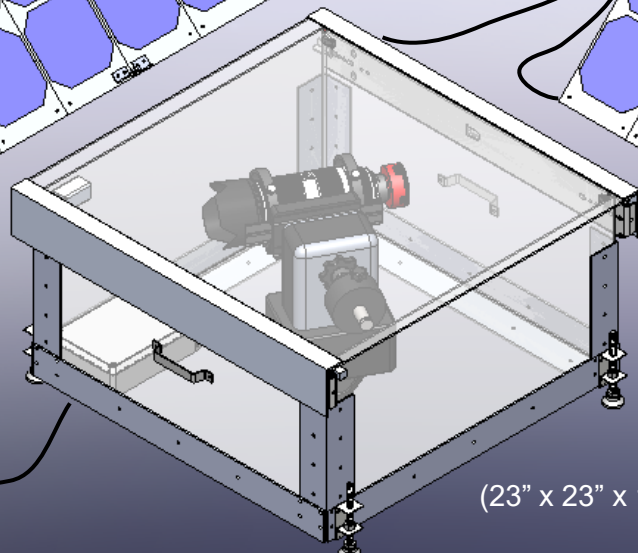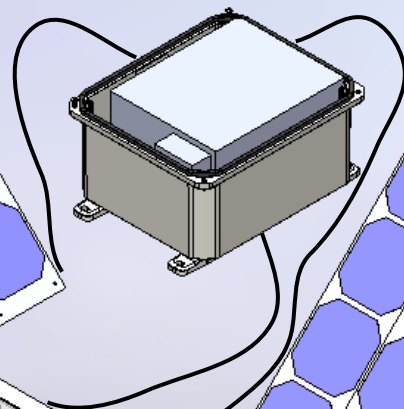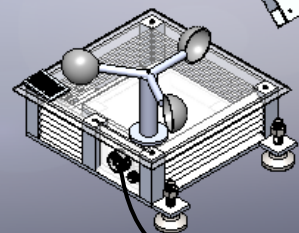
(23" x 23" x 12")
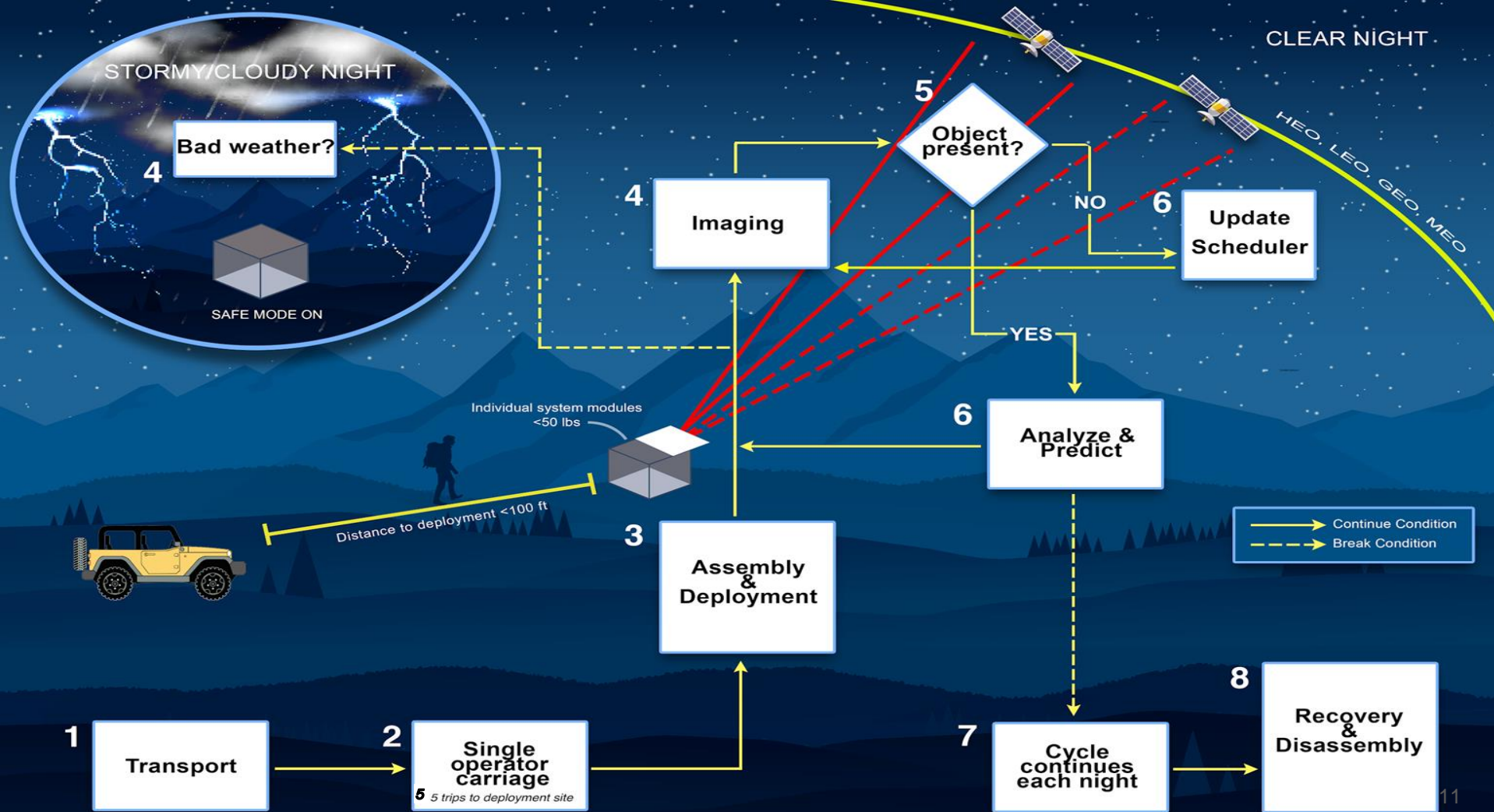
Overall Physical Block Diagram
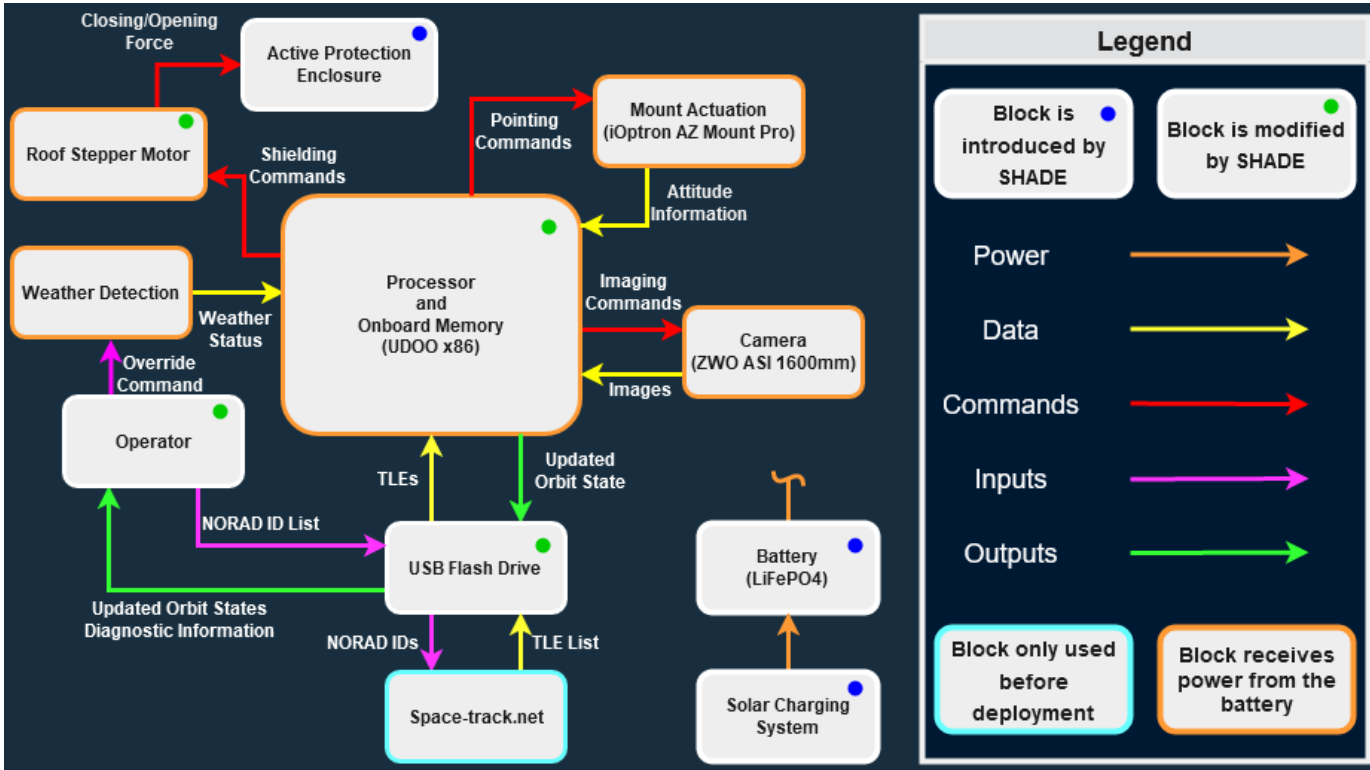
Power System FBD

Schedule

Timeline › Project Overview › Schedule › Manufacturing › Budget
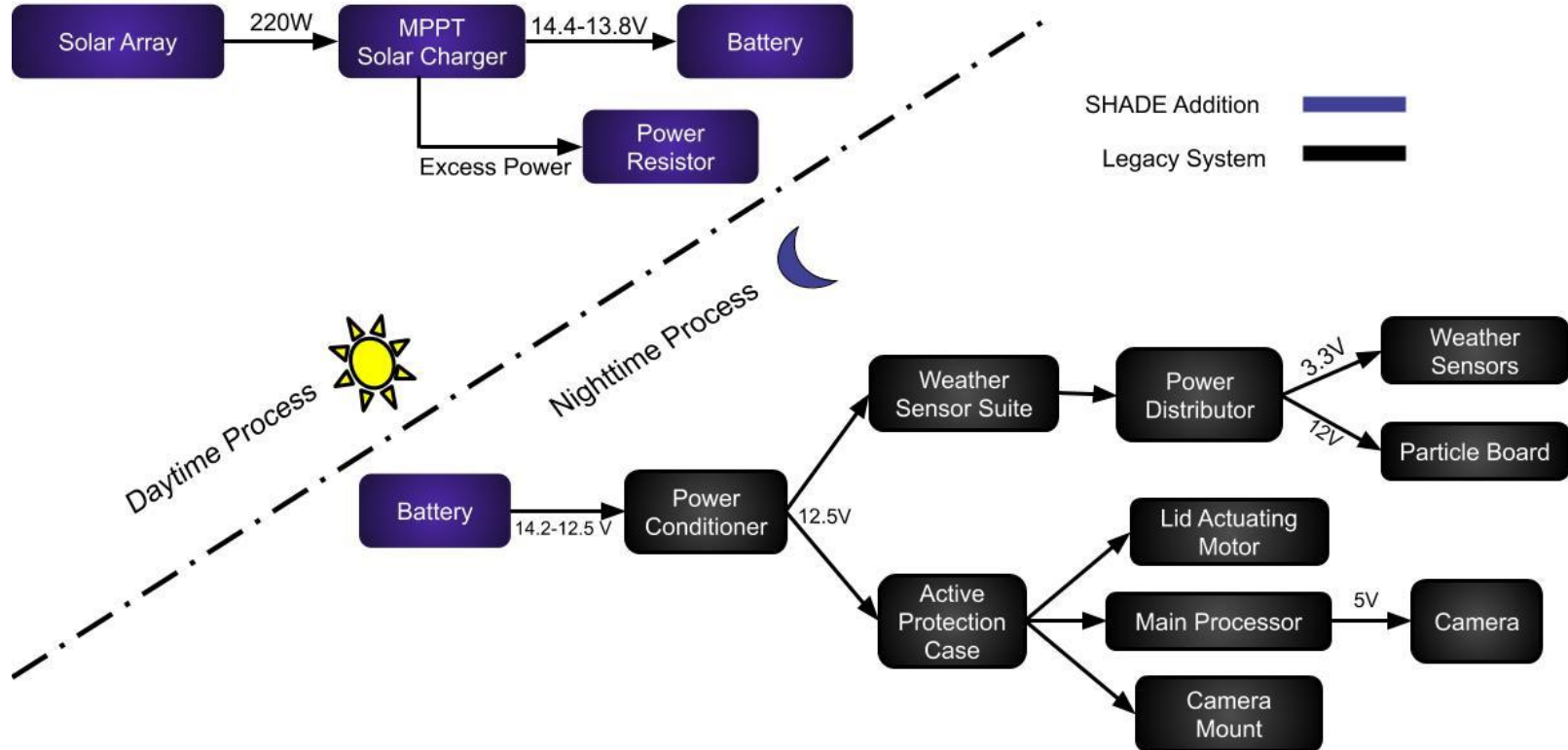
Schedule Changes Since CDR

Legacy Scheduler Testing
- Cannot be tested without significant software modifications
- All scheduler tests will be conducted once SHADE scheduling software is up and running

University Closure Until Feb. 15 (COVID)
- R2R access approved for most team members on 1/28, this delay pushes hardware manufacturing back 1-2 weeks. (To begin Feb 1st)

No Roof Access for System Tests
- Per University Policy.
- We are currently exploring other location options for multi-night system tests.

Spring Development Schedule

Power

Active Protection

Software

Full System Tests

Timeline | Project Overview | Schedule | Manufacturing | Budget
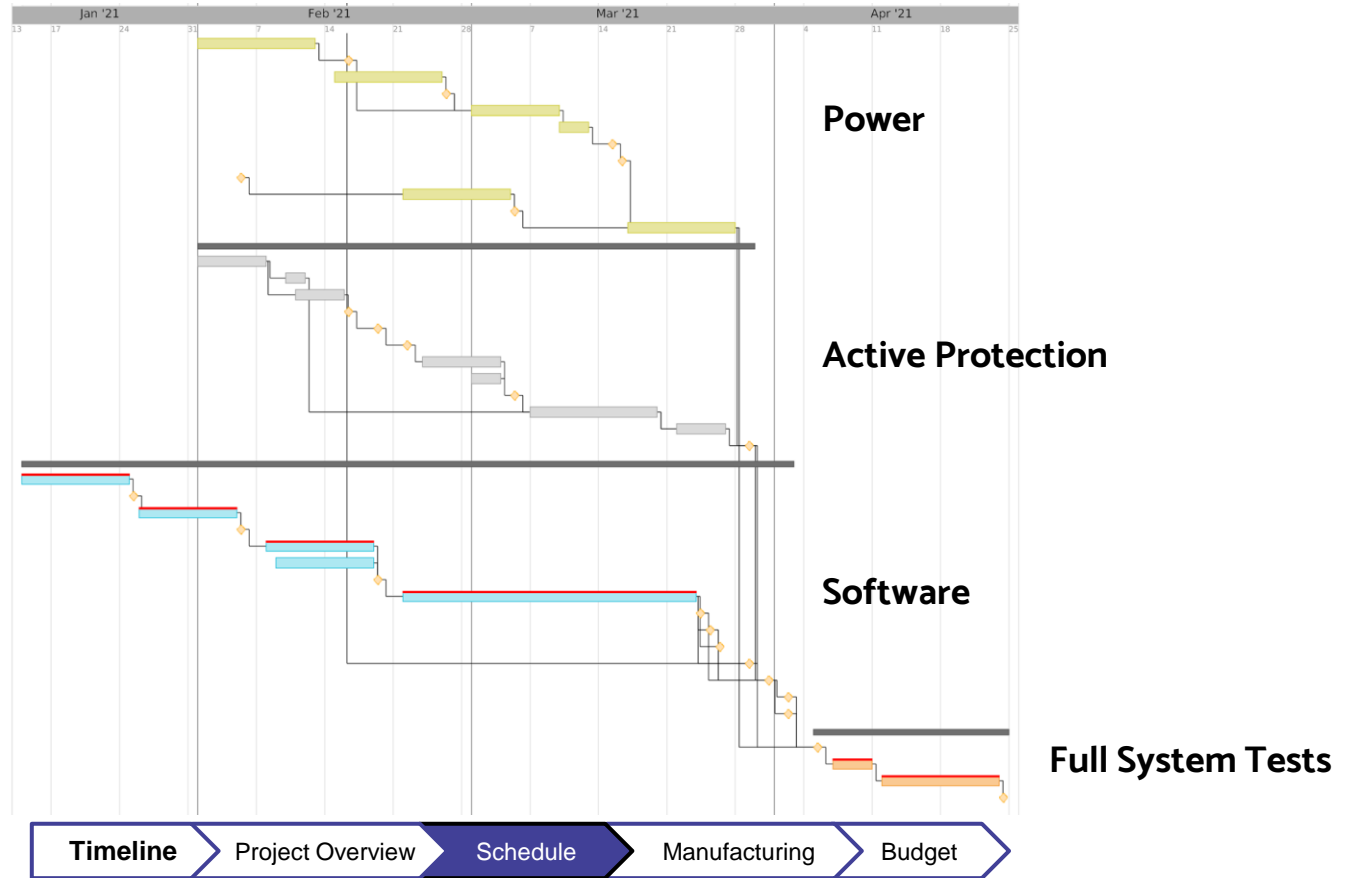
Power System Critical Path

Solar Panel Graduation Tests

Timeline > Project Overview > Schedule > Manufacturing > Budget
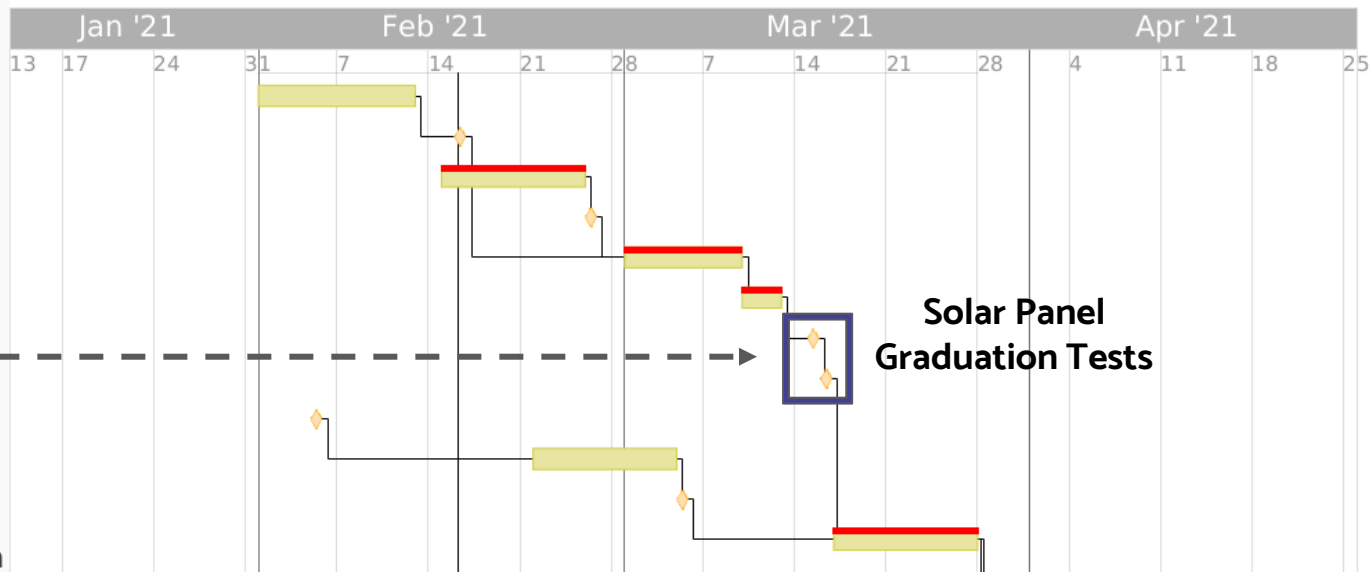
Active Protection Critical Path

AP Enclosure Graduation Tests

AP Sub-system Test
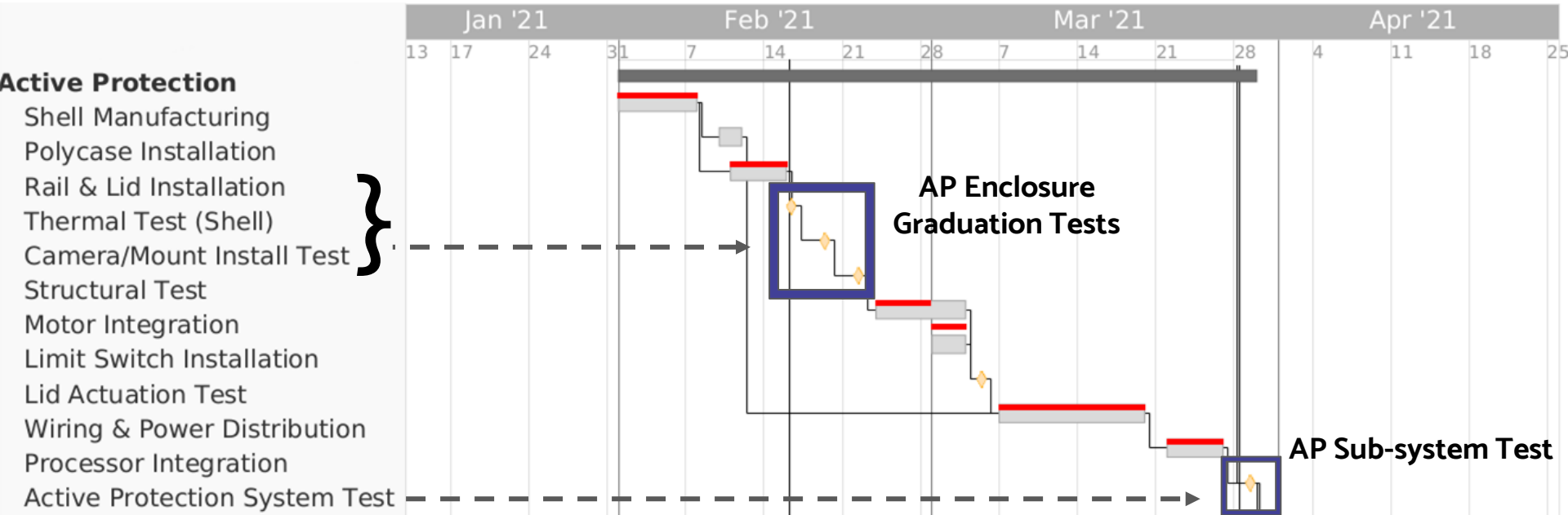
Software Systems Critical Path
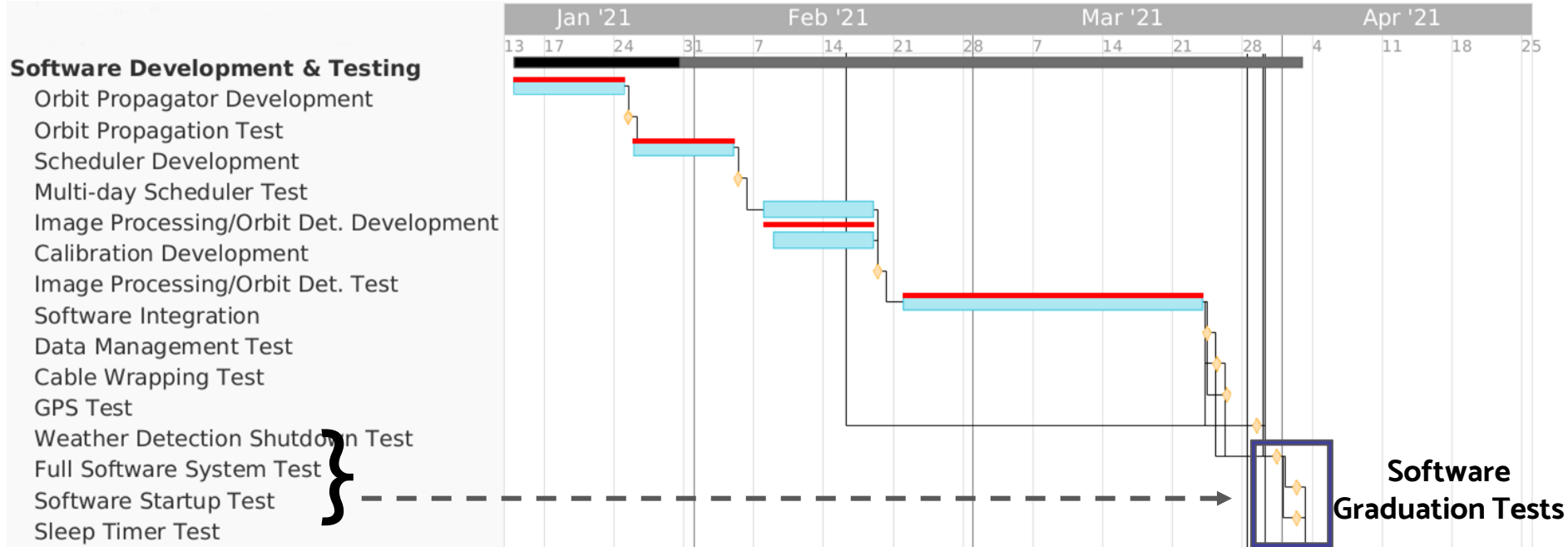
Manufacturing

Manufacturing Overview

Power System: Solar Panels

Part Ordering
Part Arrival
Manufacturing
Assembly

Power System: Power Module

Part Ordering
Part Arrival
Manufacturing
Assembly

Modularity: Active Protection

Part Ordering
Part Arrival
Manufacturing
Assembly

Software

Part Ordering
Part Arrival
Development
Integration

Legend:
- Complete
- In Progress
- Not Started
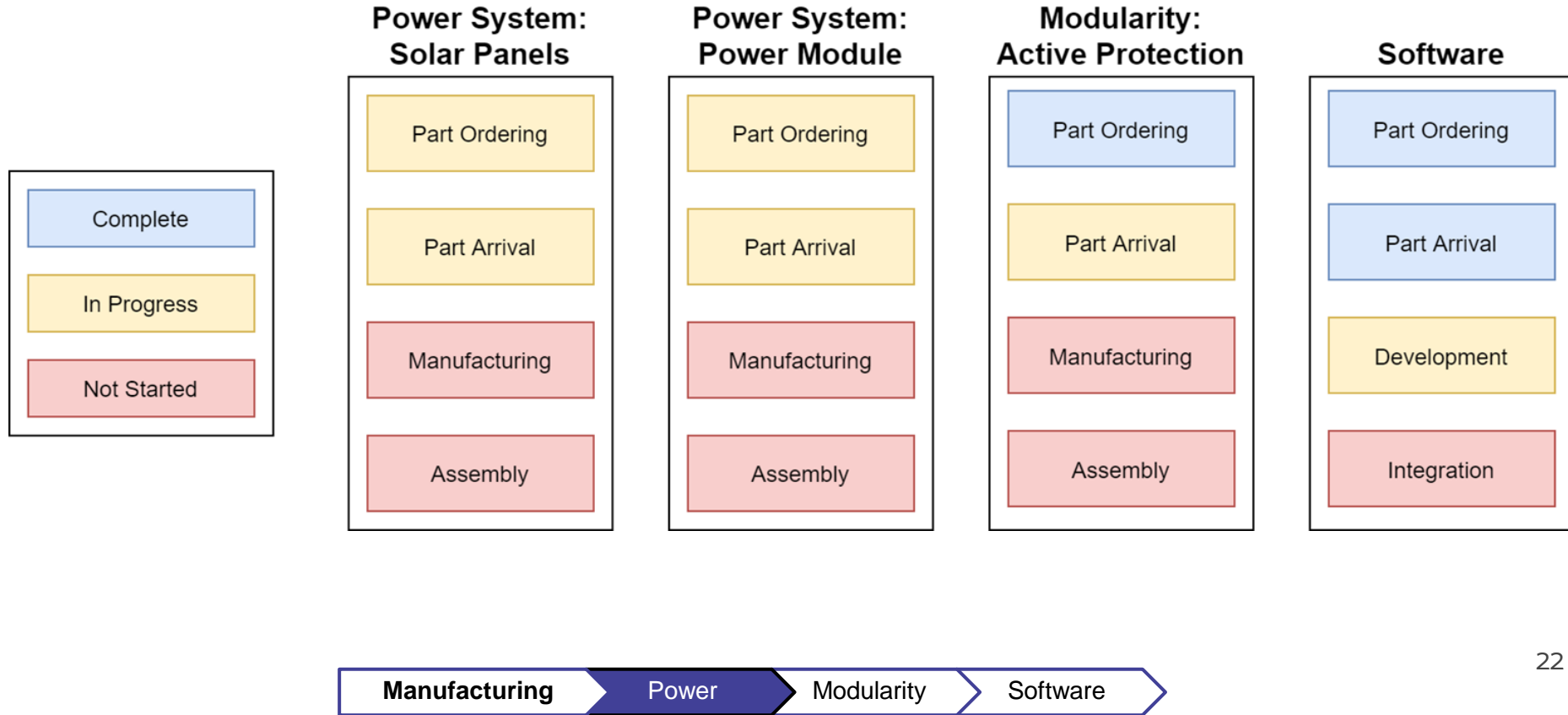
Manufacturing ▸ Power ▸ Modularity ▸ Software

Power System

Design Change - New Stands

- Shorter leg length
- Placed along longer side (minimizes tipping hazard)
- Lower weight/closer to center of mass
- Friction hinges allow for adjustable incidence angle

- Made of aluminum square tube
    - 21 " in length
    - 1 mm x 1 mm in size
    - Same structure as frame parts
    - 28.36 " x 42.17 " aluminum backplate

Manufacturing | Power | Modularity | Software
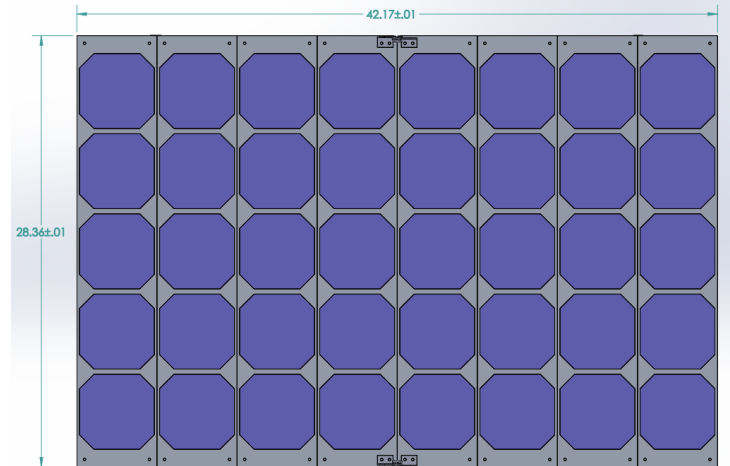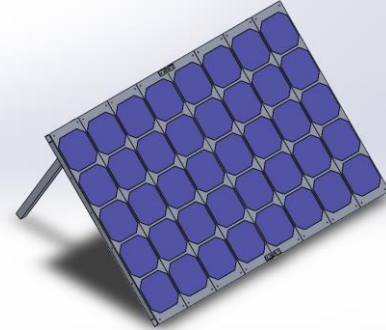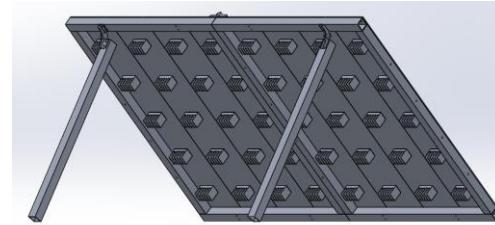
Solar Panel Manufacturing Process

Manufacturing Locations
- Woodshop
- Project space
- Large oven?

Tools/Equipment Required:
- Basic hand tools
- Drill press
- Hand soldering equipment

- All materials have arrived except thermal epoxy - ETA: mid February
  - Contingent on CU w/ 15 day lead
- Use machinist dye to increase measurement visibility
- Use wood jig to locate the heatsinks and provide clamping surface for heatsinks
  - Needs to be built

Manufacturing | Power | Modularity | Software
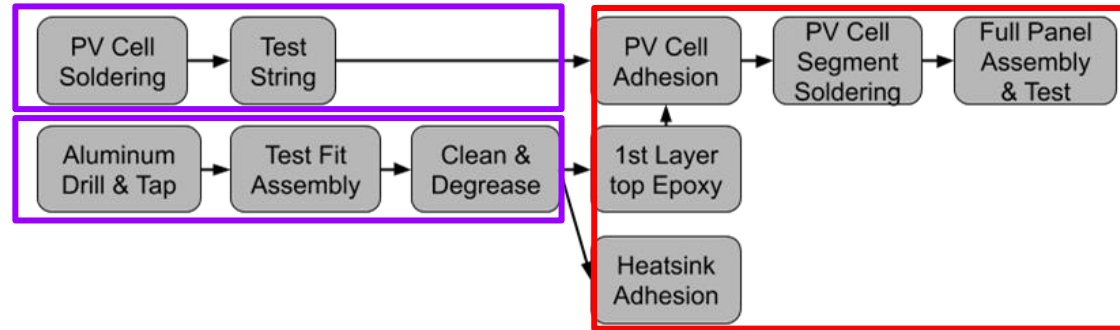
Solar Panel Manufacturing - PV Cells

Solar Cells

Aluminum
Back Plate

Thermal
Epoxy

Heat Sink
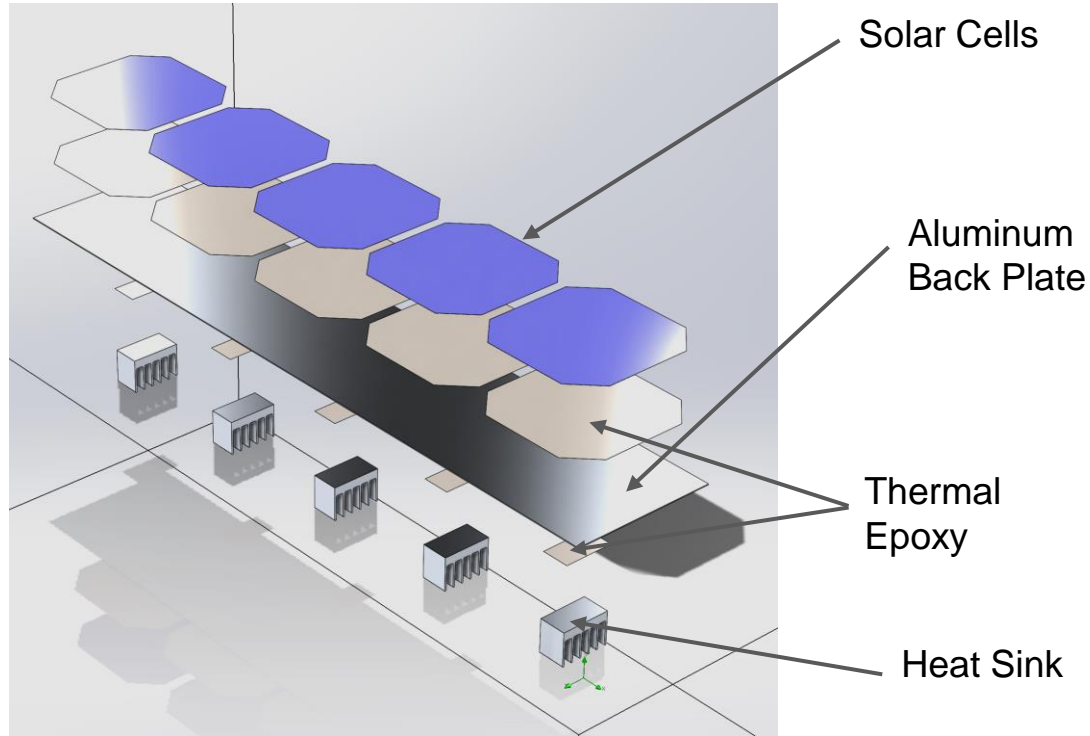
- Test solar cells for continuity prior to epoxy
  - Limits large scale manufacturing errors
- Solar segment adhesion to backplate represents greatest challenge

Manufacturing | Power | Modularity | Software
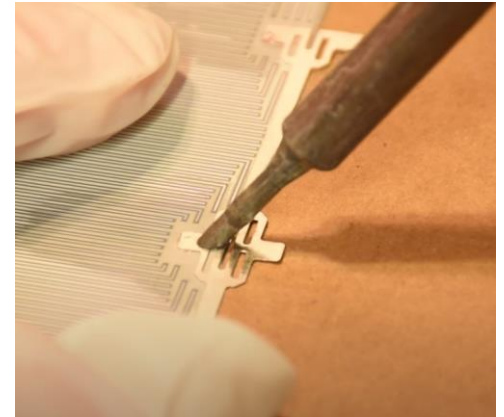
Solar Panel Manufacturing - Frame

- Two frame parts for different lengths of aluminum backplate
    - Four parts for both types per panel
- Aluminum tubes cut to specified lengths
    - 21.08" and 26.36"
- Holes for hinges and attachment of aluminum backplate
    - Holes drilled for 8-32 screws
    - 0.1640" in diameter

Manufacturing | Power | Modularity | Software
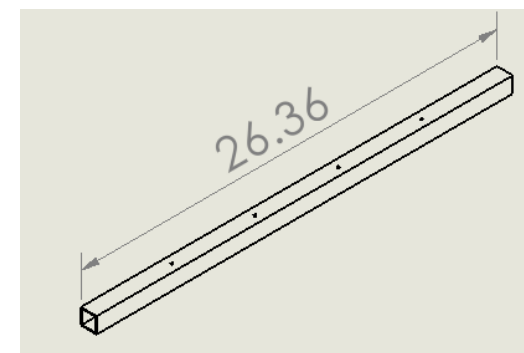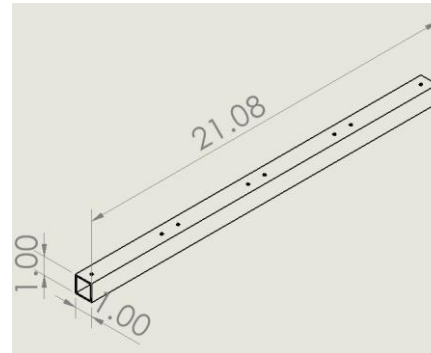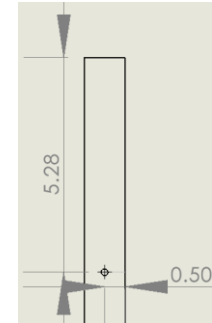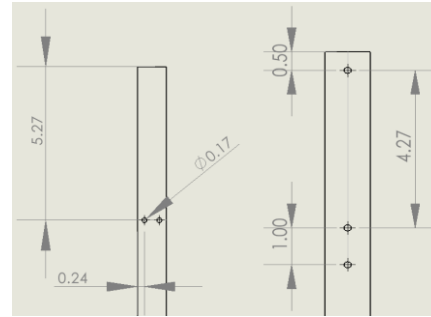
Power Module

Core components have arrived!

- Battery, charge controller
- Ordered wall charger for desktop testing
- Ordering isolation switch

Next Steps
- Mock up layout to properly size and order COTS box
- Battery duration test
    - Contingent on wall charger

Once COTS box arrives
- Measure, cut, install electrical wires
- Solder weather resistant connectors and install them
- Build power umbilical

Manufacturing | Power | Modularity | Software

Modularity

Active Protection - Overview

Completed Items

- CAD design and part drawings.
- Blueprint for manufacturing and assembly.
- All parts have been ordered.
- Disassembly of WRAITH legacy items to use for SHADE's enclosure.

To Do (begin ~Feb 3th)

- Receive roof corner guards.
- Manufacturing:
    - Side corner guards.
- Assembly:
    - Active protection enclosure (polycarbonate walls are pre-cut).
    - System components within enclosure.

| **Manufacturing** | Power | Modularity | Software |
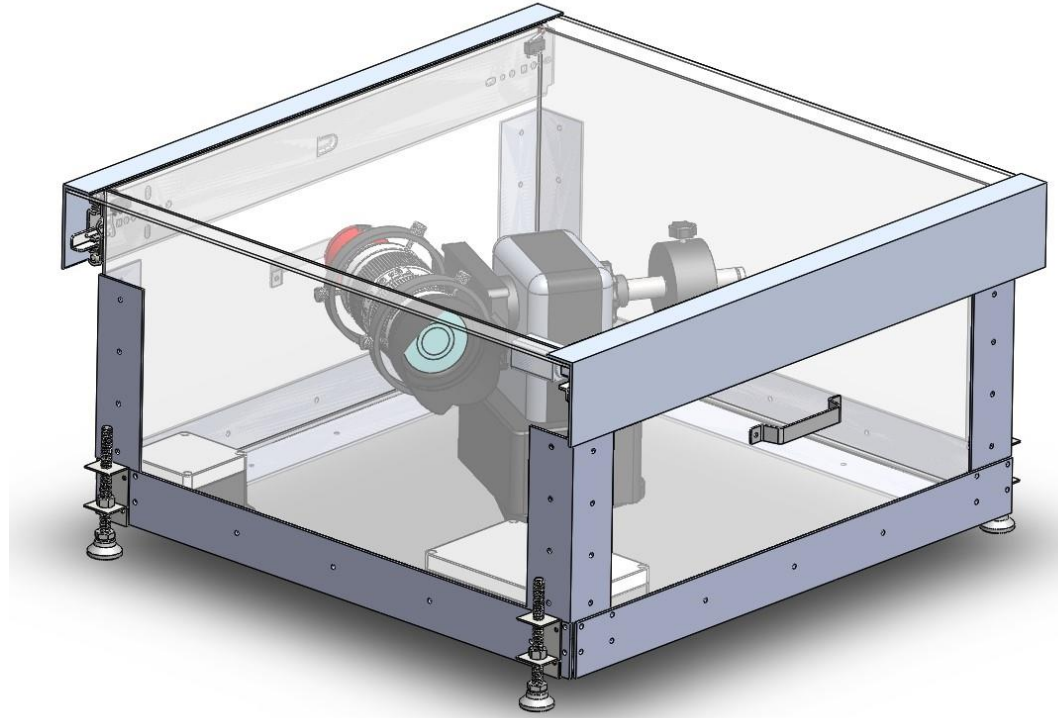
Active Protection - Status

Arrived Items

- Polycarbonate sheets.
- Silicone caulk.
- Liquid Gasket.
- Weatherstrip guards.
- Cool Coat thermal protection paint.
- Leveling feet.
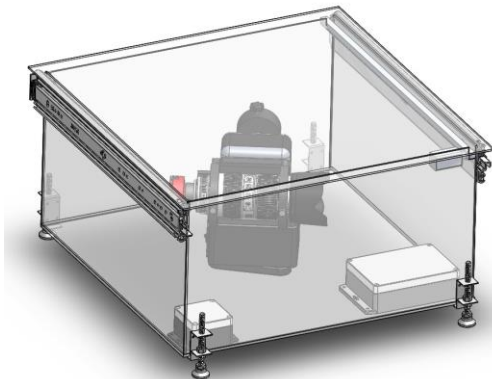
Legacy Items

- Accuride rails.
- Stepper motor and rack gear.
- Limit switches.

Modularity: Active Protection

- Part Ordering
- Part Arrival
- Manufacturing
- Assembly

- Complete
- In Progress
- Not Started

Items Ordered

- Corner guards (roof and sides).
    - Arrival: ~Feb 15th.
    - **Limiting factor**

Items Still Needed (Home Depot)

- Enclosure handles.
- Screws, nuts, washers.

Manufacturing 〉 Power 〉 Modularity 〉 Software
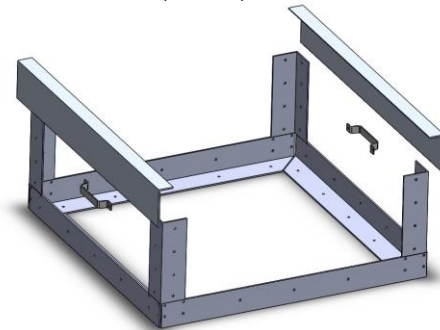
Active Protection - Manufacturing

Corner Guards

Tools:

- Hand saw, measuring tape, power drill, metal file.

Method:

- Obtain the ordered 10 ft length of aluminum rail.

- Mark four 23" lengths and four 7" lengths.

- Cut corner rails on marks following part specifications/drawings from 10 ft piece.

- Drill holes in rails following part drawings.

| **Manufacturing** | Power | Modularity | Software |
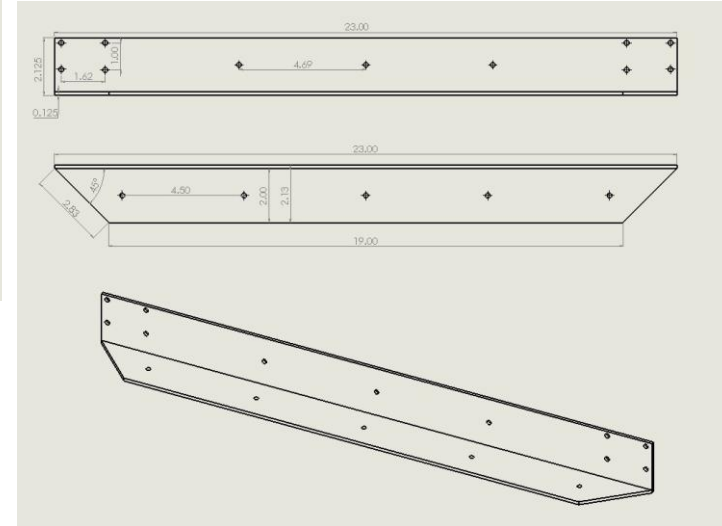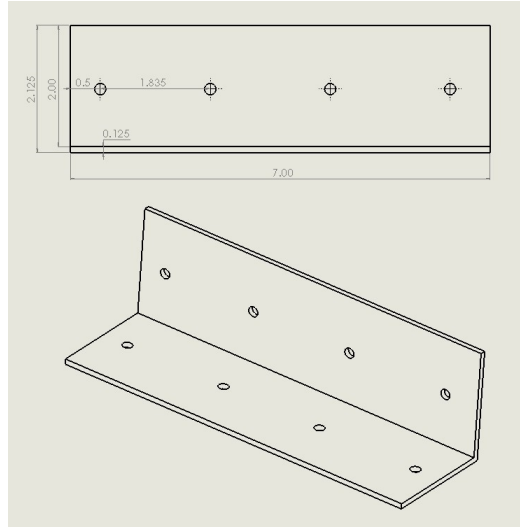
Active Protection - Assembly

Enclosure

Tools:

- Measuring tape, power drill, metal file, nuts, bolts, screws, paint brush.

Method:

- Obtain all active protection system materials.

- Follow part drawings for assembly of enclosure.

- Coat fully-assembled enclosure using Cool Coat white paint.

- ***Ensure screws are installed from outside of system for polycarbonate walls and use washer on inside.
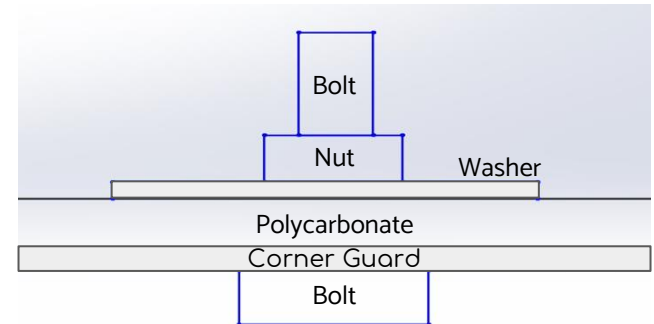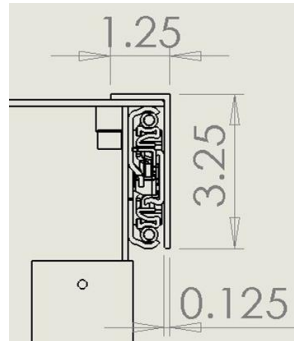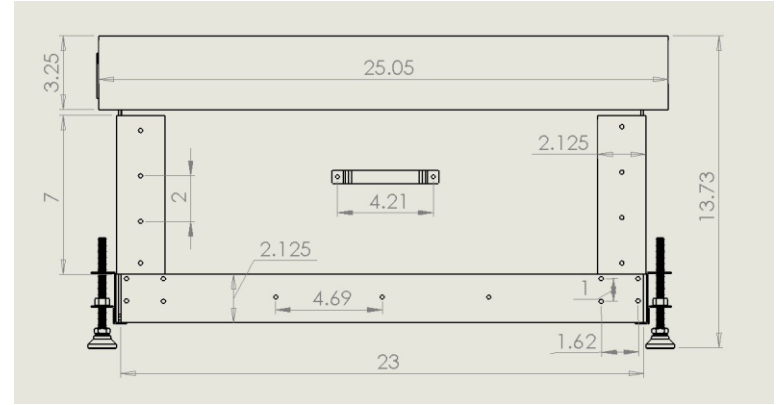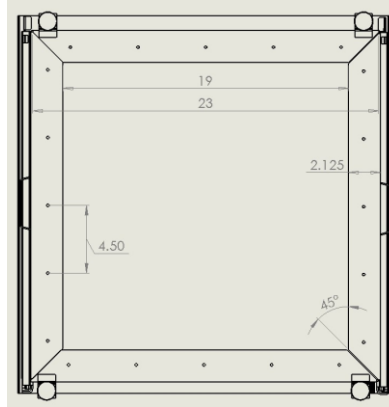
Manufacturing ⟩ Power ⟩ Modularity ⟩ Software

Software Systems

New Software Structure
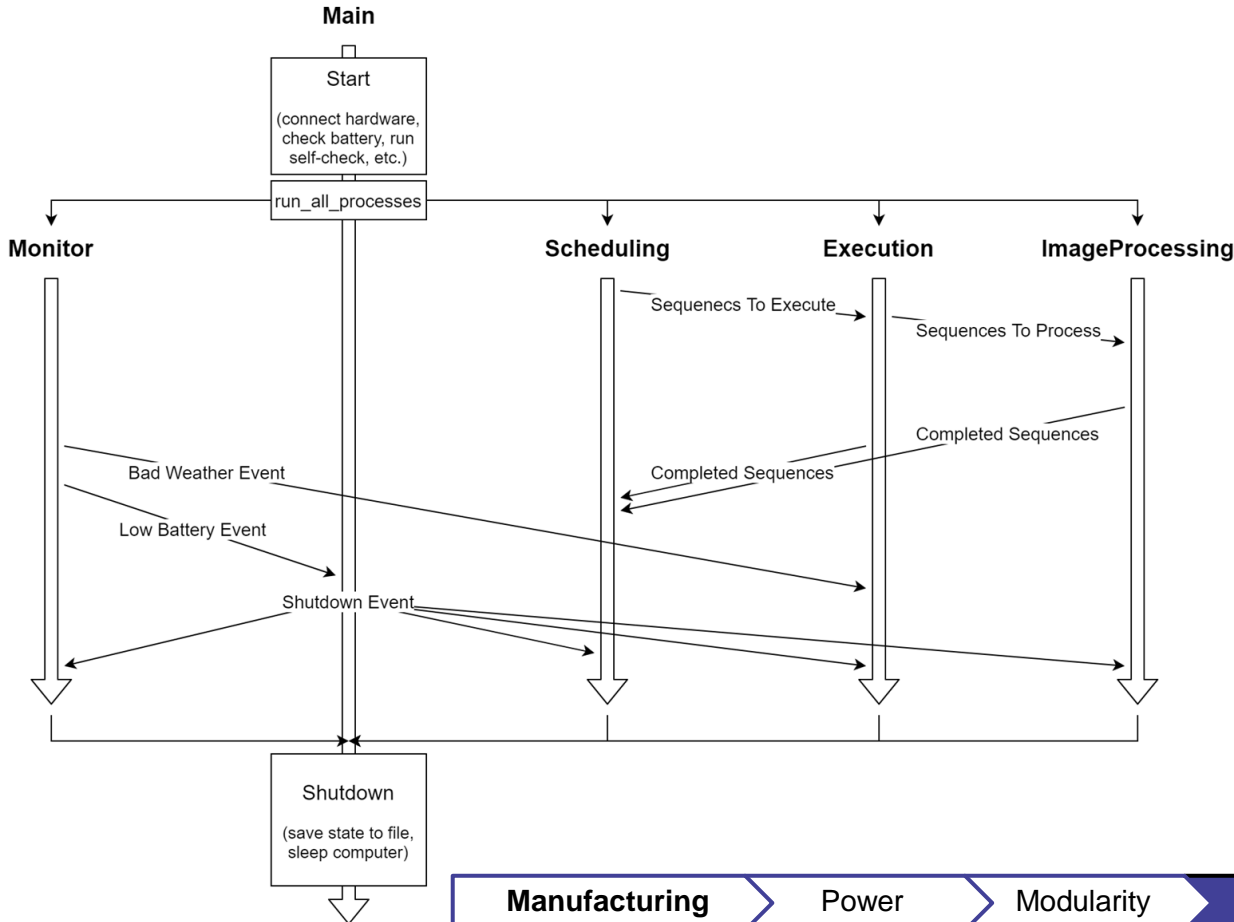
Key Features / Improvements

- State-based model, rather than deterministic
    - Allows for a true "live scheduler"
    - More elegant handling of weather/battery events

- Parallelized in a way that allows inter-process communication
    - Previous software limited to using the filesystem

- Can write and load current state to file
    - Can sleep/resume computer to save power
    - Multi-night deployments

Manufacturing | Power | Modularity | Software

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Software Scope and Status

Operating System
- Automatic Login
- Software Start
- Sleep timers

Main
- Connect Hardware
- Read State
- Self Check?
- Spawn Processes
- Detect Idle Status
- Save State

Weather Detection
- Detect Weather
- Read Battery Voltage
- Read Remote Shutdown

Scheduling
- Read Input Data
- Propagate
- Create Passes
- Create Sequences
- Live Schedule Modification
- Orbit Determination

Execution
- Initial Calibration
- Weather/Safe Mode
- Stage Command
- Camera Command
- Calibration Correction
- Search Algorithm

Image Processing
- Streak Detection
- Astrometry

Legend:
- Complete
- Test Ready
- In Development
- Not Started

Manufacturing | Power | Modularity | Software

1st Priority: Hardware Control

Operating System	Main	Weather Detection	Scheduling	Execution	Image Processing
Automatic Login	Connect Hardware	Detect Weather	Read Input Data	Initial Calibration	Streak Detection
Software Start	Read State	Read Battery Voltage	Propagate	Weather/Safe Mode	Astrometry
Sleep timers	Self Check?	Read Remote Shutdown	Create Passes	Stage Command	
	Spawn Processes		Create Sequences	Camera Command	
	Detect Idle Status		Live Schedule Modification	Calibration Correction	
	Save State		Orbit Determination	Search Algorithm	

Legend:
- Complete
- Test Ready
- In Development
- Not Started

Manufacturing > Power > Modularity > Software

2nd Priority: Calibration

	Operating System	Main	Weather Detection	Scheduling	Execution	Image Processing
	Automatic Login	Connect Hardware	Detect Weather	Read Input Data	Initial Calibration	Streak Detection
	Software Start	Read State	Read Battery Voltage	Propagate	Weather/Safe Mode	Astrometry
	Sleep timers	Self Check?	Read Remote Shutdown	Create Passes	Stage Command	
		Spawn Processes		Create Sequences	Camera Command	
		Detect Idle Status		Live Schedule Modification	Calibration Correction	
		Save State		Orbit Determination	Search Algorithm	

Legend:
- Complete
- Test Ready
- In Development
- Not Started

Manufacturing > Power > Modularity > Software

3rd Priority: Weather Detection

Operating System

Automatic Login

Software Start

Sleep timers

Main

Connect Hardware

Read State

Self Check?

Spawn Processes

Detect Idle Status

Save State

Weather Detection

Detect Weather

Read Battery Voltage

Read Remote Shutdown

Scheduling

Read Input Data

Propagate

Create Passes

Create Sequences

Live Schedule Modification

Orbit Determination

Execution

Initial Calibration

Weather/Safe Mode

Stage Command

Camera Command

Calibration Correction

Search Algorithm

Image Processing

Streak Detection

Astrometry

Complete

Test Ready

In Development

Not Started

Manufacturing > Power > Modularity > Software

4th Priority: Data Processing

Operating System	Main	Weather Detection	Scheduling	Execution	Image Processing
Automatic Login	Connect Hardware	Detect Weather	Read Input Data	Initial Calibration	Streak Detection
Software Start	Read State	Read Battery Voltage	Propagate	Weather/Safe Mode	Astrometry
Sleep timers	Self Check?	Read Remote Shutdown	Create Passes	Stage Command	
	Spawn Processes		Create Sequences	Camera Command	
	Detect Idle Status		Live Schedule Modification	Calibration Correction	
	Save State		Orbit Determination	Search Algorithm	

Legend:
- Complete
- Test Ready
- In Development
- Not Started

Manufacturing > Power > Modularity > Software

Budget

Budget Comparison

Fall 2020 Budget: $3,540.00

Updated Budget: $3,750.00

Total Spent: $2,566.23

Purchased **79.5%** of budgeted items, used **51.3%** of funds

Updated Budget

Subsystem	Estimated Cost	Budget	Margin
Active Protection	$434.90	$590.00	16%
Power	$2,023.70	$2,310.00	11%
Software	$313.98	$350.00	10%
Legacy	$94.00	$300.00	75%
Deposit	$200.00	$200.00	0%
Total	$3,093.07	$3,750.00	17%

Updated Budget

Subsystem	Budget
Active Protection	$590.00
Power	$2,310.00
Software	$350.00
WRAITH Recovery	$300.00
Deposit	$200.00
Total	$3,750.00

SHADE Budget Allocation

- Active Protection System — 16%
- Power — 62%
- Software — 9%
- WRAITH Recovery — 8%
- Deposit — 5%
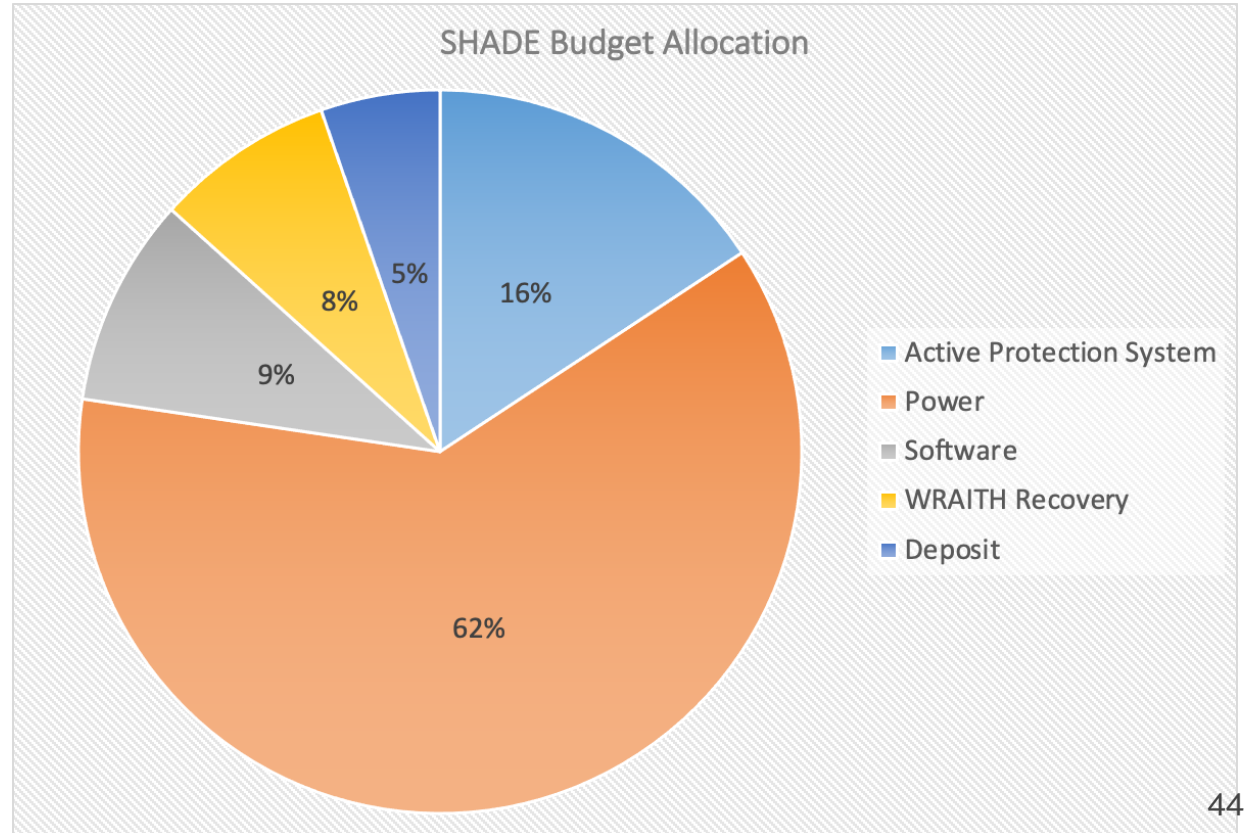
Parts Received	
Aluminum Tubing	$116.56
Aluminum Sheets	$132.25
LifePO4 Smart Battery	$747.95
1.813" Wide Extruded Aluminum Heatsink - 1 in	$86.22
SmartSolar MPPT 75 I 15 charge controller	$118.15
Friction Hinge	$139.36
Solar Cells	$279.99
Polycarbonate sheets	$302.02
Silicon Seal Strips	$10.99
Rain Guard Water Sealers SP-2001	$43.29
Leveling Feet	$15.99
Loctite Anaerobic Gasket	$15.47
UDOO x86 2.0	$278.00

- ■ Active Protection System
- ■ Power
- ■ Software

Parts Pending	Lead Time
Epotek EK2000 Thermal Adhesive	15 business days
Custom Aluminum Corner Guards	10 business days

Questions?

Backup Slides

SHADE Functional Requirements

1) SHADE shall predict locations and visibility windows for objects in LEO, MEO, GEO, and HEO.

2) SHADE shall function autonomously in standard operating conditions for at least two nights.

3) SHADE shall autonomously enter and exit a safe mode to protect itself from adverse weather.

4) SHADE shall autonomously track objects in LEO, MEO, GEO, and HEO.

5) SHADE shall image objects with apparent magnitude of less than 10.

6) SHADE shall create and save orbit estimates for each object within 5 mins of the end of the associated visibility window.

New to SHADE

7) SHADE shall be deployed & recoverable in 30 minutes by a single operator.

8) SHADE shall be capable of making observations on multiple nights during a single deployment.

Timeline | Project Overview | Schedule | Manufacturing | Budget

Power Manufacturing Method

- All metals have been pre cut by manufacturer
    - Will remeasure prior to starting the manufacturing process
- Prepare aluminum for assembly
    - Locate, center punch, drill, and tap holes
- Prepare surfaces for thermal epoxy
    - Sand, degrease, locate
- Prepare solar cells
    - Pre flux and tin cells for better solder joint
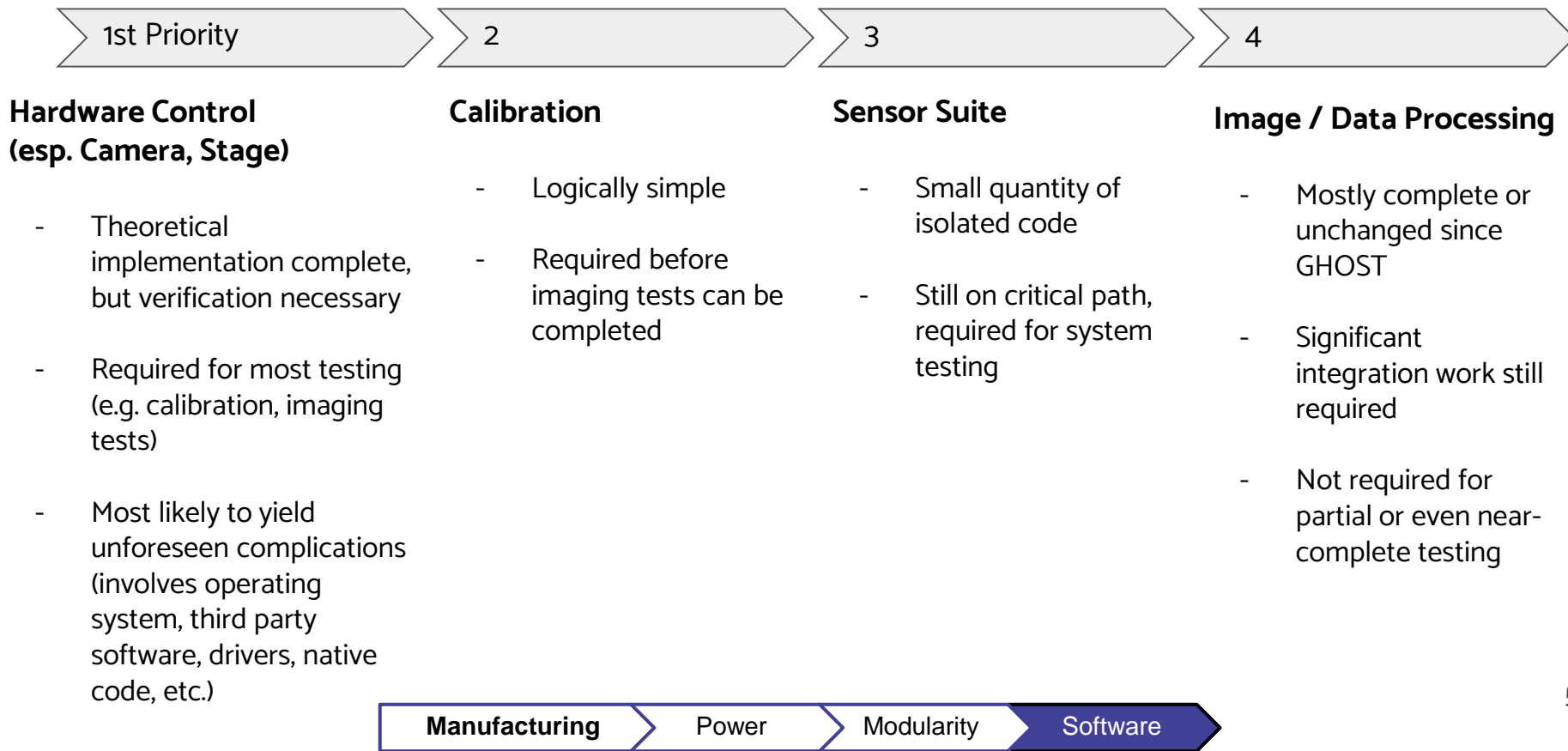
Budget Comparison (backup)

Fall

Subsystem	Estimated Cost	Budget	Margin
Active Protection	$412.35	$490.00	16%
Power	$1,998.62	$2,250.00	11%
Software	$313.98	$350.00	10%
WRAITH	$85.00	$345.00	75%
Deposit	$200.00	$200.00	0%
Total	$2,929.96	$3,540.00	17%

Spring

Subsystem	Estimated Cost	Budget	Margin
Active Protection	$434.90	$590.00	16%
Power	$2,023.70	$2,310.00	11%
Software	$313.98	$350.00	10%
WRAITH	$94.00	$300.00	75%
Deposit	$200.00	$200.00	0%
Total	$3,093.07	$3,750.00	17%

Upcoming Development

| 1st Priority | 2 | 3 | 4 |

Hardware Control (esp. Camera, Stage)

- Theoretical implementation complete, but verification necessary

- Required for most testing (e.g. calibration, imaging tests)

- Most likely to yield unforeseen complications (involves operating system, third party software, drivers, native code, etc.)

Calibration

- Logically simple

- Required before imaging tests can be completed

Sensor Suite

- Small quantity of isolated code

- Still on critical path, required for system testing

Image / Data Processing

- Mostly complete or unchanged since GHOST

- Significant integration work still required

- Not required for partial or even near-complete testing
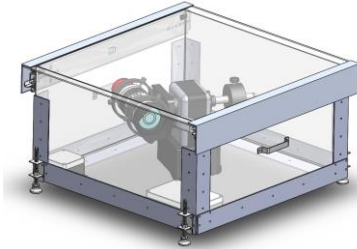
| **Manufacturing** | Power | Modularity | Software |

Transport Modules

Trip #1:

Active Protection Enclosure:
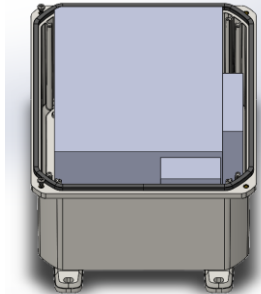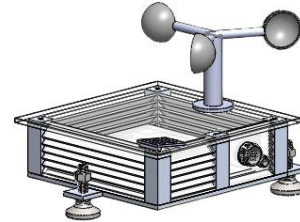Weight: 35 lb

Trip #2:

Environmental Suite & Power Module:
Weight:
- Suite: 5 lb
- Power Mod: 25.55 lb

Trip #3:

Actuation Mount & Telephoto Lens/Camera:
Weight: 18 lb

Trip #4/5:

2 Solar Panels:
Weight: 26.15 lb (each)