WIIGLS

Weightless Integrated Instrument for Ground-based Laboratory Sensing

Preliminary Design Review

October 3rd, 2022

ASEN 4018 – 012, Team 11

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Presentation Outline

1. Project Overview
2. Trade Studies
3. Risk Analysis
4. Current Design Space
5. Moving Forward
6. Appendix

Project Overview

WIIGLS

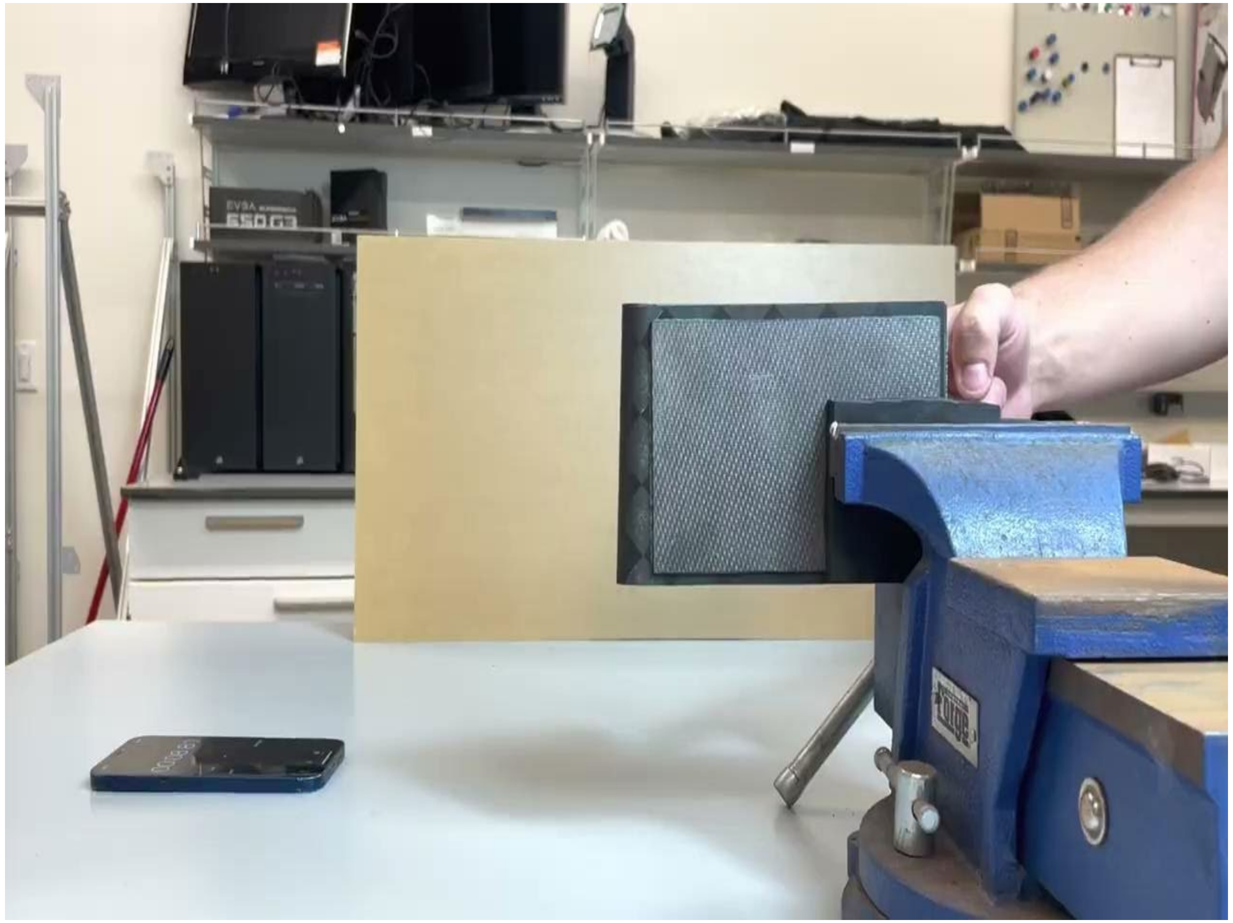
Mission Statement

Our mission is to create a modular **W**eightless **I**ntegrated **I**nstrument for **G**round-based **L**aboratory **S**ensing (WIIGLS) to characterize the dynamic motion of a deployable panel structure.

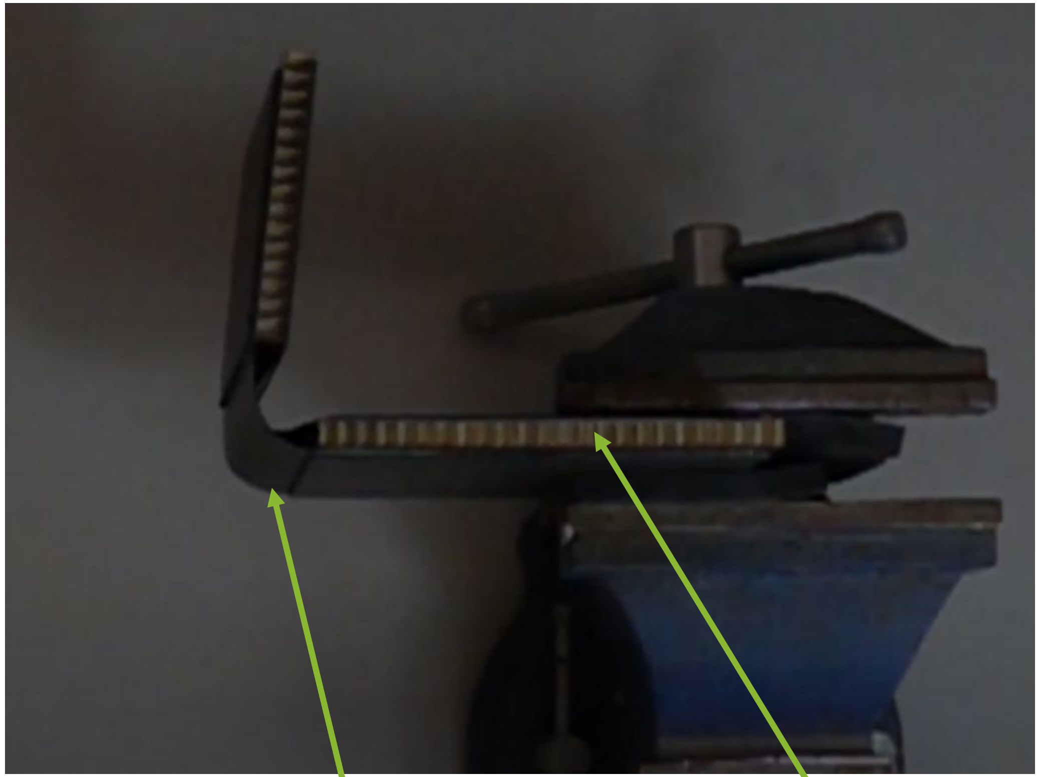
Panel Deployment

Slow-Motion Deployment

Full-Speed Deployment

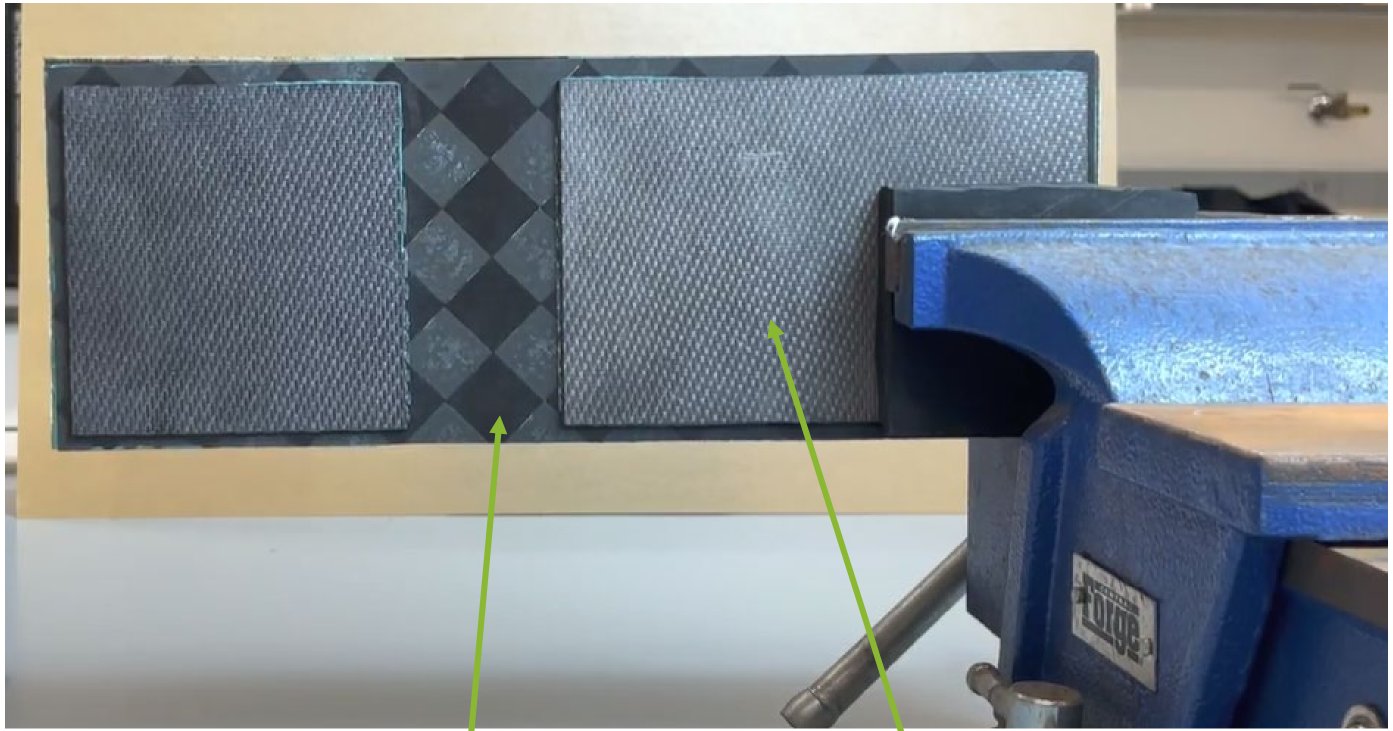


Hinge-Panel System



Hinge

Honeycomb Paneling



Carbon Fiber Composite Sheets

Carbon Fiber Reinforcement

Concept of Operations: Project Level

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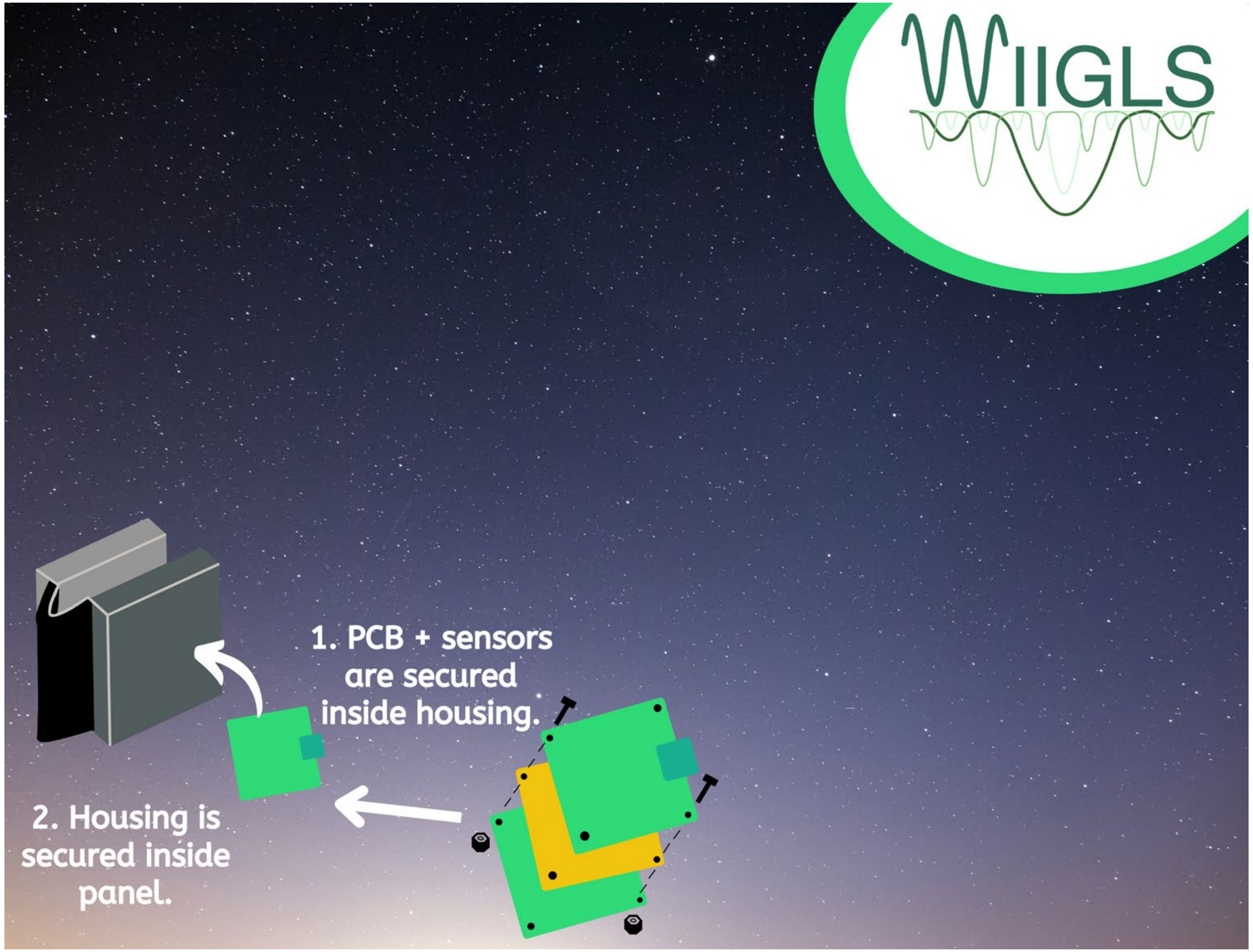

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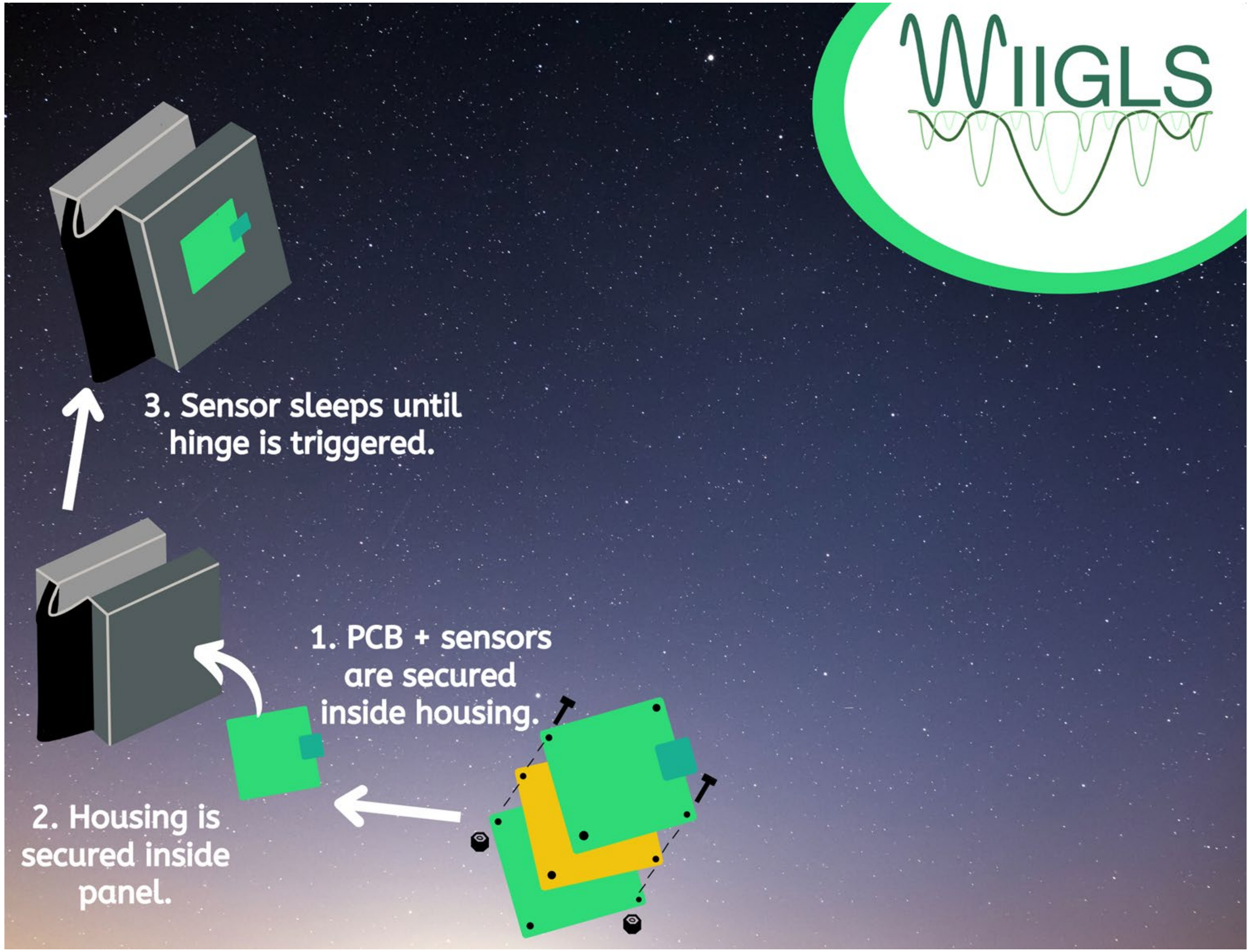

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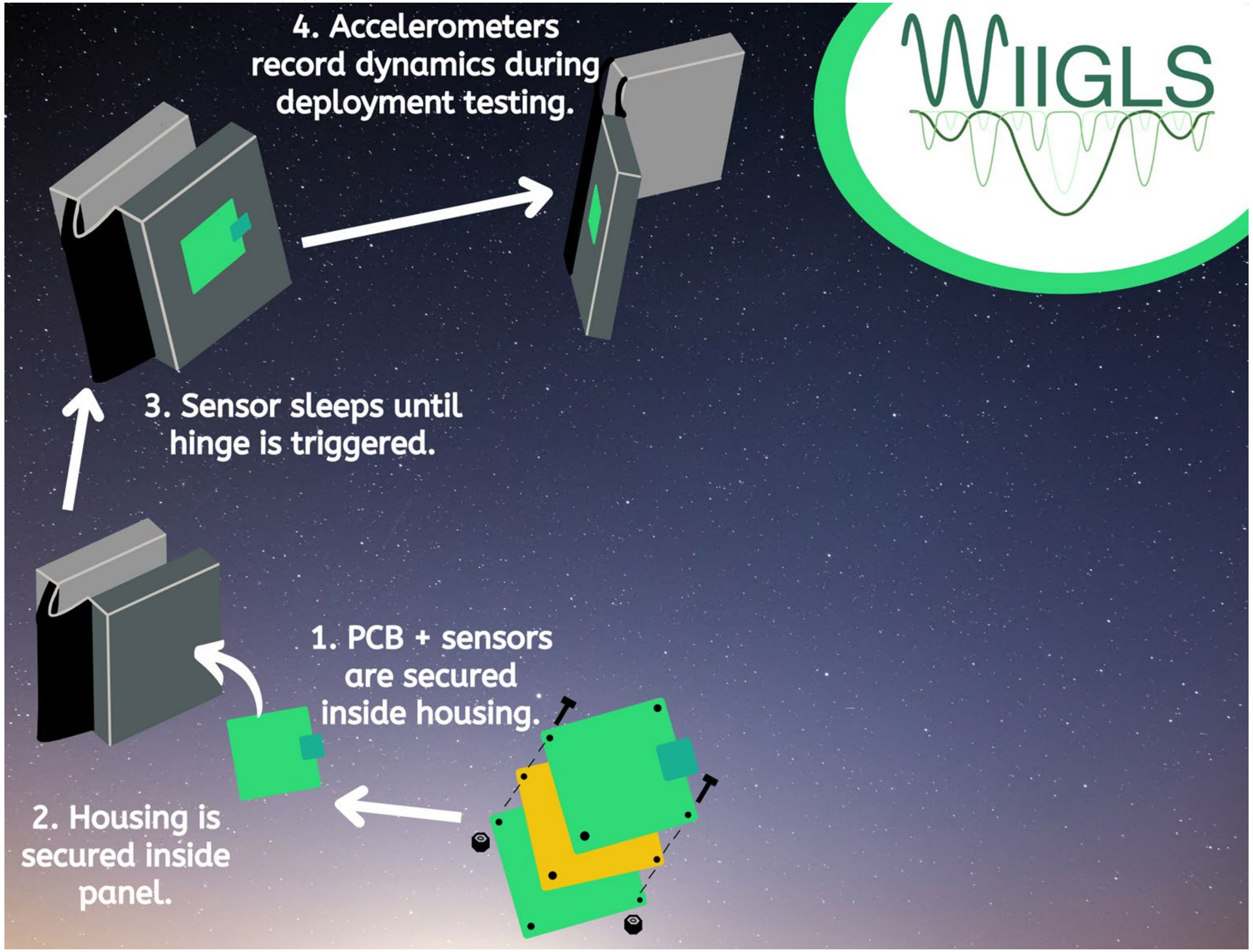

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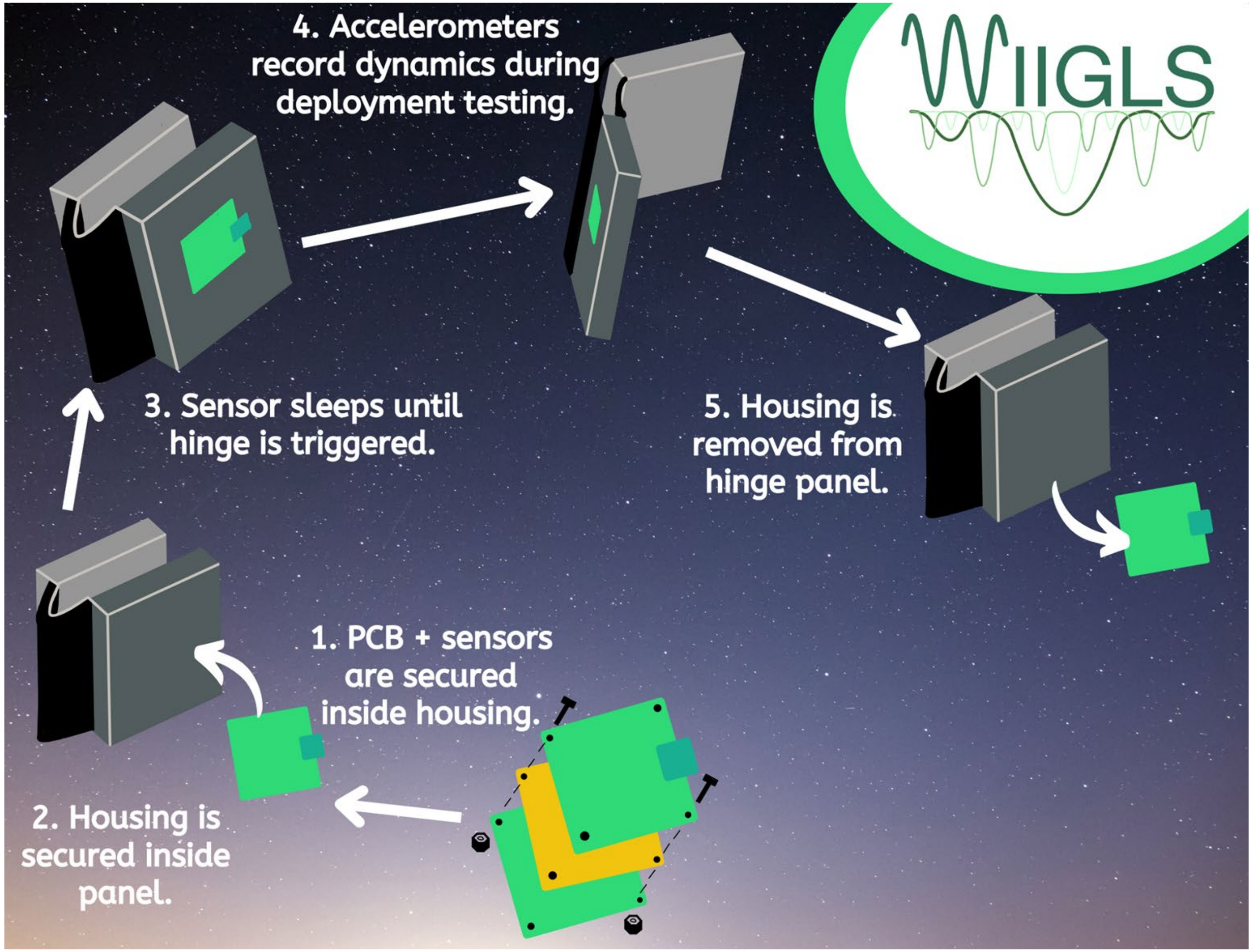

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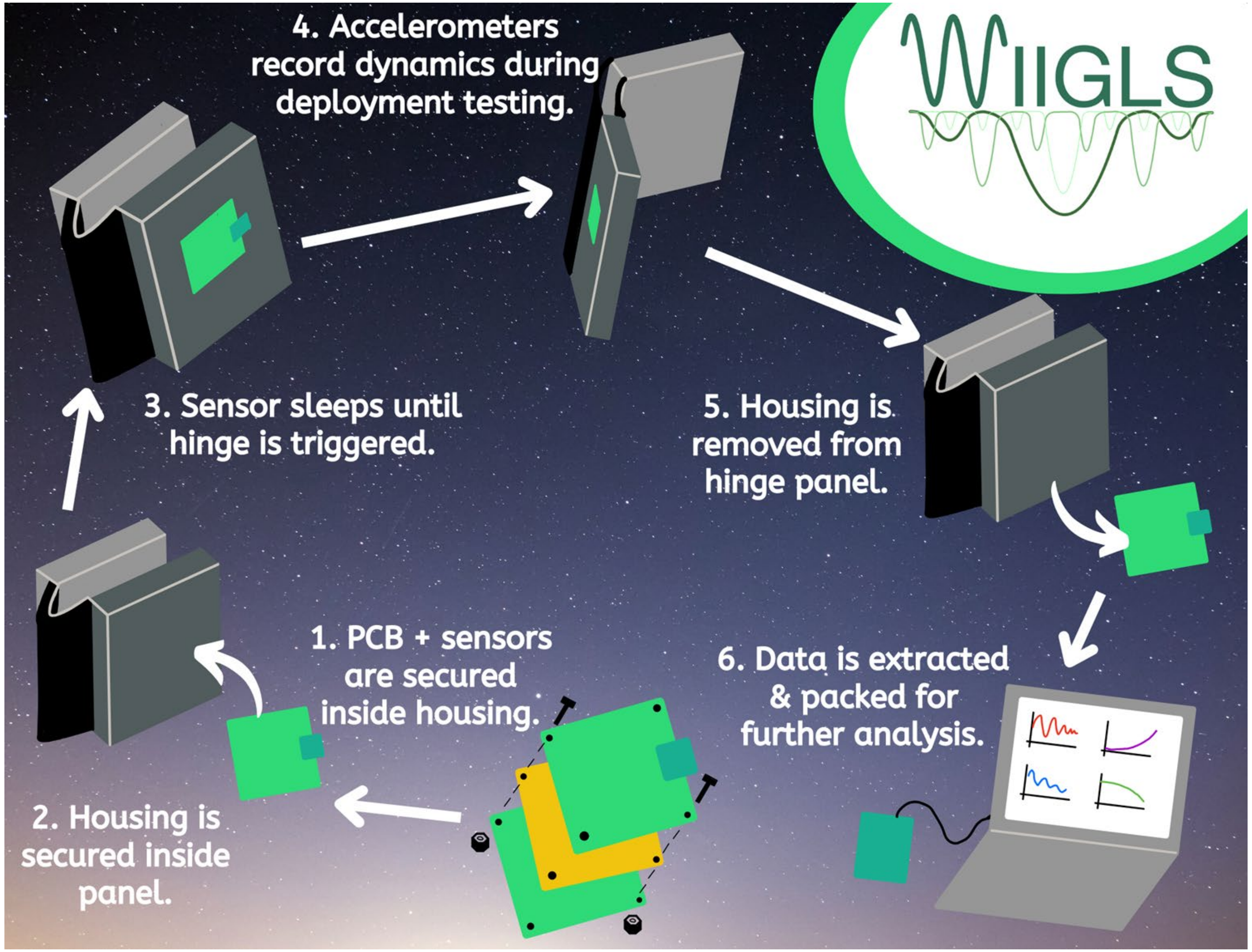
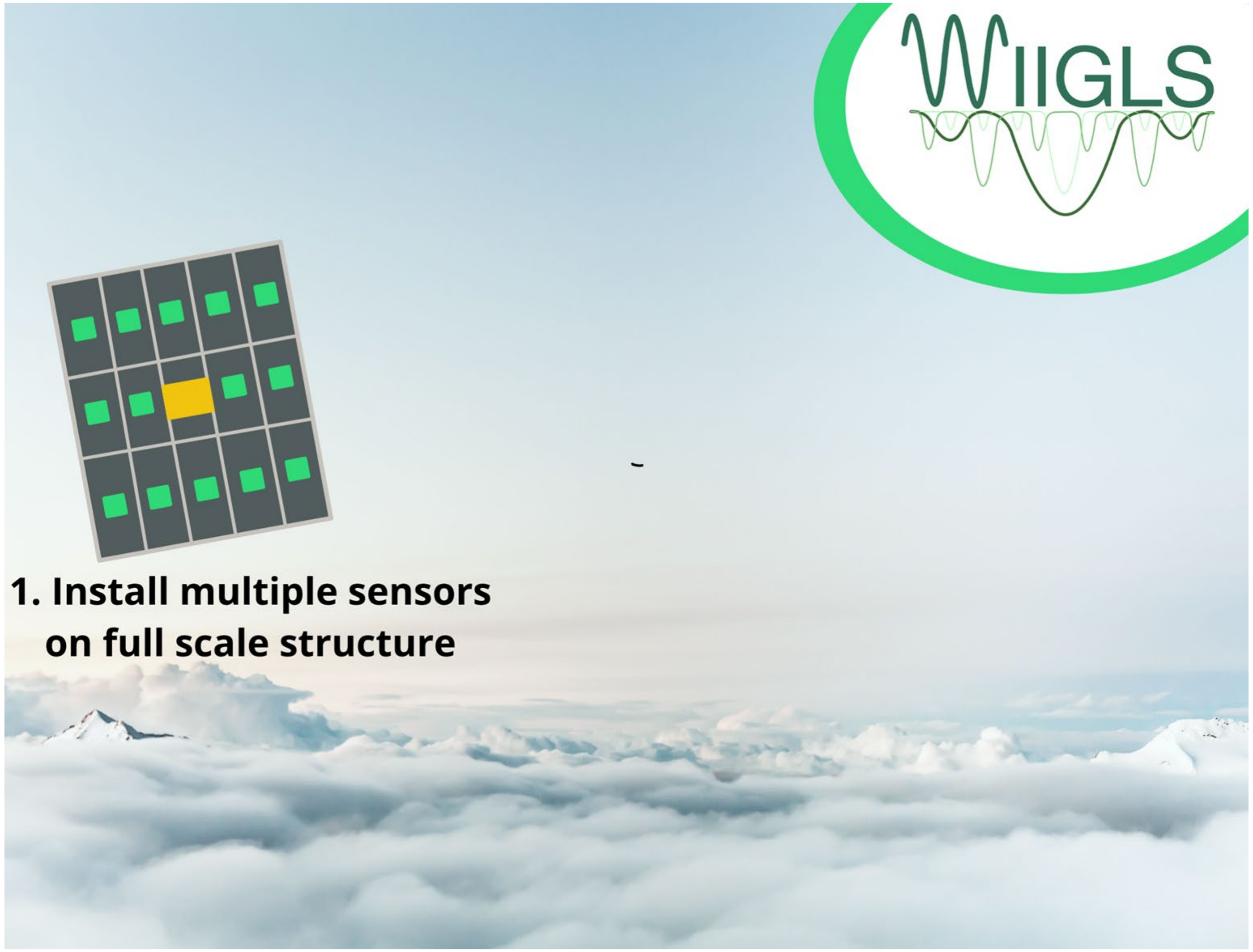


Concept of Operations: Mission Level



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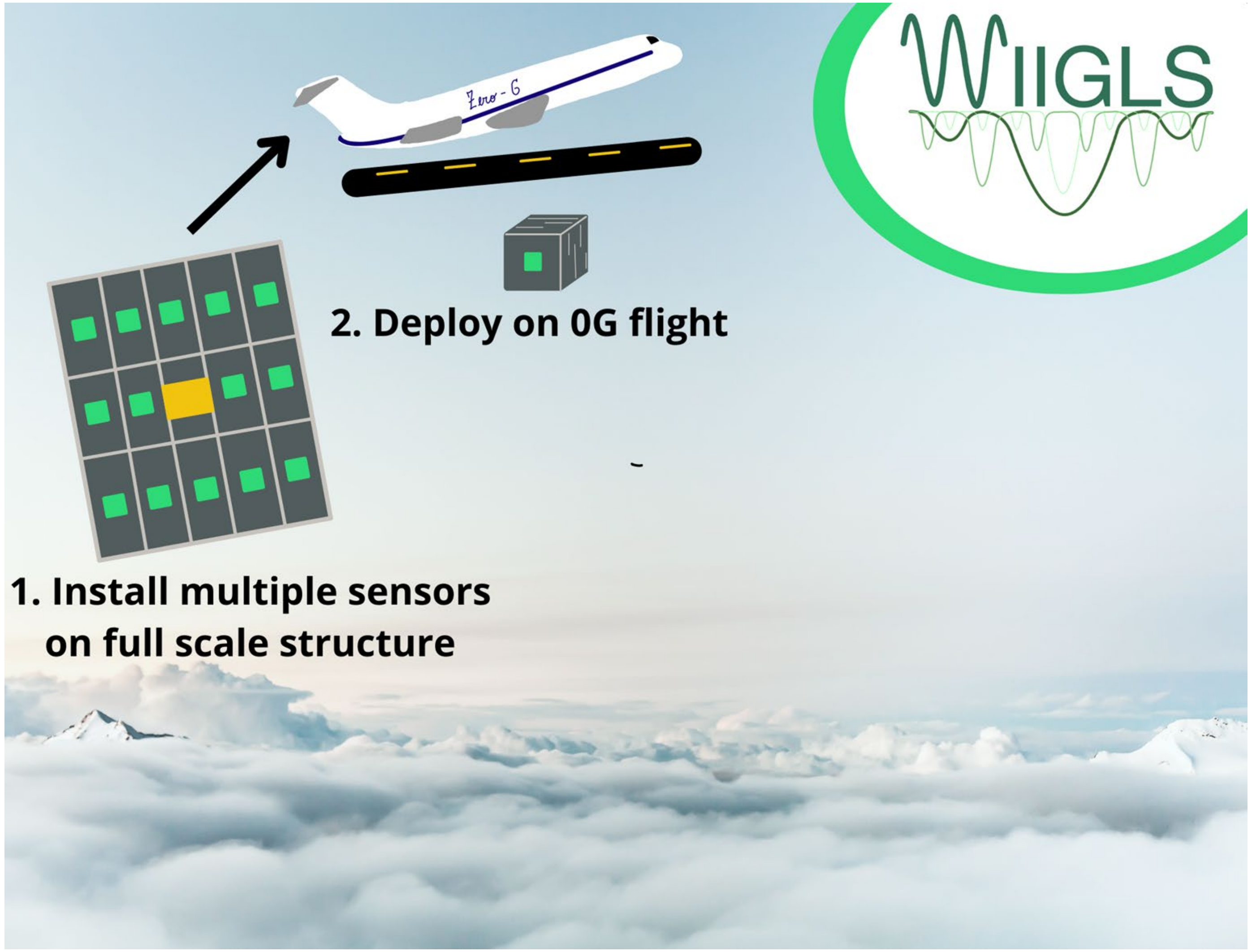
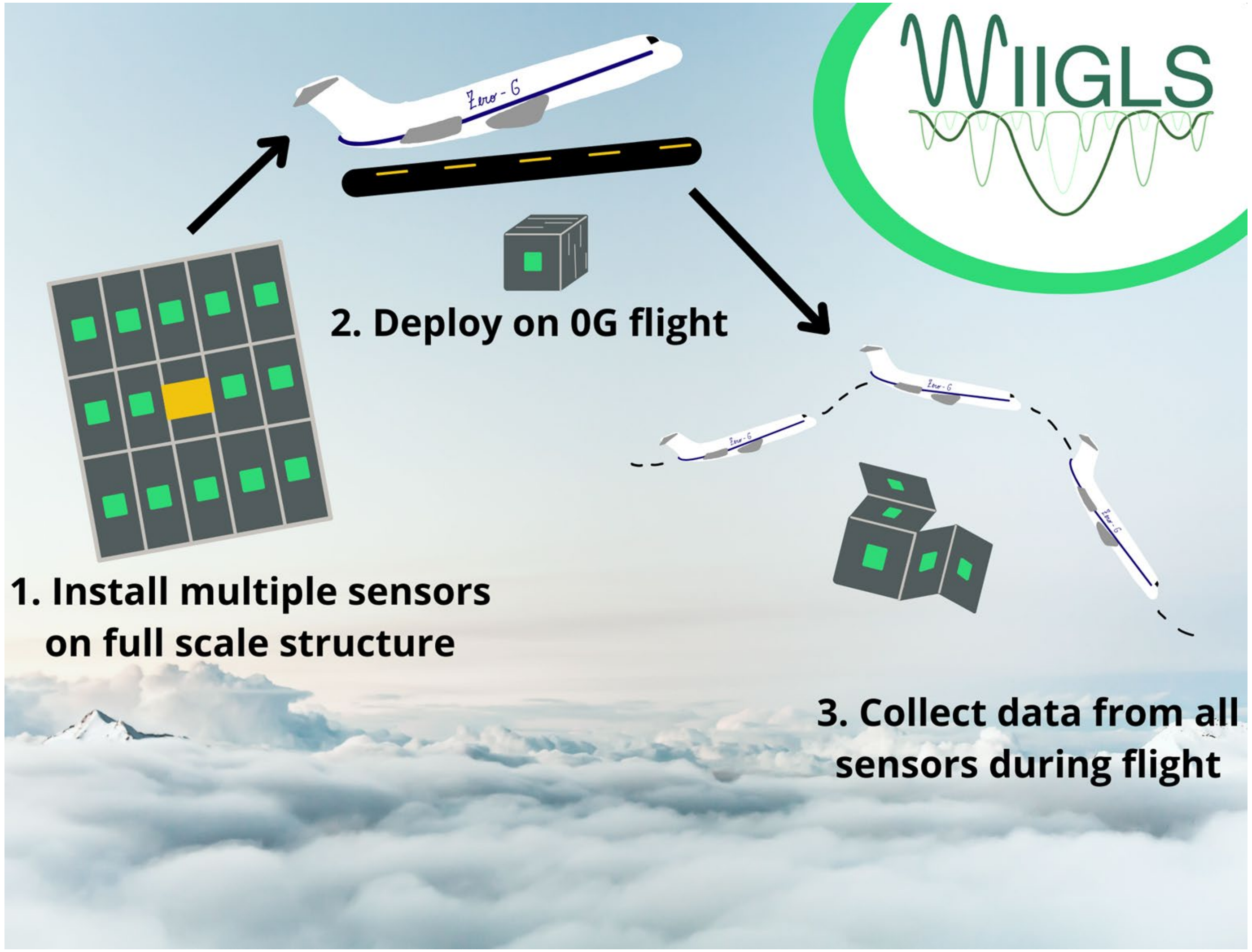
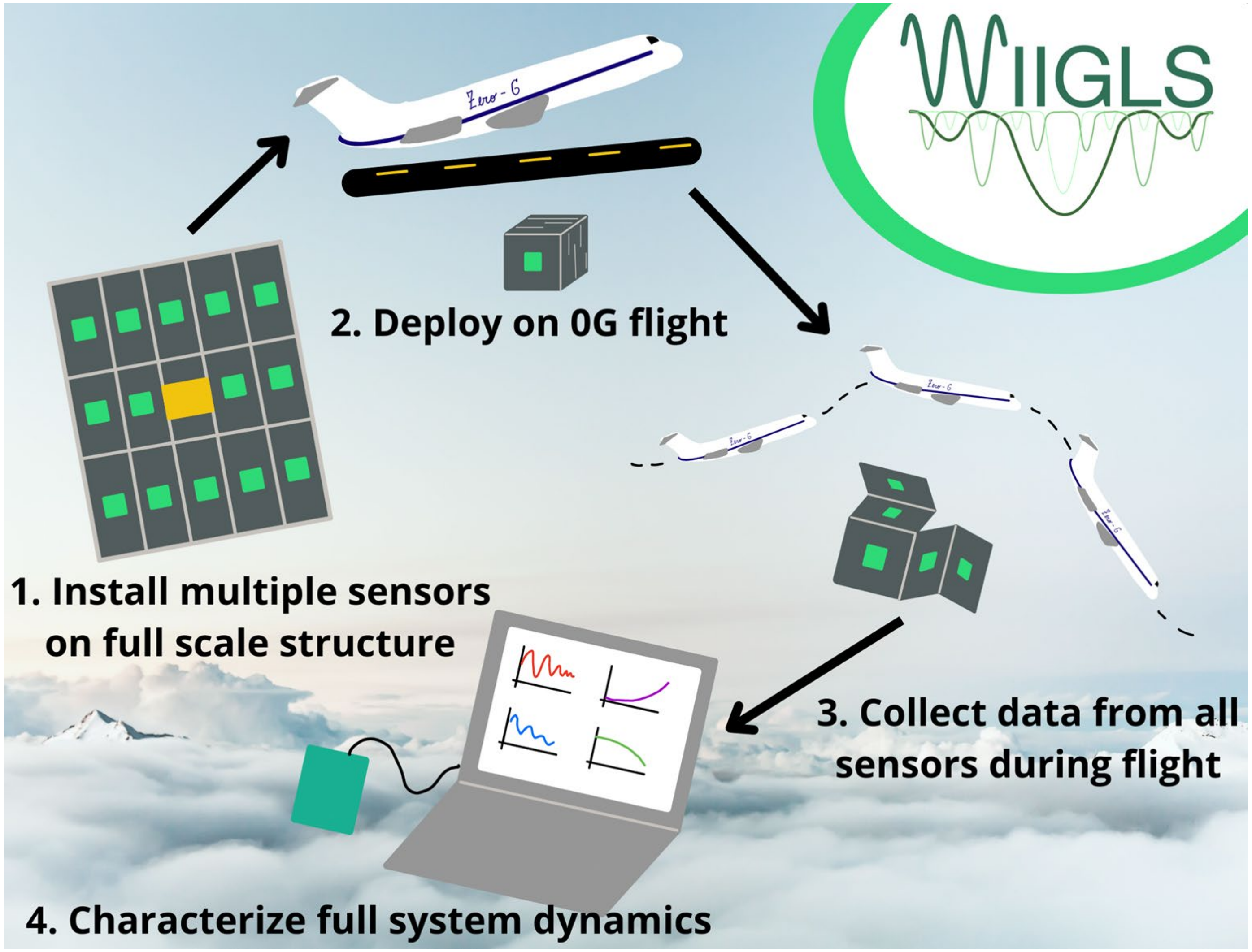


Concept of Operations: Mission Level



Concept of Operations: Mission Level



Key Functional Requirements

Requirement ID	**Title**	**Description**
FR1	Mission	System shall accurately record deployment motion of attached panel structure.
FR2	Integration	System shall fit into the provided panel structure without obstructing deployment or changing the dynamics of the system.
FR3	Budget	System shall cost less than $750 per unit.
FR4	Mobility	System shall be quickly removable/replaceable from panel to be tested.
FR5	Power	System shall be able to record data for up to an hour, with an additional hour of standby.

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Design Requirements

Design Element	Description	FR ID:
DR1.1	System shall record deployment dynamics to within 5% of optically tracked motion.	FR1
DR1.2	System shall survive deployment forces and environments without damage.	FR1
DR2.1	System shall be contained within a 30 x 20 x 0.5 cm volume.	FR2
DR2.2	System shall weigh less than 300g.	FR2
DR2.3	System shall have a symmetrical mass distribution about the long axis.	FR2
DR3.1	Sensors shall cost less than $TBD.	FR3
DR3.2	Processors shall cost less than $TBD.	FR3
DR3.3	Mounting system shall cost less than $75.	FR3
DR4.1	Sensor suite shall be able to be comfortably removed or installed within 5 minutes.	FR4
DR5.1	System shall have sufficient battery life to record data for 1 hour and stand by for 1 hour.	FR5
DR5.2	System shall have sufficient on-board storage for 1 hour of data recording.	FR5

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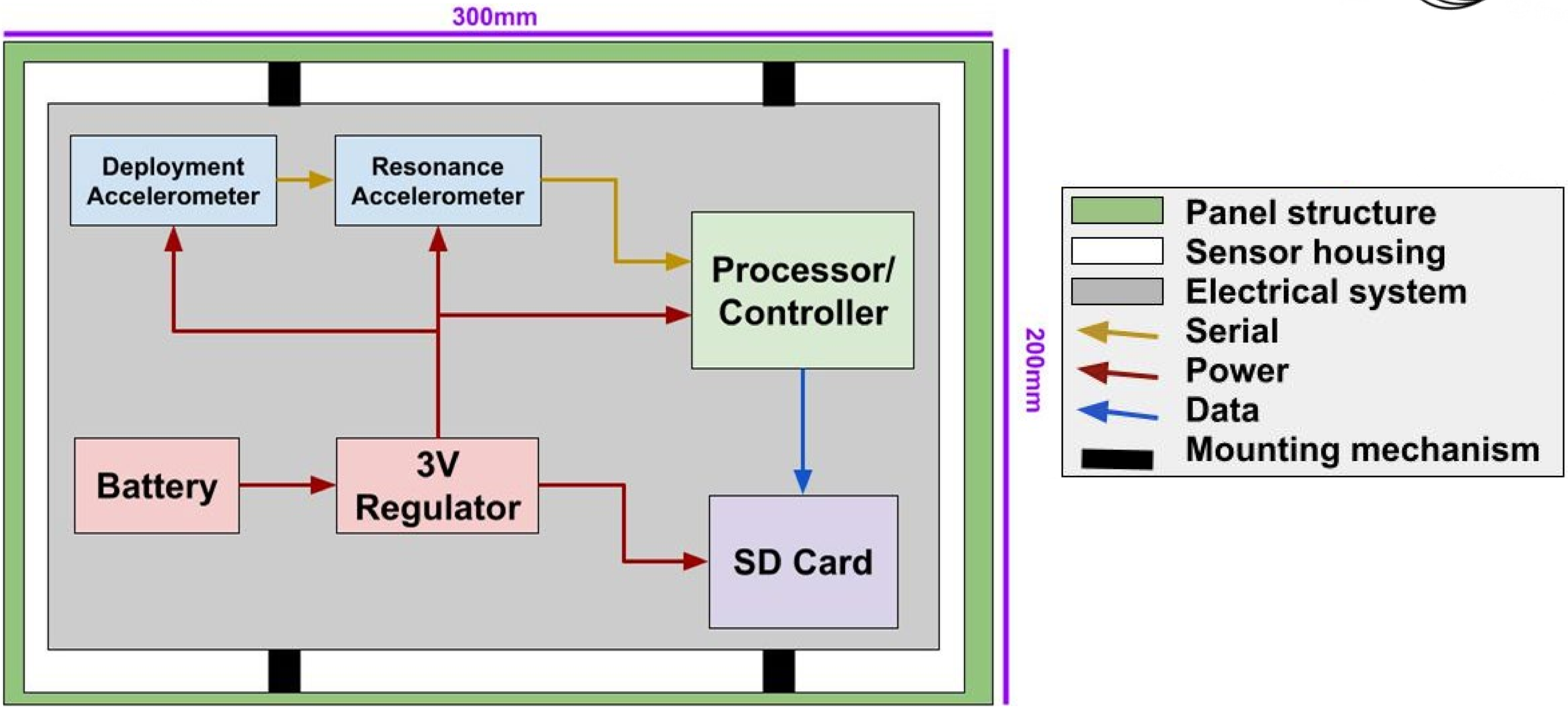
Critical Project Elements

CPE	Title	Description
CPE1	Sensing Hardware	Must be able to record linear accelerations and angular velocities accurately.
CPE2	Power Source	Must be able to remain independently powered for 2 hours.
CPE3	Integration	Sensor Suite must be integrated in such a fashion so that the hinge can open/close (or deploy) as intended.
CPE4	Housing	Housing must remain secure through deployment and predicted G-loads.

Functional Block Diagram



Trade Study Summary

Title	Description	Requirements & CPE
Suite Insertion	How to best distribute the CG and survive G-loads.	FR1, FR2, FR4, CPE3,
Housing Attachment	How to avoid deployment interference and maximize insertion/removal ease.	FR1, FR2, FR4, CPE4,
Accelerometer	How to survive G-loads and accurately record accelerations within budget.	FR1, CPE1
Microcontroller/ Microprocessor	How to maximize processing speed and minimize power consumption within budget.	FR1, CPE1

*All trades are dependent on correct G-load predictions

Coding Language	Dependent on microcontroller trade study.	N/A

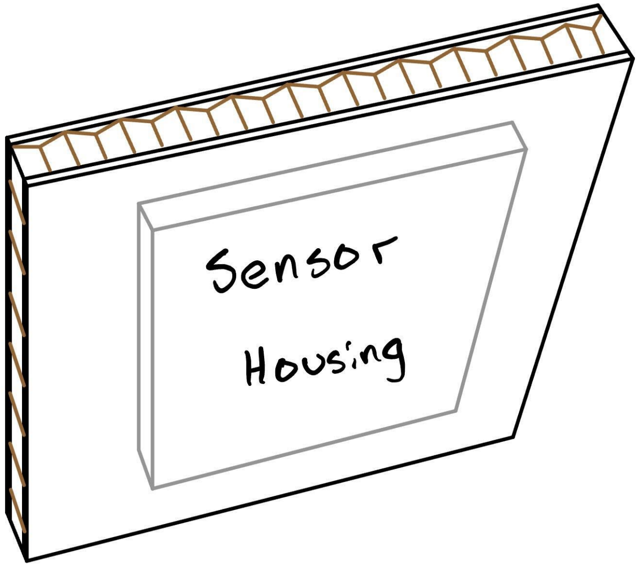
Trade Studies

Tristan Workman, Victoria Lopez & Matthew Pabin

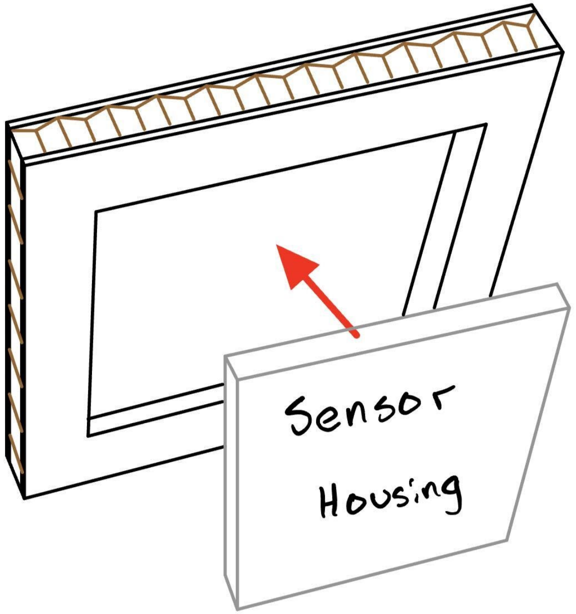
Mechanical DRs & CPEs

DR 2.3	System shall have a symmetrical mass distribution about the long axis.
DR 4.1	Sensor suite shall be able to be comfortably removed or installed within 5 minutes.
CPE 3	Sensor Suite must be integrated in such a fashion so that the panel can open/close (or deploy) as intended.
CPE 4	Housing must remain secure through deployment and predicted G-loads.

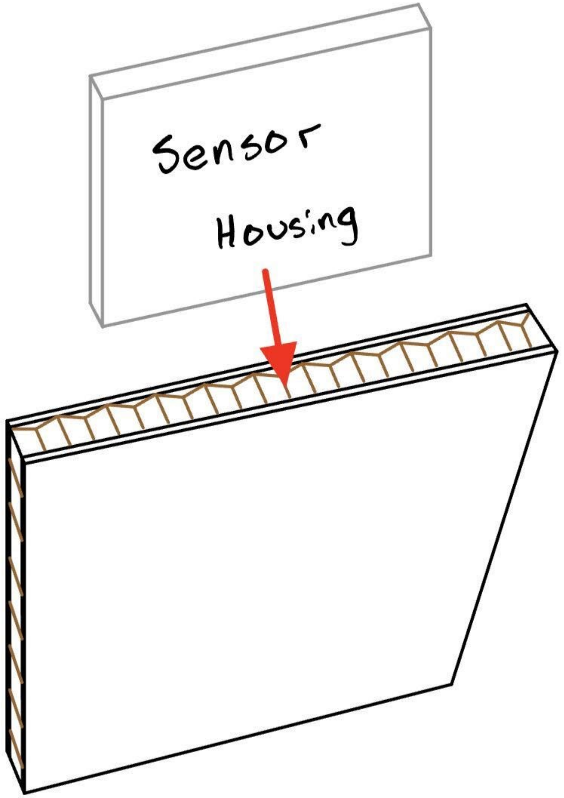
Preliminary Design Sketches



Externally Mounted



Insertion Through Paneling



Slide Through Honeycomb

Suite Insertion/Connection Trade Study

Metric	Description	Weight	Requirement
Impact to dynamics	The rigidity, mass distribution, and security of the placement of the housing on the paneling.	0.3	FR 2, DR 2.3
Reliability/Survivability	Ability to survive initial shock and subsequent movement consistently.	0.35	DR 1.2
Size and Weight	The dimensions and the total mass of the structure.	0.2	DR 2.1, 2.2, 2.3
Insertability/Removability	Ease and amount of time for insertion and removal.	0.15	DR 4.1

Suite Insertion/Connection Trade Study

	Slide Through Honeycomb	Insert Through Paneling	Attached Externally to Panel
Impact to dynamics (0.3)	4	3	2
Reliability/Survivability (0.35)	5	4	4
Size and Weight (0.2)	5	4	3
Insertability/ Removability (0.15)	4	3	5
TOTAL =	4.55	3.55	3.35

Housing Attachment Trade Study

Metric	Description	Weight	Requirement
Impact to dynamics	The rigidity, mass distribution, and security of the connection between the housing and paneling.	0.35	FR 2, DR 2.3
Reliability/Survivability	Ability to survive initial shock and subsequent movement consistently.	0.35	DR 1.2
Size and Weight	The additional volume to the housing and mass of method.	0.1	DR 2.1, 2.2, 2.3
Insertability/Removability	Ease and amount of time for insertion and removal.	0.2	DR 4.1

Housing Attachment Trade Study

	Washer + Bolts	Epoxy	Expanding Thumb Screw
Impact to dynamics (0.35)	3	4	2
Reliability/Survivability (0.35)	5	5	3
Size and Weight (0.1)	3	5	4
Insertability/Removability (0.2)	5	1	5
TOTAL =	4.1	3.85	3.15

Electrical DRs & CPEs

DR 1.1	System shall record deployment dynamics to within 5% of optically tracked motion.
DR 3.1	Sensors shall cost less than $TBD.
CPE 1	Must be able to record linear accelerations and angular velocities accurately.
CPE 2	Must be able to remain independently powered for 2 hours.
CPE 3	Sensor Suite must be integrated in such a fashion so that the hinge can deploy as intended.

Sensor Trade Study

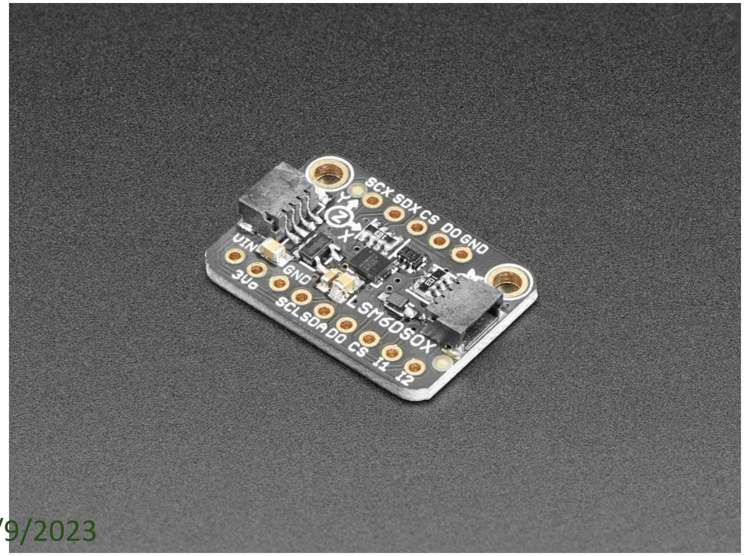
Metric	Description	Weight	Requirement
Sensing capabilities	Amount of Gs the sensor is capable of sensing.	0.3	FR1, D1.1.1, D1.1.3, D1.1.4
Microcontroller/ microprocessor interface	Type of communication to/from sensor (Digital vs. Analog).	0.3	FR1, D1.1.2
Axis	Amount of degrees of freedom.	0.15	FR1, D1.1.3, D1.1.4
Bandwidth	Range of the speed of obtaining output data.	0.15	FR1, D1.1.2
User interface	Ease of use (sufficient documentation).	0.1	FR1

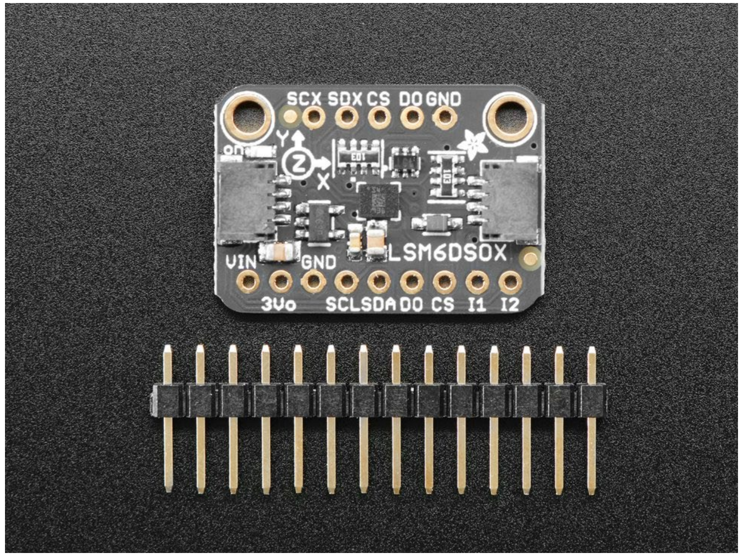
Sensor Trade Study

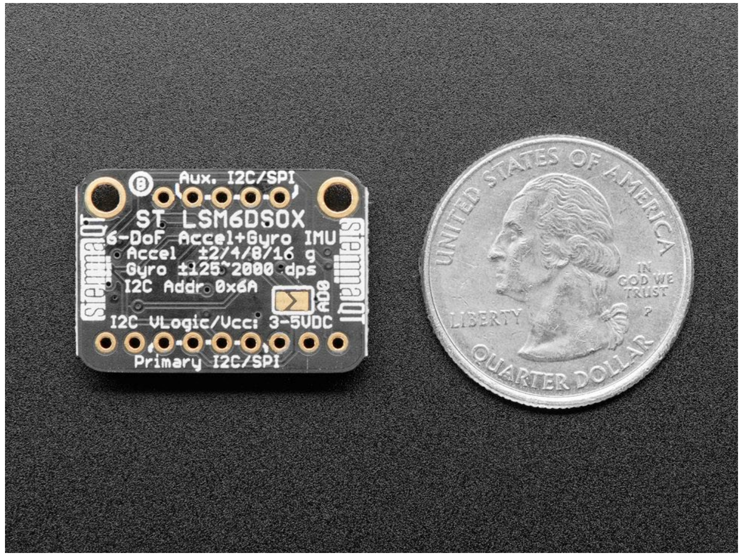
	Accelerometer			IMU	
	ADXL375	ADXL345	ADXL326	MPU6050	LSM6DSOX
Sensing capabilities (0.3)	5	3	3	4	4
Microcontroller/ microprocessor interface (0.3)	5	5	1	2	5
Axis (0.15)	3	3	3	5	5
Bandwidth (0.15)	2	3	1	5	4
User interface (0.1)	5	5	4	1	5
TOTAL =	4.25	3.7	2.3	3.5	4.5

Sensor Design Selection

	Dimension [mm]	Weight [g]	Degrees of Freedom	Interface	Sensing capabilities [Gs]	Voltage Range [V]	Shock Capabilities [Gs]	Bandwidth [kHz]
LSM6DSOX	25.6 x 17.8 x 4.6	1.7	6	SPI/I2C	2,4,6,8,16	3-5	10,000	1.6-6.7







Microcontroller/Microprocessor Trade Study

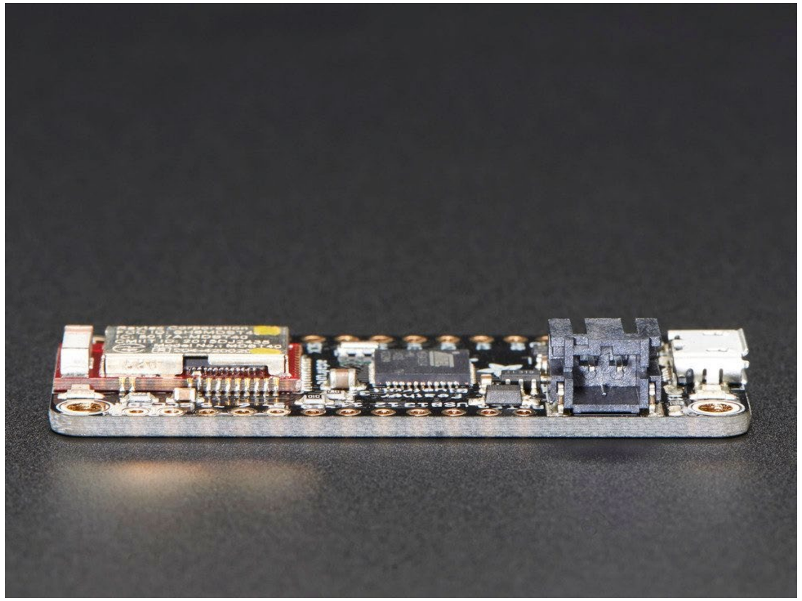
Metric	Description	Weight	Requirement
User interface	Ease of use (sufficient documentation).	0.2	D1.1
Mass	Weight of the microcontroller/microprocessor.	0.1	FR2, D2.2
Power consumption	Amount of power needed for the microcontroller/microprocessor to work.	0.3	FR5, D5.1
Processing speed	Range of the speed of obtaining output data.	0.25	D1.1
Dimensions	Size of the microcontroller/microprocessor.	0.1	FR2, D2.1
Cost	Monetary value of the microcontroller/microprocessor.	0.05	FR3, D3.2

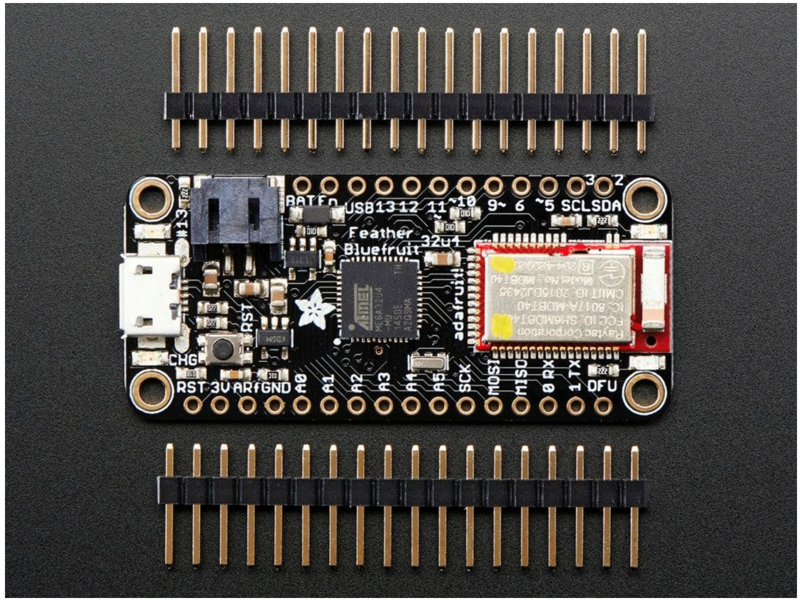
Microcontroller/Microprocessor Trade Study

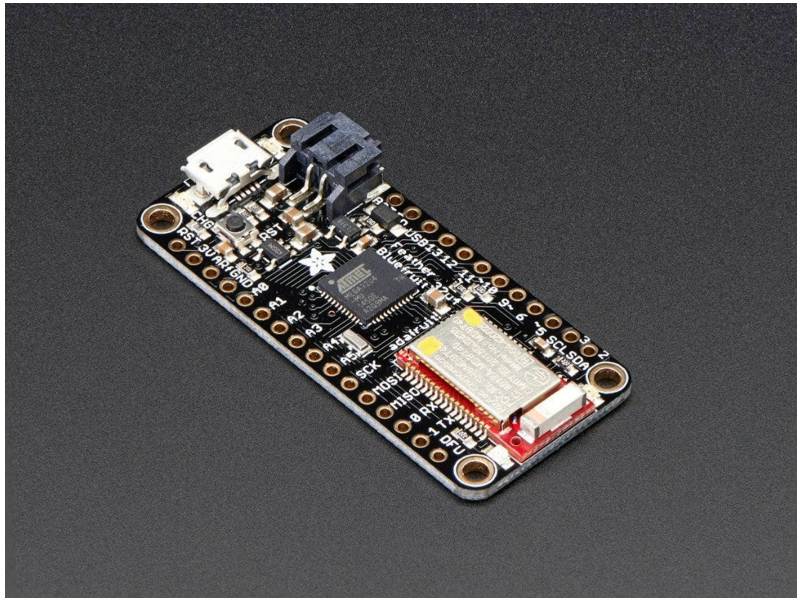
Metric	Arduino Pro Micro	Teensy 4.1	RPi Pico	RPi Zero 2W	Feather 32u4
User interface (0.2)	3	4	2	2	4
Mass (0.1)	4	3	5	3	5
Power consumption (0.3)	5	3	1	1	5
Processing speed (0.25)	2	4	3	5	2
Dimensions (0.1)	2	2	5	3	1
Cost (0.05)	4	4	4	3	4
TOTAL =	3.4	3.4	2.65	2.7	3.6

Microcontroller Design Selection

	Dimension [mm]	Weight [g]	Power Consumption [mA]	Processing Speed [MHz]	Cost
Feather 32u4	51 x 23 x 8	5.7	~10	8	$25



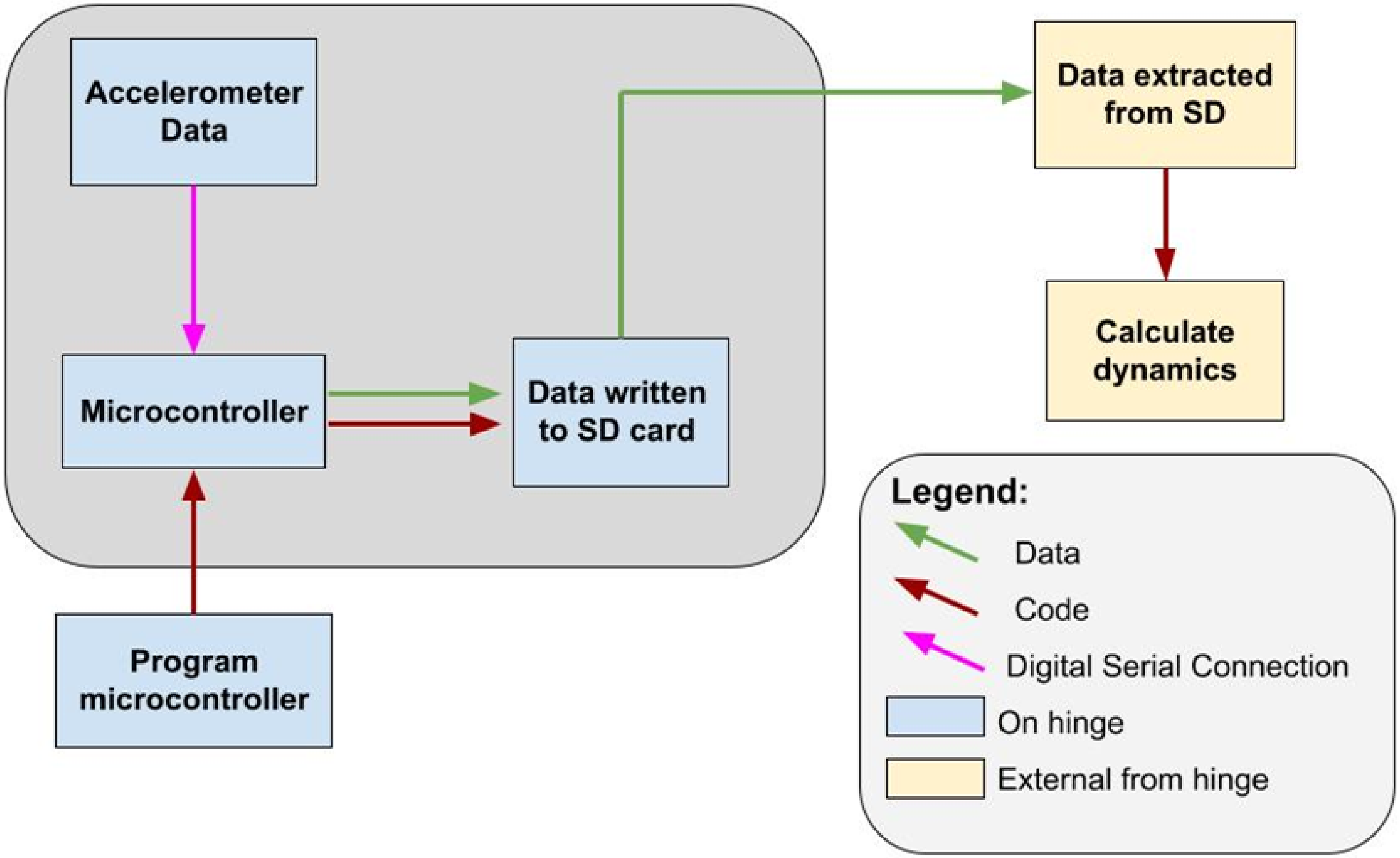




Software DRs & CPEs

DR 1.1	System shall record deployment dynamics to within 5% of optically tracked motion.
DR 1.1.3	Sensors shall record accelerations on 3 axes of up to 16 Gs within an accuracy of 5% of the optically tracked motion.
DR 1.1.4	Sensors shall record vibrations on 6 axes of up to 4 Gs within an accuracy of 5% of the optically tracked motion.
CPE 1	Must be able to record linear accelerations and angular velocities accurately.

Software Functional Block Diagram



G-Load Prediction Method 1: Observation

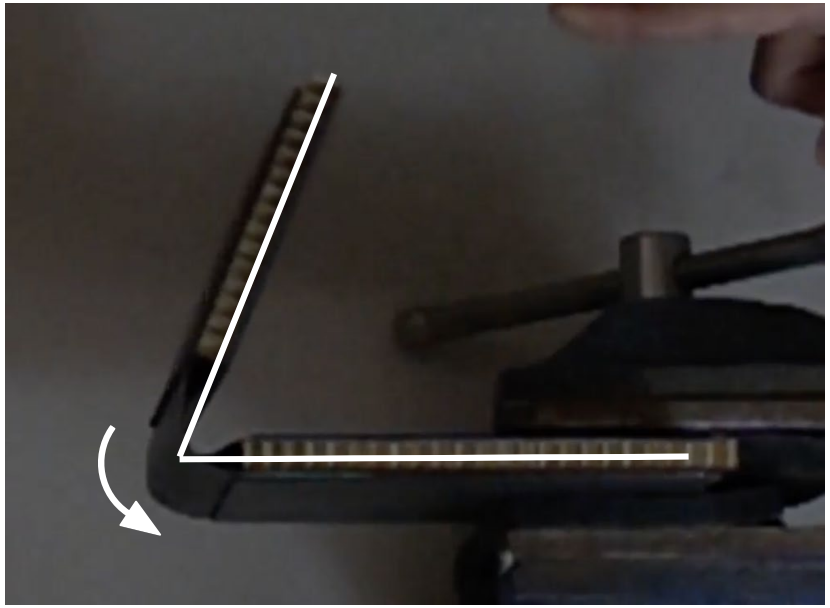
- Highest acceleration is instant of release.
- Solved for ω at several θ's, given $\theta_0 = 0$.

$$\theta = \omega t + \theta_0 \longrightarrow \omega = \theta / t$$

- Used highest calculated ω, solved for a.

$$\omega = \alpha t = at/r \longrightarrow a = \omega r/t$$

- Predicted max g-load: **10.4 Gs [102 m/s²]**

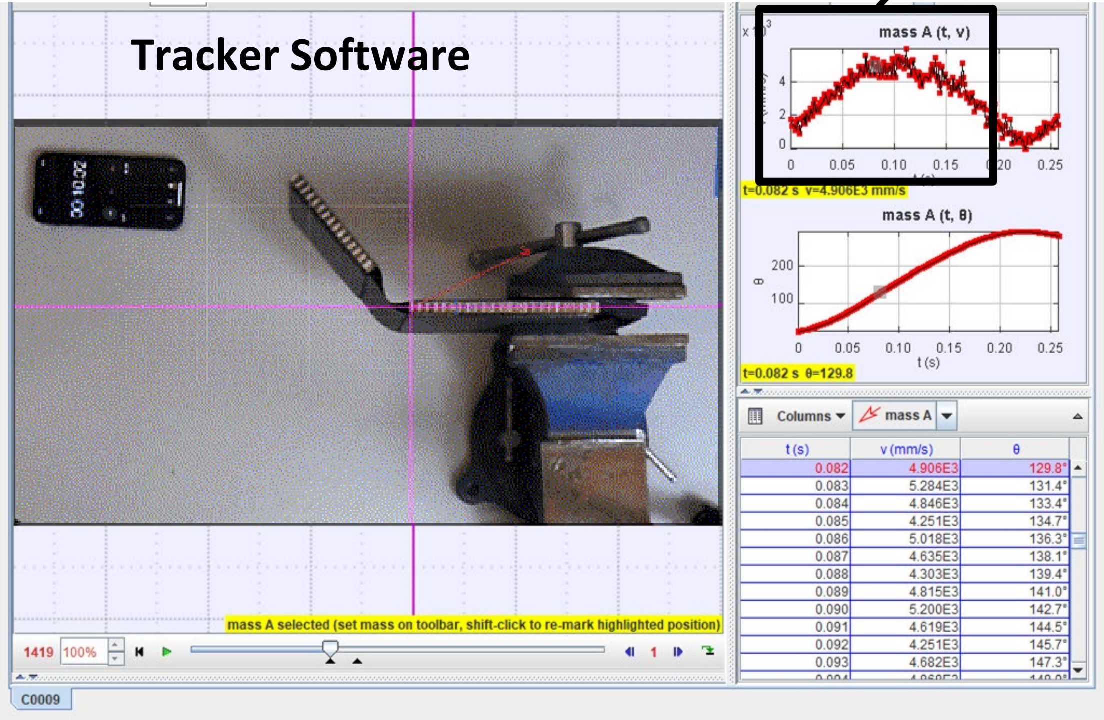


Method 2: Motion Capture Software “Tracker”

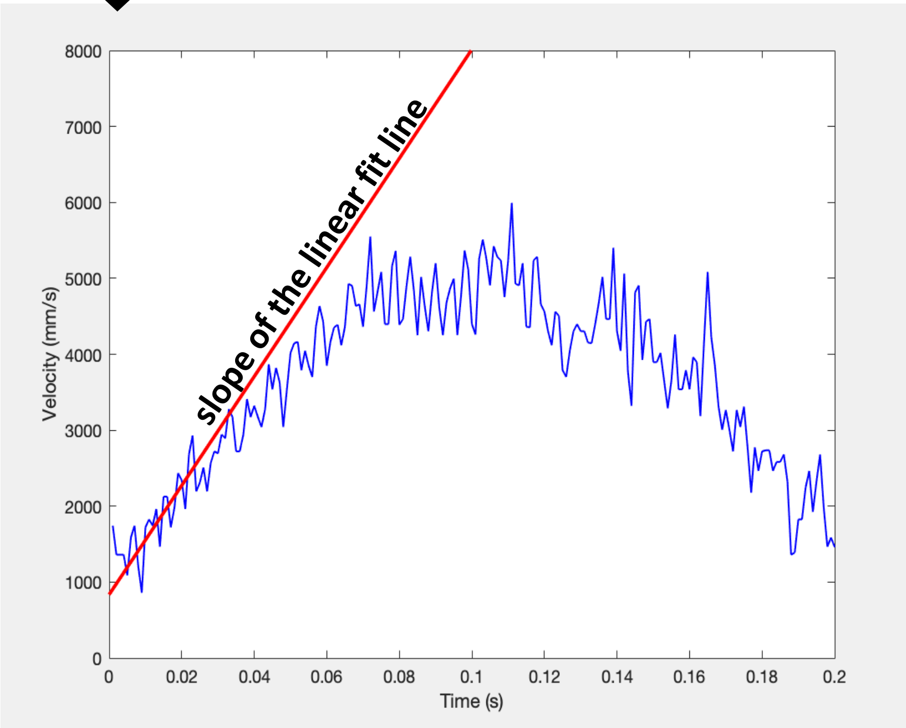
- Linear regression line through first 24 milliseconds.
- Predicted max g-load: **7.33 Gs [71.9 m/s²]**

$$v = at + v_0$$

$$v = (71.9)t + (0.836)$$



t (s)	v (mm/s)	θ
0.082	4.906E3	129.8°
0.083	5.284E3	131.4°
0.084	4.846E3	133.4°
0.085	4.251E3	134.7°
0.086	5.018E3	136.3°
0.087	4.635E3	138.1°
0.088	4.303E3	139.4°
0.089	4.815E3	141.0°
0.090	5.200E3	142.7°
0.091	4.619E3	144.5°
0.092	4.251E3	145.7°
0.093	4.682E3	147.3°



Expected Deployment G-Loading Analysis

Predicted Peak Acceleration	Factor of Safety	Accelerometer Maximums
10.4 Gs [102 m/s^2]	1.5	< 16G [156.96 m/s^2]

Risk Analysis

Céu Gómez

High Risk/Uncertainty Elements

- **CPE 1**
  - Difficulty in characterizing expected motion after initial deployment
  - Sensor sizing and response rate dependent on motion
- **CPE 3**
  - Battery monitoring and protection

CPE1 - Modeled Deployment G-Load

#:	Risk:	Mitigation:
1	Loading exceeds sensor range	**Add a margin of error to predicted G-loads**
2	Loading exceeds safe structural tolerance	**Design structure to factor of safety**
3	Modal vibration Nyquist frequency exceeds sensor polling rate	**Synchronous serial interface to sensors**

CPE1 - Vibrations and Frequencies

#:	Risk:	Mitigation:
4	Secondary vibrations	**Vibe table frequency analysis**
5	Structural resonance	**Install vibration dampening mechanism**
6	Sensors picking up second-stage frequencies & obscuring modes	**Analyze data from multiple sensors**

CPE3 - Battery Longevity and Safety

#:	Risk:	Mitigation:
7	Battery puncture	**Structural protection for the battery**
8	Overdraw	**Integrated battery monitoring**
9	Thermal runaway	**Thermal output modeling**

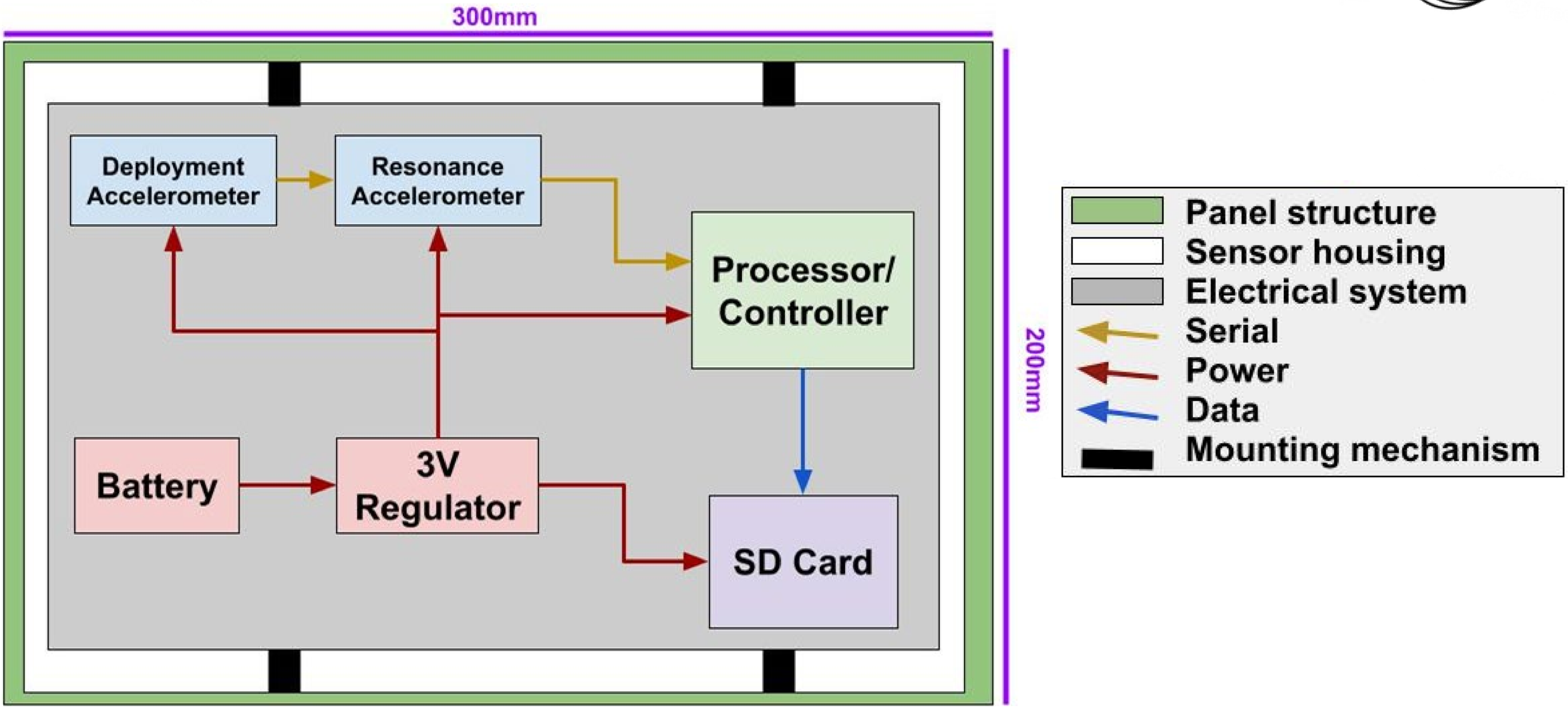
Risk Matrix

	Very Likely					
Probability	Likely			R5	Incorrect predicted G load	
	Possible			R4, R6	R1, R3	
	Unlikely	Inefficient code will produce inaccurate data				R2, R8
	Very Unlikely	Sensor suite takes longer than 5 minutes to remove or install		Cost of material/ manufacturing exceeds budget		R7, R9
		Negligible	Minor	Moderate	Significant	Severe
		Impact/Consequence		Risk Level:		
				Acceptable	Watch	Unacceptable

Current Design State

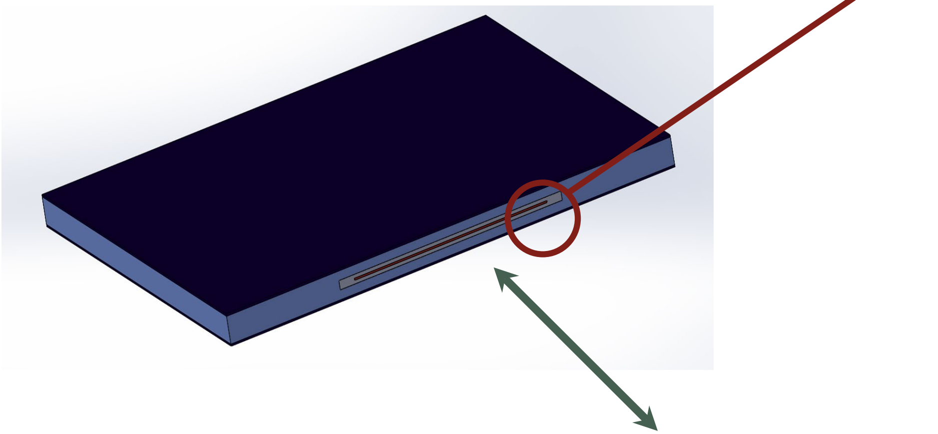
Ceu Gomez

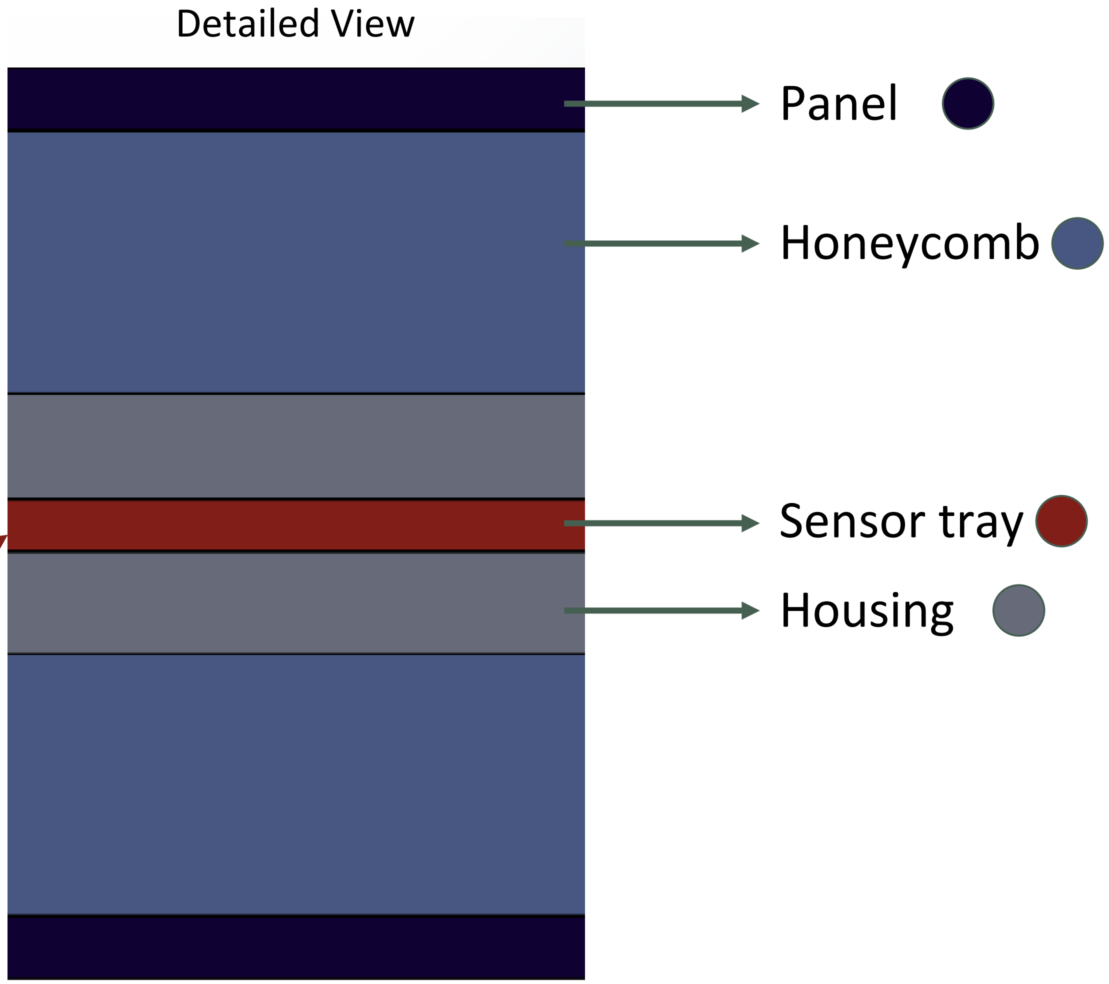
Functional Block Diagram



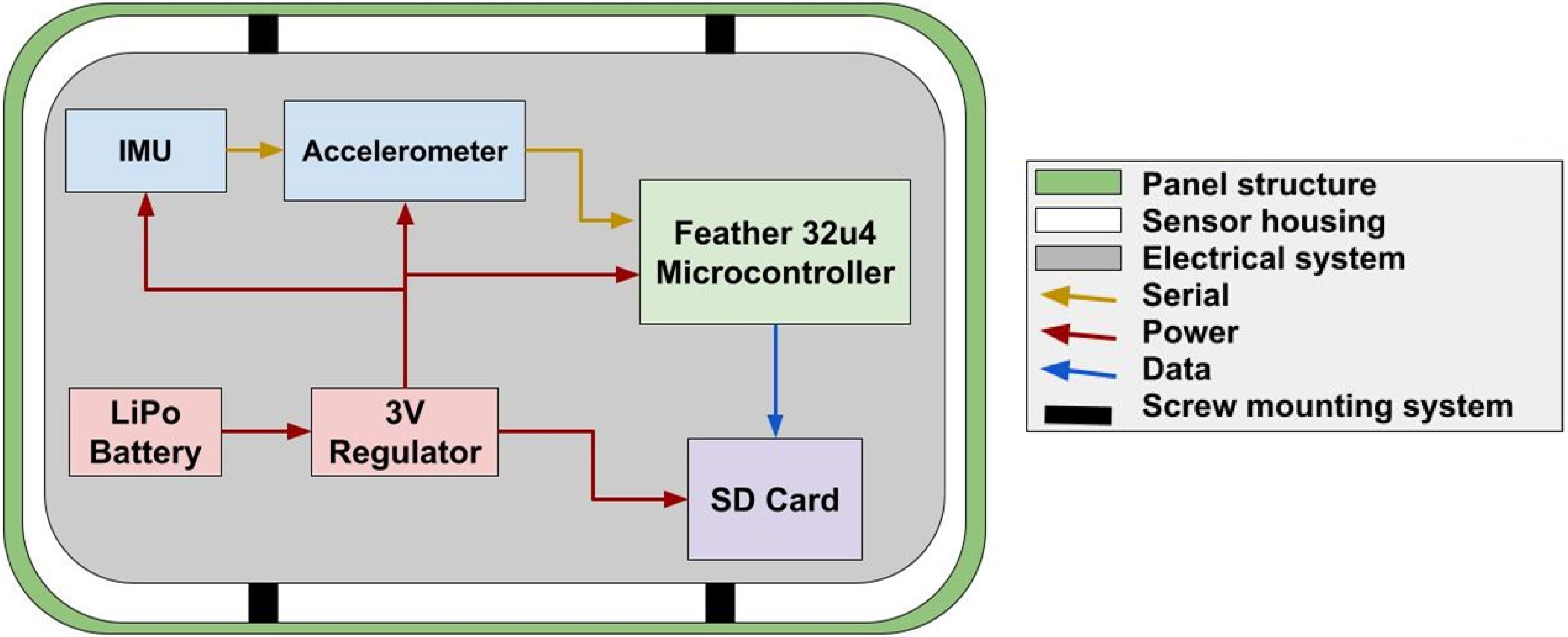
Key Design Points

- Sensors:
  - LSM6DSOX - Serial
  - ADXL375 - Serial
- Microcontroller:
  - Feather 32u4
- Slide-in structure design:
  - Washer & bolts connection
- Battery:
  - PRT-13851 Lithium-Ion Battery

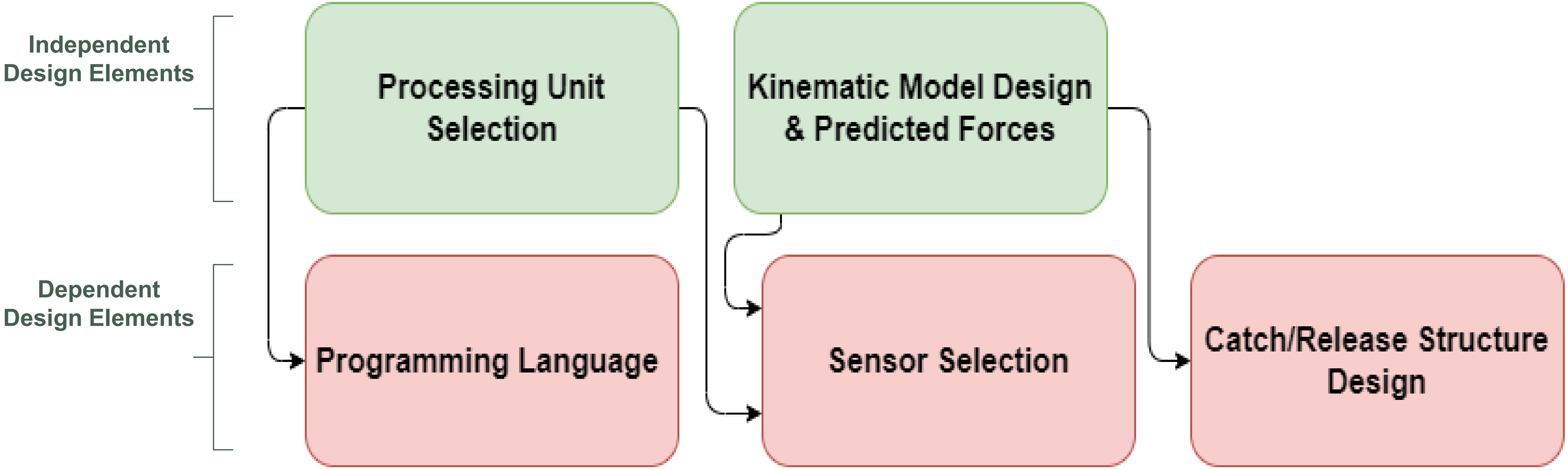




Key Design Points



Design Dependencies



Inconclusive Trade Studies & DEs

Trade Studies:

- Coding Language

Design Elements:

- Vibrational Analysis

Moving Forward

Olivia Epstein

Design Timeline & Critical Path

Finalize Design

Develop a sub-system integration plan.

Continue Design Analysis

Sensing elements, power, microcontroller, and structural materials.

Low-Level Prototyping

Prototype sensor-processor interface and design catch/release mechanism.

Validation & Testing

Develop test procedures & use vibration tables and optical tracking to verify and mitigate risks.

Simulation Test

Verify software with test data.

CDR

Acknowledgements

Team WIIGLS would like to thank Dr. Erik Knudsen, Dr. Francisco López Jiménez, Yasara Dharmadasa, Professor Trudy Schwartz, and Teaching Fellow Jasmin Chadha for their guidance, mentoring, and contributions to this presentation.

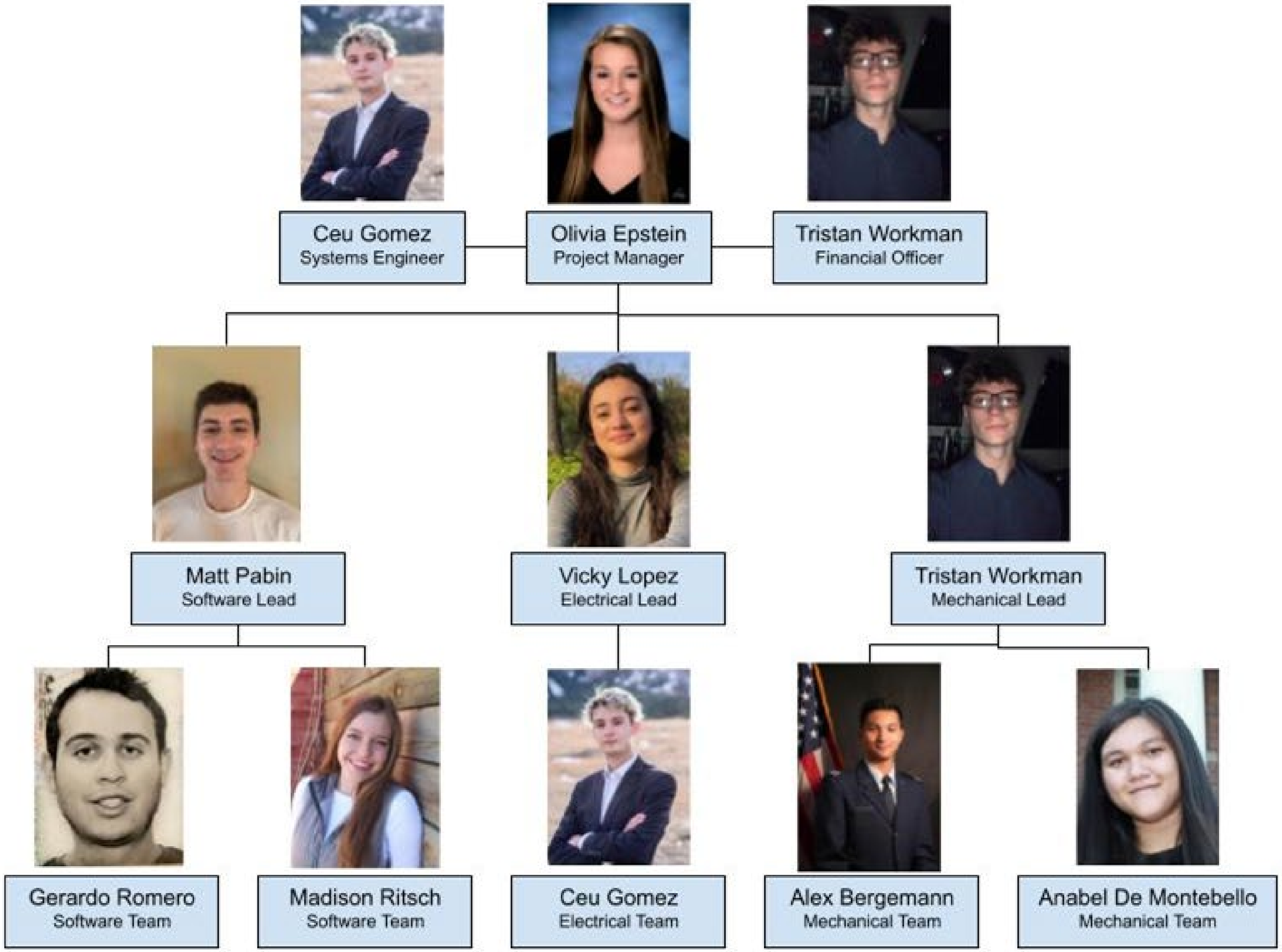
THANK YOU!

Thank you

Any Questions?

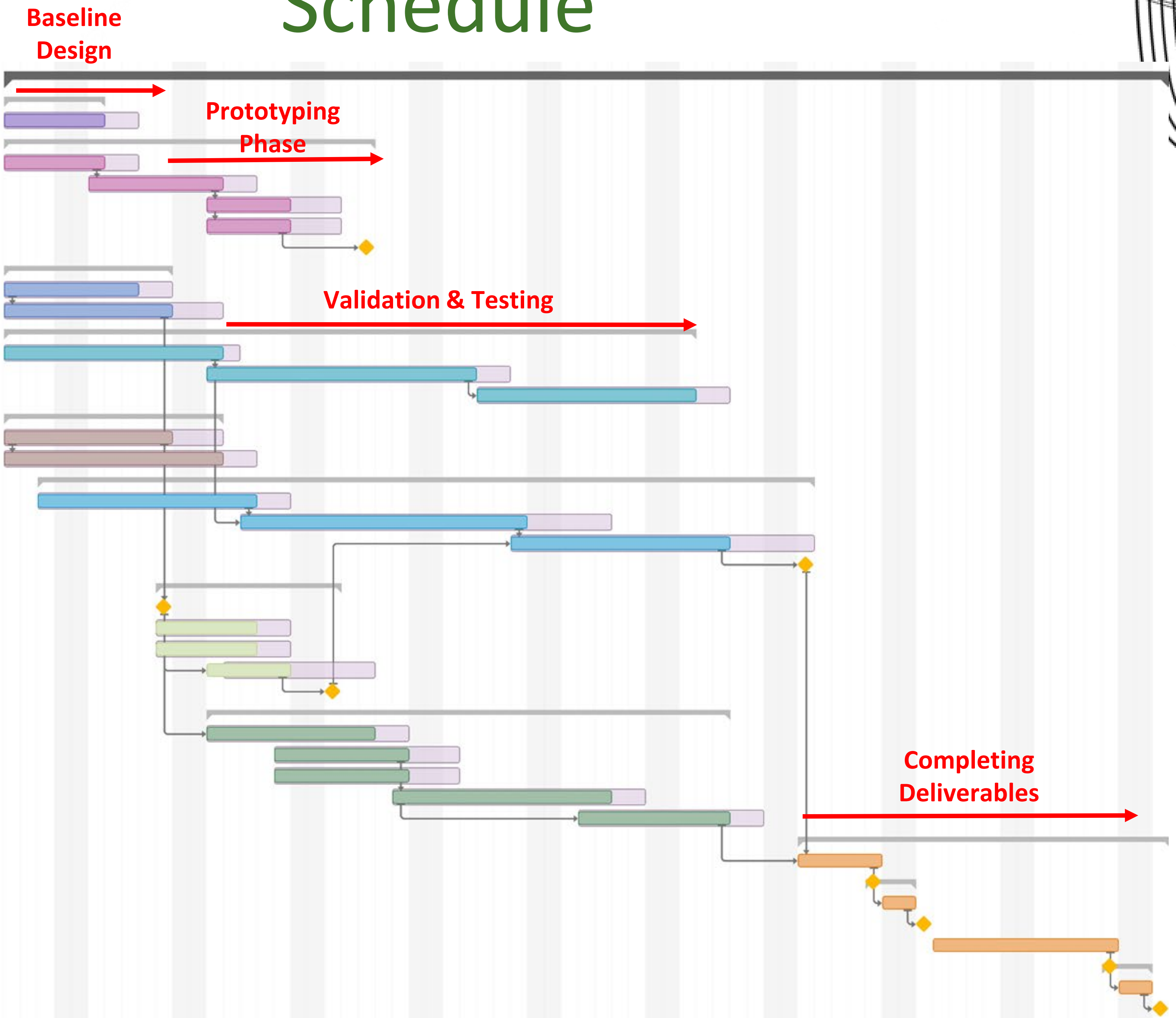
Appendix & Supporting Materials

Team Organization

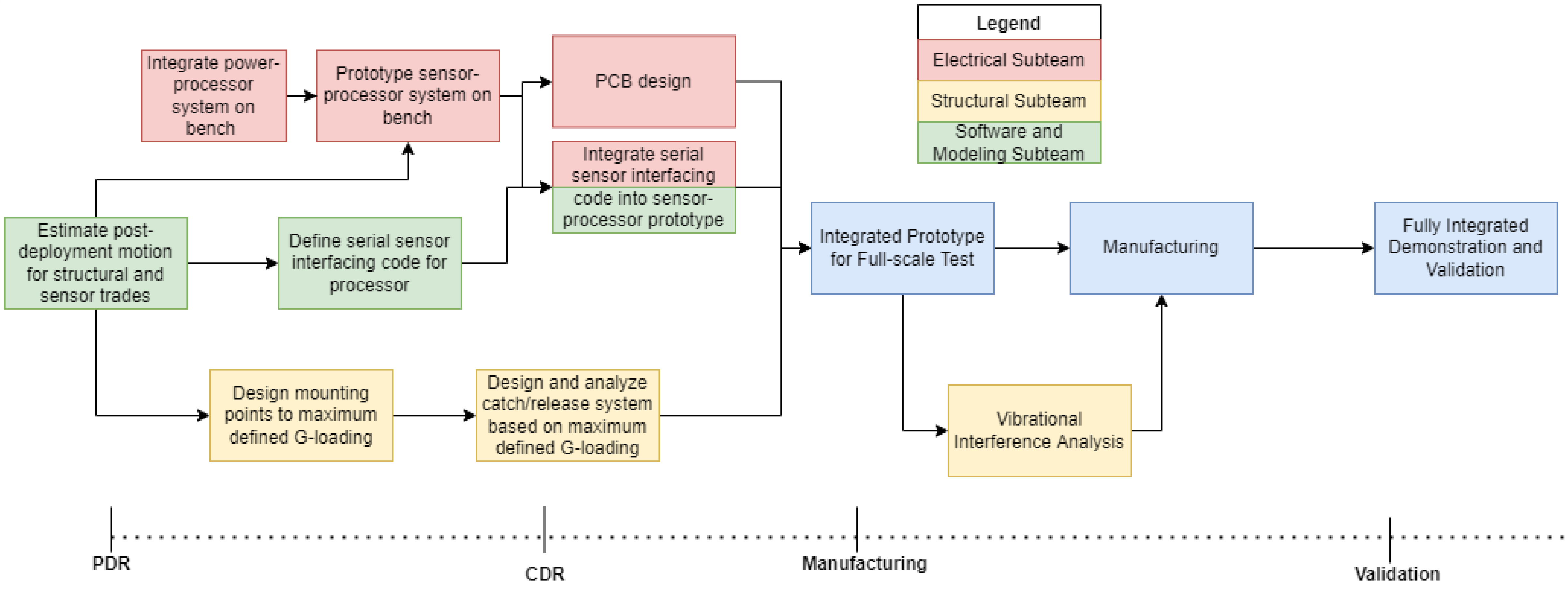


Schedule

CDR:	05/Oct	12/Dec	0%
Project Management	05/Oct	10/Oct	0%
Create CDR Slide Deck	05/Oct	10/Oct	0%
Purchasing/Budget	05/Oct	26/Oct	0%
Budget Analysis	05/Oct	10/Oct	0%
Budget Finalization	10/Oct	17/Oct	0%
Purchase Sensors	17/Oct	21/Oct	0%
Purchase Microcontroller	17/Oct	21/Oct	0%
Purchasing Complete	26/Oct	26/Oct	0%
Hardware	05/Oct	14/Oct	0%
Material Selection	05/Oct	12/Oct	0%
Baseline Suite CAD	05/Oct	14/Oct	0%
Systems	05/Oct	14/Nov	0%
Subsystem Integration ...	05/Oct	17/Oct	0%
Verification & Validation...	17/Oct	01/Nov	0%
Risk Mitigation Plan	02/Nov	14/Nov	0%
Electrical	05/Oct	17/Oct	0%
PCB Design	05/Oct	14/Oct	0%
Sensor & Power Selecti...	05/Oct	17/Oct	0%
Testing	07/Oct	21/Nov	0%
Offloader Baseline Desi...	07/Oct	19/Oct	0%
Test Proceedures	19/Oct	04/Nov	0%
Vibe Table Testing	04/Nov	16/Nov	0%
Testing Completed	21/Nov	21/Nov	0%
Prototyping	14/Oct	24/Oct	0%
Begin Prototyping	14/Oct	14/Oct	0%
Housing	14/Oct	19/Oct	0%
PCB Assembly	14/Oct	19/Oct	0%
Integration	17/Oct	21/Oct	0%
Prototyping Complete	24/Oct	24/Oct	0%
Software	17/Oct	16/Nov	0%
1D Model	17/Oct	26/Oct	0%
Electrical Interfacing Fe...	21/Oct	28/Oct	0%
Run Speed Feasibility	21/Oct	28/Oct	0%
Pseudocode	28/Oct	09/Nov	0%
Test Simulation	08/Nov	16/Nov	0%
Deliverables	21/Nov	12/Dec	0%
Complete CDR Slides	21/Nov	25/Nov	0%
Internal CDR Deadline	25/Nov	27/Nov	0%
Review and Refine	26/Nov	27/Nov	0%
CDR Due	28/Nov	28/Nov	0%
Complete Final Report	29/Nov	09/Dec	0%
Internal Final Report De...	09/Dec	11/Dec	0%
Review and Refine	10/Dec	11/Dec	0%
Final Report Due	12/Dec	12/Dec	0%



Prototyping/Modeling



Background and Motivation

Project Background:

- JPL's OMERA
  - Can fold into a small volume.
  - Requires hinges with high precision.
- Tape-Spring Hinge Study

Motivation:

It is vital to experimentally characterize all aspects of the deployment dynamics in order to reduce risk when unfolding on-orbit. Deployable structures are useful in space mission design as they allow for large surface areas, usable during the mission for sub-systems like solar panels.

Levels of Success

Objective	Success Level 1	Success Level 2
Data Collection	Record total deployment time, and characterize 2 linear accelerations and 1 rotational acceleration during deployment.	Record total deployment time, and characterize 3 linear accelerations and 3 rotational accelerations during deployment as well as during the resonance period.
Endurance	1 hour active data collection, 1 hour standby.	2 hours active data collection, 1 hour standby.
Physical Attributes	Less than 10mm thick, 30cm x 20cm. Weighs less than 300g. MOI is known.	Less than 5mm thick, 20cm x 20cm. Weighs less than 150g. MOI is known.
Cost	Less than $750 for a single unit.	Less than $500 for a single unit.
Testing	TBD physical model, single (1) hinge. Instrument will survive testing with no functional damage.	Physically accurate model to within TBD% error, Multiple (2+) sensors can be operated concurrently without interference. TBD offloader to simulate zero gravity. Instrument will survive testing with no damage.
Ease of Use	Instrument can be easily installed and uninstalled without damage.	Instrument can be easily installed and uninstalled in less than 5 minutes and without damage.

Software Plan

- Create precise models using recorded motion for various panel materials
  1. Record hinge deploying motion with optical tracking system
  2. Use optical tracking system to obtain position and velocity model
  3. Use MATLAB with obtained data to back out frequency, accelerations, G forces, etc

- Concerns with model development:
  - Camera position and angle
  - Frames per second rate on camera
  - Tracker application precision
  - Precision in panel/hinge dimensions
    - used in Tracker calculations

Budget Feasibility

Item:	Description:	Estimated Cost:
Sensor Housing	Structural material, bolts, printing, other misc. costs	$ 30
Sensor suite	Sensor, microcontroller/microprocessor,battery	$126
	TOTAL ESTIMATED COST:	$156

Mass Budget Feasibility

Item:	Description:	Estimated Mass:
Sensor Housing	Structural material, bolts, printing, other misc. mass	100 g
Sensor suite	Sensor, microcontroller/microprocessor,battery	75 g
	TOTAL ESTIMATED MASS:	175 g

Requirements Breakdown

FR	DR1	DR2	Requirement	Motivation	Validation
1	-	-	System shall accurately record deployment motion of attached panel structure.	Customer-defined requirement	Demonstration
	1.1	-	System shall record deployment dynamics to within 5% of optically tracked motion.	Derived accuracy requirement	Testing - compared to a motion-capture study
	-	1.1.1	Sensors shall record motion at double the Nyquist frequency of deployment or higher	Derived accuracy requirement	Inspection - from manufacturer
	-	1.1.2	Sensors shall record acceleration at double the Nyquist frequency of the highest-frequency resonance mode or higher	Derived accuracy requirement	Inspection - from manufacturer
	-	1.1.3	Sensors shall record accelerations on 3 axes of up to **16** Gs within an accuracy of 5% of the optically tracked motion	Derived accuracy requirement	Testing - compared to a motion-capture study
	-	1.1.4	Sensors shall record vibrations on 6 axes of up to **4** Gs within an accuracy of 5% of the optically tracked motion	Derived accuracy requirement	Demonstration
	1.2	-	System shall survive deployment forces and environments without damage	Derived safety requirement	Demonstration
	-	1.2.1	Sensors shall survive a shock of **30 Gs** without damage	Derived safety requirement	Inspection - from manufacturer
	-	1.2.2	Panel mounting interface shall be able to withstand a shock of **30** Gs without damage	Derived safety requirement	Inspection - from manufacturer
	-	1.2.3	Battery shall be able to withstand a shock of **30** Gs and temperatures of 20-40 degrees C without damage or loss of power	Derived safety requirement	Testing

Requirements Breakdown (cont.)

2	-	-	System shall fit into the provided panel structure without obstructing deployment or changing the dynamics of the system	Customer-defined requirement	Demonstration
	2.1	-	System shall be contained within a 30x20x0.5cm volume	Derived size requirement	Inspection
	2.2	-	System shall weigh less than 300g	Customer-defined weight requirement	Inspection
	2.3	-	System shall have a known moment of inertia	Derived requirement for modal analysis	Testing
3	-	-	System shall cost less than $750 per unit.	Customer-defined requirement	Inspection
	3.1	-	Sensors shall cost less than **$TBD**	Derived constraint	Inspection
	3.2	-	Processors shall cost less than **$TBD**	Derived constraint	Inspection
	3.3	-	Mounting system shall cost less than **$75**	Derived constraint	Inspection
4	-	-	System shall be quickly removable/replaceable from panel to be tested.	Customer-defined requirement	Demonstration
	4.1	-	Sensor suite shall be able to be comfortably removed or installed within 5 minutes	Derived constraint	Demonstration
		4.1.1	Sensors shall be easily detatched from panel assembly without damage to either	Derived constraint	Demonstration
5	-	-	System shall be able to record data for up to an hour, with an additional hour of standby	Customer-defined requirement	Demonstration
	5.1	-	System shall have sufficient battery life to record data for 1 hour and stand by for 1 hour	Derived constraint	Demonstration
	5.2	-	System shall have sufficient on-board storage for 1 hour of data recording	Derived constraint	Demonstration

Battery Power Thermal Analysis

Worst case scenario, completely enclosed box with 10mm thick walls of 3D printed ABS — assuming an ambient temperature of 20 C there is an increase of **1.3 C** (relatively negligible).

$$k = \frac{Q\Delta x}{A(T_{amb} - T_{interior})}$$

k = 0.17 $\frac{W}{m^2/K}$, $Q = P\Delta t$, Δx = 10 mm, A = 0.133 m^2

Coding Language Trade Study Matrix

Software Language Trade Study											
Language	**Prefrence**	**Pref. Weight**	**Ability**	**Ab. Weight**	**Processor Compatibility**	**PC Weight**	**Speed to Write**	**S2W Weight**	**Speed to Run**	**S2R Weight**	**Total**
MATLAB	5	0.05	5	0.2	1	0.4	5	0.05	2	0.3	2.5
C	1	0.05	2	0.2	4	0.4	1	0.05	5	0.3	3.6
C++	3	0.05	3	0.2	5	0.4	2	0.05	5	0.3	4.35
Python	4	0.05	4	0.2	4	0.4	4	0.05	4	0.3	4
Notes:											
- Speed to run is heavily dependent on the software team's ability to write efficient code, not just the speed of the language itself											
- The selected processor may completely dictate which language we use and elimiate any choice we have to make											
Arduino Pro Mini: C++											
Raspberry Pi Pico: C/C++, Python											
Raspberry Pi Zero: C/C++, Python											
Beaglebone: C/C++, Pyhton											

Processing Trade Study

Metric	Description	Weight	Requirement
User interface	Ease of use (sufficient documentation)	0.2	D1.1
Mass	Weight of the microcontroller/microprocessor	0.1	FR2, D2.2
Power consumption	Current draw at nominal voltage	0.3	FR5, D5.1
Processing speed	Maximum clock frequency & computational efficiency estimate	0.25	D1.1
Dimensions	Size of the microcontroller/microprocessor	0.1	FR2, D2.1
Cost	Price and lead time	0.05	FR3, D3.2

Metric	Arduino Pro Micro	Teensy 4.1	RPi Pico	RPi Zero 2W	Feather 32u4
User interface (0.2)	3	4	2	2	4
Mass (0.1)	4	3	5	3	5
Power consumption (0.3)	5	3	1	0	5
Processing speed (0.25)	2	4	3	5	2
Dimensions (0.1)	2	2	5	3	1
Cost (0.05)	4	4	4	3	4
TOTAL =	3.4	3.4	2.65	2.4	3.6

Sensor Trade Study

Metric	Description	Weight
Sensing capabilities	Amount of Gs the sensor is capable of sensing	0.2
Shock survivability	Amount of G's the sensor can withstand before breaking	0.01
Dimensions	Dimensions of the sensor	0.1
Mass	Weight of the sensor	0.08
Microcontroller/microprocessor interface	Type of communication to/from sensor (Digital vs. Analog)	0.08
Axis	Amount of axis the sensor is capable of sensing	0.2
Ease of attachment	How easy the sensor is to mount to a PCB board	0.05
Voltage range	Range of input voltage the sensor needs for functioning	0.1
Output data rates range	Range of the speed of obtaining output data	0.1
User interface	Ease of use (sufficient documentation)	0.08