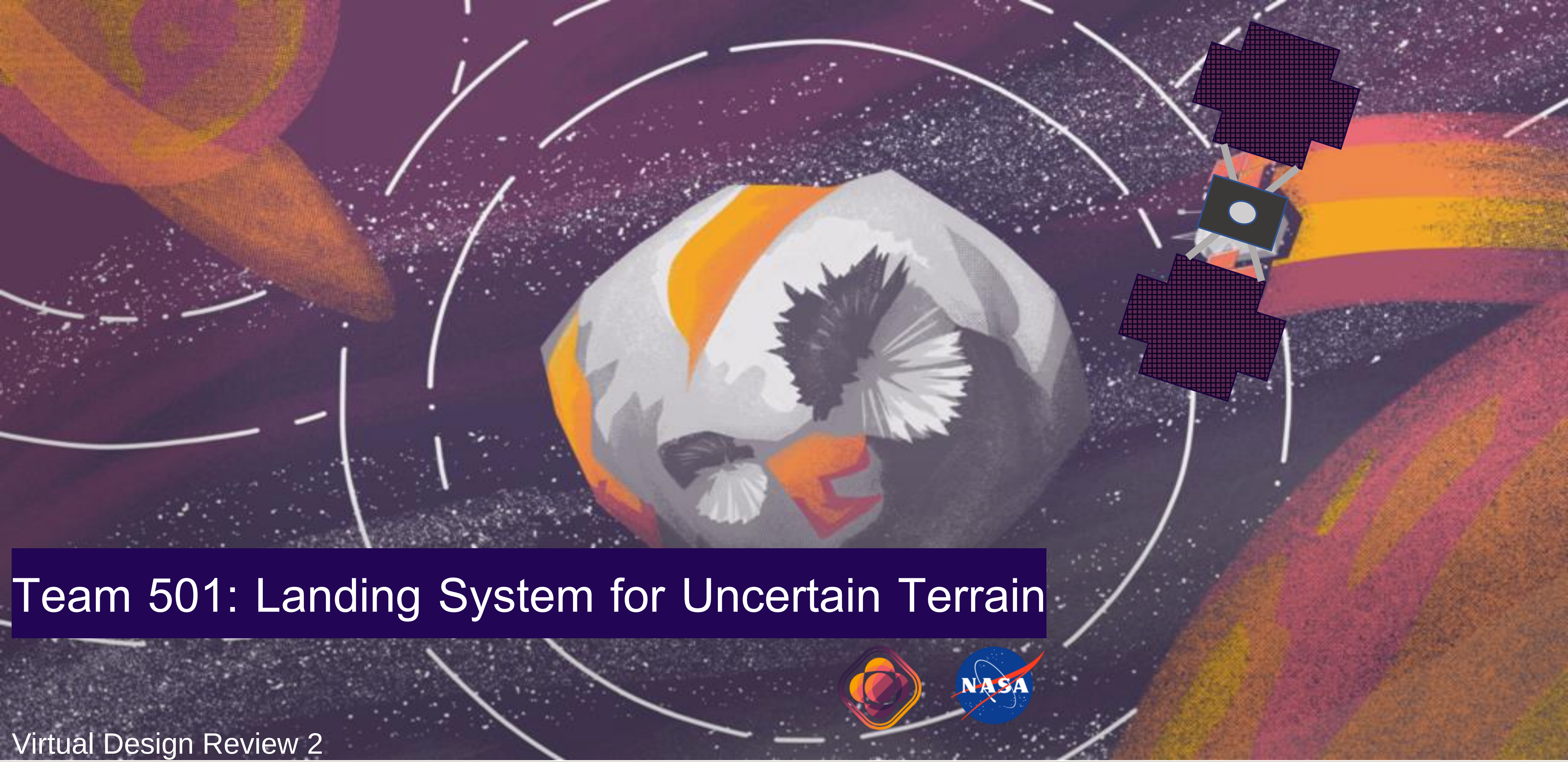


Team 501: Landing System for Uncertain Terrain

Virtual Design Review 2

Team Introductions

Saralyn Jenkins
Mechanical Systems Engineer

Elzbieta Krekora
Materials Engineer

Andrew Sak
Controls Engineer

Julio Velasquez
Mechanical Engineer

Julio Velasquez

Sponsor and Advisor

Engineering Mentor
Cassie Bowman, Ed.D.
Associate Research Professor, ASU

Academic Advisor
Camilo Ordóñez, Ph.D.
ME Teaching Faculty

Julio Velasquez

Objective

The objective of this project is to design a landing system capable of safely landing on the assumed range of hypothesized surfaces and terrains of 16 Psyche.

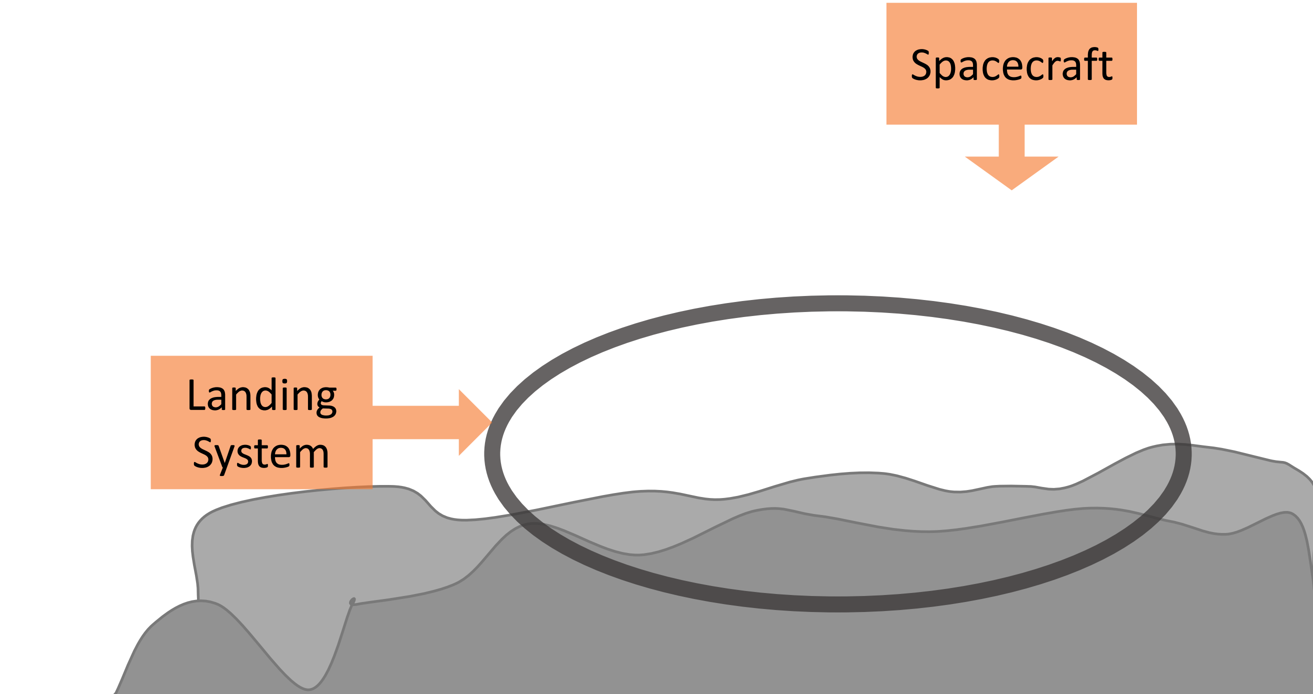
Julio Velasquez

Project Overview

Psyche: Believed to be an exposed core of an early planetesimal that lost its rocky outer layers due to violent collisions billions of years ago

Our Mission:
To design the landing system (i.e. what lands/supports the spacecraft)

Terrain:
Psyche has hypothesized uncertain terrain (i.e. rocky, uneven and metallic)



Julio Velasquez

Customer Needs

The system is capable of successfully landing on the hypothesized terrains of Psyche.

The device can withstand or dissipate the potential energy from the fall and impact velocity.

The system is autonomous.

The system can support the weight of spacecraft and payload without damaging it.

The landing system supports the weight/size of the spacecraft based off previous missions.

The system does not have to be reusable.

Julio Velasquez

Assumptions

Operated in minimal gravity, space temperatures and conditions

Controlled autonomously without manual maneuvering of the system

Spacecraft will carry landing system without issue

Will not land in a hole or other extreme conditions

Power to operate landing system is supplied by spacecraft

Julio Velasquez

Critical Targets

Dampens impact energy

Prevent lander from tipping

Lander can accommodate for any of the hypothesized surfaces

The lander is stable on Psyche’s surface

The system can support the weight of the lander

Julio Velasquez

Targets

Operation	What's Being Measured/Quantified	Target
Houses Payload	Dimensions of CHONKE (estimated until dimensions received)	0.5 x 0.5 x 0.5 m
Houses Sensors	Acceleration, velocity, angular position sensors length and volume	0.254-12.7 mm; 1.29-025.81 mm^2
	Technology used to detect objects and measure distance (volume)	0.929-2.787 m^2
	Force sensors (volume)	5.81-19.35 mm^2
Houses Electrical Board	Dimensions	101.52 x 53.3 mm
Houses Actuators	Volume of actuators	0.019 m^2
Houses Wiring	Diameter of each wire	0.05 mm
Prevents Tipping	Tipping angle to correct	10 degrees
Support Weight	Weight of spacecraft, payload, and other instruments	1472 N
Prevents Enviromental Damage of Hardware	Cosmic dust and other particles size	0.1 mm
Dampens Impact Energy	Amount it needs to dissipate/dampen	2700 W
Impact Velocity	Maximum impact velocity	6 m/s
Reads Acceleration	Acceleration resolution to read	0.1 m/s^2 and within 10% of real value
Mass of Lander	Mass	150 kg
Reads Velocity	Velocity resolution to read	0.1 m/s and within 10% of real value
Reads Position	Position resolution to read	0.1 m and within 10% of real value
Reads Angle	Angle resolution to read	0.1 degrees and within 10% of final value
Reads Topography	Measure elevations within range	~0.2 m
Adjusts Orientation	Angle of lander relative to surface (in any direction)	20 degrees
Secures Position on Astroid	Change in position on all three axis	0 degrees
Reduces Velocity	Velocity of the lander as it touches down on surface	<3 m/s

Existing Designs

Mars Phoenix Lander

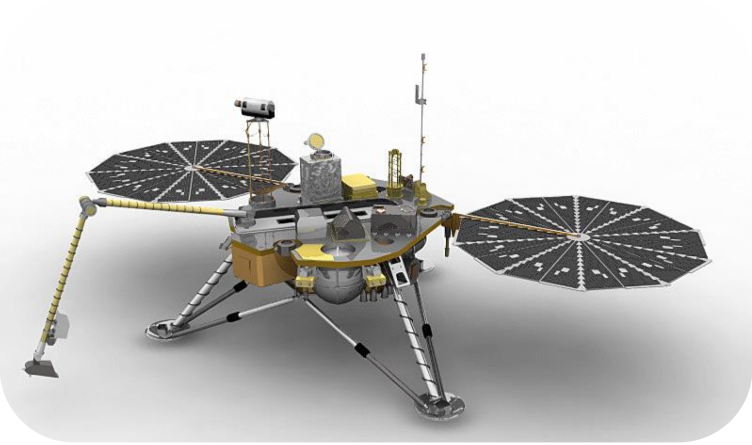
- Landed on Mars
- Rocky flat surface
- Set of 3 legs with 3 components
- Mass: 350kg

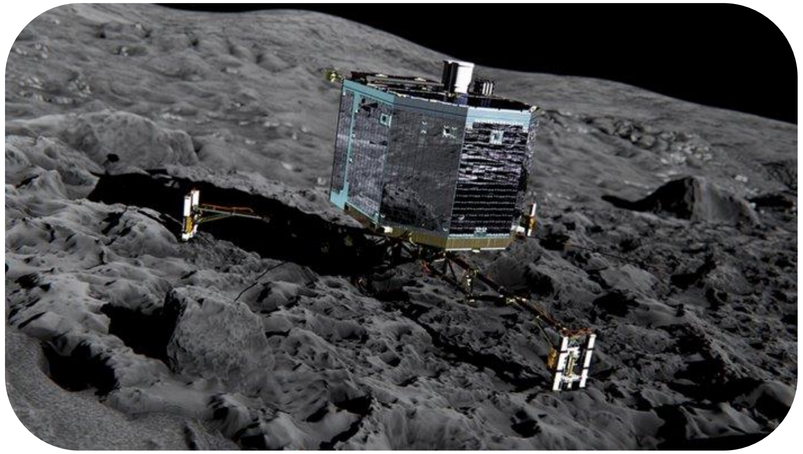
Philae Lander

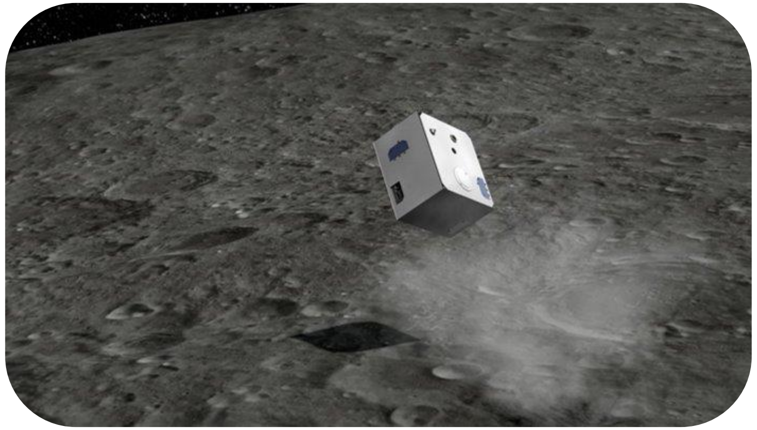
- Landed on a comet 67P; contained ice
- Legs support the lander
- Drilled into surface
- Mass: 100kg

Mascot Lander

- Landed on Ryugu asteroid
- Rocky surface
- Box shape, swinging arm inside to ”hop” or flip
- Mass: 10kg







Julio Velasquez

Lander Components

Decided to divide into components of what we consider is the main areas of the landing system.

Suspension
- Dampening system
- Crushable components

Legs
- Geometry
- Number of legs
- Adaptability

Feet
- Ability to grip
- Adjustability
- Size

Sensors
- Orientation
- Acceleration
- Position

Base
- Position of leg attachment
- Connection type

Julio Velasquez

Concept Generation

Brainstorming

Biomimicry

Crapshoot

Forced Analogy

Julio Velasquez

Medium Fidelity Concepts

4 Impact Legs, Springboard Base, 3 Stability Legs

Single Impact Leg, Springboard Base, 3 Stability Legs

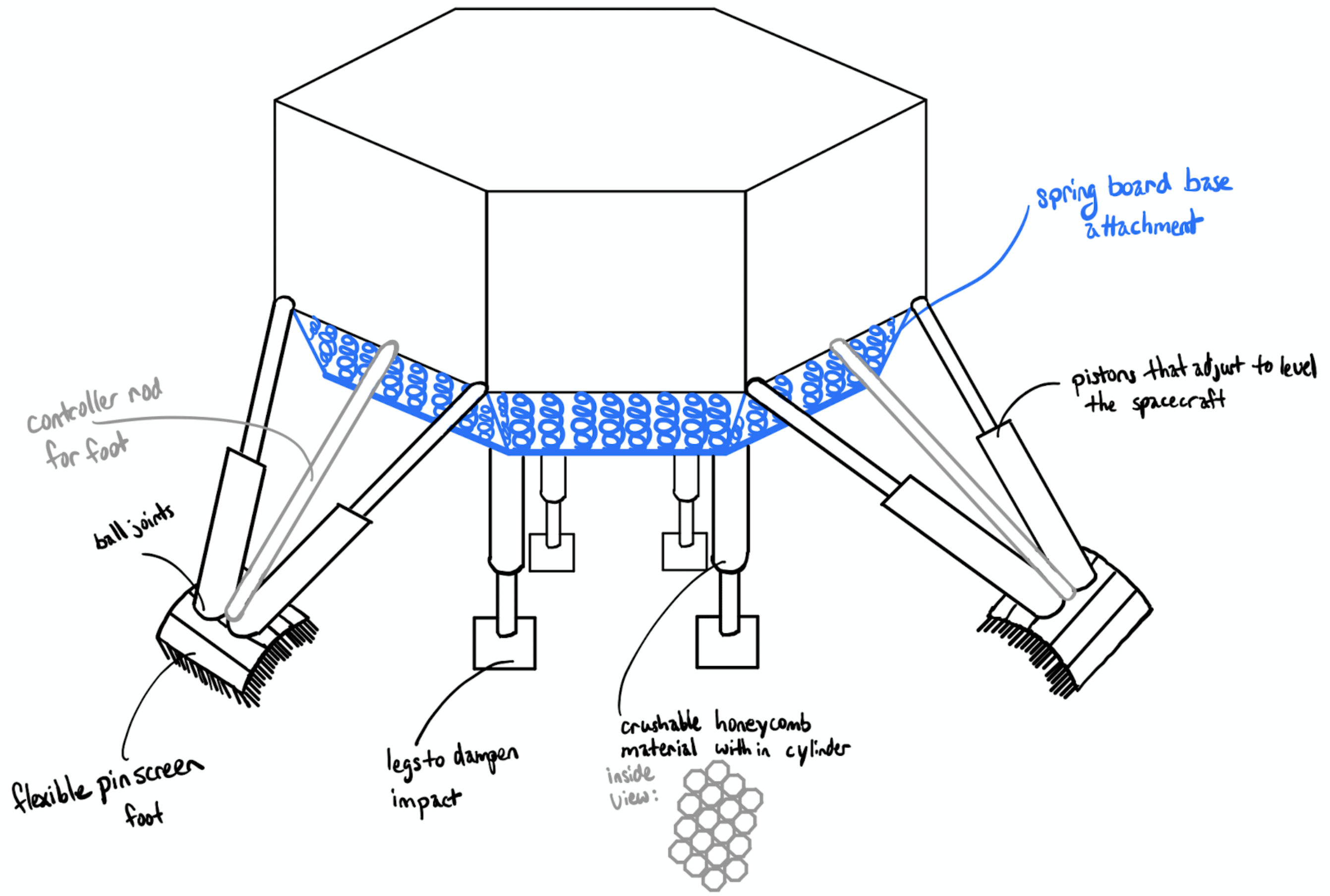
6 Impact Legs with 4-Webbed Stability Legs

Single Impact Leg with 6-Pointed Stability Legs

Single Impact Leg with 3-Webbed Stability Legs

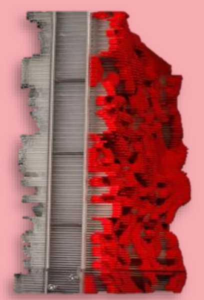
Elzbieta Krekora

4 Impact Legs, Springboard Base, 3 Stability Legs



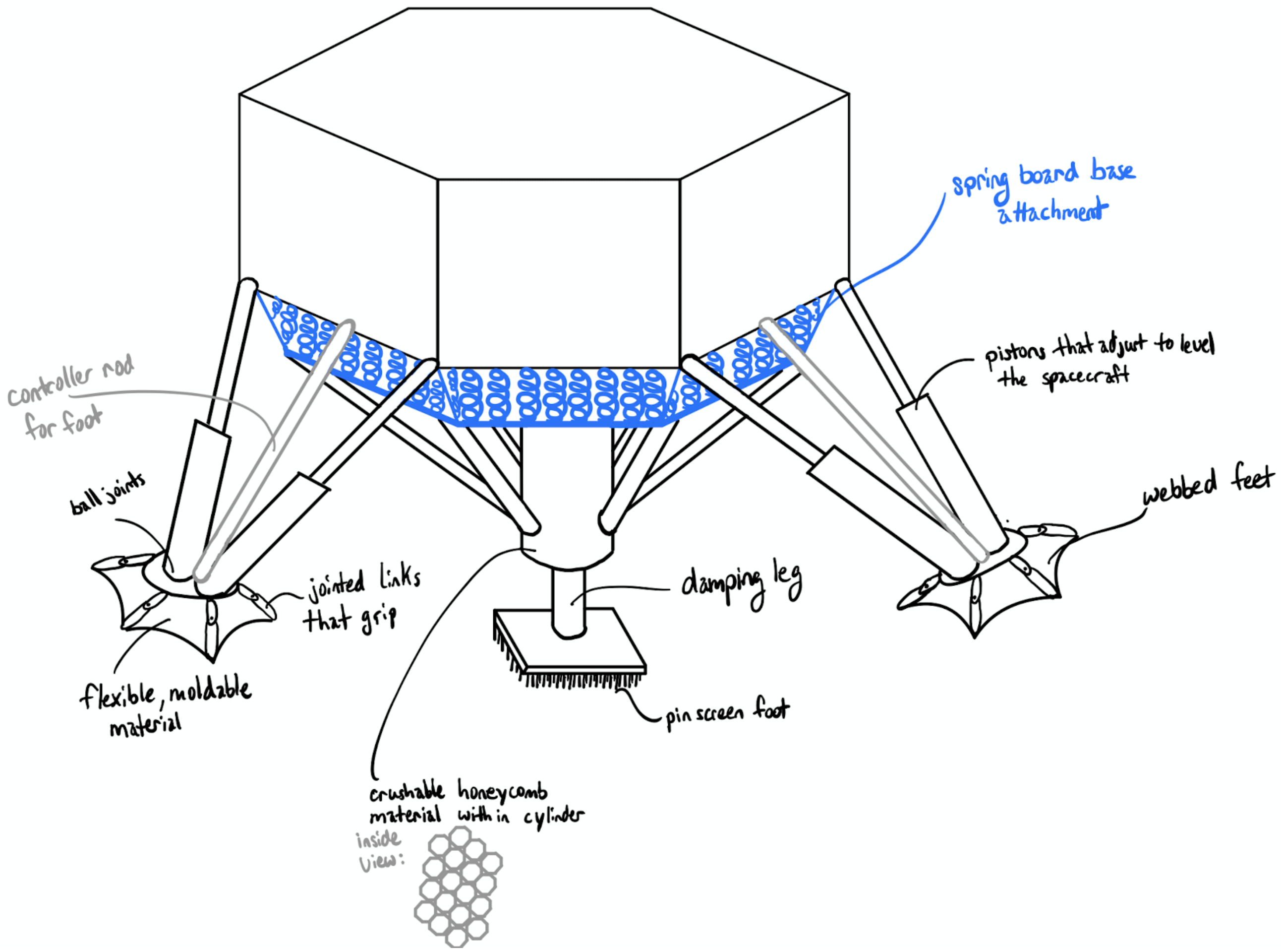
Key Features

- Springboard base for dampening
- Four crushable honeycomb structure legs
- Ball joint attached piston support legs
- Pin screen feet



Elzbieta Krekora

Single Impact Leg, Springboard Base, 3 Stability Legs

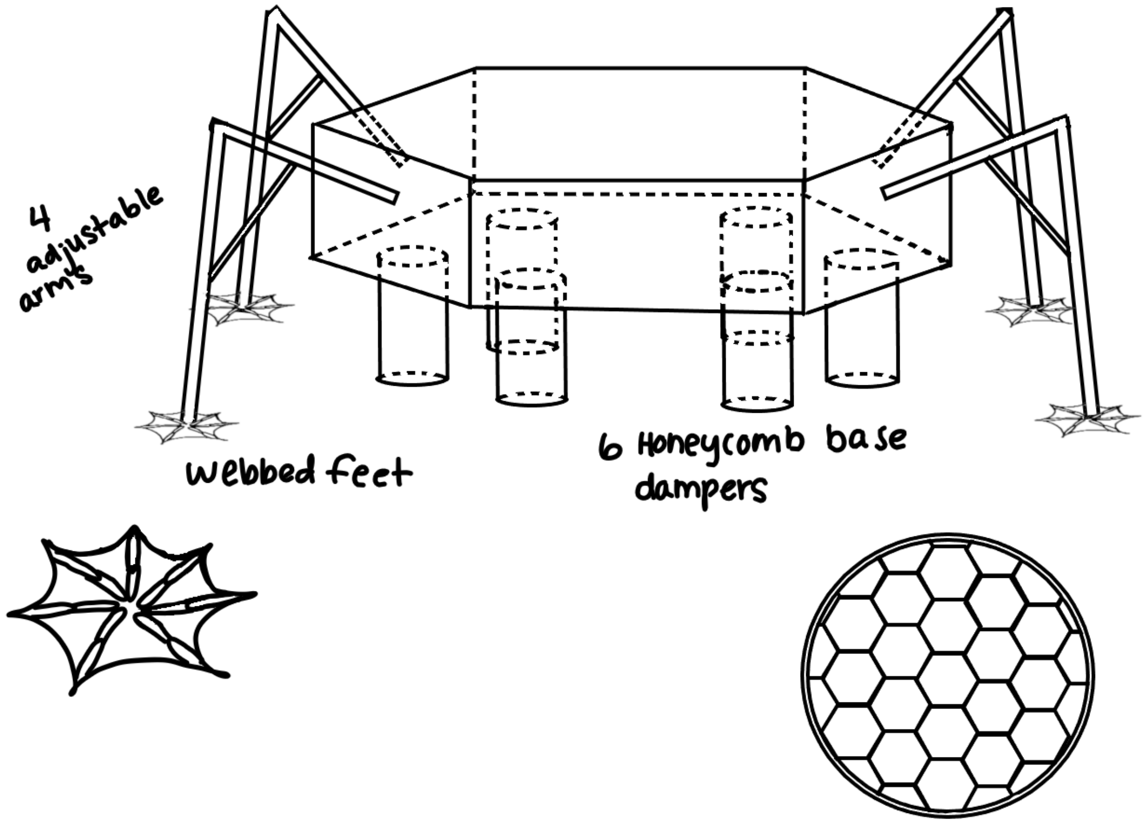


Key Features

- Springboard base for dampening
- One large crushable honeycomb structure leg with pin screen foot
- Ball joint attached piston support legs
- Webbed feet with individual moving links

Elzbieta Krekora

6 Impact Legs with 4-Webbed Stability Legs

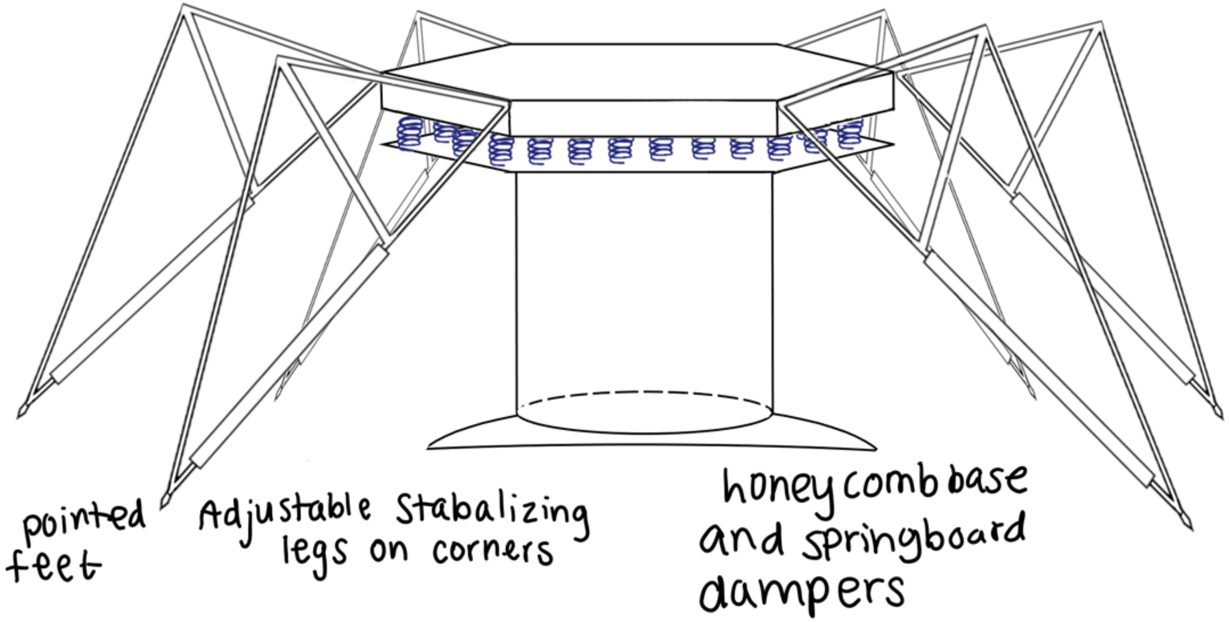


Key Features

- Six crushable honeycomb structure base legs for dampening
- Four adjustable positioning legs
- Webbed feet with individual metal links for gripping

Elzbieta Krekora

Single Impact Leg with 6-Pointed Stability Legs

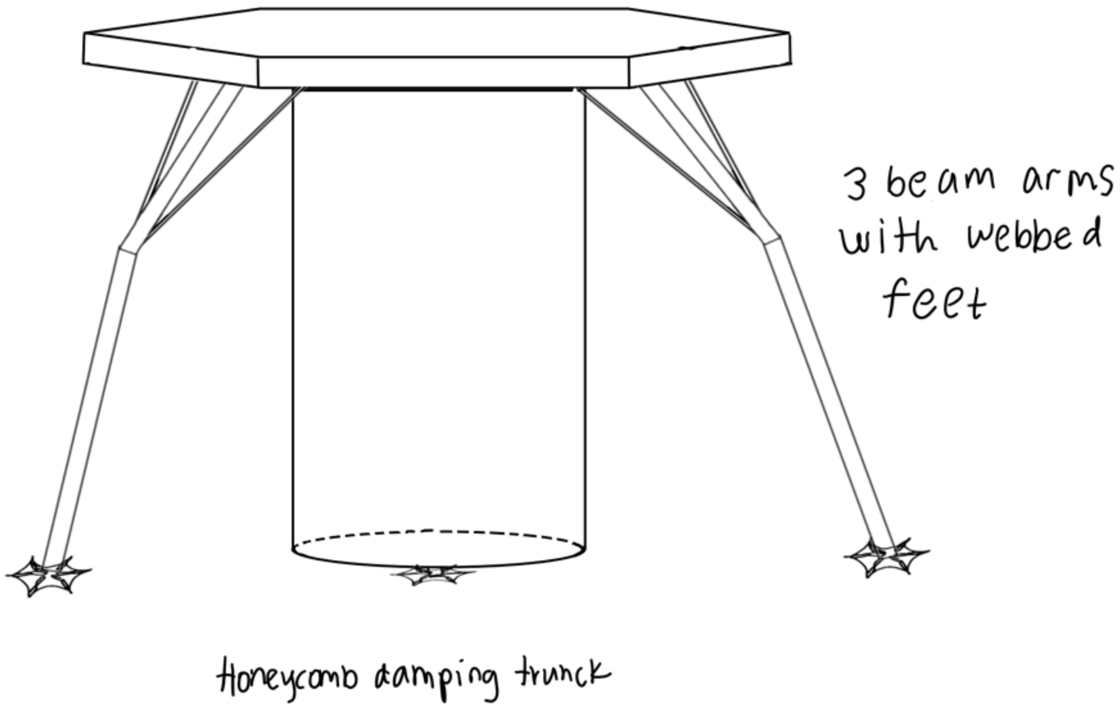


Key Features

- Springboard base for dampening
- One large crushable honeycomb structure leg
- Ball joint attached piston support legs
- Pointed feet

Elzbieta Krekora

Single Impact Leg with 3-Webbed Stability Legs



Key Features

- Large honeycomb damping trunk attached at the bottom of base
- Three 3 beam arms surrounding trunk
- Center beam internal honeycomb structure
- Webbed Feet

Elzbieta Krekora

High Fidelity Concepts

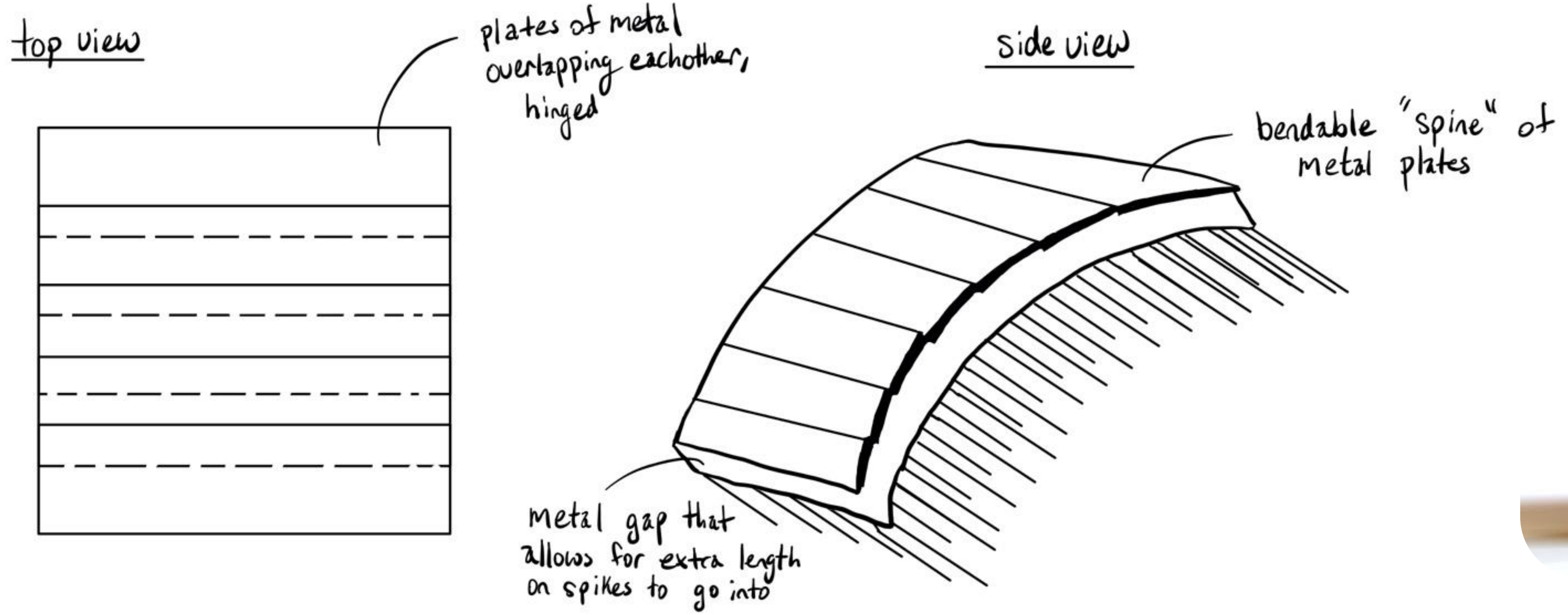
Double A-Arm Suspension

Single A-Arms Suspension

Grasshopper Suspension

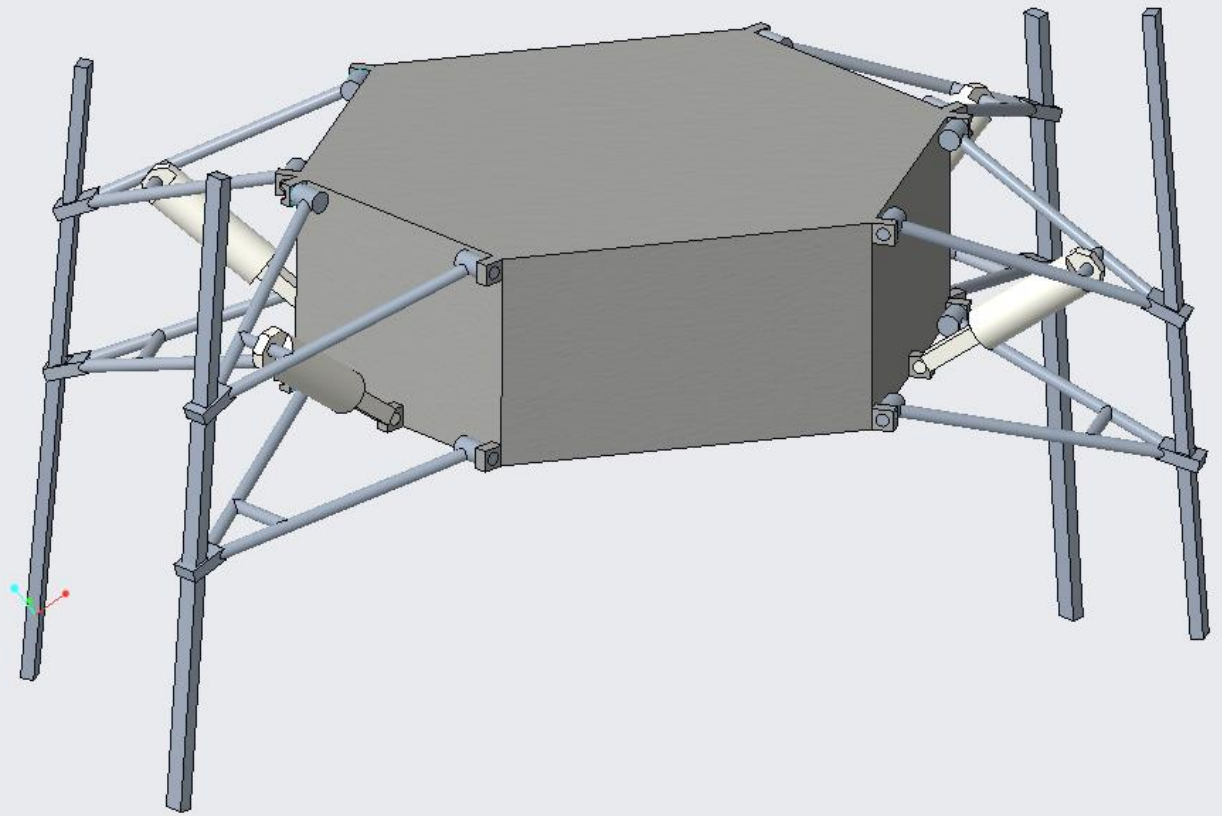
Julio Velasquez

Feet for High Fidelity Concepts



Julio Velasquez

Double A-Arm Suspension



Key Features

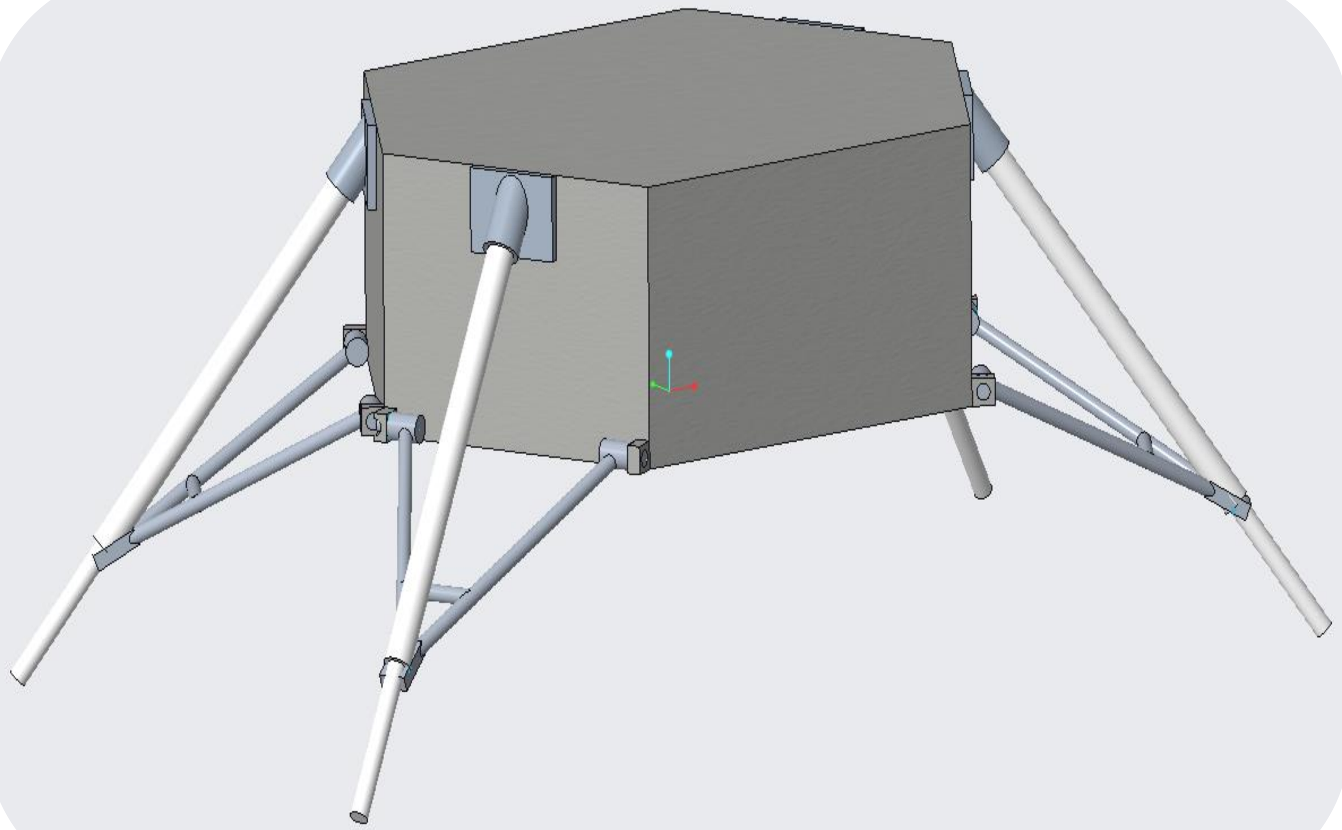
- 4 Crushable Cylinders
- Adjustable Rack and Pinion Legs
- Pin Screen Feet

Crushable Cylinders will absorb first impact

Racks and Pinion adjust legs independently

Julio Velasquez

Single A-Arm Suspension



Key Features

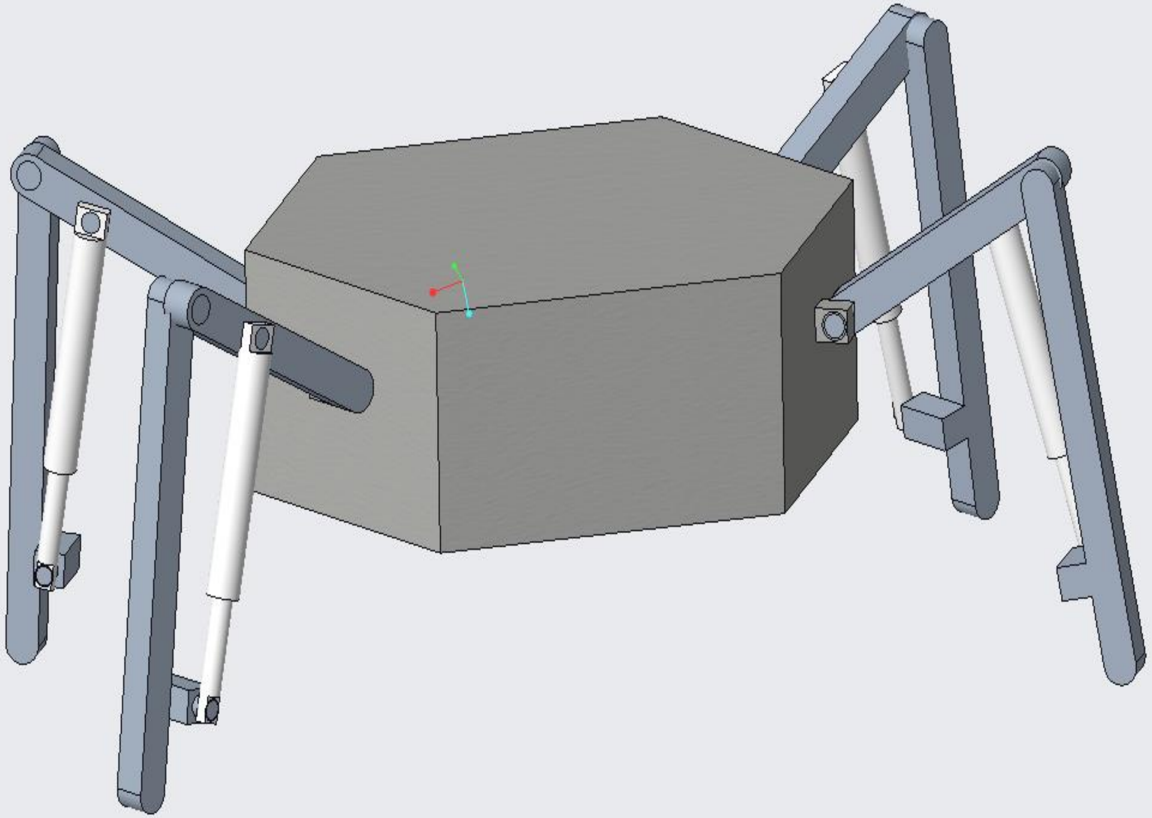
- Four piston legs for adjusting orientation
- Rigidly attached to spacecraft
- Single A-arm for leg support

Fixed Cylinders both absorb impact and adjust position

Feet connected with ball joints for better adjustability

Julio Velasquez

Grasshopper Suspension



Key Features

- Four angled legs with revolute joints
- Piston connecting the two-leg links for adjustability
- Fully extended upon impact for dampening
- Legs adjust after touchdown

Julio Velasquez

Selection Process

Binary Pairwise Comparison

House of Quality

Pugh Chart

Analytical Hierarchy Process

Elzbieta Krekora

Binary Pairwise Comparison

Withstands or dissipates the potential energy from the fall

Supports the spacecraft and associated components

Adjusts to the hypothesized terrains of Psyche

The system is autonomous

The system does not have to be reusable

Elzbieta Krekora

House of Quality

Supports Weight

Secures Position on Asteroid

Dampens Impact Energy

Reads Lander Data

Prevents Tipping

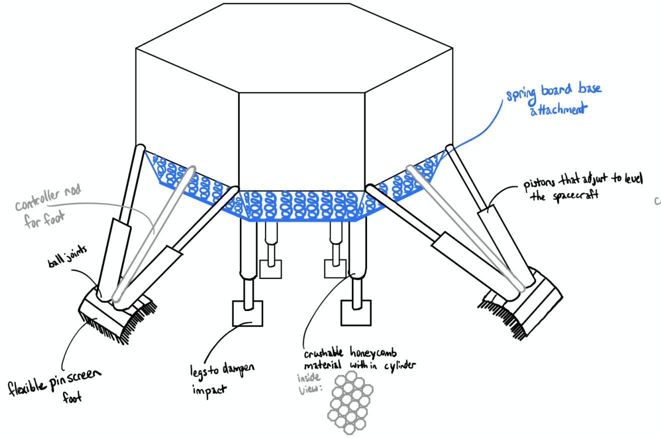
Adjusts Orientation

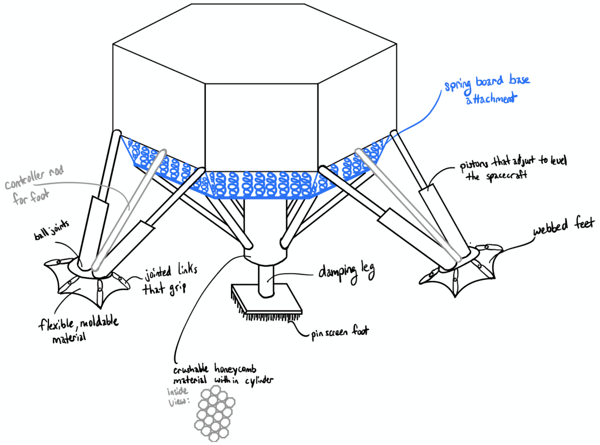
Senses Surrounding Topography

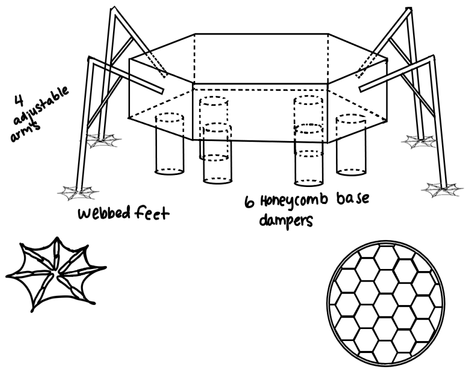
Houses Components

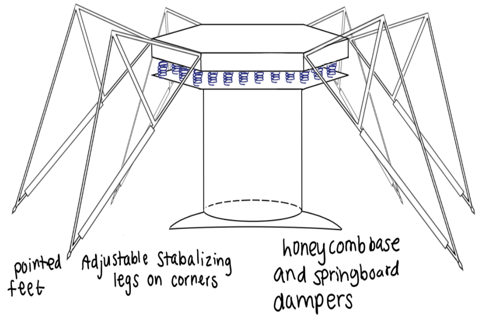
Elzbieta Krekora

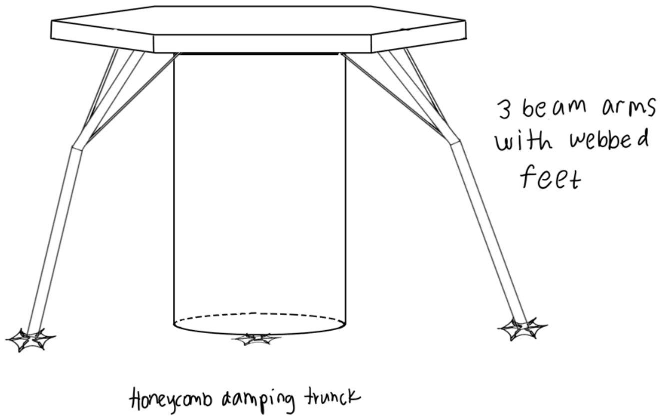
Pugh Charts

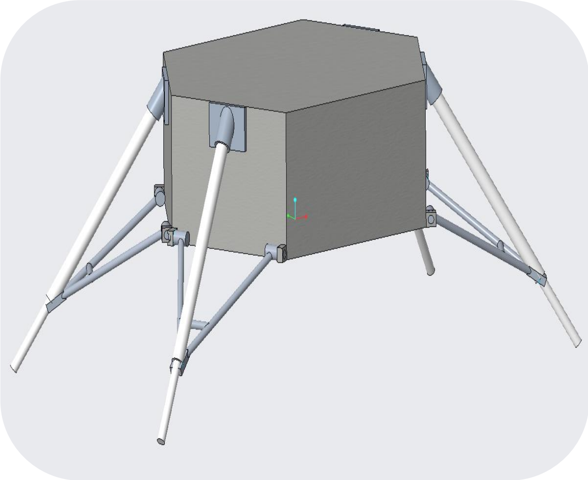


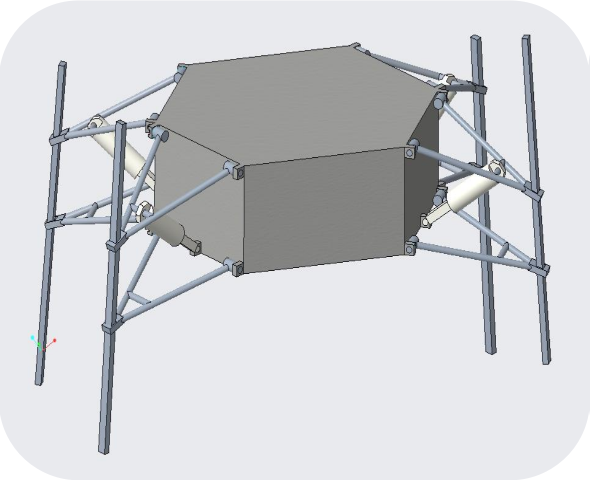


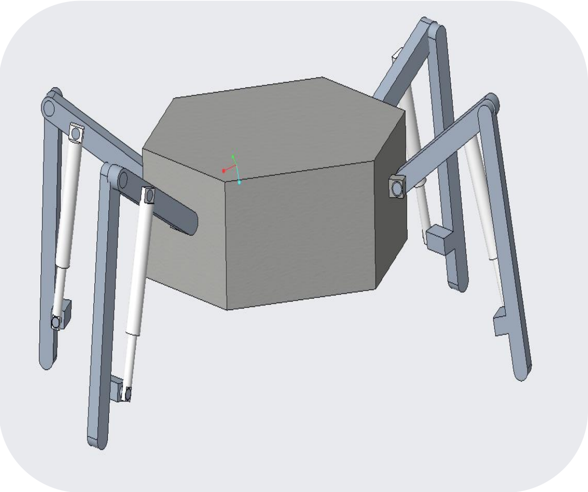






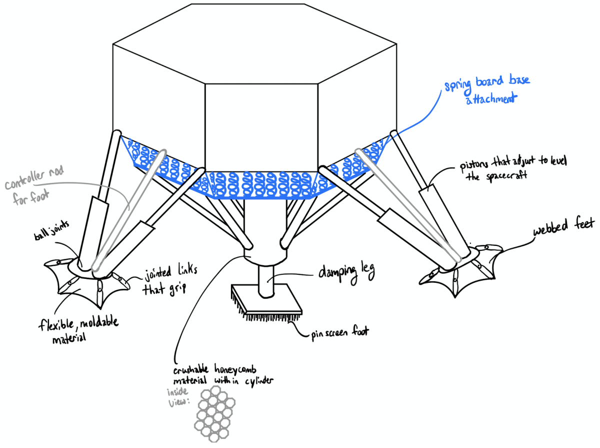


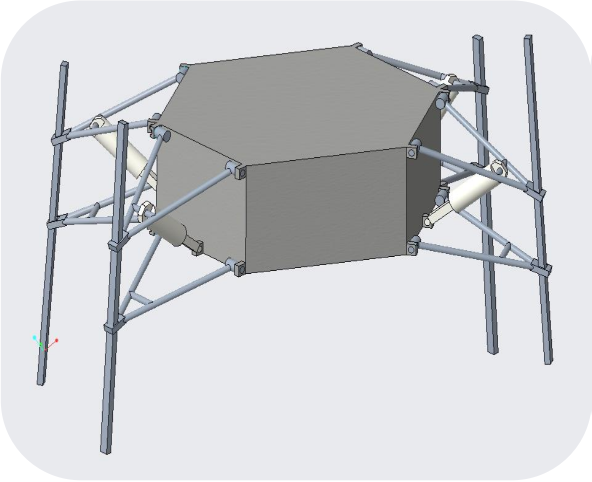


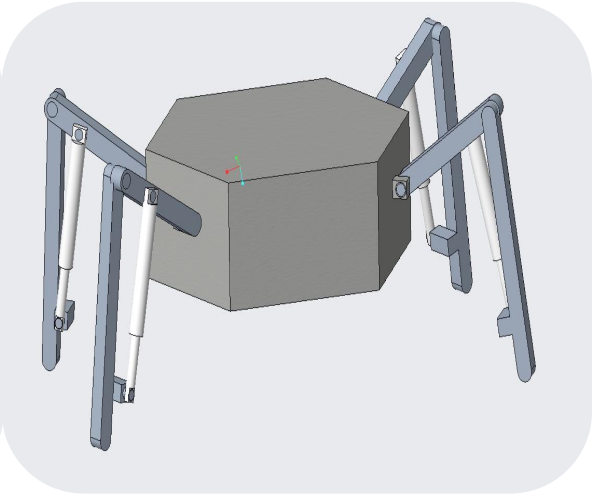


Elzbieta Krekora

Pugh Charts

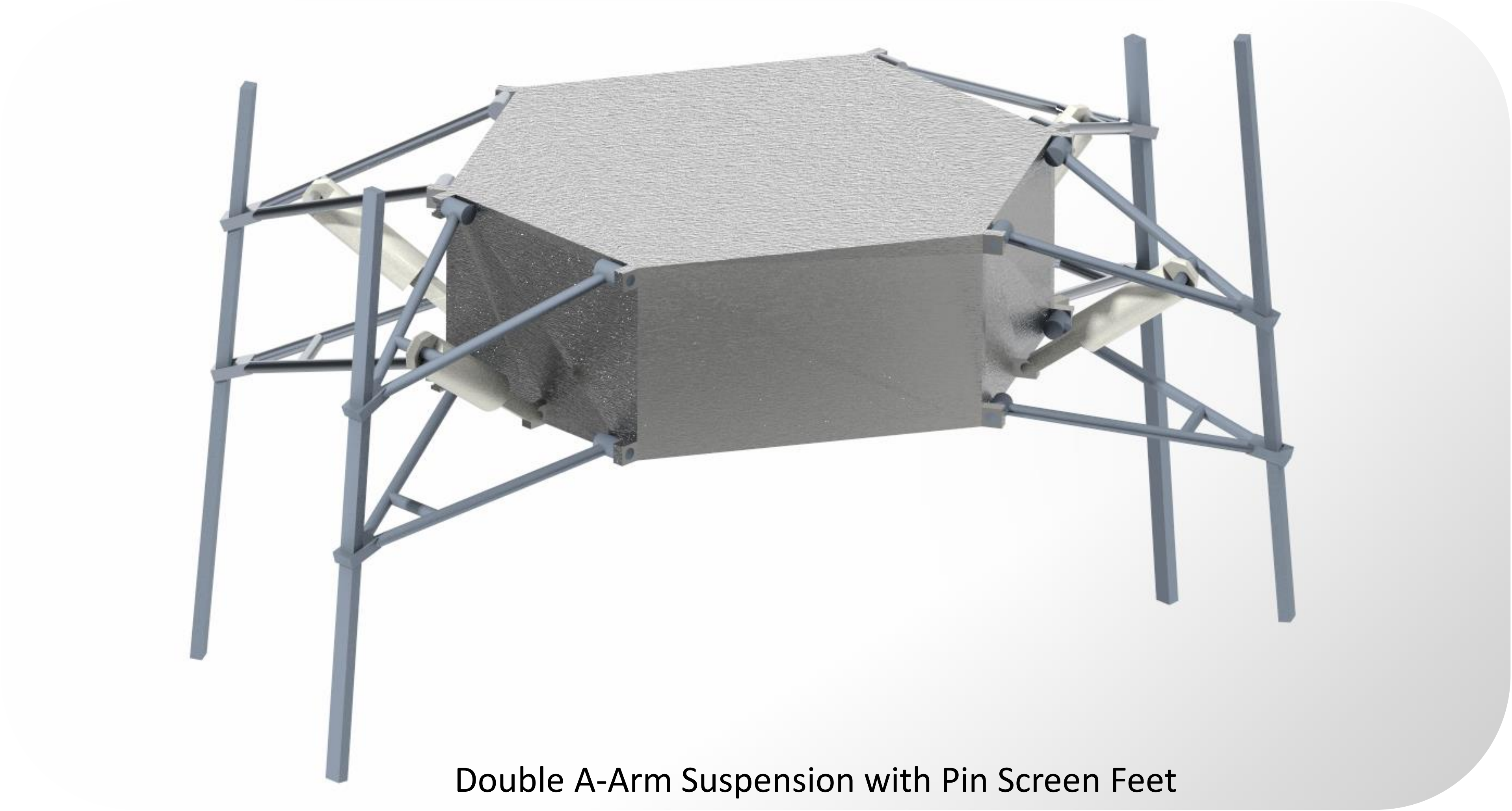






Elzbieta Krekora

Final Selection



Double A-Arm Suspension with Pin Screen Feet

Elzbieta Krekora

Future Work

Further Research on Crushable Components

Establish Validation Process for Prototyping/Simulation

Simulate Model and Individual Components

Prototype Components/System

Elzbieta Krekora

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In Depth | Rosetta & Philae –. (2014). NASA Solar System Exploration. https://solarsystem.nasa.gov/missions/rosetta-philae/in-depth/

NASA Psyche Mission Wallpaper | Virtual Backgrounds. (2020, July 14). Psyche Mission. https://psyche.asu.edu/psyche-wallpaper-backgrounds/

https://www.istockphoto.com/video/pinscreen-waves-gm472661787-10761536

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Julio Velasquez
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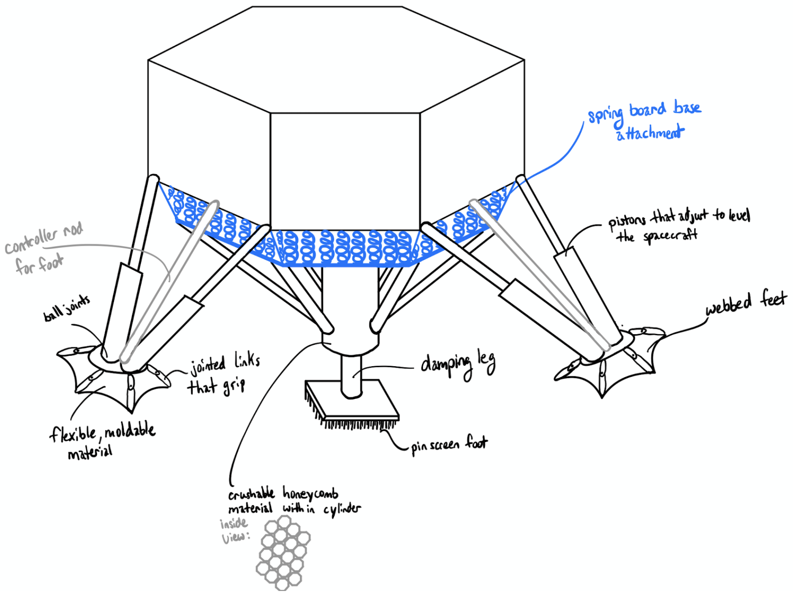
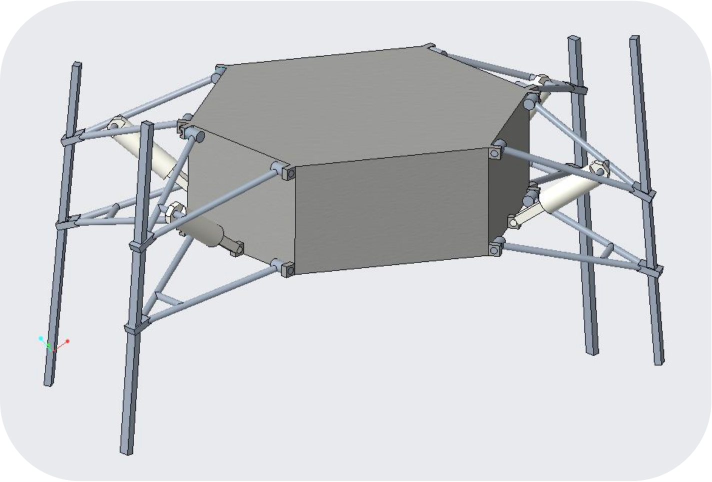
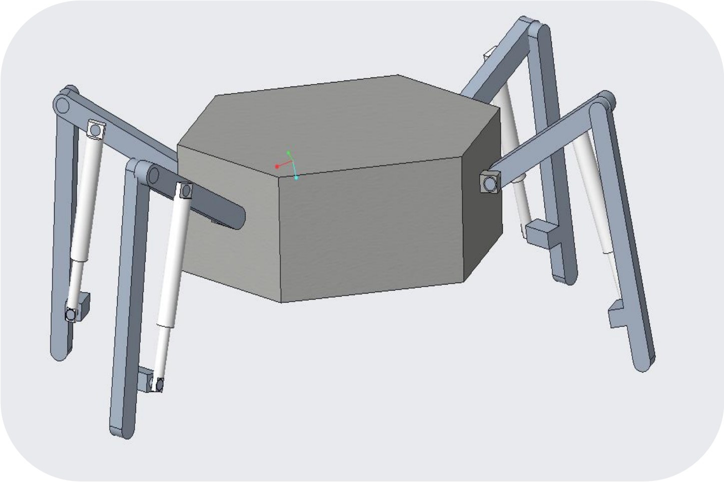
Pugh Charts







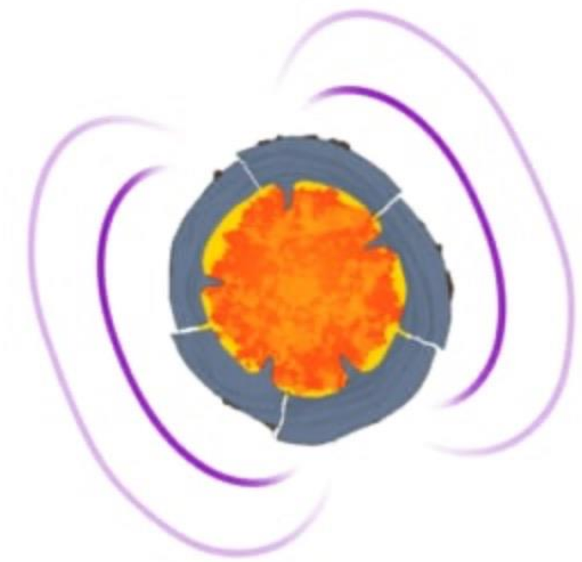
Elzbieta Krekora

About Psyche

Believed to be an exposed core of an early planet that lost its rocky outer layers due to violent collisions billions of years ago

First mission to investigate a world of metal rather than of rock and ice

Offers possibility of finding information on planet cores



Saralyn Jenkins

About the Mission

Current Mission

Set to launch August 2022 to survey Psyche closer

Future Mission

If findings found to be interesting a lander will be sent at a future date

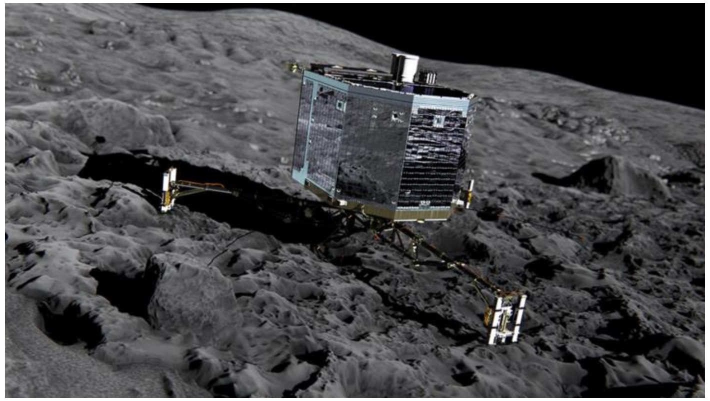
Our Mission

To design the landing gear for the future landing space craft

Saralyn Jenkins

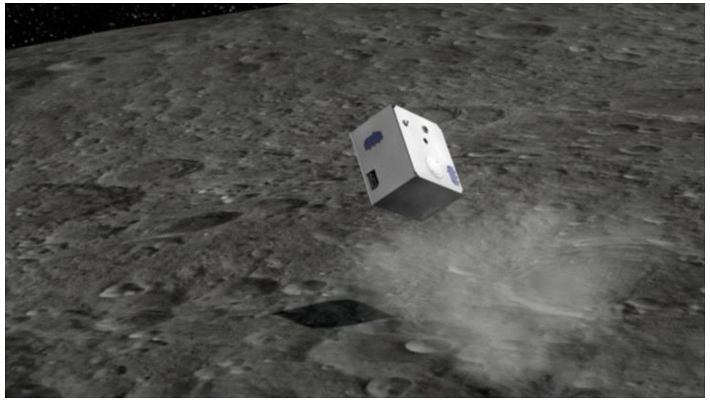
Initial Research of Past Landers

Philae



- Landed on a comet 67P; contained ice
- Legs support the lander
- Drilled into surface
- Mass: 100kg

MASCOT



- Landed on Ryugu asteroid
- Rocky surface
- Box shape, swinging arm inside to ”hop” or flip
- Mass: 10kg

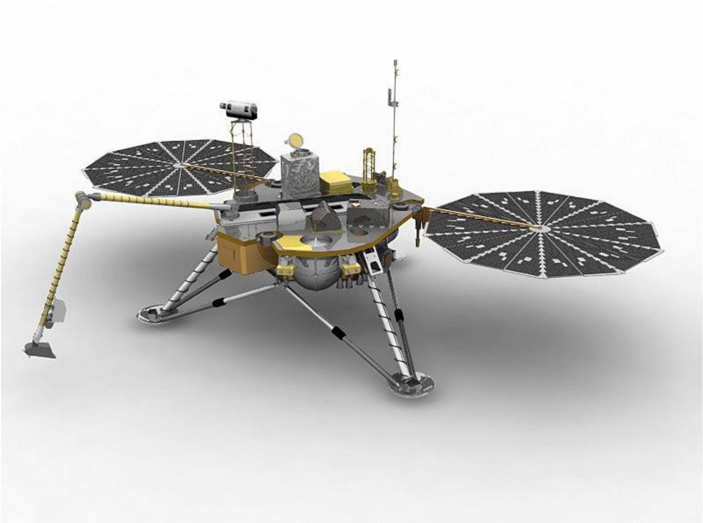
Saralyn Jenkins

Initial Research of Past Landers

Lunar Module Eagle

- Landed on the moon
- Flat surface
- Manually controlled thrusters
- Mass: 7,327 kg

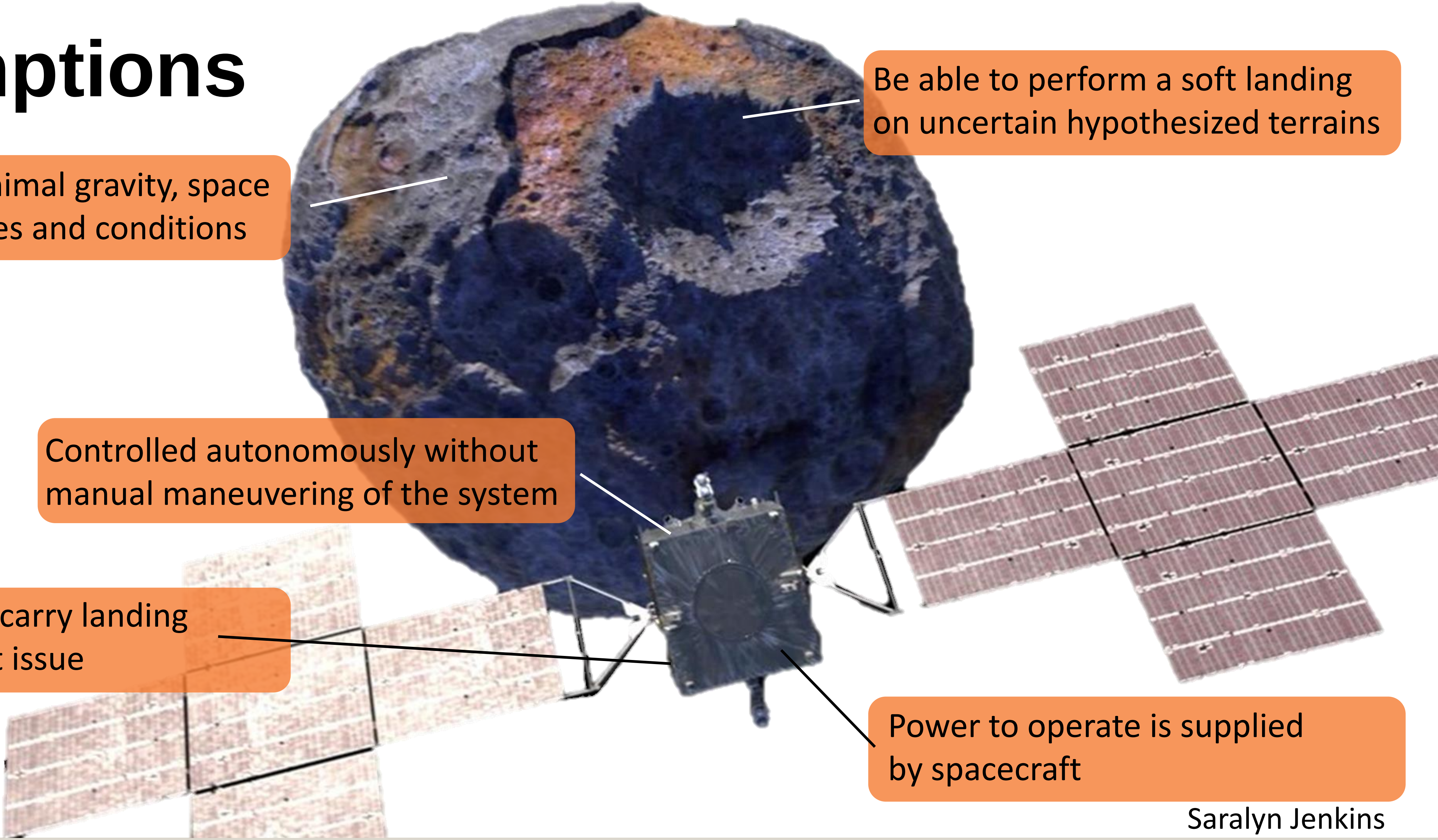
Phoenix



- Landed on Mars
- Rocky flat surface
- Set of 3 legs with 3 components
- Mass: 350kg

Saralyn Jenkins

Assumptions



Operated in minimal gravity, space like temperatures and conditions

Be able to perform a soft landing on uncertain hypothesized terrains

Controlled autonomously without manual maneuvering of the system

Spacecraft will carry landing system without issue

Power to operate is supplied by spacecraft

Saralyn Jenkins

Key Goals

Account for various terrains such as high relief terrain with rocky debris, and metallic terrain

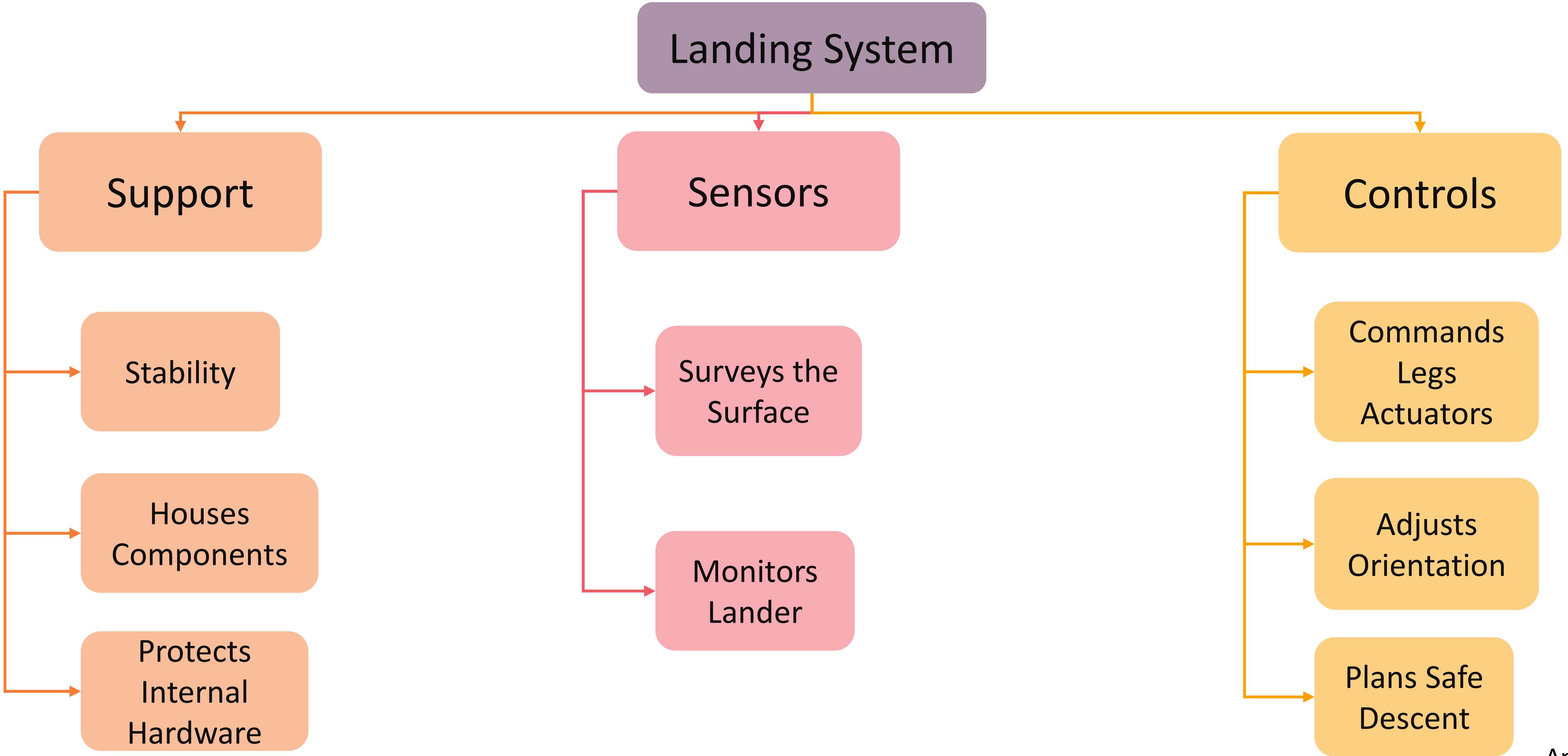
Protec… d from damage … landing

Prevent sp…cecraft from ti…ng and …pping

Ab… impact velocit… …anding

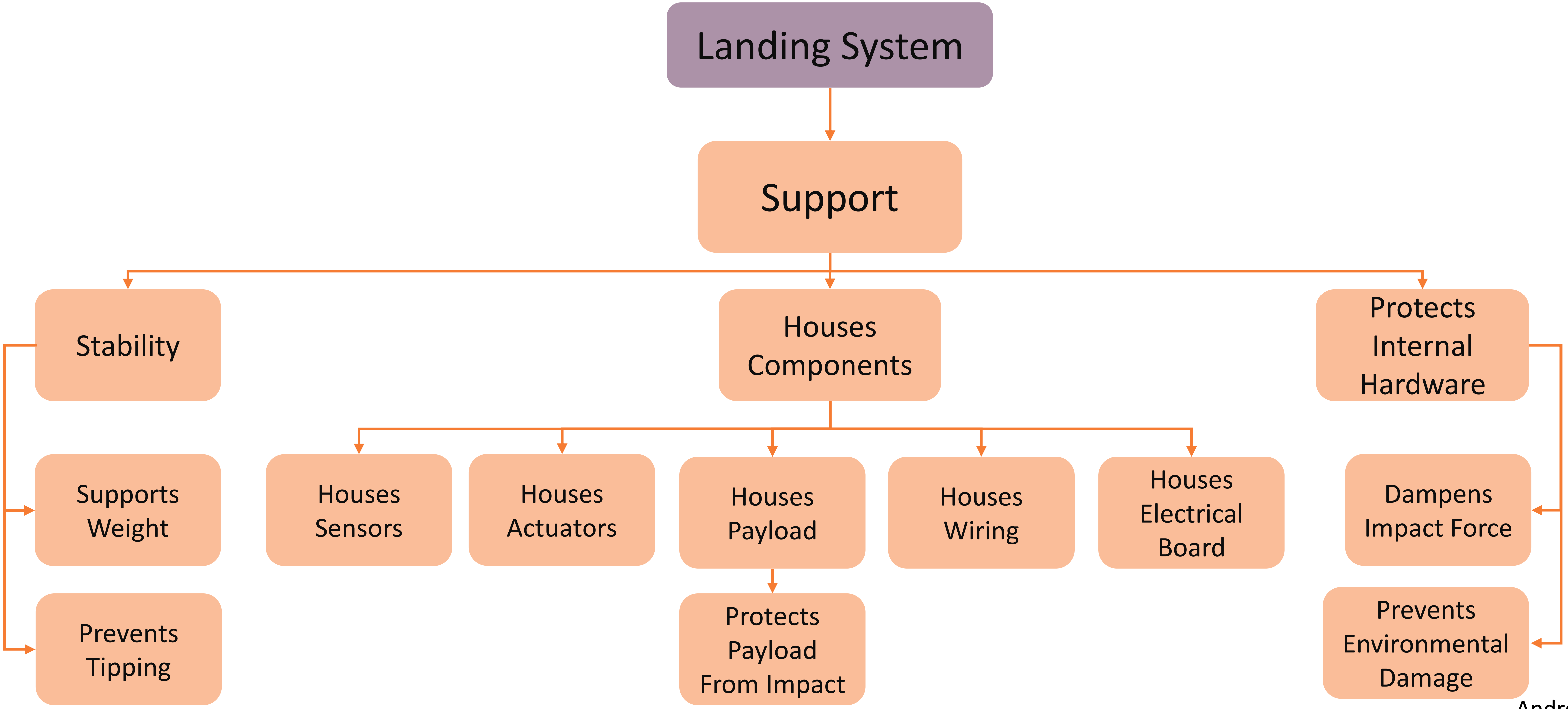
Saralyn Jenkins

Functional Decomposition



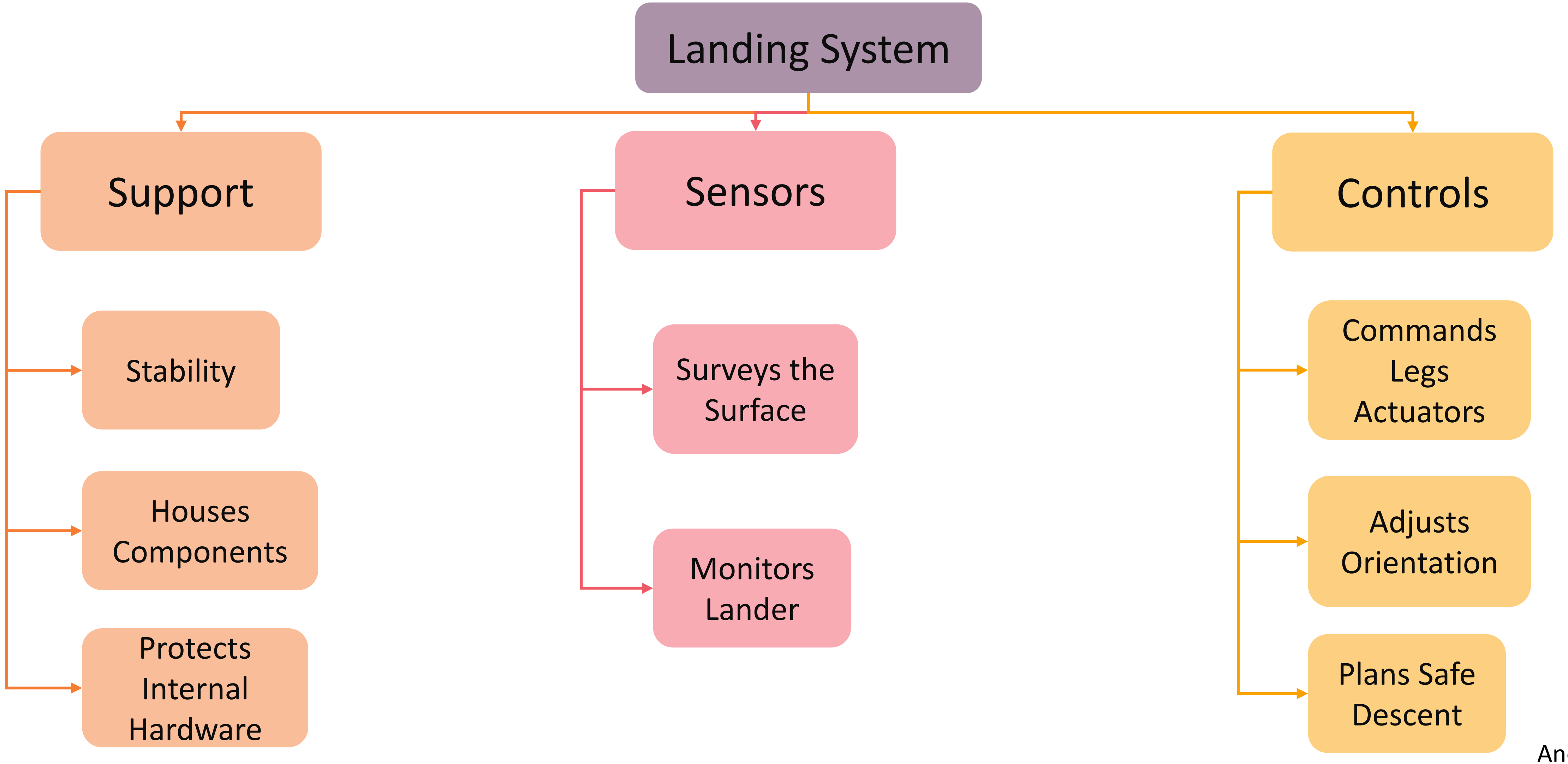
Andrew Sak

Functional Decomposition



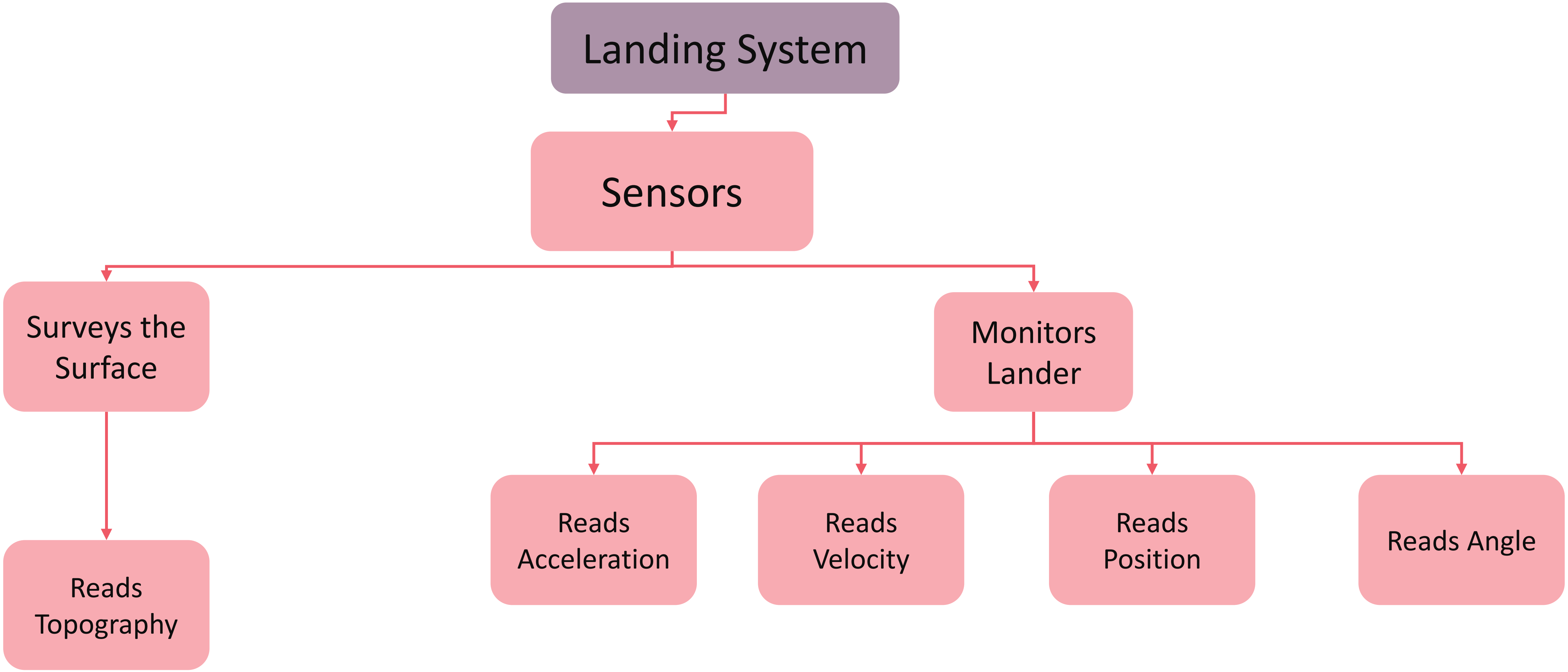
Andrew Sak

Functional Decomposition



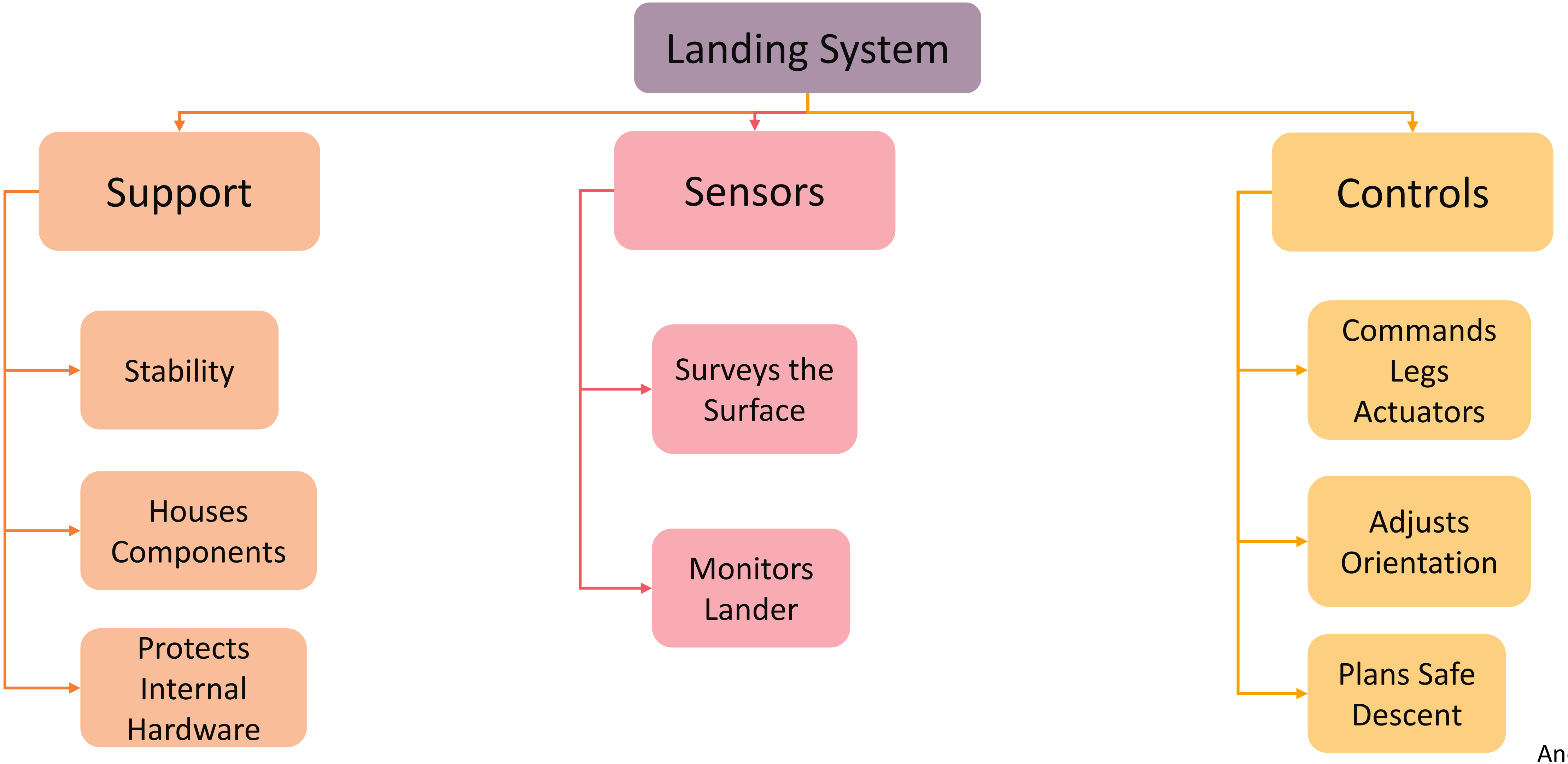
Andrew Sak

Functional Decomposition



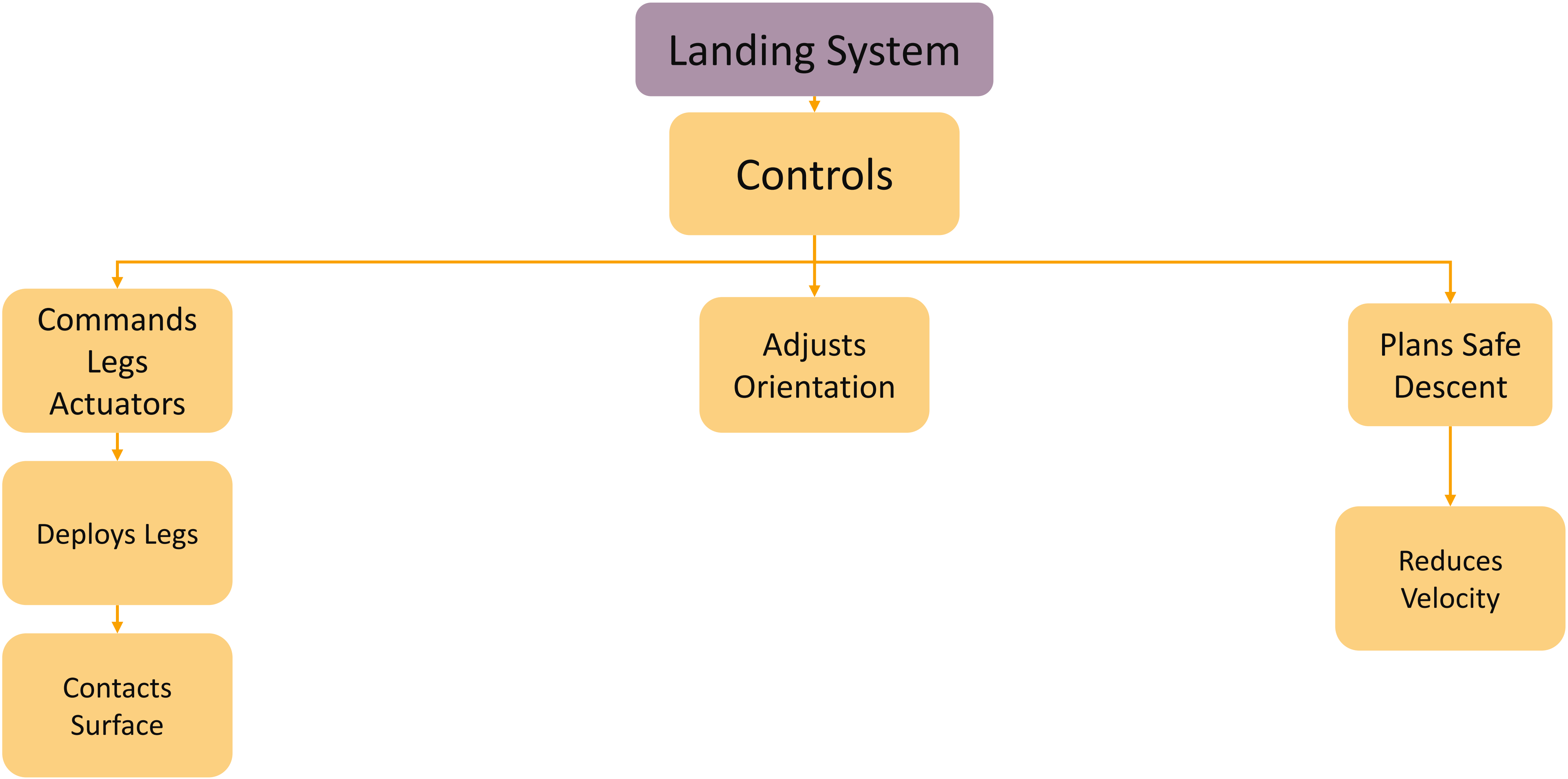
Andrew Sak

Functional Decomposition



Andrew Sak

Functional Decomposition



Andrew Sak

Functional Decomposition Matrix

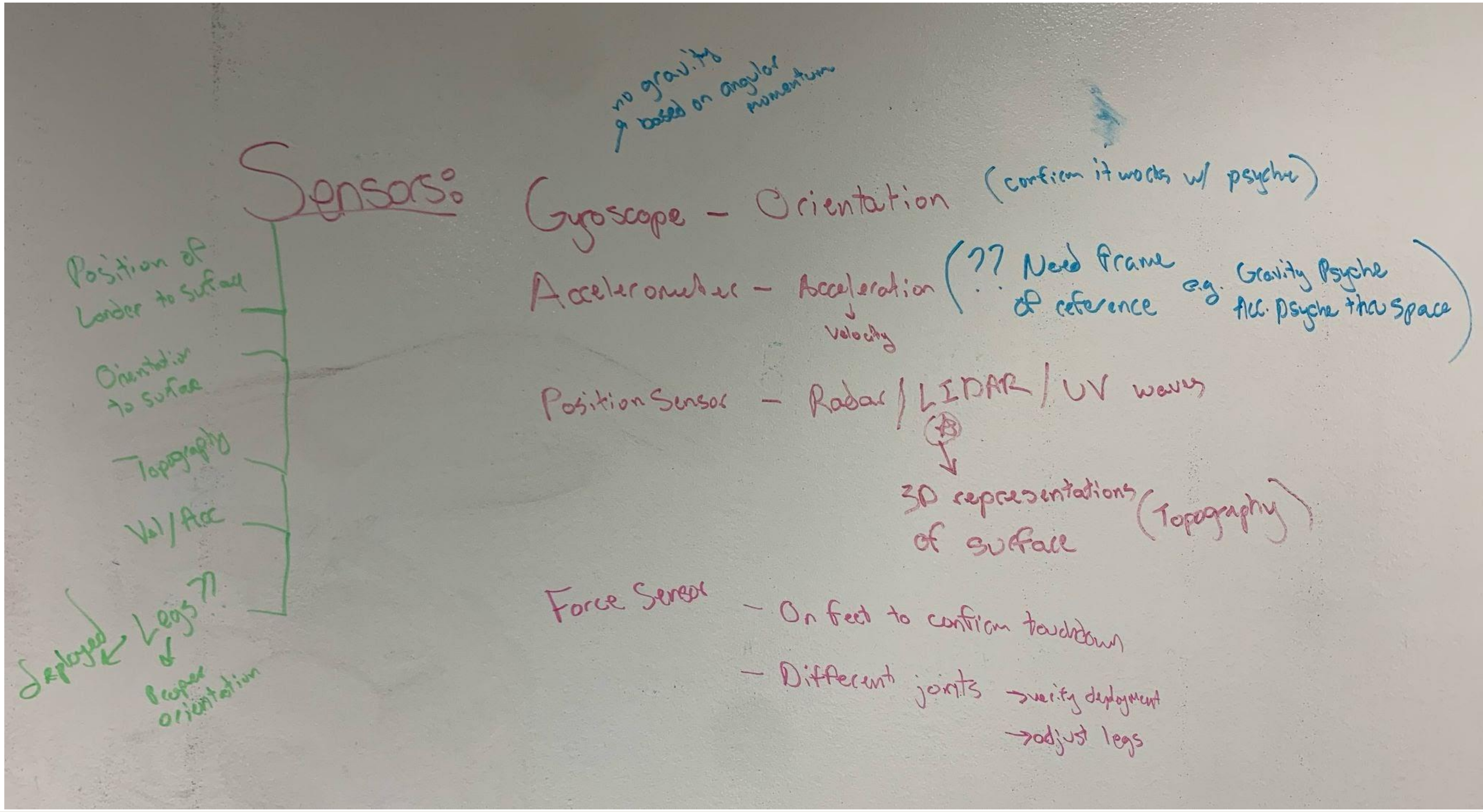
Minor Functions	Support	Sensors	Controls
Houses Payload	X		
Houses Sensors	X		
Houses Actuators	X		
Houses Electrical Board	X		
Houses Wiring	X		
Prevents Tipping	X	X	X
Supports Weight	X		
Prevents Environmental Damage of Hardware	X		
Dampens Impact Forces	X		
Reads Velocity		X	
Reads Position		X	
Reads Angle		X	
Reads Topography		X	
Deploys Legs	X	X	X
Reduced Velocity		X	X

System/Major Functions

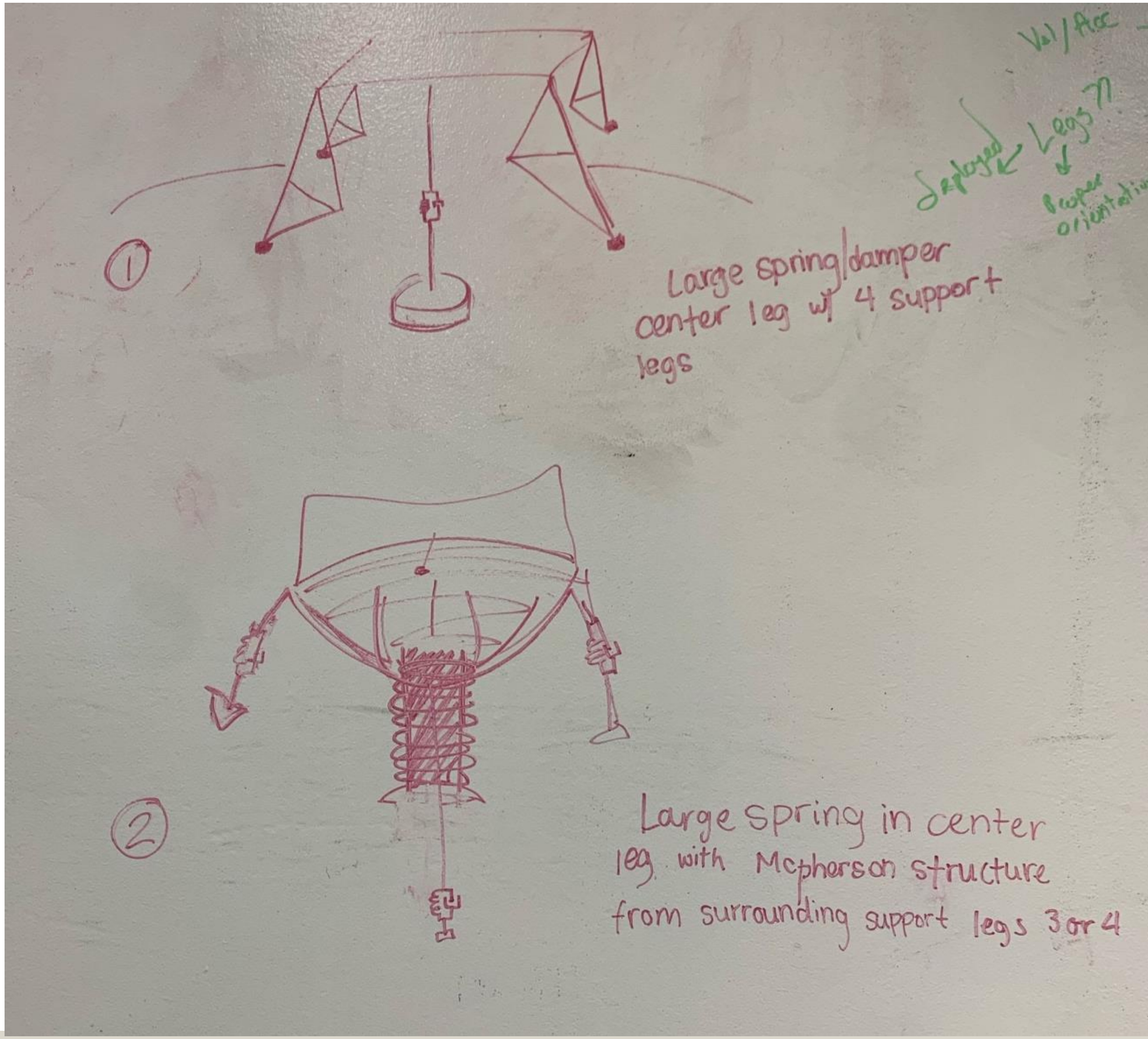
Andrew Sak

Backup Slides

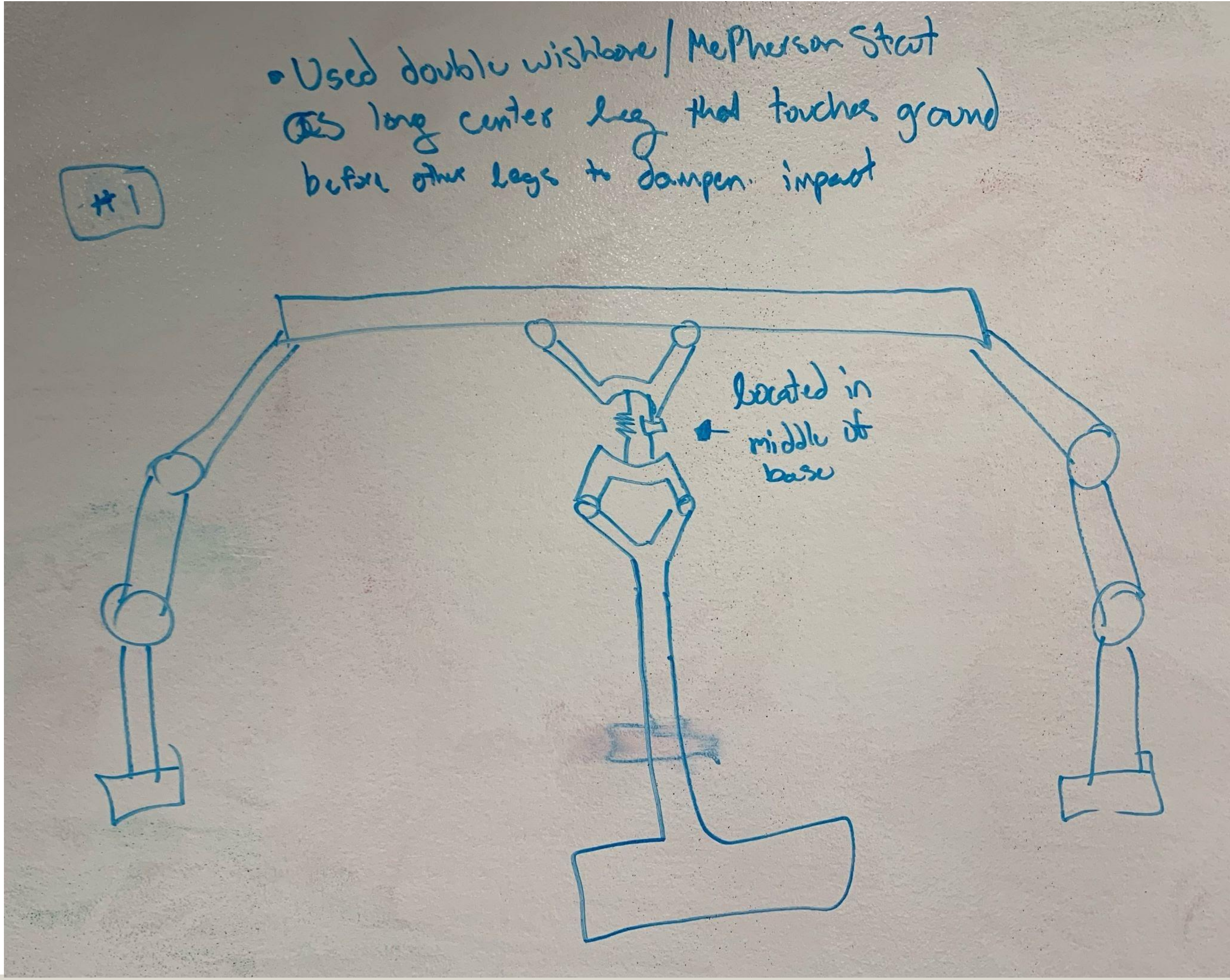
Sensors


no gravity
based on angular momentum
Sensors:
Gyroscope - Orientation (confirm it works w/ psyche)
Accelerometer - Acceleration
Velocity
(?? Need frame of reference e.g. Gravity Psyche Acc. psyche thru space)
Position Sensor - Radar / LIDAR / UV waves
3D representations of surface (Topography)
Force Sensor - On feet to confirm touchdown
- Different joints
→verify deployment
→adjust legs
Position of Lander to surface
Orientation to surface
Topography
Vel/Acc
Legs??
Deployed
Proper orientation

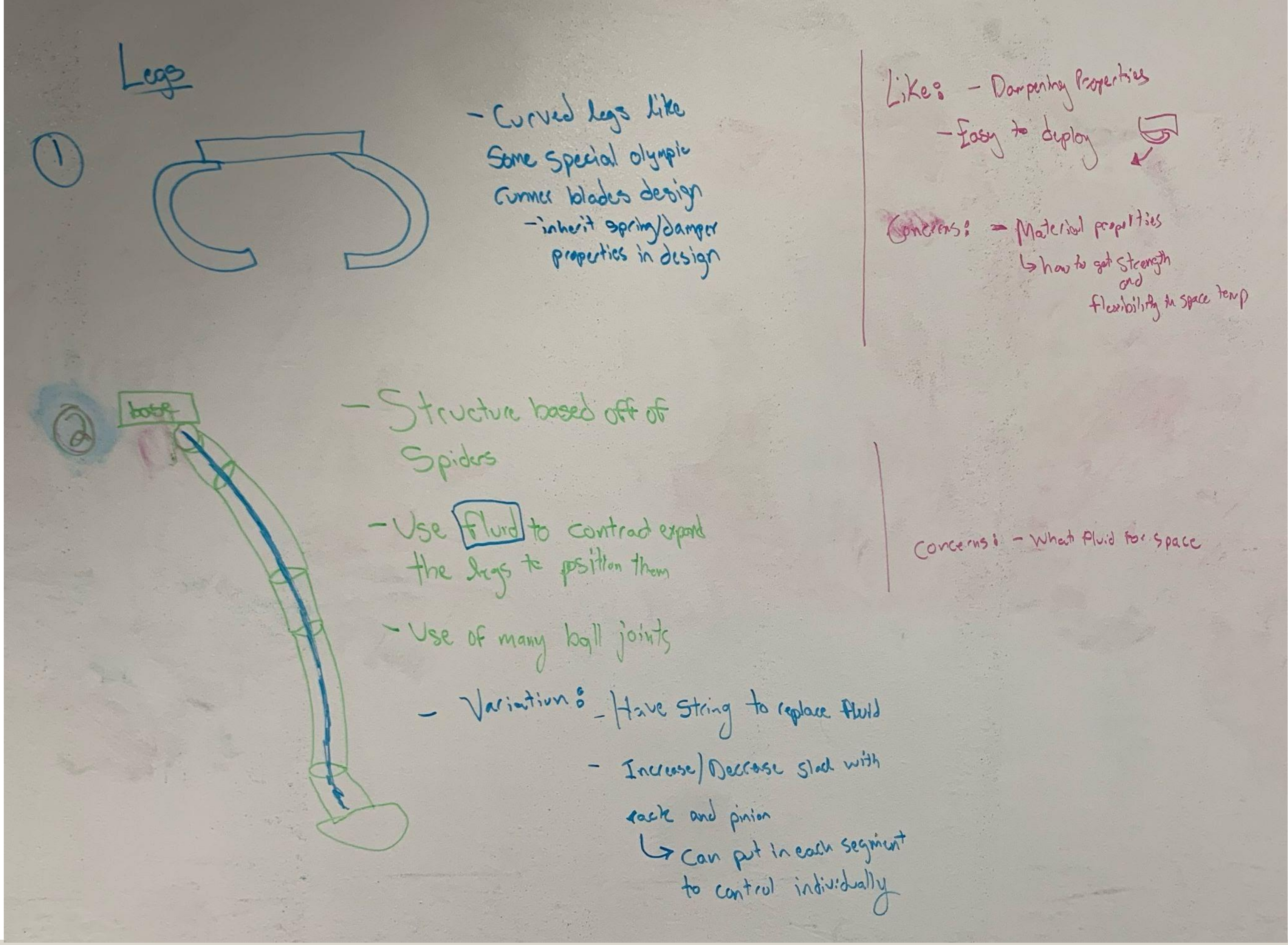
Concept 1


Vel/Acc
Deployed
Legs??
1
Large spring/damper center leg w/ 4 support legs
2
Large spring in center leg with Mcpherson structure from surrounding support legs 3 or 4

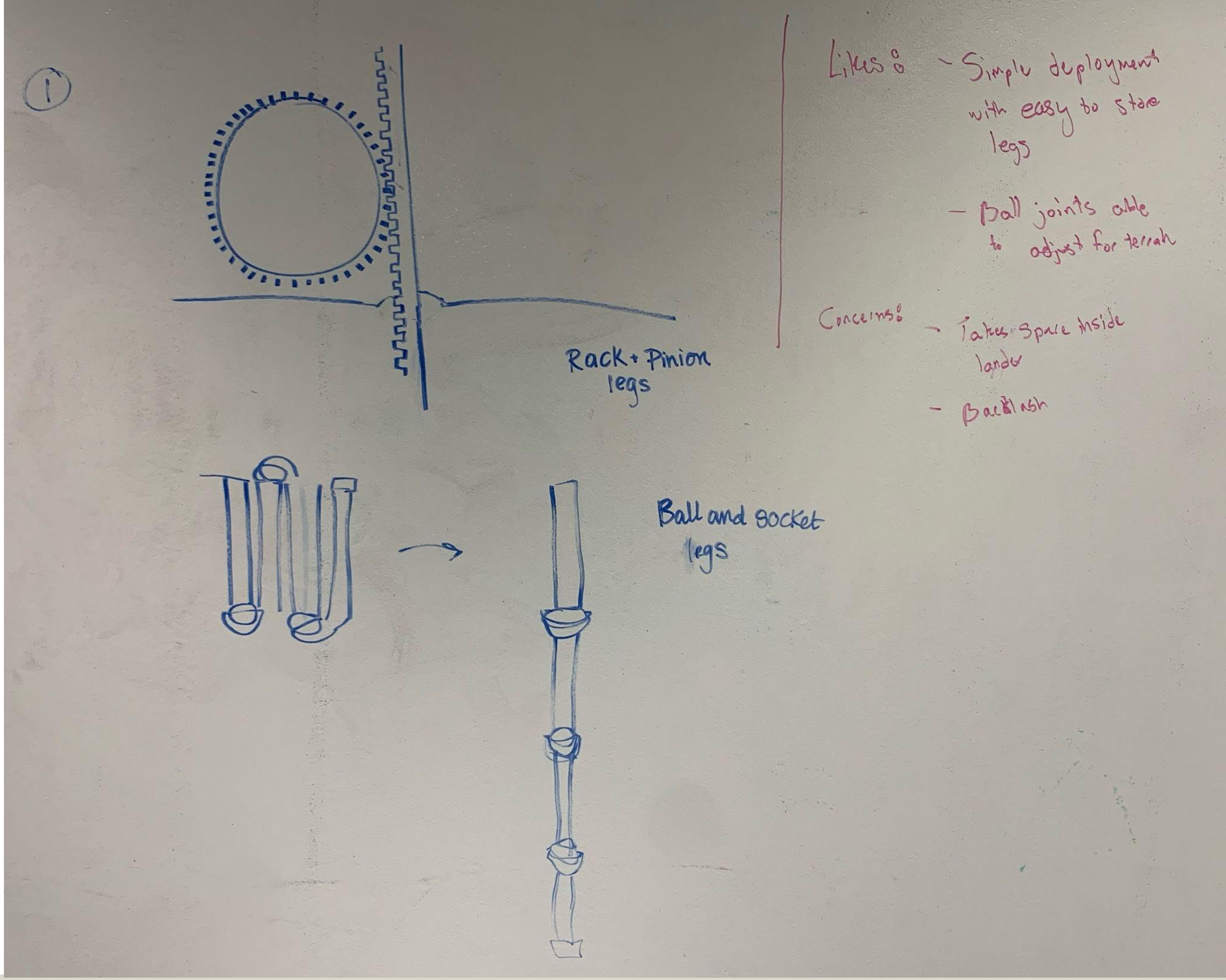
Concept 1


• Used double wishbone / McPherson Strut
long center leg that touches ground
before other legs to dampen impact
#1
located in
middle of
base

Legs

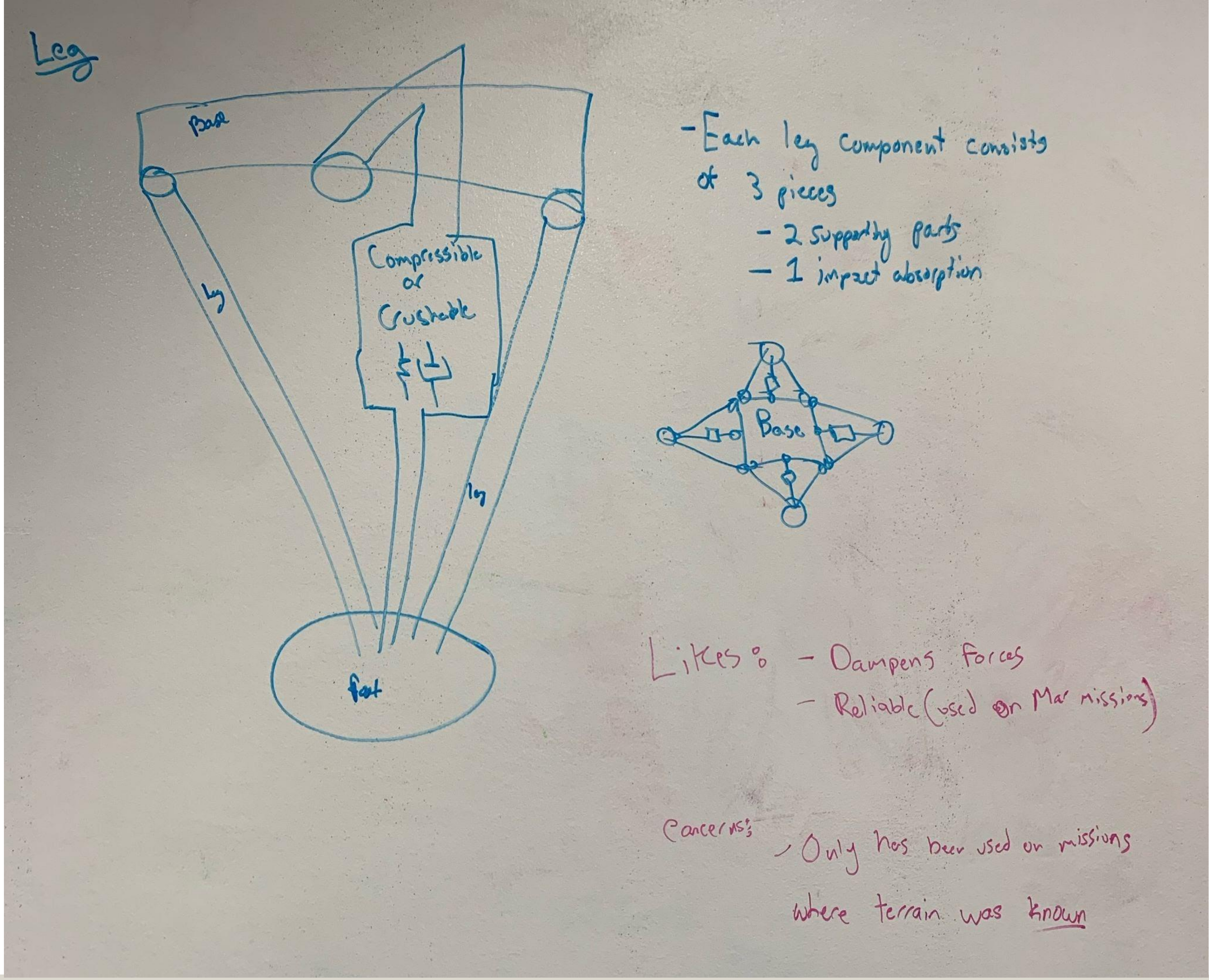

Legs
1
- Curved legs like Some special olympic runner blades design
- inherit spring/damper properties in design
Like: - Dampening Properties
- Easy to deploy
Concerns: - Material properties
↳ how to get strength and flexibility to space temp
2
base
- Structure based off of Spiders
- Use fluid to contract expand the legs to position them
- Use of many ball joints
- Variation: - Have string to replace fluid
- Increase/Decrease slack with rack and pinion
↳ Can put in each segment to control individually
Concerns: - What fluid for space

Legs



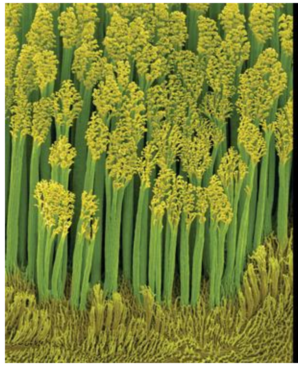
1
Rack + Pinion legs
Likes:
- Simple deployment with easy to store legs
- Ball joints able to adjust for terrain
Concerns:
- Takes space inside lander
- Backlash
Ball and socket legs

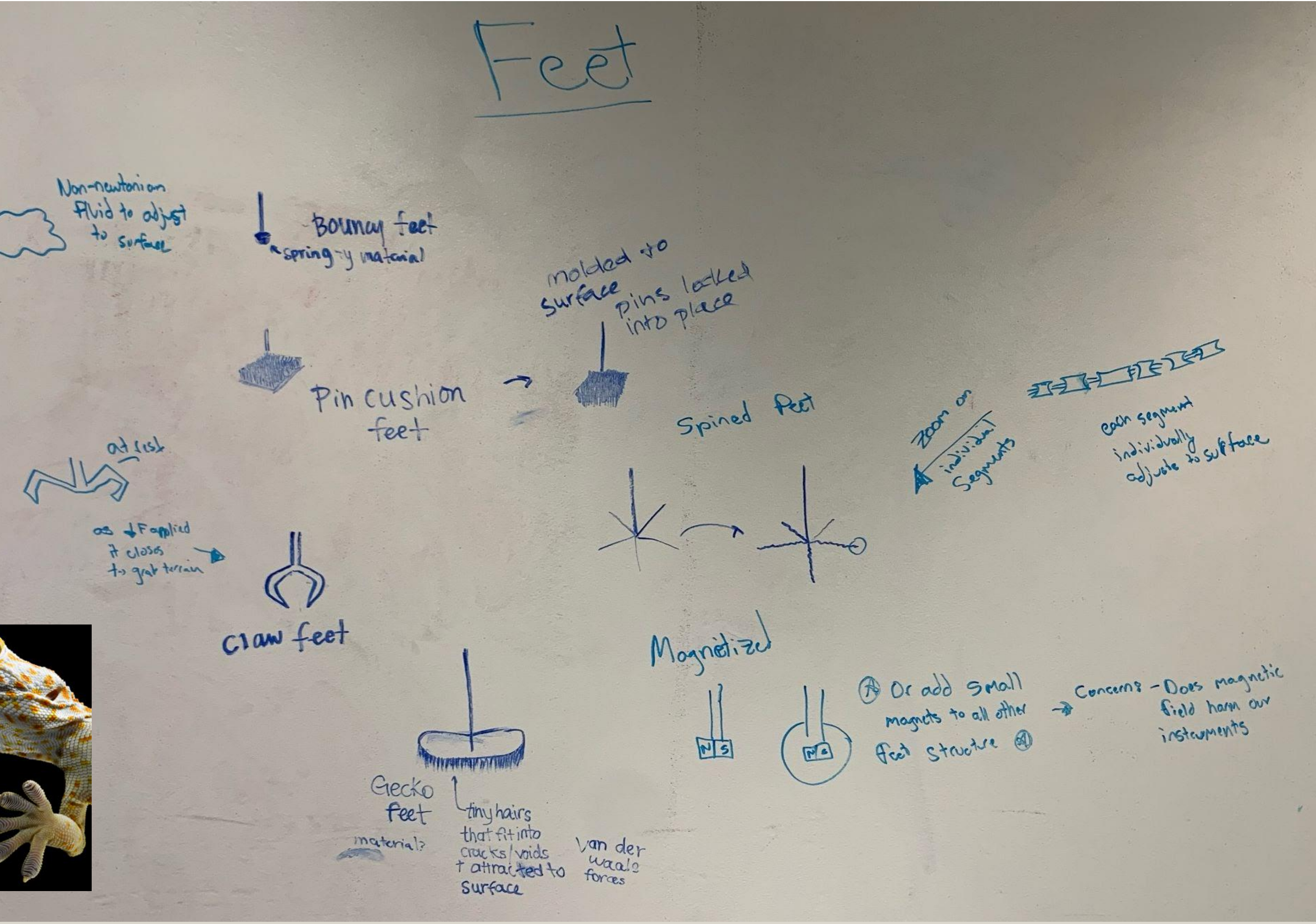
Legs



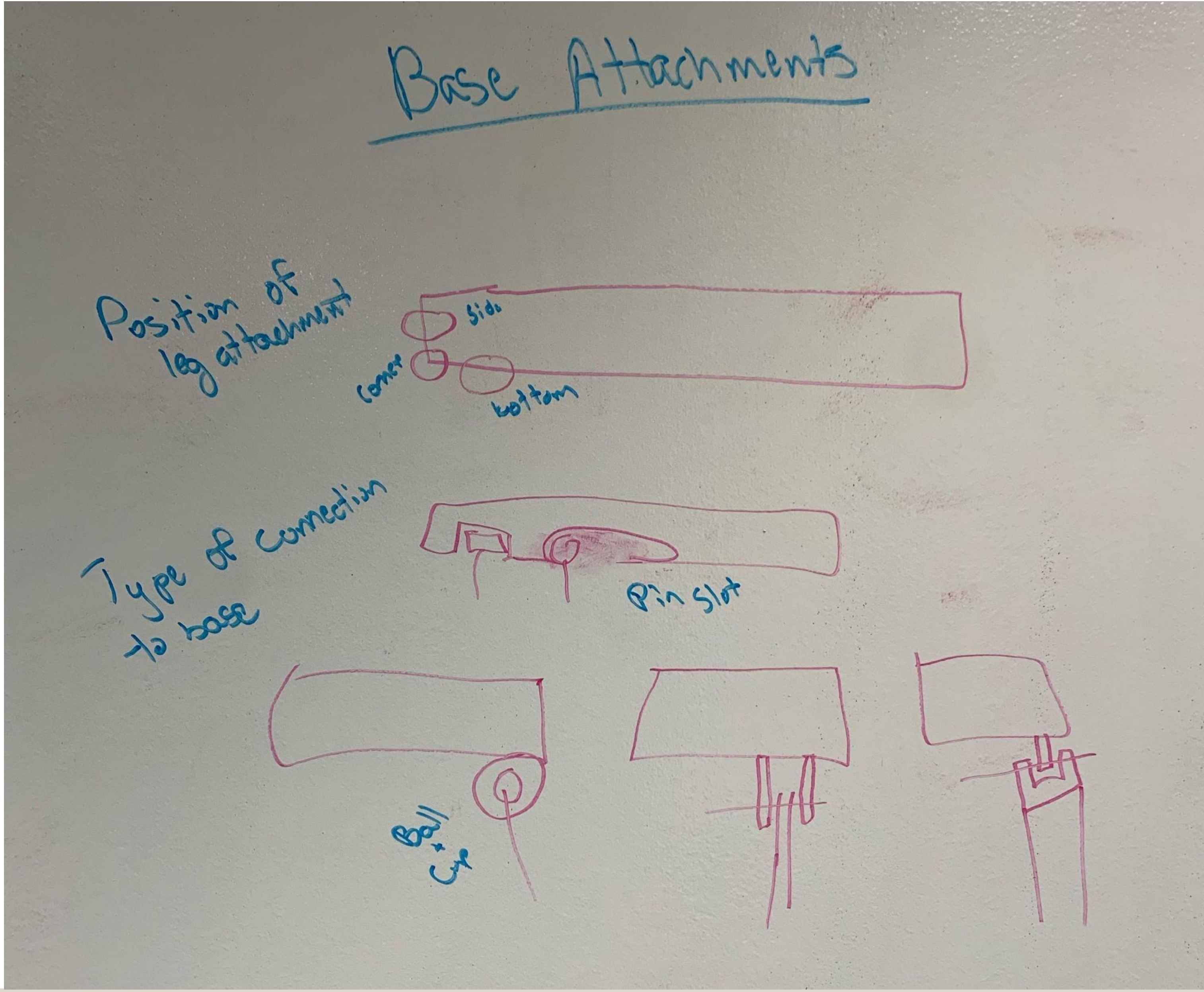
Leg
Base
Leg
Compressible or Crushable
leg
Foot
-Each leg component consists of 3 pieces
- 2 supporting parts
- 1 impact absorption
Base
Likes: - Dampens forces
- Reliable (used on Mar missions)
Concerns: - Only has been used on missions where terrain was known

Feet

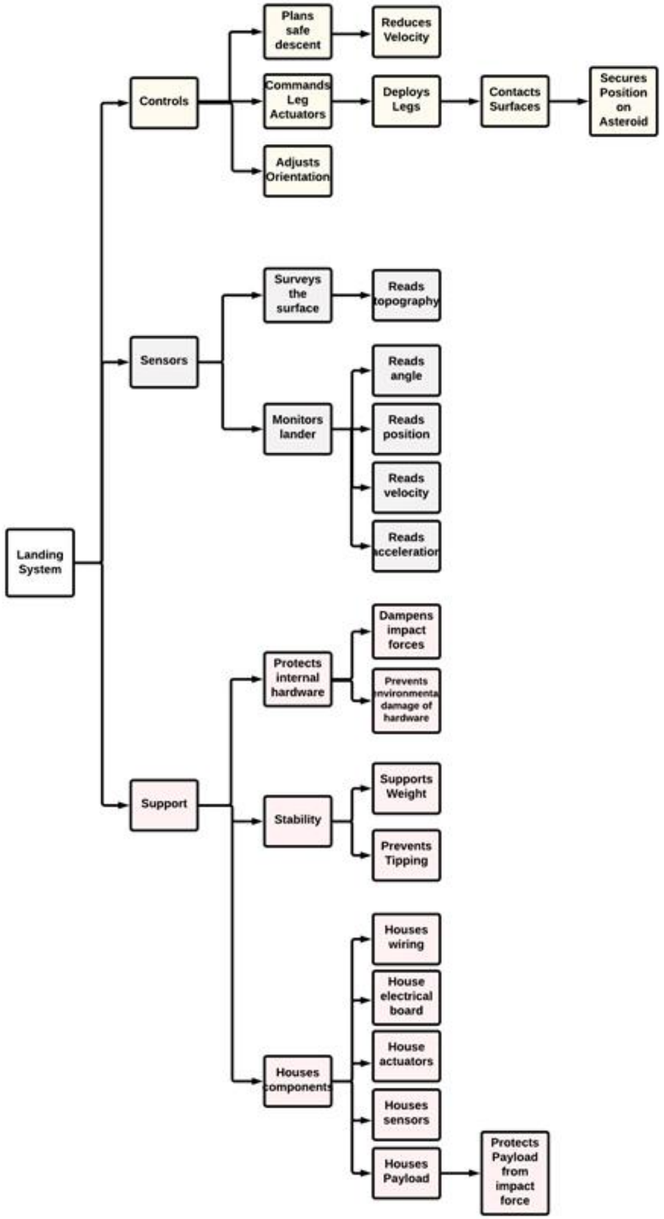



Feet
Non-newtonian fluid to adjust to surface
Bouncy feet
spring-y material
molded to surface
pins locked into place
Pin cushion feet
Spined feet
Zoom on individual segments
each segment individually adjusts to surface
at first
as F applied it closes to grab terrain
Claw feet
Magnetized
Or add small magnets to all other feet structure
Concerns - Does magnetic field harm our instruments
Gecko feet
material?
tiny hairs that fit into cracks/voids + attracted to surface
Van der waals forces

Base


Base Attachments
Position of leg attachment
Side
corner
bottom
Type of connection to base
Pin slot
Ball + cup

Functional Decomp Backup



Landing System
Controls
Plans safe descent
Reduces Velocity
Commands Leg Actuators
Deploys Legs
Contacts Surfaces
Secures Position on Asteroid
Adjusts Orientation
Sensors
Surveys the surface
Reads topography
Monitors lander
Reads angle
Reads position
Reads velocity
Reads acceleration
Support
Protects internal hardware
Dampens impact forces
Prevents environmental damage of hardware
Stability
Supports Weight
Prevents Tipping
Houses components
Houses wiring
House electrical board
House actuators
Houses sensors
Houses Payload
Protects Payload from impact force

Functional Decomposition Matrix

MINOR FUNCTIONS	SYSTEM		
	Major Function		
	Support	Sensors	Controls
Houses Payload	X		
Houses Sensors	X		
House Actuators	X		
Houses Electrical Board	X		
Houses Wiring	X		
Prevents Tipping	X	X	X
Supports Weight	X		
Prevents Environmnetal Damage of Hardware	X		
Dampens Impact Forces	X		
Reads Velocity		X	
Reads Position		X	
Reads Angle		X	
Reads Topography		X	
Deploys Legs	X	X	X
Reduces Velocity		X	X

Customer Needs

Question Asked	Customer Statement	Interpreted Need
What is the possible size/weight of the spacecraft the landing gear will support?	"Look at previous missions to small planets for reference sizes. Look at other landers and the rovers they carried, but we don't want to send something big and expensive."	The landing system supports the weight/size of the spacecraft based off of previous missions.
Does the spacecraft have storage underneath?	"Yes, look at the rover previously made by a FAMU-FSU Team for a reference size."	The system can support the CHONKE Rover without damaging it.
What is the estimated impact velocity of the spacecraft?	"It will be similar to that of previous space missions to land on small planets."	The device can withstand or dissipate the potential energy from the fall and impact velocity.
What are the possible landing sites at Psyche?	"Let everyone know that the lander will be able to handle the hypothesized terrains. Better knowledge of where to land will come after completion of the upcoming orbiter mission. From the orbiter we can determine where the best place is to land and set the lander to go there."	The system is capable of successfully landing on the hypothesized terrains of Psyche ie. rocky, mostly metal, ect.
Is the team responsible for the control of the impact velocity of the spacecraft?	"Assume the lander has been brought to a reasonable impact velocity by other equipment. This impact velocity would be based off previous space missions and what you conclude."	Ability to withstand impact and land from assumed impact velocity.
Is the spacecraft returning to Earth? If so, is the team responsible for the landing system for the return?	"No, assume the spacecraft is staying on Psyche."	The system does not have to be reusable.
Does the landing system require any remote controls for manual maneuvering?	"The system needs to be autonomous. Psyche is too far to pilot any spacecraft."	The system is autonomous.