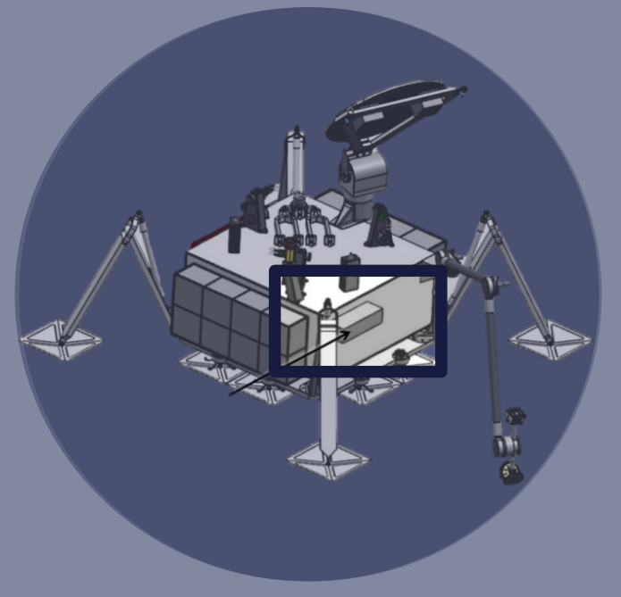
Northeastern University
College *of* Engineering

Europa Lander:
Docking and Sample Transfer System

Eileen Butler, Colin Davis, Christopher Kerr,
Leo Stolov, Kathryn Sweeney
Design Team

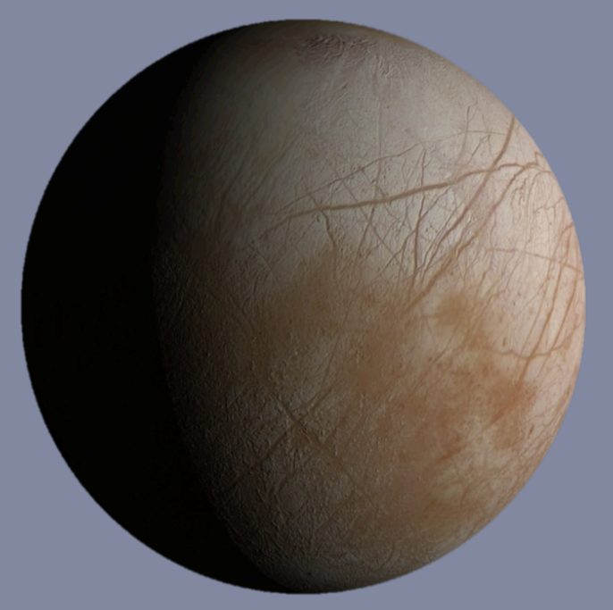
Prof. Randy Erb
Faculty Advisor

Problem Statement



Design a proof of concept system for the Europa Lander mission that is capable of receiving a surface sample from a robotic arm, then verifying and delivering the proper sample volume to the lander's scientific instruments.

Background



Europa, one of Jupiter's moons, may have the potential to host life. NASA JPL is exploring the concept of sending a lander to Europa's surface to collect samples with a robotic arm and analyze them with instruments located in the lander. However, the current lander concept lacks a solution for delivering the collected samples from the excavation arm to the instruments.

Constraints

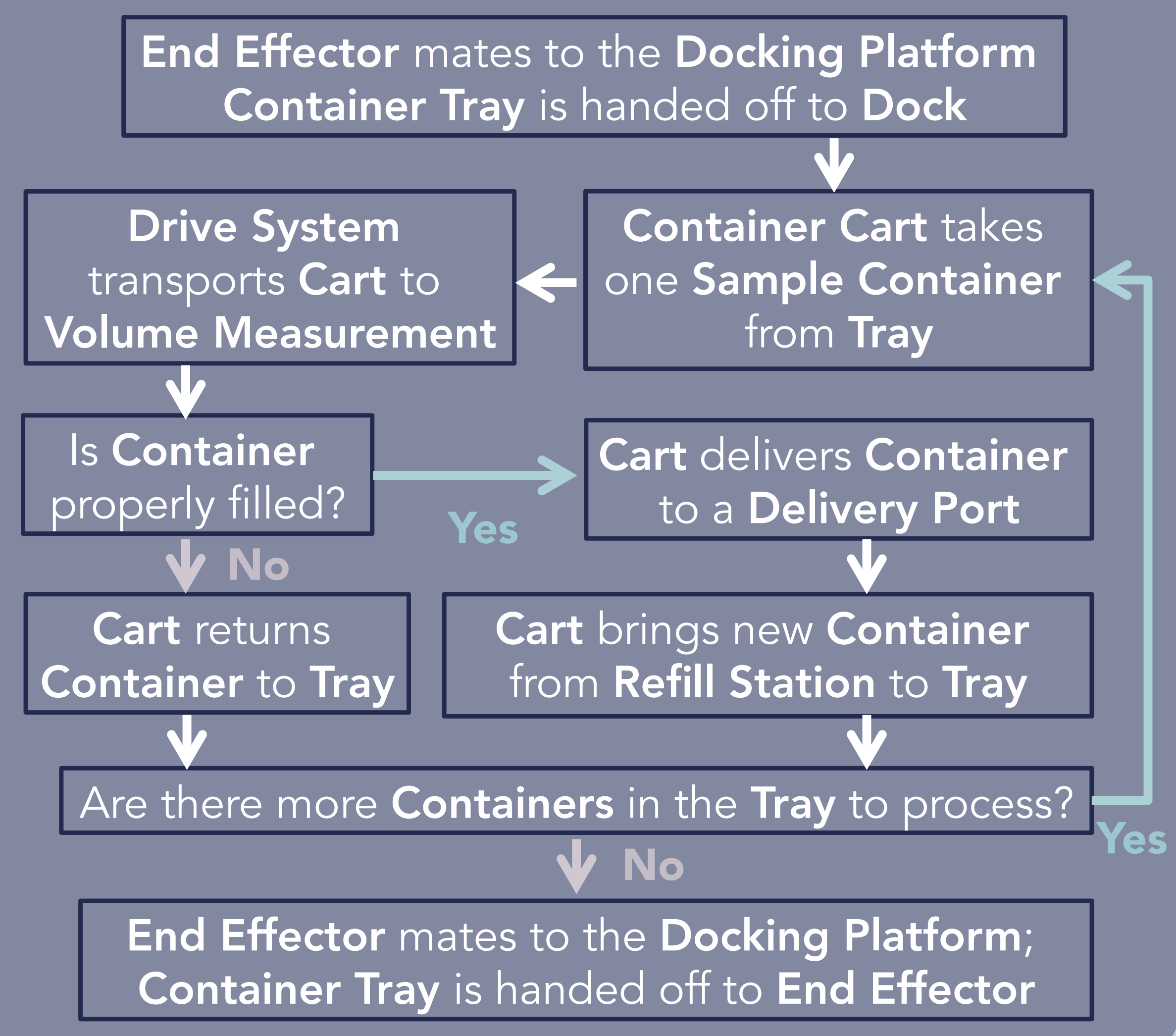
Performance Capabilities

- Sample Security – minimize sample loss or contamination
- Europan Environment – consider cryogenic temperatures (80-130 K), near vacuum (0.1 μPa), low gravity (1.315 m/s²)
- Thermal Management – maintain samples at <150 K
- Autonomy – design can perform functions autonomously

Physical Requirements

- Low Mass – 2 kg
- Low Power – 2.25 kWh
- Volume Envelope – 25 cm x 25 cm x 50 cm

Container Journey – Logic Flow



End Effector mates to the **Docking Platform**
Container Tray is handed off to **Dock**

Container Cart takes one **Sample Container** from **Tray**

Drive System transports **Cart** to **Volume Measurement**

Is **Container** properly filled?

Yes → **Cart** delivers **Container** to a **Delivery Port**

No → **Cart** returns **Container** to **Tray**

Cart brings new **Container** from **Refill Station** to **Tray**

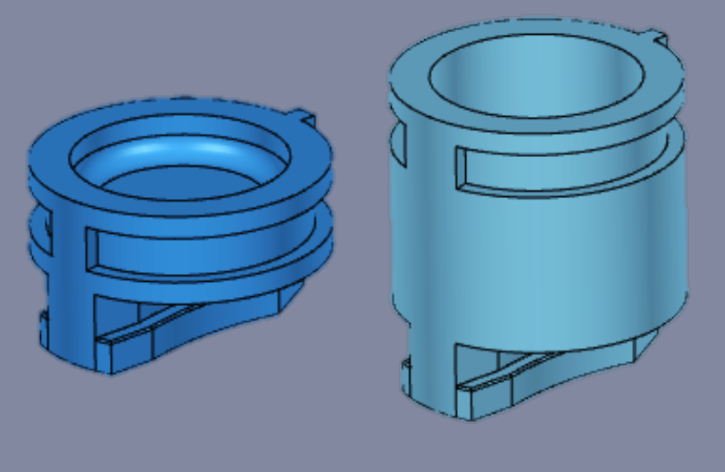
Are there more **Containers** in the **Tray** to process?

Yes → **Container Cart** takes one **Sample Container** from **Tray**

No → **End Effector** mates to the **Docking Platform**; **Container Tray** is handed off to **End Effector**

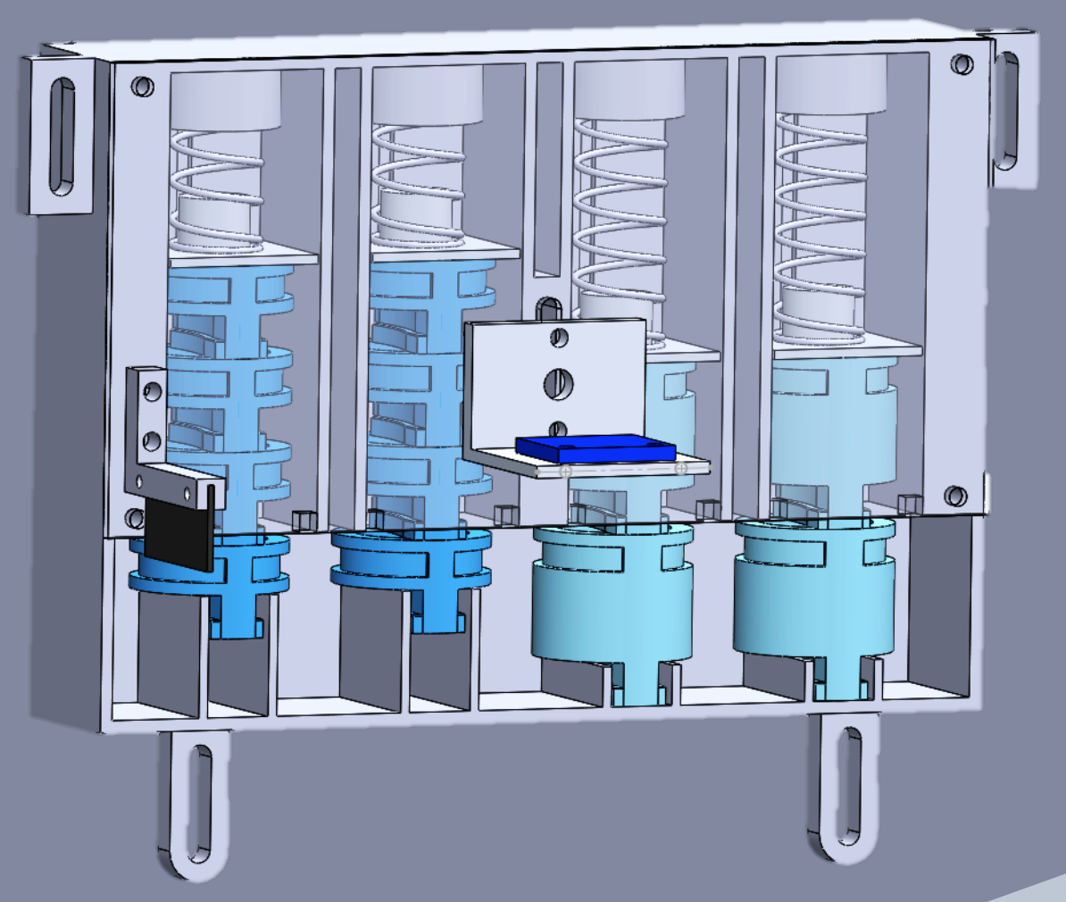
Design and Development

Sample Containers



- Two different sample container volumes: 1 cc and 5 cc
- Three samples per round: two 1 cc and one 5 cc
- Five rounds for fifteen samples total

Volume Measurement and Container Refill

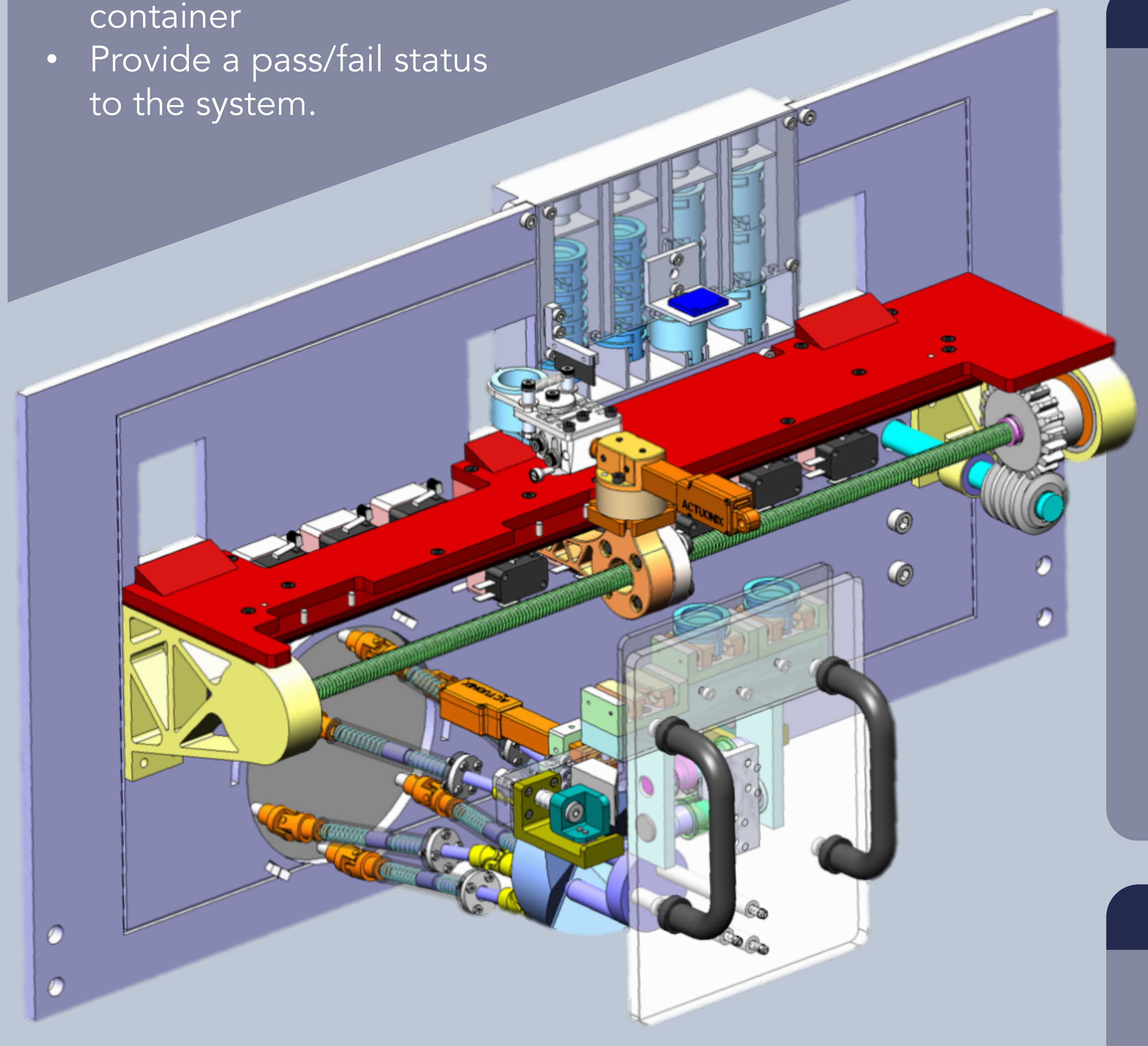


Refill Station

- Spring driven
- Eight replacement 1 cc
- Four replacement 5 cc

Volume Measurement

- Infrared light sensor calculates volume by measuring distance between the sample surface and the top of the container
- Provide a pass/fail status to the system.



Drive System

Lead Screw and Lead Nut

- Allows for linear transport of payload
- Facilitates position control and accurate movement
- Easy to control

Worm and Gear Drive

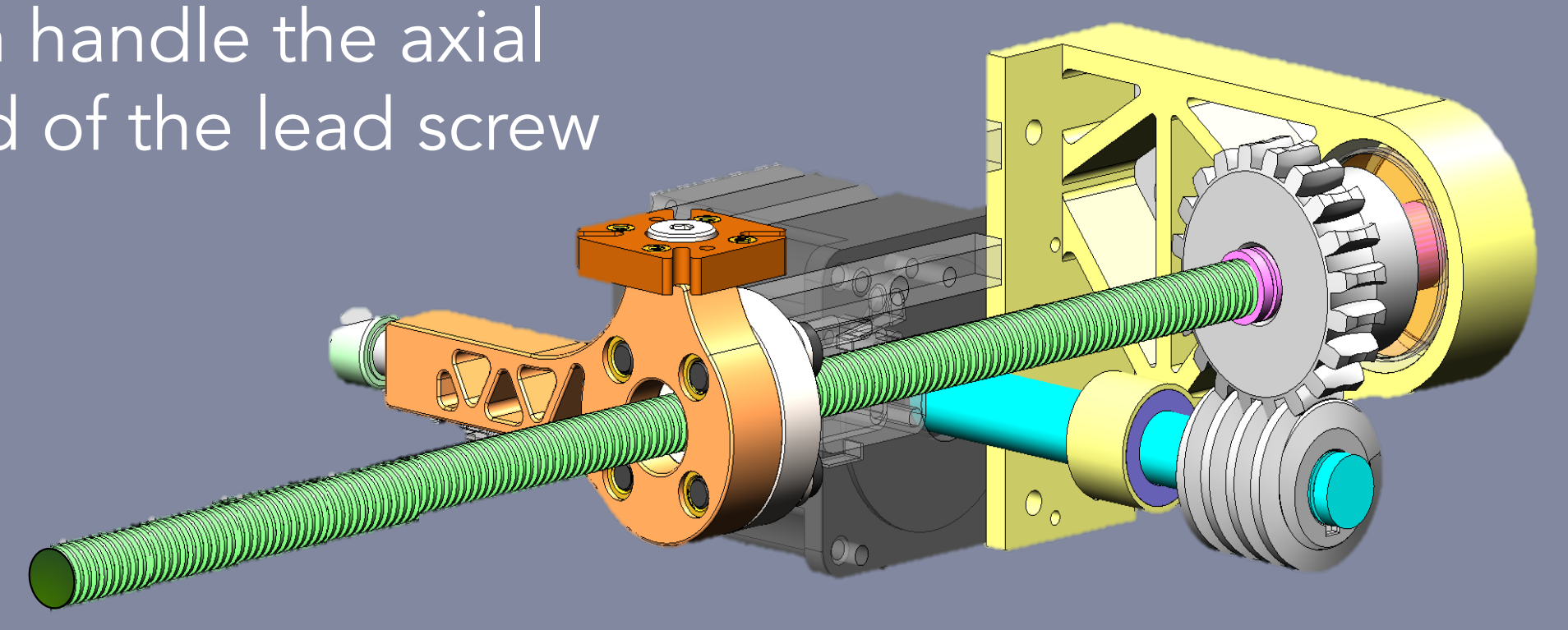
- Facilitates 90° power transfer
- Cannot be backdriven

Stepper Motor

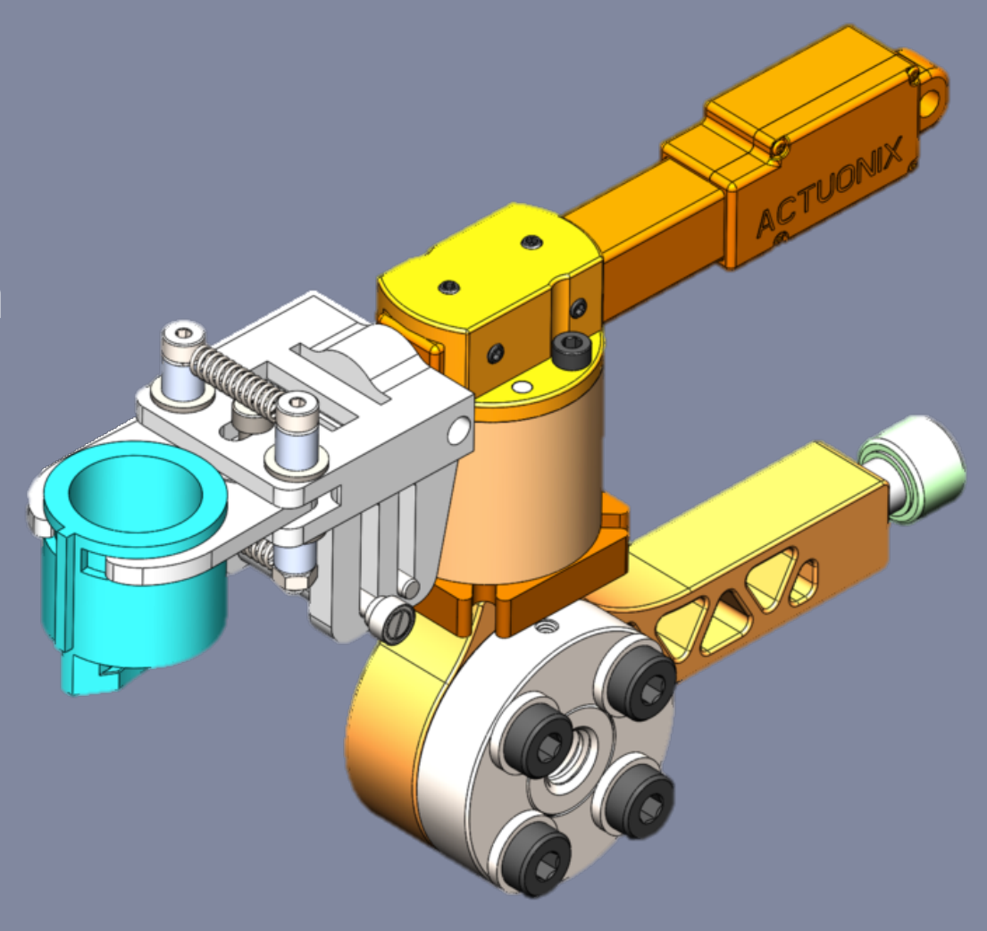
- High precision
- Low error
- Easy to control

Roller Tapered Bearings

- Can handle the axial load of the lead screw



Container Cart

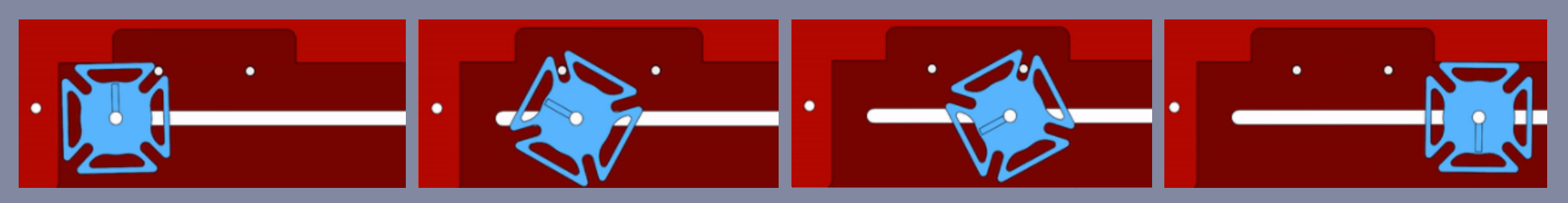


Toggle Gripper

- Over-center concept toggles between open and closed positions
- Activated by linear actuator
- Grasps and moves sample containers

Geneva Drive

- Converts continuous linear motion into discrete rotary motion
- Rotates cart by 180° at a time so that the container can face relevant stations



Kinematic Coupling

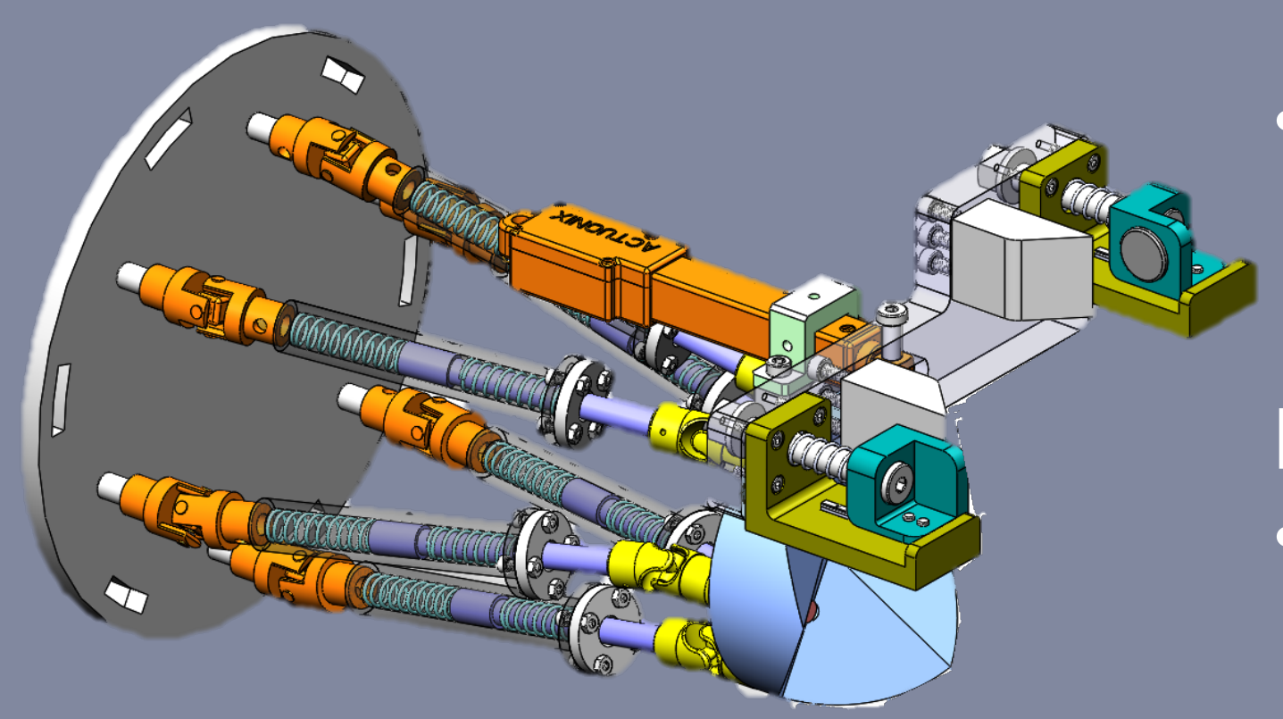
- Only allows one fully constrained position in six degrees of freedom
- Mates with end effector

Stewart Platform

- Can move in all degrees of freedom
- Adjusts for ± 3 cm variance of robotic arm

Handoff Feature

- Ramps actuate lock cams
- Holds container tray with magnets



Docking and Handoff

Container Tray

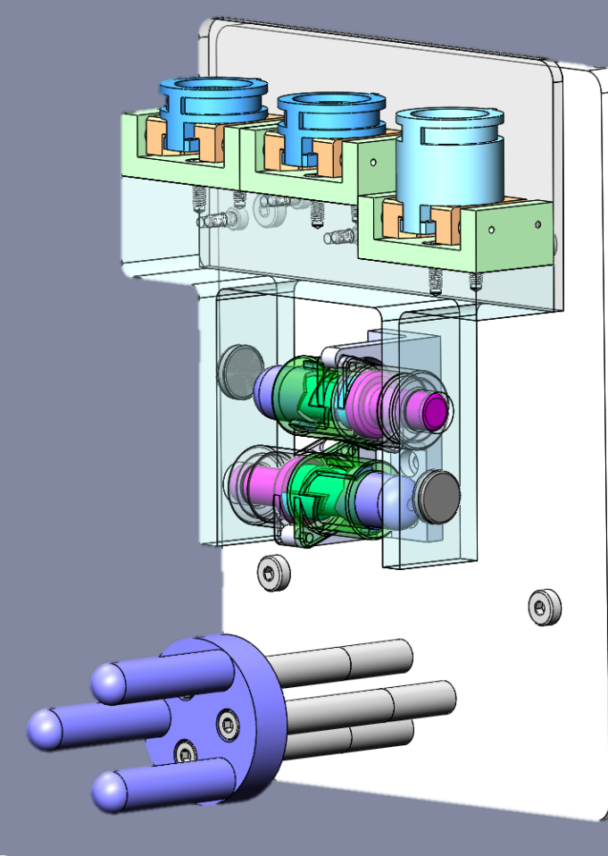
- Carries containers between end effector and docking platform
- Uses passive spring-loaded bottom grippers to hold containers

Lock Cams

- Lock container tray to end effector
- Buttons switch between lock and unlocked positions

End Effector

- Mates with kinematic coupling



Deliverable

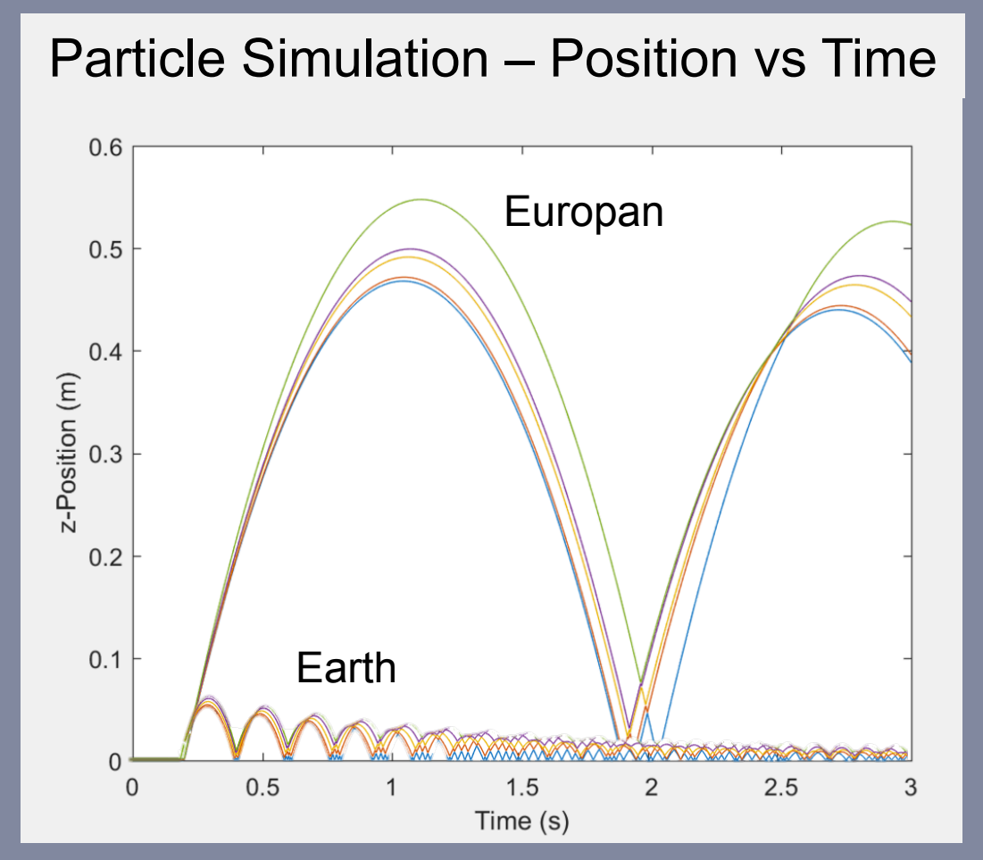
Physical Prototype | Design Solution | Relevant Analysis

The prototype acts as a proof of concept and checks the mechanical and operational viability of the various subsystems. Any functions that cannot be tested in-house shall be evaluated with analysis. Per JPL, vibration and fatigue are not to be considered at this time.

Analysis

Particle Simulation

Purpose: To get a better understanding of how sample particles would behave in a low-gravity vacuum environment and ensure the protection of the Europan sample once it is in a container.

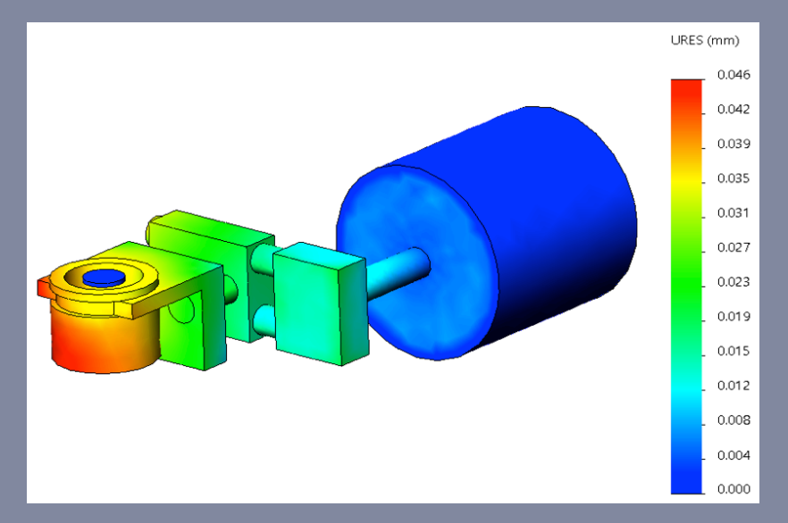


Method: Used MATLAB to map one-dimensional response of particles in an Earth environment compared to a Europan environment.

Result: This simulation showed that the settling time of particles on Europa is far greater than on Earth. To secure sample as it is transported, it is recommended that a transparent cover is added to all containers.

Thermal Management

Purpose: Characterize the expected thermal conditions to determine whether the sample will be kept within temperature limits.



Method: Used SolidWorks to perform steady-state heat transfer analysis using recommended materials and their properties.

Outcomes and Future Recommendations

JPL has expressed that they find the outcome of this project to be an extremely successful proof of concept demonstrating an end to end solution. In the future, the system can be improved by optimizing geometry, utilizing precision manufacturing techniques, and taking steps to reduce friction.

Acknowledgements

The group would like to recognize NASA JPL for their ongoing feedback that guided the development of this project, with special thanks to our point of contact, Chris Yahnker, for his invaluable advice and guidance.