Verification and Validation of a Conceptual Model of the Auto-Rigging Payload Handling and Off-Loading System Using LEGO Technic System and Three-Dimensional Printed Parts

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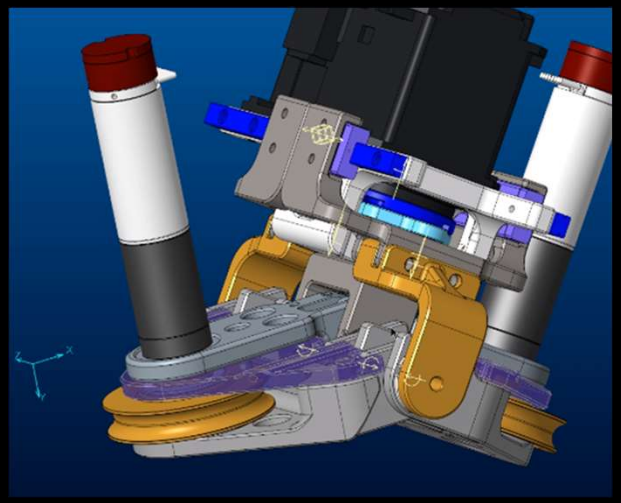


Structural Mechanics and Concepts Branch

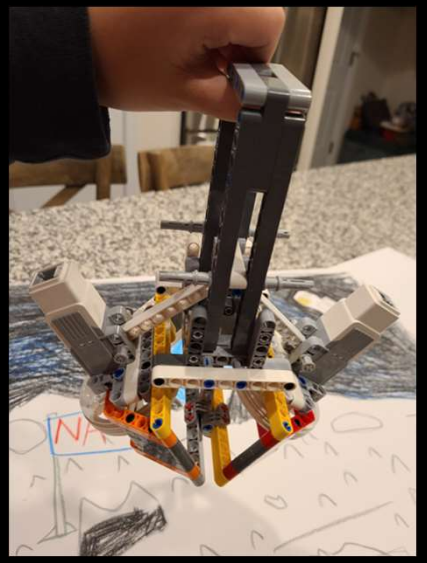
NASA Langley Research Center

Hampton, VA

SciTech

January 6 - 10, 2025

Orlando, FL

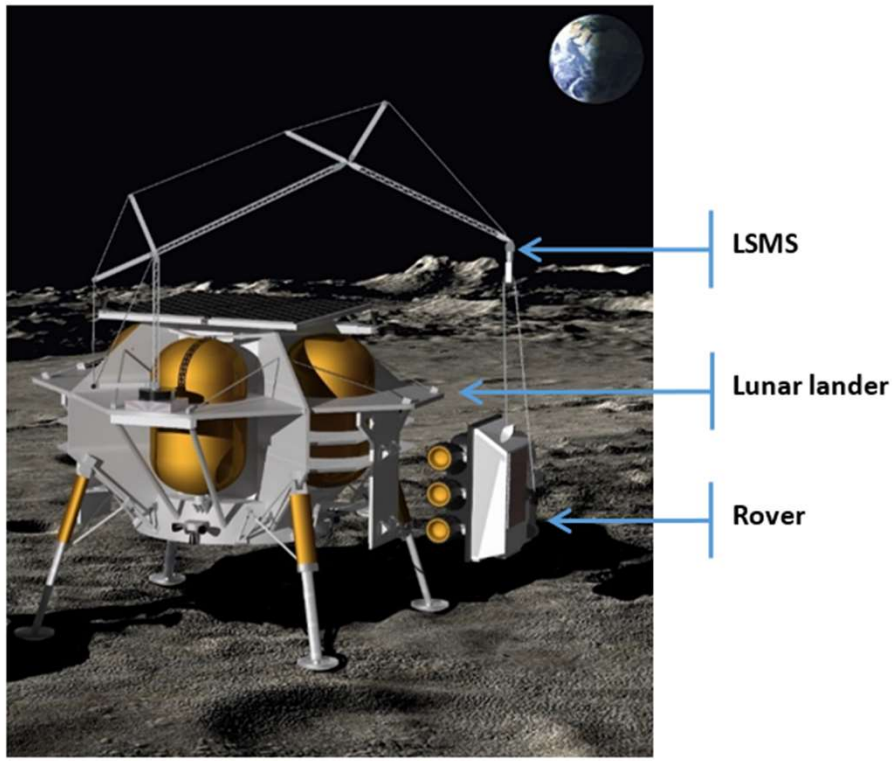


Outline

- Autonomous lifting consideration for future Moon and Mars mission
- Auto-Rigging Payload Handling and Off-Loading System Loading System (ARPHOLS)
  - Capstan-cable-driven system (CCDS)
  - Three- and four-point cable attachment system
- Conceptual validation of ARPHOLS
- Hardware development under Covid-19
- Verification and Validation of the LEGO* conceptual model (CM)
- Outreach activity
- Summary

* The use of trademarks or names of manufacturers in this report is for accurate reporting and does not constitute an official endorsement, either expressed or implied, of such products or manufacturers by the National Aeronautics and Space Administration

Autonomous lifting consideration for future Moon and Mars mission

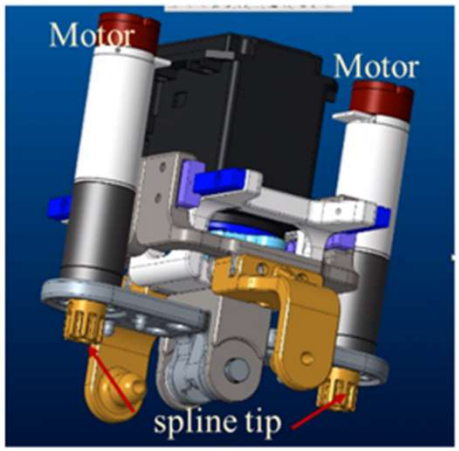


- Optimize for common payload
- Keep it simple for payload
- Support wide range of payloads with added features
- Consider lightweight vectran cord
- Likely 1-5 uses (minimum cycles)
- Potential to use terrestrial ground handling interfaces

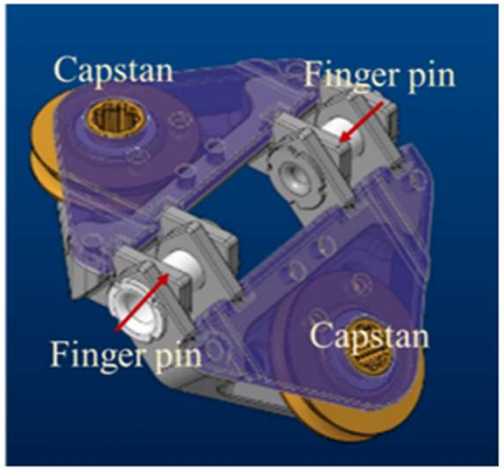
<u>Suggest</u>

- Use a tool to manage the lifting
- Dedicated rigging for each payload or rigging harness (cordage, etc. between tool and payload)

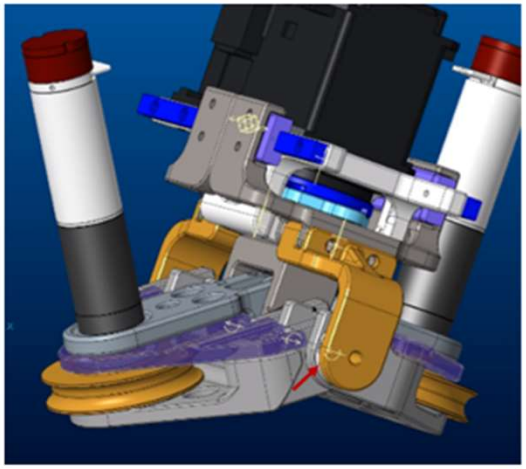
Capstan-Cable-Driven System (CCDS)



Motor-mounting joint



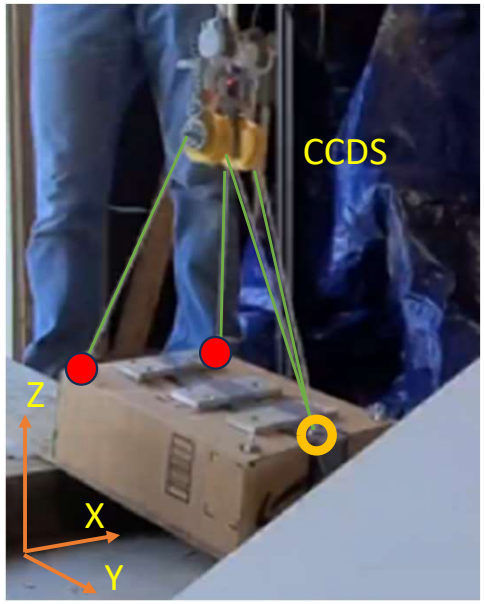
Capstan joint gripper

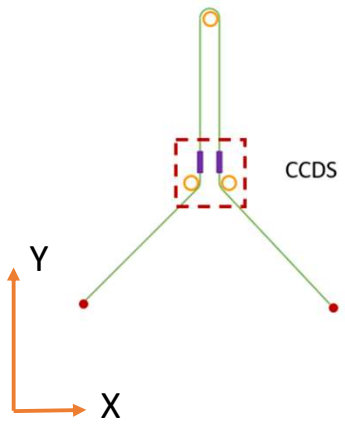


Attached mounting joint and capstan joint gripper

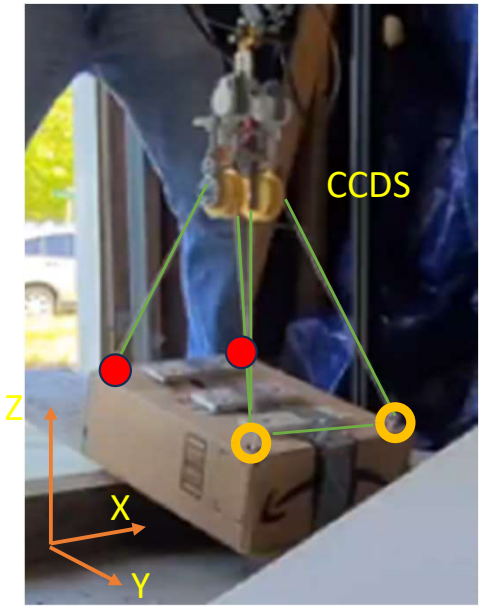
Adjust the lifting angle to level or tilt the payload to achieve the desired position and match the targeted destination

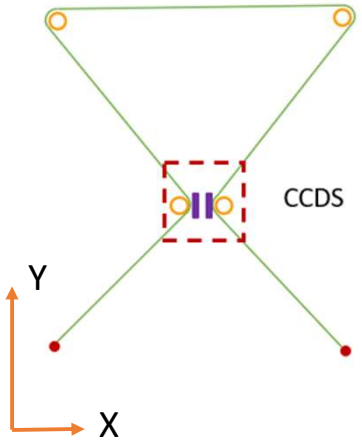
Three- and four-point cable attachment system

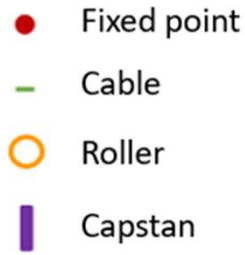




Three-point cable attachment system





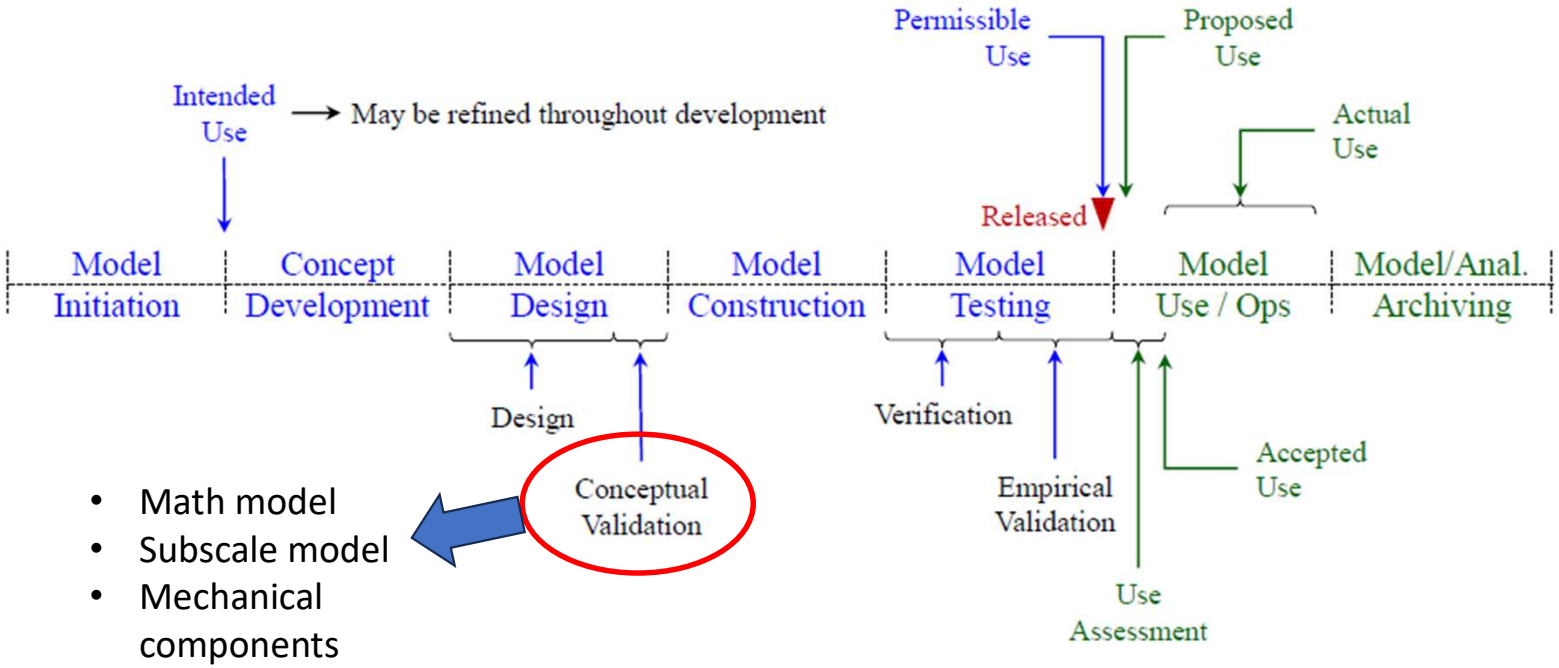


Four-point cable attachment system

Adjust the rotational control for orientating the payload

Modeling and simulation - conceptual validation

Modeling and Simulation (M&S) Life Cycle [1]



- Math model
- Subscale model
- Mechanical components demonstration

[1] NASA-STD-7009A, "Standard for Models and Simulation," December 7, 2016.

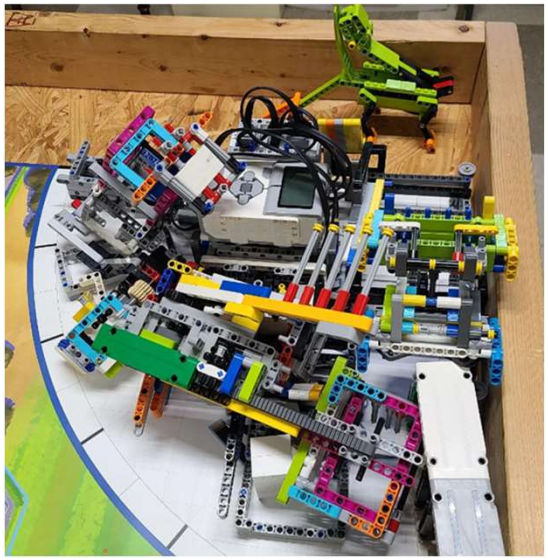
Hardware development under Covid-19

Limited resources

- No in-person meeting
- No hardware components
- No lab access

Available resources

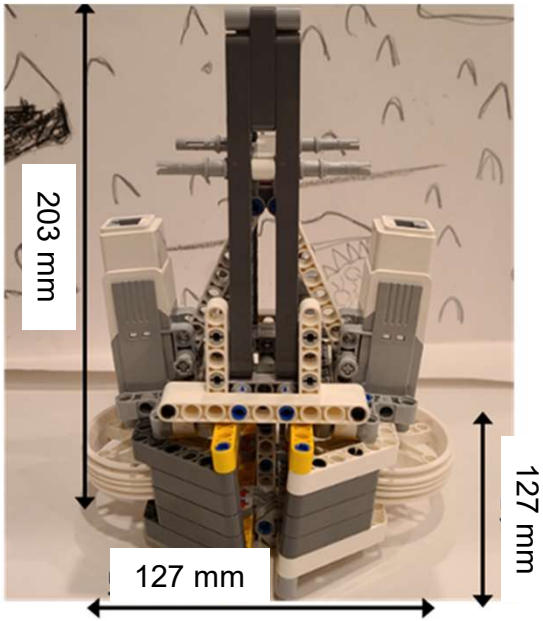
- 3D printer
- TEAM Site
- Personal workplace
- LEGO (Personal use)



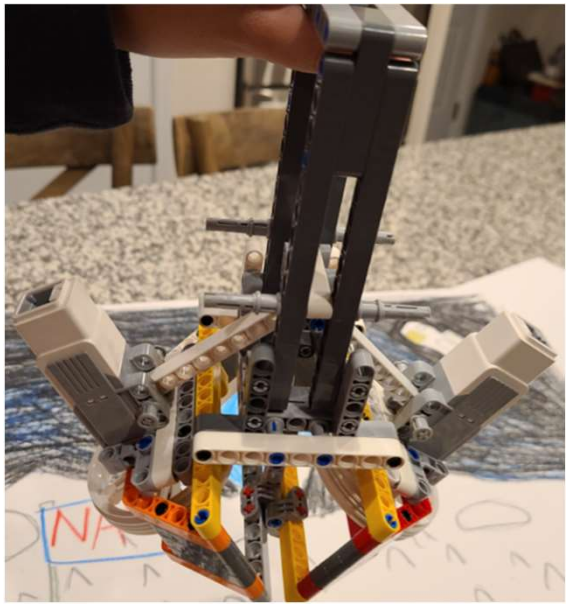
LEGO Technic System Example
(LEGO* Education EV3 Set)

During this time, researchers explored creative approaches to develop a conceptual model and validation methods

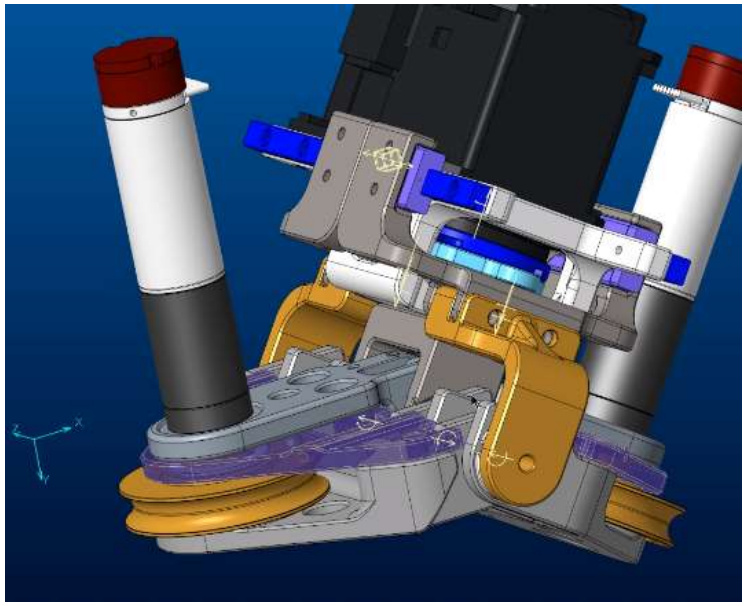
LEGO conceptual model of ARPHOLS



Closed position of LEGO CCDS



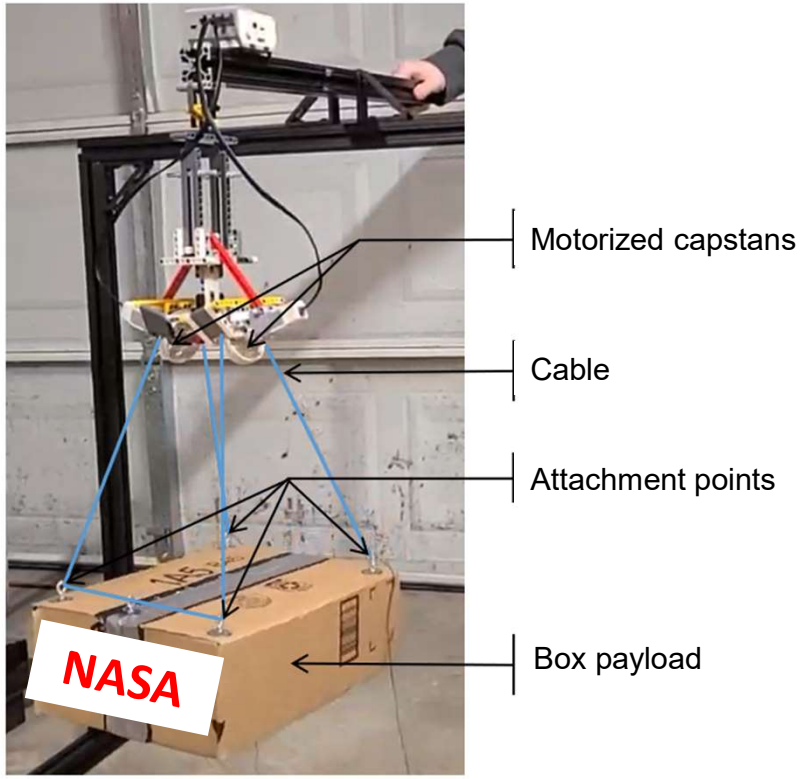
Open position of LEGO CCDS

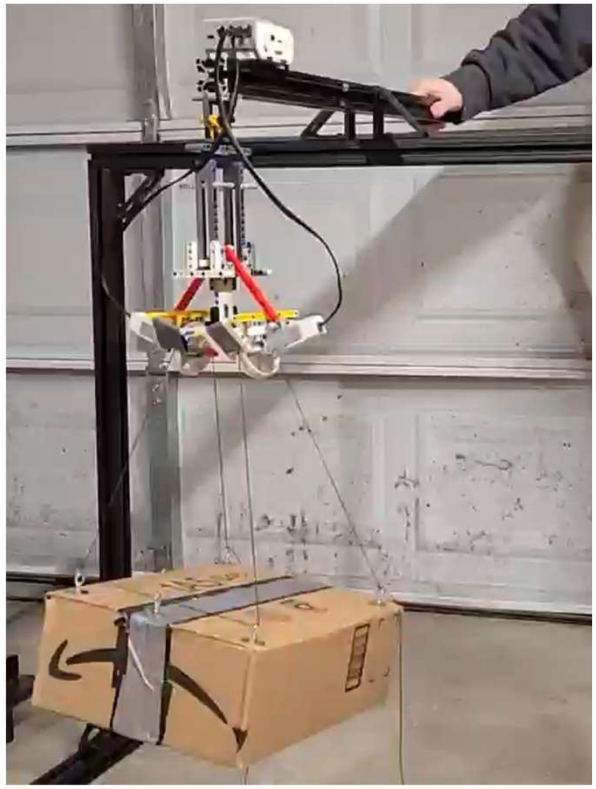


Conceptual design of CCDS

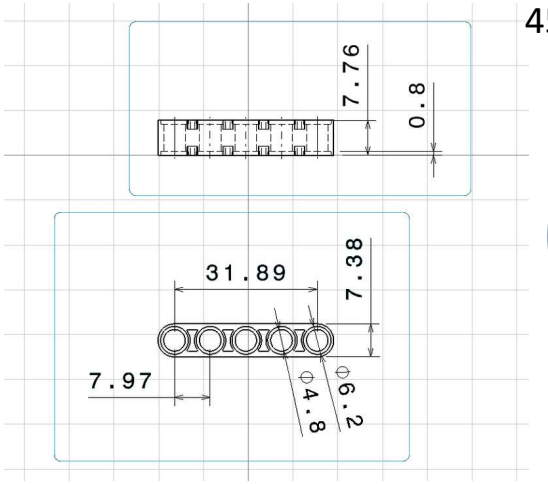
Demonstration of ARPHOLS leveling function

ARPHOLS (Four-point cable attachment system)



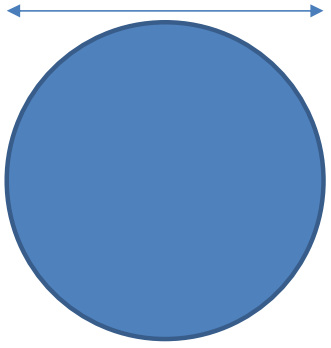


Pulley design



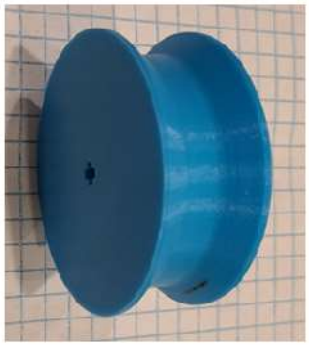
Lego bar dimension
(unit mm)

45 mm ~ 50 mm diameter

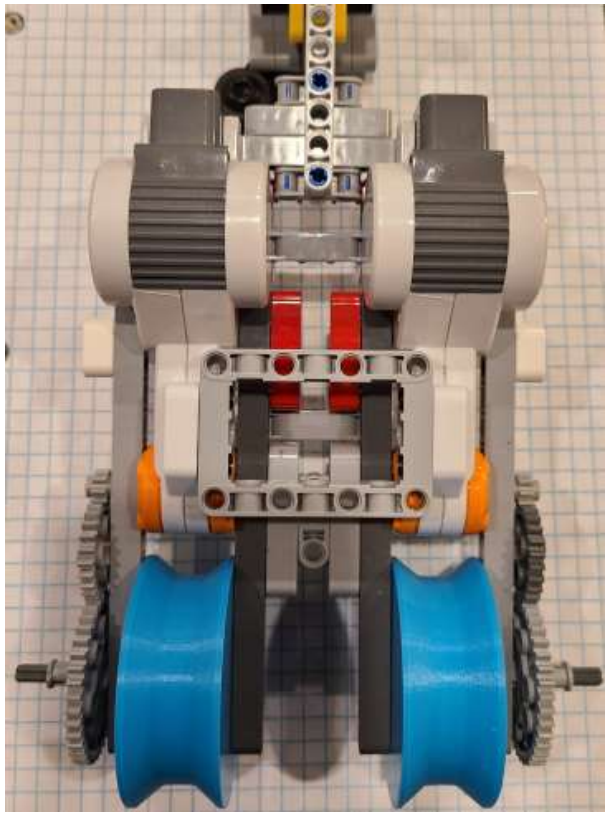


Either 7.76 mm x 3 mm
Or 7.76 mm x 5 mm

Pulley
profile

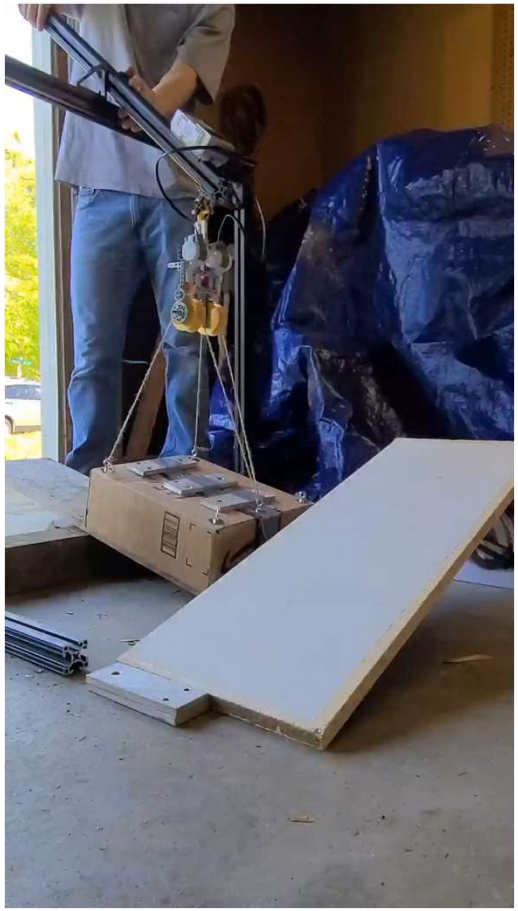


CCDS with pulleys

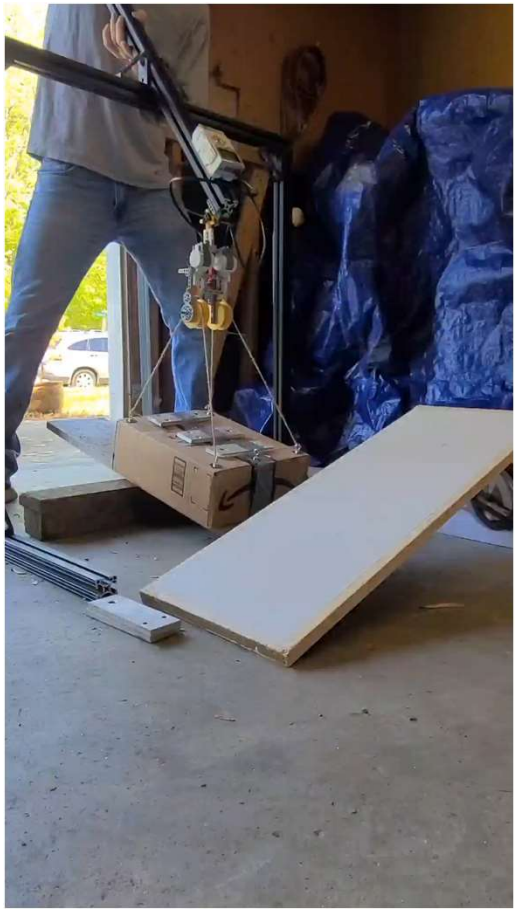


Demonstration of ARPHOLS leveling function

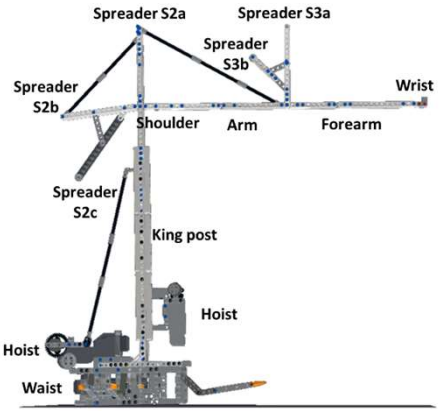
Three-point cable attachment system



Four-point cable attachment system

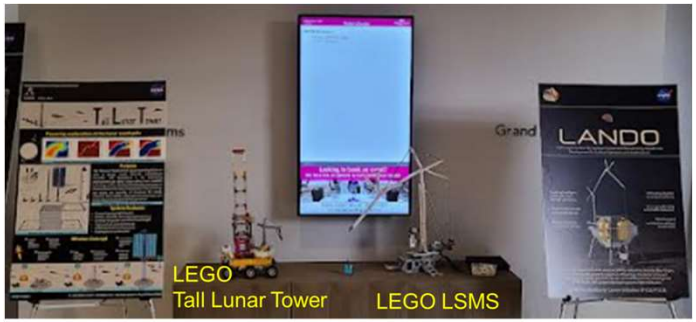


Outreach activity (LEGO display models)



LEGO Lightweight Surface Manipulation System (LSMS)

LEGO Tall Lunar Tower concept model



in-space servicing, assembly and manufacturing technology transfer day workshop in October 2022.

NASA LaRC Open house in October 2023

NASA Mobilizes Resource for HBCU Scholars, Highlighted at Conference September 2024

Summary

- The Auto-Rigging Payload Handling and Off-Loading System (ARPHOLS) was designed to enable autonomous lifting for future space missions
- In 2020, on-site work at NASA's Langley Research Center was suspended due to Stage 4 COVID-19 response protocols
- A new conceptual validation method for the ARPHOLS design was explored, resulting in the development of a conceptual model using a LEGO Technic set
- The capabilities of ARPHOLS were successfully demonstrated and validated through testing with the subscale LEGO model
- LEGO display models of the LSMS and TLT were created and showcased at NASA outreach events