SPACE DEPOT

PASSIVE CAPTURE TOOL DOCK

ABSTRACT

- The Passive Capture Tool Dock (PCTD) provides a simple and reliable docking solution for EVA tools used during spacewalks.
- Designed for passive retention, the system allows one-handed operation by astronauts wearing EVA gloves.
- The dock is fully compatible with the MWS Swingarm system, ensuring smooth integration with existing EVA setups.
- The design emphasizes ease of use, fatigue reduction, and mechanical reliability in a microgravity environment.
- Analytical modeling and CAD simulations were conducted to verify performance, strength, and operability under space conditions.

PROJECT BACKGROUND

Extra-Vehicular Activities (EVA) are essential tasks routinely performed aboard the International Space Station (ISS). Different tools are used during these missions and it is crucial to have a secure stowage system for these tools that are ergonomically viable for astronauts to use during these long EVAs.

The current stowage system used aboard the ISS uses a bayonet type twist locking system that requires two hands to actuate. The goal of this project is to create a new tool stowage system that requires one hand to stow and retrieve tools. This new system will help astronauts aboard the ISS by providing them with a less physically and mentally demanding tool capture process throughout prolonged missions outside of the ISS.

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GOALS & OBJECTIVES

The main goal of the Passive Capture Tool Dock (PCTD) is to design a **passive retention docking system**, which will store the EVA tools for use in extravehicular activities. The PCTD will be designed to be **properly integrated with the MWS Swingarms**. Another primary feature of this product is the ability of the astronauts to **easily and fully operate with only one hand**, which will ensure a **fatigue reduction both mentally and physically**. The actual process of passively securing and retrieving the tools will be a **simple and efficient process**, due to the fact that it takes into account the limited mobility of the EVA gloves and the space suit overall.

ANALYSIS

Determining the maximum allowable shear force V_{allow} on the 3/8-inch diameter 6061-T6 aluminum pin under combined loading conditions (shear, bending, torsion, and axial tension) using a Factor of Safety (FoS) = 5 per NASA JSC 65829 guidelines.

Table 1#: Given Data regarding the 6061-T6 Aluminum Pin

Parameter	Symbol	Value	Units	Reference
Pin Diameter	d	0.375	in	Design geometry
Material	—	6061-T6 Aluminum	—	[1]
Yield Strength	σ_y	40,000	psi	[1]
Allowable von Mises Stress	$\sigma_{vm,allow}$	8,000	psi	Derived ($\sigma_y/5$)
Eccentricity	e	0.125	in	Estimated misalignment
Torque	T	40	lbf·in	EVA twist load
Axial Force	N	50	lbf	Preload/tether tension
Cross-Sectional Area	$A = \pi d^2/4$	0.11045	in²	[2]
Moment of Inertia	$I = \pi d^4/64$	9.70×10⁻⁴	in⁴	[2]
Polar Moment of Inertia	$J = \pi d^4/32$	1.94×10⁻³	in⁴	[2]
Outer Radius	$c = d/2$	0.1875	in	Geometry

Stress Components

1. Direct Shear Stress

$$\tau_s = \frac{V}{A} = \frac{V}{0.11045} = 9.05\,V\ (psi)$$

2. Bending Stress (from load eccentricity e)

$$\sigma_b = \frac{V e c}{I} = \frac{V(0.125)(0.1875)}{9.70\times10^{-4}} = 24.17\,V\ (psi)$$

3. Torsional Shear Stress

$$\tau_t = \frac{Tc}{J} = \frac{40(0.1875)}{1.94\times10^{-3}} = 3,866\ psi$$

4. Axial Stress

$$\sigma_a = \frac{N}{A} = \frac{50}{0.11045} = 453\ psi$$

Combined von Mises Stress

The total stress in the pin under combined loading is given by the von Mises relation:

$$\sigma_{vm} = \sqrt{(\sigma_a + \sigma_b)^2 + 3(\tau_s^2 + \tau_t^2)}$$

Substituting all components:

$$\sigma_{vm} = \sqrt{(453 + 24.17V)^2 + 3[(9.05V)^2 + (3866)^2]}$$

Solving for Allowable Force

Set $\sigma_{vm} = \sigma_{vm,allow} = 8,000\ psi$:

$$\sqrt{(453 + 24.17V)^2 + 3[(9.05V)^2 + 3866^2]} = 8000$$

Solving for V:

$$V_{allow} = 137\ lbf\ (single\ shear)$$

Determining the maximum allowable through-force F_{allow} on the buckle window ligament (net-section across the window) for a 6061-T6 aluminum plate, including stress concentration and combined (normal + shear) von Mises effects, using Factor of Safety (FoS) = 5 (yield basis; JSC 65829 practice).

Table 2#: Given Data regarding the 6061-T6 Aluminum Buckle

Parameter	Symbol	Value	Units	Reference
Plate width	W	1.00	in	Design geometry
Window width	w	0.50	in	Design geometry
Thickness	t	0.25	in	Design geometry
Edge distance (near edge)	e	0.30	in	Design geometry
Material	—	6061-T6 Aluminum	—	[1]
Yield strength	σ_y	40,000	psi	[1]
Allowable von Mises	$\sigma_{vm,allow}$	8,000	psi	Derived $(\sigma_y/5)$
SCF (rect. hole, filleted corners)	$K_t^{(\sigma)}$	2.7	—	[4]
SCF (shear)	$K_t^{(\tau)}$	1.7	—	[4]

Nominal Stress Components (per unit force F)

- Net-section tension across ligament

$$\sigma_{nom} = \frac{F}{t(W-w)} = \frac{F}{0.25\cdot0.50} = \frac{F}{0.125} = 8\,F\ (psi\ per\ lbf)$$

- Shear-out along the near edge

$$\tau_{nom} = \frac{F}{2te} = \frac{F}{2\cdot0.25\cdot0.30} = \frac{F}{0.15} = 6.6\bar{6}\,F\ (psi\ per\ lbf)$$

Apply Stress Concentration Factors

$$K_t^{(\sigma)}\sigma_{nom} = 2.7\cdot 8F = 21.6\,F\ psi, \qquad K_t^{(\tau)}\tau_{nom} = 1.7\cdot 6.6\bar{6}F = 11.33\,F\ psi.$$

Combined von Mises Stress

$$\sigma_{vm} = \sqrt{(K_t^{(\sigma)}\sigma_{nom})^2 + 3\,(K_t^{(\tau)}\tau_{nom})^2}.$$

Substitute:

$$\sigma_{vm} = \sqrt{(21.6F)^2 + 3\,(11.33F)^2}.$$

Solve for Allowable Force

Set $\sigma_{vm} = \sigma_{vm,allow} = 8,000\ psi$:

$$(21.6F)^2 + 3\,(11.33F)^2 = 8000^2 \Rightarrow F = \frac{8000}{\sqrt{21.6^2+3\cdot11.33^2}} = \frac{8000}{\sqrt{466.56+385.13}} = \frac{8000}{29.18}$$

$$F_{allow} \approx 274\ lbf$$

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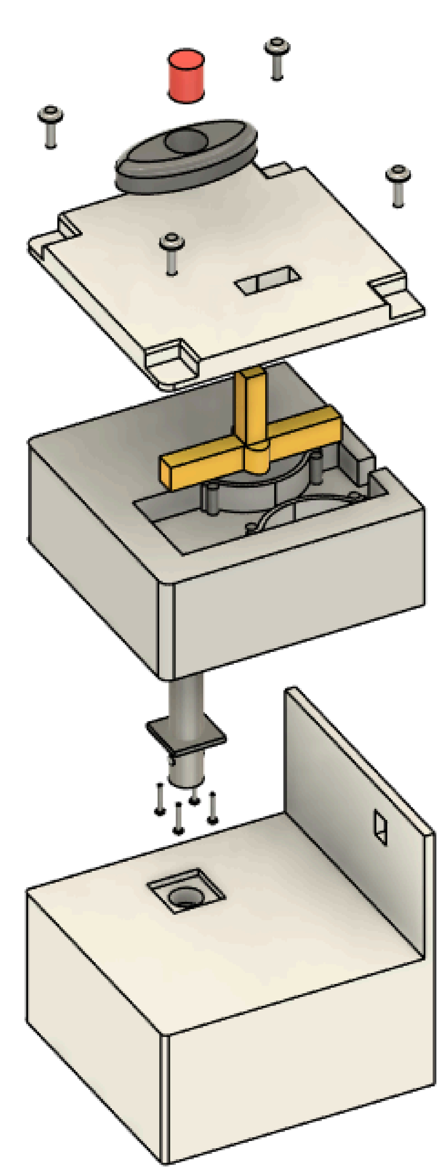
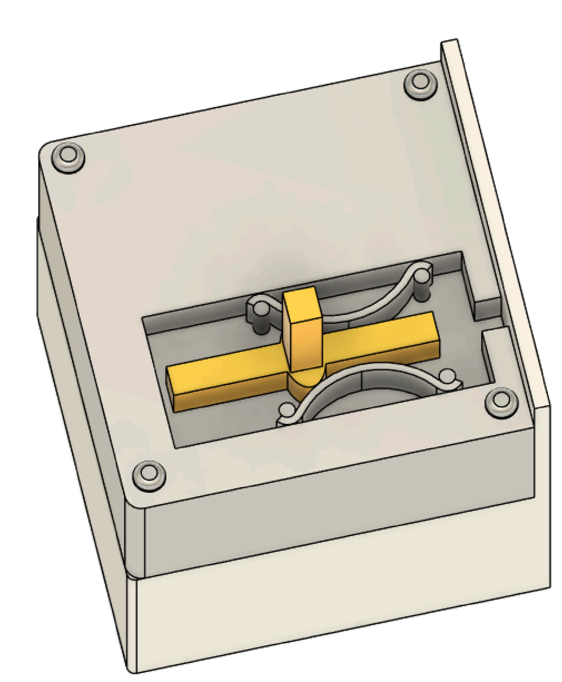
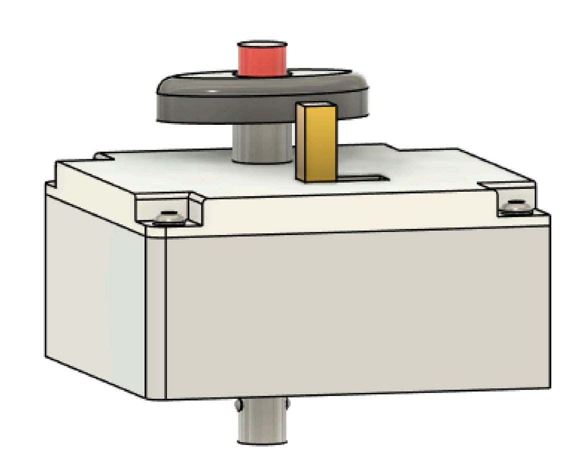
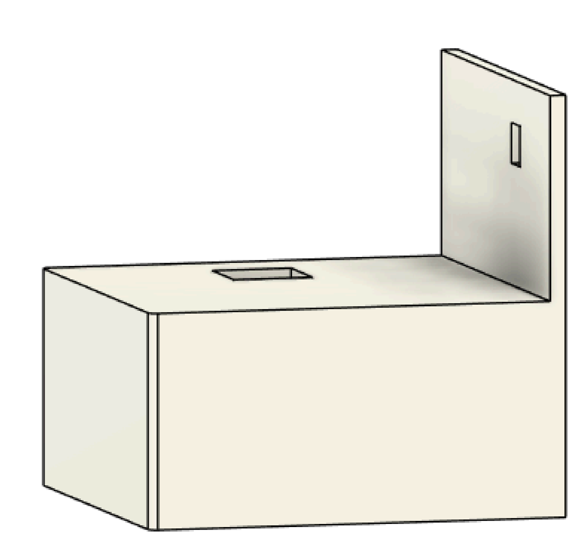
MODELS









FUTURE WORK

- Add alignment guides or tapered entry features for easier docking
- Perform material testing
- Perform functionality testing
- Conduct finite element analysis
- Perform environmental and durability testing
- Develop additional design iterations to identify further improvement opportunities

CONCLUSIONS

- The PCTD meets its main goal of enabling efficient and secure tool handling during EVA operations.
- Testing and analysis confirm the durability and stability of the design under expected space forces.
- The passive capture mechanism offers a significant improvement in ergonomics and time efficiency.
- The system enhances astronaut safety and productivity by minimizing effort and tool loss risks.
- Future work will focus on prototype testing and integration into EVA simulations for final validation.

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REFERENCES