Structural Tensegrity for Optimized Retention in Microgravity

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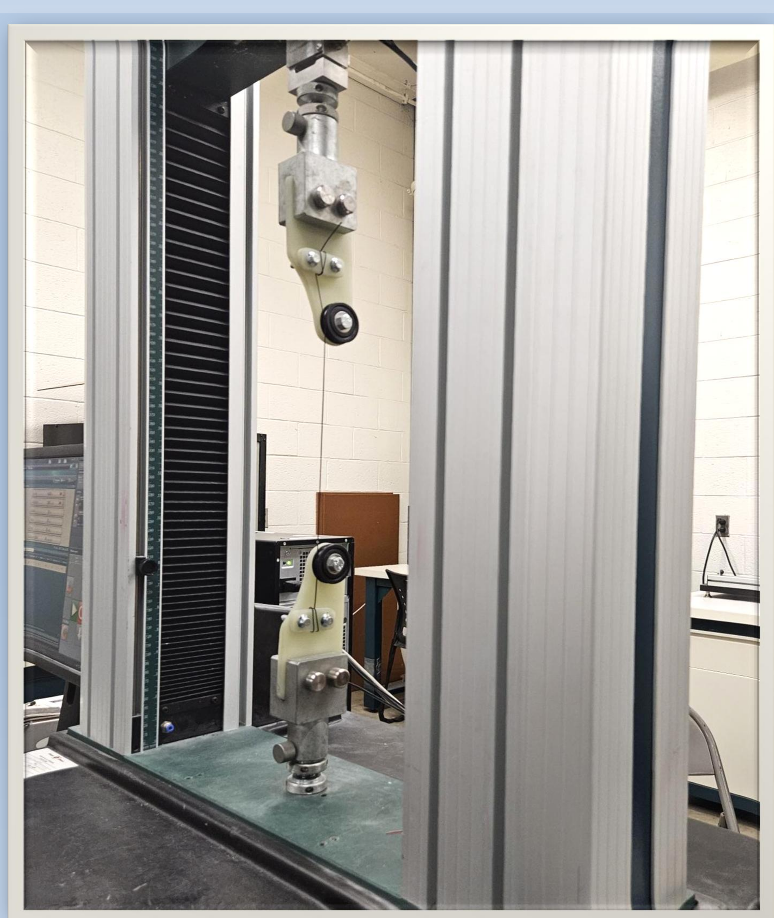
S.T.O.R.M

Purpose & Challenge

- **Tensegrity** = isolated compression nodes suspended in a continuous tension network
- Six Ti struts conduct ≈ **28 W at 20 K**, forcing costly boil-off on lunar depots
- **HuLC goal**: keep conductive leak ≤ **5 W** and survive **5 g axial / 2 g lateral** loads
- Aim: **> 90 % heat-leak cut** and **≥ 38 kg mass saving** without redesigning the tank

Methods

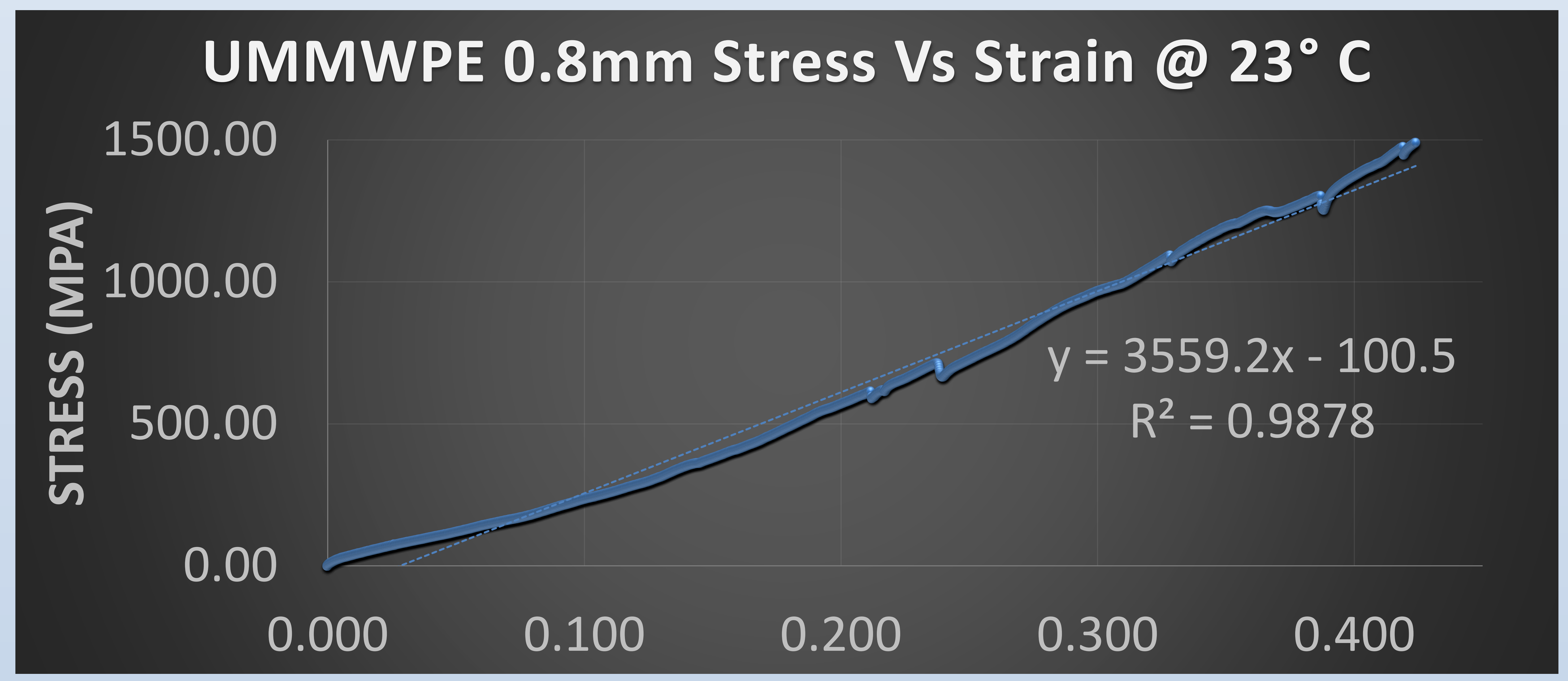
- Replace six Ti struts for a **pure-tension tensegrity lattice of 4 mm Dyneema SK-99 cables**
- **C-Channel Ti-6Al-4V J-hooks** redirect 607 kN launch compression into axial cable tension—no bending
- **Figure-of-Merit: $[Str/(k*\rho)]$ trade** singled out SK-99: **100× better** than titanium
- CAD-driven FEA shows global mode **445 Hz** and **MoS ≥ 2.0** in all load cases
- Eye-splice pull **confirms splice efficiency**; next step is LN_2 coupon tests (FY-26)

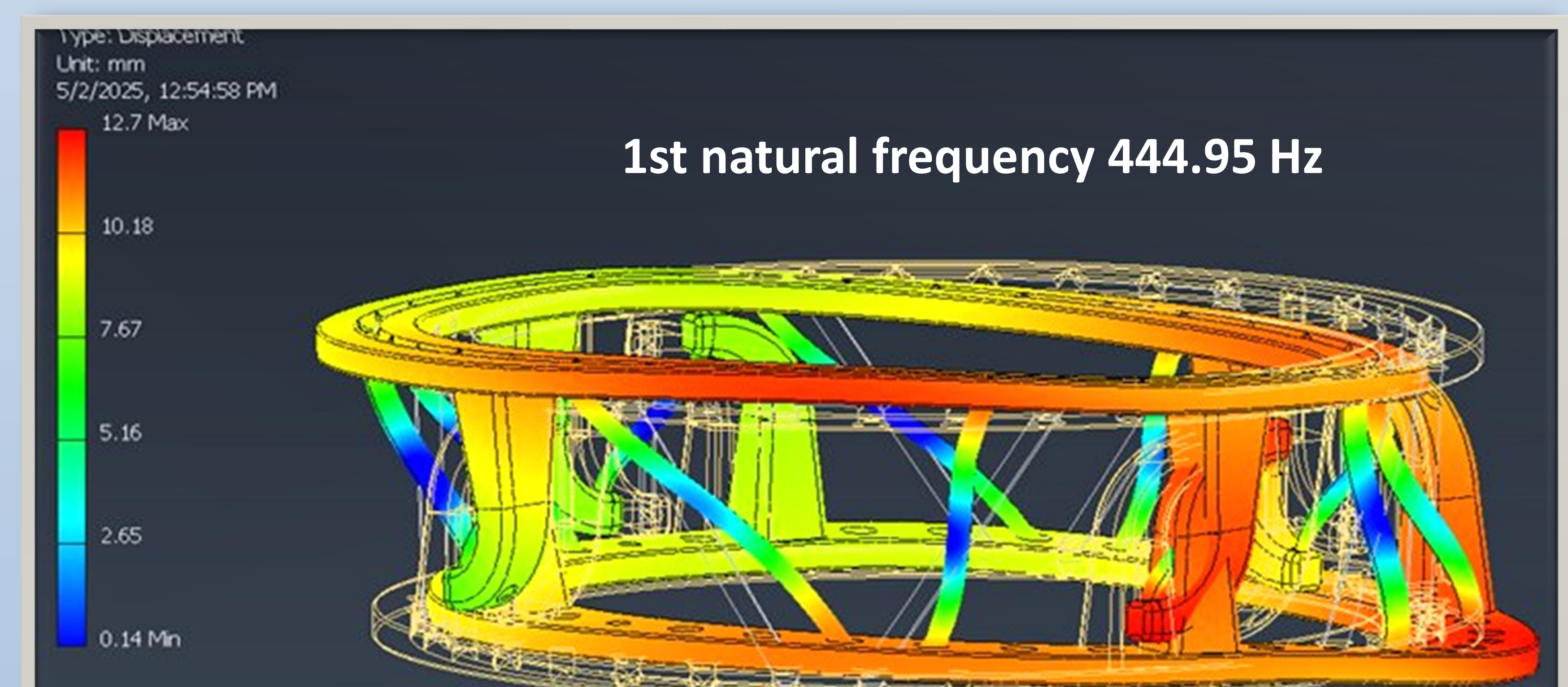


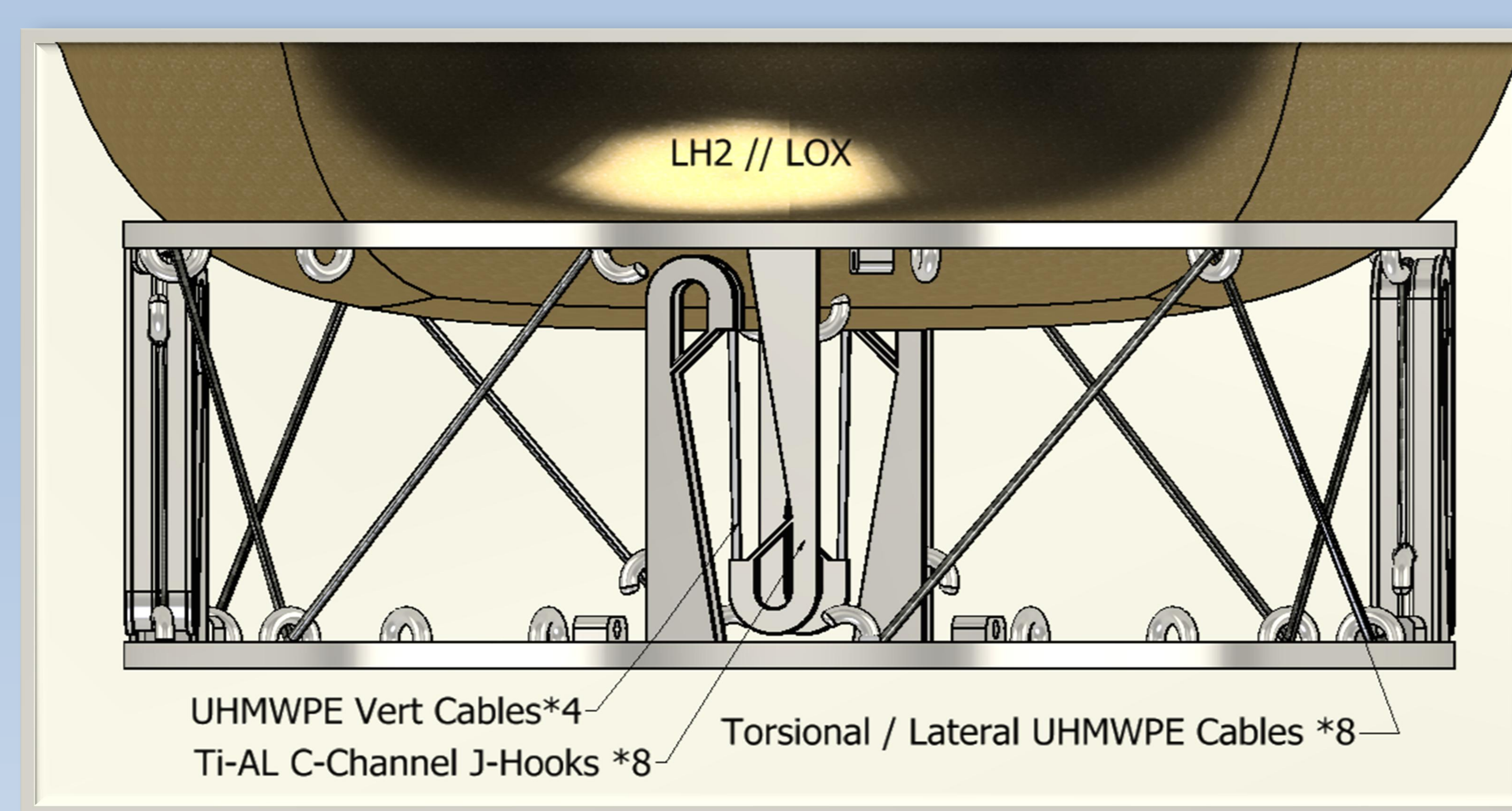
(Left)Tensile Testing Adapter Setup
(Right) Dyneema Sample with Brummel eye splice

Figure of Merit $[\sigma/\rho * \kappa]$ Material Comparison

Material	$\sigma_{f\ @20K}$ (MPa)	k ($W\ m^{-1} K^{-1}$)	ρ ($kg\ m^{-3}$)	σ /ρk
Dyneema SK-99	5300	0.46	970	11.9
Dyneema SK-75	3600	0.46	970	8.07
Kevlar-49	3200	1.73	1440	1.28
Ti-6AL-4V	1200	6.7	4430	0.04



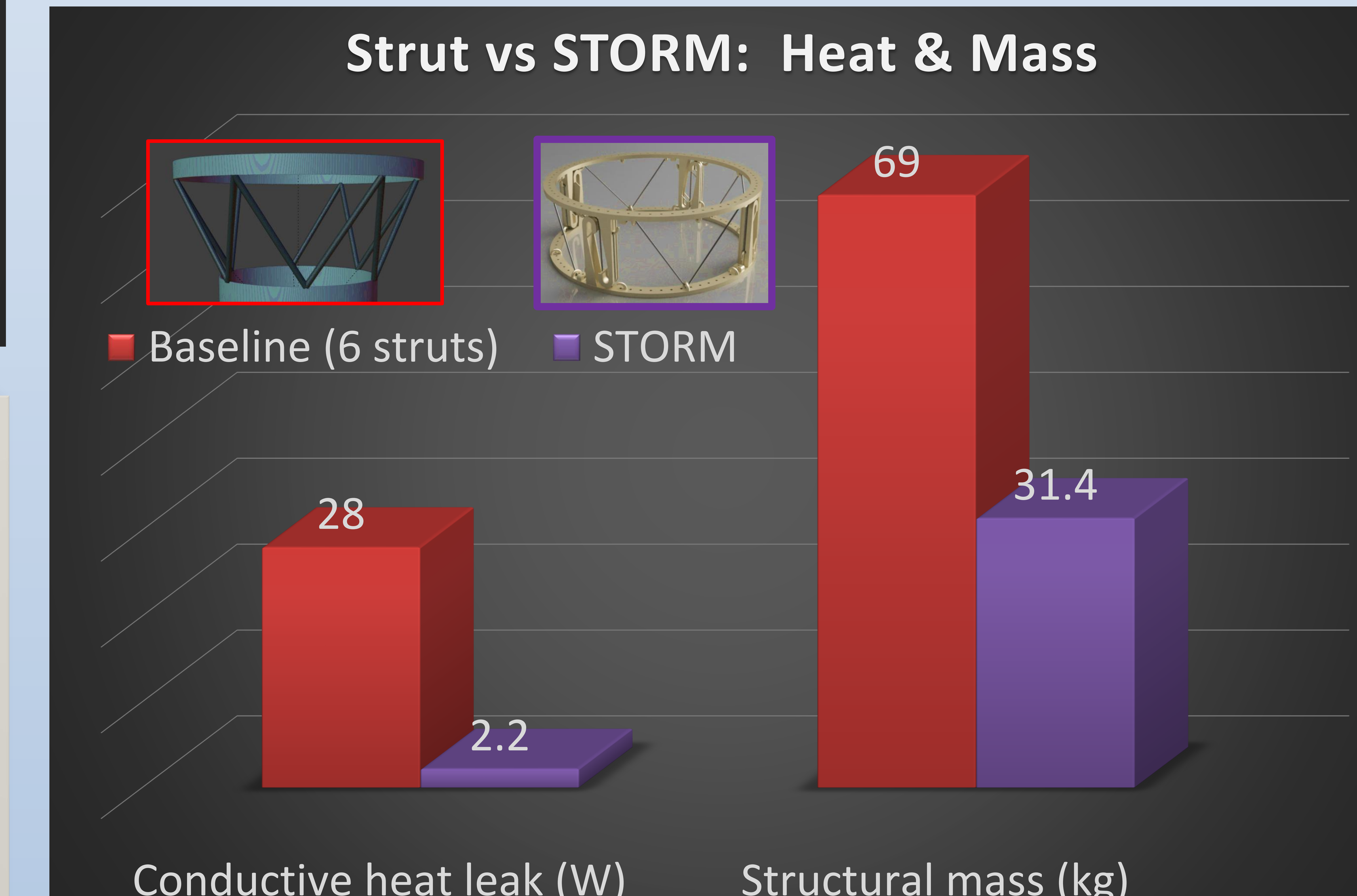




Proposed Tensegrity Support System (S.T.O.R.M.)

Results & Conclusions

- Conduction drops to **2.2 W → > 90 % heat-leak reduction** versus baseline
- **[UHMWPE]: ↓Temp = ↓conductivity+↑ Strength**
- **Mass: 31 kg** assembly saves ≈ **38 kg** vs. metal struts—plus cryocooler downsizing
- First mode **22× above** the HuLC 20 Hz requirement; launch safety factors **all > 2**
- Path-to-flight: coupon tests ’25 → TRL-5 ground vibration ’27 → **TRL-6 ISS Pallet demo ’29**



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NASA HuLC HUMAN LANDER CHALLENGE