

# On-Site Refueling Device Proposal

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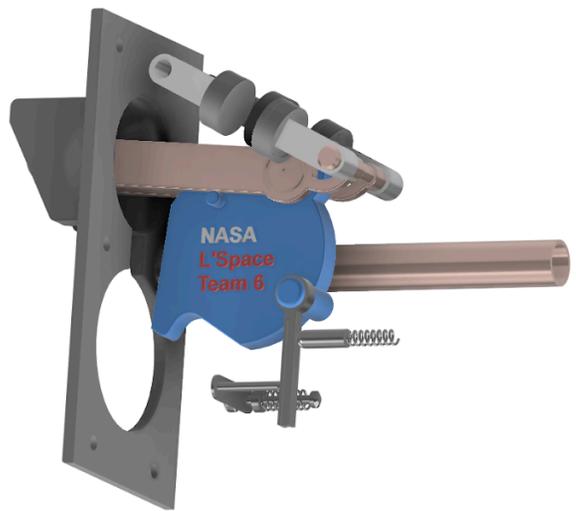
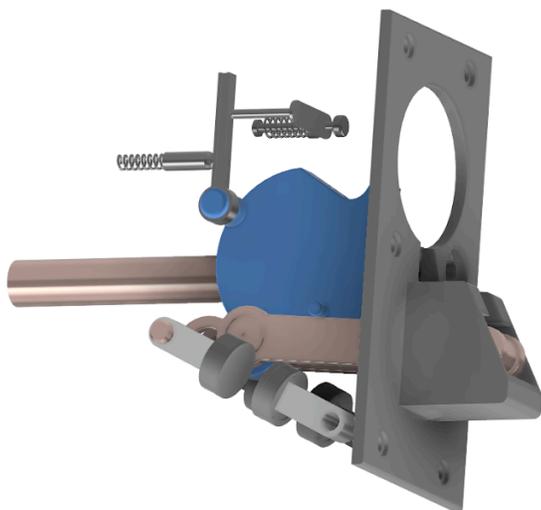
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**Abstract:**

The On-Site Refueling Device project aims to develop a small-scale proof-of-concept for a Universal Magnetic Docking Interface (UMDI). With a projected 5-10% increase in refueling connection efficiency and 2-10 times more cycles it will supersede the current state of art berthing mechanisms for spacecraft docking and refueling. This project will demonstrate high-efficiency contactless fuel transfer on a laboratory scale using a magnetic coupling mechanism. This innovation will prove beneficial in the refueling process of key fuel depots in NASA's Artemis II&III, Mars missions and current developments like the Starship refueling operation.

**Technology Merit and Work Plan:**

See Appendix A for the Quad Chart summarizing the project's objectives, team members, and performance metrics. A visual concept diagram illustrating the mechanical layout of the magnetic docking interface is also included (Fig 1).

Current spacecraft refueling relies on heavy mechanical connectors with robotic systems and complex interfaces that add mass, reduce adaptability, and increase failure risk. The UMDI will serve as a modular, contactless solution, simplifying operations through magnetic coupling and enabling fluid transfer without mechanical latching. The prototype will include magnetic coupling plates, a fluid channel, sealing features, modular testing configurations, transparent components, and integrated sensors.

The state-of-the-art includes traditional fuel lines with mechanical couplings weighing 15 - 25 kg per connection (limited to specific propellant types); in robotic refueling missions, complex systems requiring precise positioning add an additional mass of 30-40 kg; experimental contactless systems, it is limited to laboratory demonstrations and it is unproven in relevant environments. These systems have complex mechanisms with numerous failure points that are costly. The UMDI in comparison is a simpler lightweight design that uses self-aligning magnets reducing failure points, wear and tear, and need for extreme precision. It's also versatile with many propellants in operation and development. In terms of the technical challenges and risks we have the following:

- Achieve a balance between strong coupling and easy detachment to facilitate seamless docking and undocking
- Ensure the alignment of magnetic fields remains consistent across varying operational conditions

## Developing a Reliable Fluid Transfer Line

- Designing a sealing barrier to prevent leakage in microgravity or in vacuum environments
- Ensuring fluid transfer efficiency while minimizing turbulent fluid flow on the boundary layer
- Managing energy consumption required for maintaining and modulating the magnetic field
- Developing a fluid transfer valve design that works with our universal docking interface
- Ensure compatibility with multiple fuel types and spaceflight refueling standards

## Testing and Simulation Data

- Developing robust structural test environments that assess system performance
- Implementing computational fluid dynamics (CFD) models to refine designs before physical prototyping

Risk mitigation strategies include: interactive design testing, multiple magnetic configuration options and subject expert consultations whose areas of expertise are on fluid dynamics and magnetic field. Moreover, in terms of the performance metrics, they involve the following:

- Magnetic coupling strength: Sufficient to maintain connection during fluid transfer (quantified during testing)
- Leakage rate: less than 1% of transferred volume during laboratory testing
- Connection stability: maintain a stable connection during simulated movement
- Fluid transfer rate: establish baseline metrics for scaled system
- Reusability: more than 10 coupling cycles without degradation

Development includes Phase 1 (design and modeling, Months 1 - 2), Phase 2 (fabrication, Months 3 - 6), Phase 3

- Optimizing Magnetic Field Strength and Stability:

Challenges to infusion include scaling, adapting to space environments, fuel compatibility, and spacecraft integration. The project complements NASA’s Robotic Refueling Mission and commercial technologies by focusing on the coupling system.

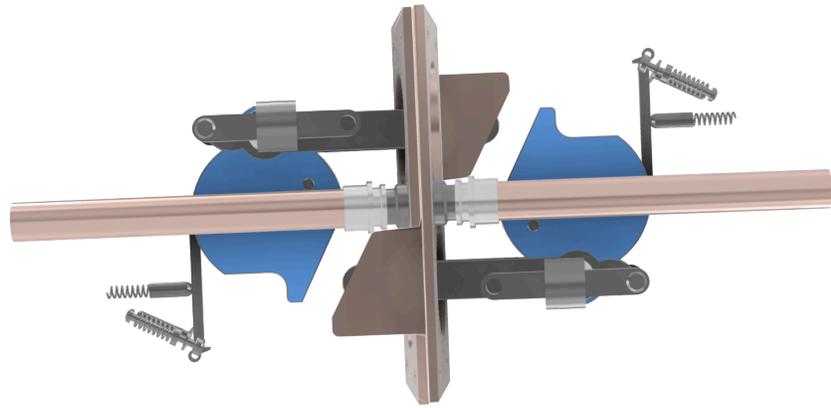
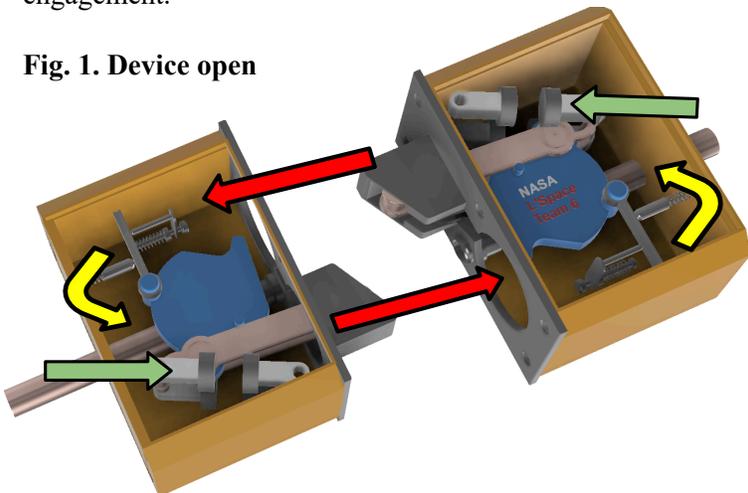
**System Design Approach**

To solve the complex challenge of safely and reliably refueling satellites in orbit, the team developed a mechanical-magnetic hybrid docking system that ensures passive alignment and secure locking during fluid transfer. The mechanical system is inspired by the proven robustness of railway train Willison/SA3 couplers. It incorporates a two-part Push-to-Lock & Magnetic mechanism designed to be both mechanically simple and providing safety redundancy in harsh space conditions. The design reduces the need for active motor control systems, allowing for more robust operation in autonomous or semi-autonomous refueling missions.

The docking interface consists of a rectangular protruding block and a matching socket on the opposing satellite body. As the satellites approach one another, the rectangular peg aligns itself into the receiving hole, ensuring translational and rotational alignment. Once the block is inserted, it physically interacts with a cantilever inside the housing, forcing it upward. This motion causes a rotational shift in the internal blue locking plate, securing the connection.

At this point, integrated neodymium magnets on both the male and female docking internals take over. These magnets assist in the final engagement, pulling the components together and ensuring a strong initial contact even with slight misalignment. The magnetic force also helps to reduce wear and fatigue on the mechanical components by minimizing impact during final lock engagement.

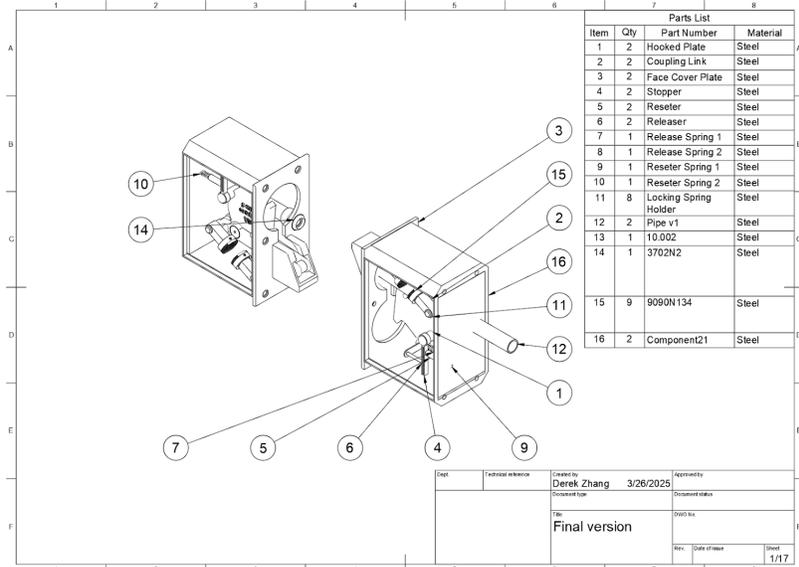
**Fig. 1. Device open**



**Fig. 2. Diagram of On-Site Refueling Device docking closed**

**Project Management Approach:**

Deliverables include design documentation, a functional prototype, test data, and a final report. Budget totals \$10,000, with \$4,000 for materials, \$2,000 for equipment rental, \$1,500 for testing, \$2,000 for stipends, and \$500 for documentation. Resources include lab access, machining tools, 3D printing, CAD software, and fluid/magnetic testing setups. Skills needed are mechanical design, electromagnetics, CAD, fluid dynamics, lab testing, and data analysis. The project requires 1,200 labor hours: 300 for design, 200 for build, 300 for testing, 300 for analysis, and 100 for management. The core team contributes 900 hours, and student assistants and advisors contribute the remaining 300.



**Fig. 3. Drawing sheet schematics of On-Site Refueling Device**

### Teaming and Workforce Development:

Derek Zhang leads design and CAD work and co-founded Cornell's Liquid Propulsion team. Mateo Rodriguez manages operations with leadership from student organizations. David-Chuku Agwu supports budgeting and logistics. Avanthika Vuppala contributes scientific planning with NASA MCA experience. David Torres and Matthew Hernandez specialize in systems and CAD engineering. Luciene Oyola Rodriguez supports research planning. Time commitments are 5 hours per week for Derek Zhang, Avanthika Vuppala, and Luciene Oyola Rodriguez; and 4 -

5 hours per week for Mateo Rodriguez, David-Chuku Agwu, David Torres, Matthew Hernandez. Undergraduate researchers will be mentored by core team members, supporting NASA workforce goals.

Refer to Appendix B for details on the NASA New Technology Report submission. A complete list of references is available in Appendix C.



Fig. 4. Cornell University Manufacturing facility

## Appendix A - Quad Chart

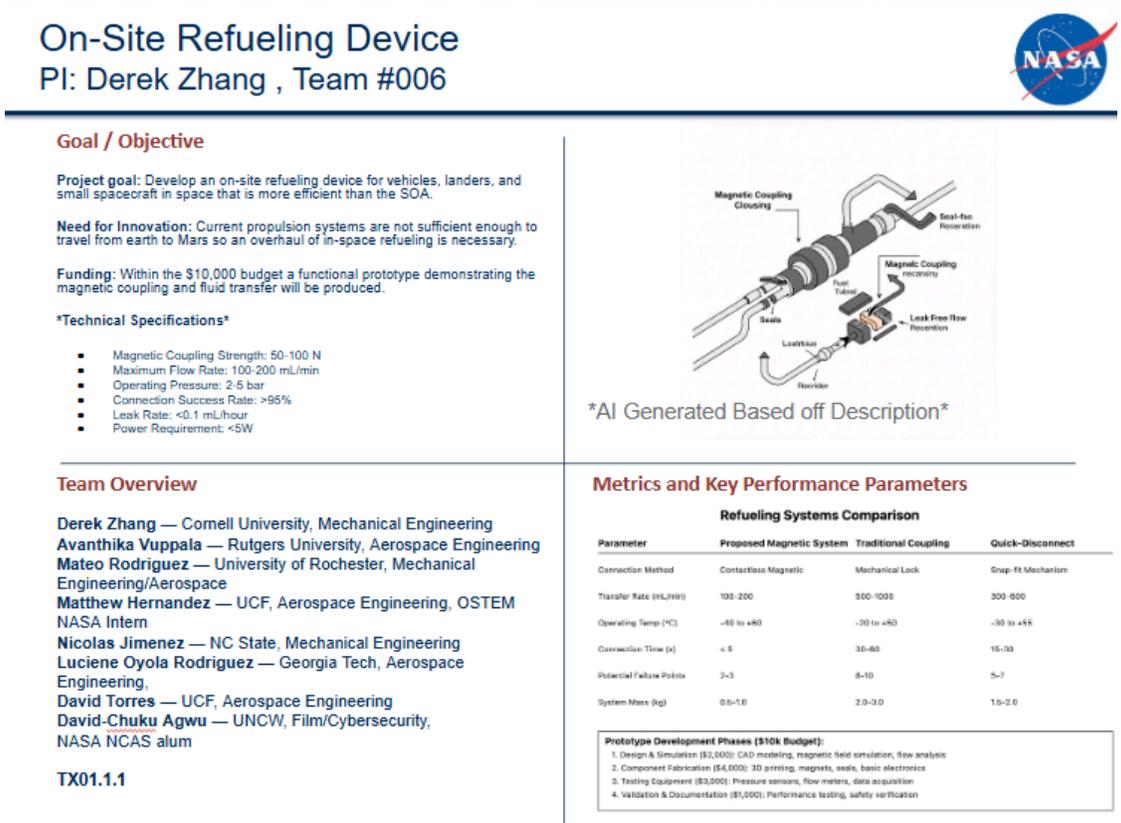


Figure 1: Quad Chart

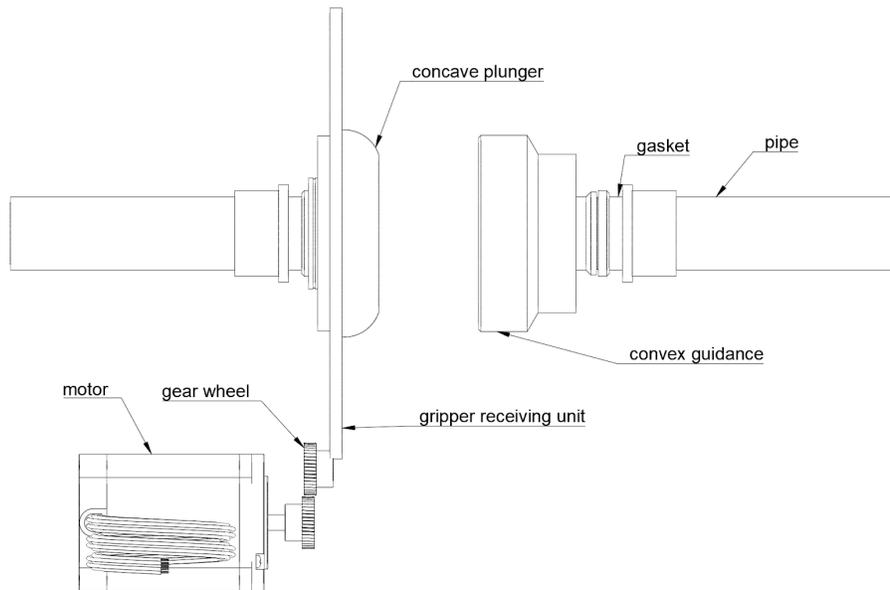


Figure 2: Early Concept Diagram