Target Summary

1.1 Background Research

The team arrived at the selected targets and metrics by conducting research into each function and comparing it to the desired customer needs. With the research in mind, the team was able to quantify a reasonable target for the corresponding functions.

To be able to measure fuel leakage, research was done into leakage and propellant loss with current coupler systems. The different environments for coupler use were also taken into consideration for leakage minimization. Additionally, we contacted our sponsor get to an idea of how much their current coupler system leaks and what a realistic goal for reduction of propellant loss would be.

Regarding heat transfer into the system, factors such as radiation, friction, and insulation were investigated. Since our coupler is expected to have a 90-day lifetime for lunar missions, solar radiation is an important factor to consider when examining heat entering the system. We aim to limit the amount of heat entering the system to prevent fuel boil-off. The team plans to monitor the interior of the system as well as conduct multiple simulations with the different factors affecting the system.

The function for coupler connection must allow for a slight tolerance for vehicle misalignment. It is assumed that the coupler system will not be tasked with tolerating any more alignment than the specified target given.

It is important for the coupler to maintain its structural integrity. The coupler should be able to survive the mission time frame and protect essential components. Forces acting on the system during operation and harsh environmental factors affect the longevity of the coupler. It is important to consider the materials chosen as they need to survive the stated obstacles. The team has investigated materials to use for the coupler that are appropriate for its application.

1.2 Target Derivation

The metrics derived in this target summary will serve as qualitative features of the system that will be measured during the operation of the coupler in order to ensure success. The targets defined will be the goal figure with clear units for the determined metrics previously mentioned. Following functional decomposition, the necessary functions of the coupler system were determined to be of five fundamental systems: fueling, thermal management, durability, connection, disconnection. These systems were broken down into subsystems and the into specific functions of the system as seen in the hierarchy chart from Figure 1 in the previous section. Metrics for these functions were carefully determined by considering the physics of the coupler, specifically regarding how it has to operate in various environments. Previous work from the In-Space Cryogenic Propellant Storage project from FAMU-FSU College of Engineering (COE) senior design team 512 in 2022 was also used during this stage. The team then combined this with specific critical target information provided by our NASA-MSFC Sponsor James Buzzell that is in accordance with their necessities for the project. For some functions, the chosen targets were selected more broadly due to specific elements of the design having not been selected yet. For example, regarding structural integrity, the exact material for the coupler has not been chosen yet so the target was selected as a percentage of deformation.

Also, for the functions of opening and closing the valve, the exact mechanism and its geometry has not yet been decided, so the chosen targets measured in degrees may require adjustment later in the project depending on the design chosen by the team. This is also the case for the function requiring that the system be protected from foreign matter. The target chosen may require adjustment as the project unfolds due to changes in structure, geometry, etc.

All critical functions along with their designated metrics and targets can be seen in the next subsection. The entire collection of targets and metrics for the coupler system as well as the specified targets provided by NASA can be seen in appendix C.

1.3 Critical Targets and Metrics

Table 3 below illustrates the critical functions for the coupler system along with their respective metrics and targets as determined by Team 520. The most important general functions of the coupler system are to actively seal the coupler, hold cryogenic fluid, maintain pressure, and reduce heat transfer.

Table 3: *Critical Targets and Metrics*

Function	Metric	Method of Validation	Target
Minimize fuel leakage	Fuel leakage rate	Measure change in volumetric flow rate over time using flowmeter	≤ 50 SCIM internal ≤ 500 SCIM external
Limit heat from entering the system	Pipe interior temperature	Measure entrance and exit temperatures of fluid using thermocouples	≤ 80 K

Function	Metric	Method of Validation	Target
Tolerate vehicle misalignment	Angular displacement	Measure angular displacement of coupler halves using an RVDT	$\leq$ 0.25 in. maximum total non-concentricity
Maintain structural integrity	Material yielding	Measure strength of components using tensile testing	$\leq$ 5% plastic deformation of chosen material
Open/close valve	Angular displacement of valve mechanism	Measure angular displacement of valve mechanism using an RVDT	180 degrees
Protect system from foreign matter	Particulate matter in system	Measure particle distribution and size using a laser diode	$\leq$ 50 ppm
Level pressure	Pressure difference	Measure pressure difference between coupler halves using a manometer	$\leq$ 100 psid
Purge excess fuel	Internal pipe pressure	Measure pressure in each half of the coupler using pressure transducers	14.7 psia (earth condition) 1.45E-15 psia (deep space condition)

Function	Metric	Method of Validation	Target
Connect/disconnect coupler	Force between both mating halves	Measure connection/disconnection force using force transducer	≥ 10 N

1.3 Method of Validation and Discussion of Measurement

Testing will be conducted for each function to verify that our design meets our critical targets. Our first critical target, minimizing fuel leakage can be tested at the National High Magnetic Field Laboratory under supervision from Dr. Vanderlaan. The volumetric flow rate is measured/calculated using a venturi flow meter. Cryogenic fuel that leaks from the connector over a duration of time is recorded which will allow the team to obtain the standard cubic inch per minute (SCIM). Internal pipe temperature can be measured using thermocouples, which is a sensor that takes a generated voltage and converts it to a temperature. Maintaining structural integrity can be quantified by material properties. Tensile testing can be conducted to determine the ultimate strength and yielding stress that the chosen material for our design possesses. Identification of whether the valve is open or closed is determined by the angular displacement of the valve mechanism. To measure the angular displacement a Rotary Variable Differential Transformer (RVDT) will be used. An RVDT is a transducer that provides an AC output voltage that is proportional to angular displacement. To measure the pressure difference between the depot and vessel, a manometer will be used. Two pressure transducers can also be used to measure the internal pipe pressure to ensure that enough excess fuel is purged. The connection and disconnection of the coupler will be measured using a force transducer. A force transducer is a load cell sensor or a sensor that converts an input mechanical load into an electrical output signal, and when connected to the coupler will display a force in newtons.

1.4 Targets Beyond Functions

While the above targets are necessary in order to meet the requirements presented by our sponsor, there are other targets beyond the functions that should be addressed. One of these targets is a leak alert system. The team is considering implementing components to the design that will allow for an alert system to be designed in the case of a substantial fuel leak during transfer. It is important to remember the scope of this project does not include the design of any fuel tank or spacecraft components, but it may be beneficial to design aspects of the coupler such that they can be integrated into those systems in the future. This will also be considered for a scenario where substantial excess heat enters the system which would cause rapid boil-off of the fuel.

1.5 Summary

The team will be running tests and simulating various scenarios to verify the correct materials and methods to achieve the targets set for the project. Any simulations and calculations will consider earth, lunar, and spacelike environmental conditions. Specific targets and metrics have been carefully examined and selected to ensure that the coupler project achieves the goals of our sponsor. While most of these targets will be permanent for the duration of the project as they've been provided by our sponsor, others may require adjustment during the next several phases due to selection of materials, geometry, components, and the desired goals of the sponsor.

Testing methods to validate the chosen targets have been selected and will be used to verify the chosen design. All targets, metrics, and testing methods were carefully considered along with the provided requirements by our sponsor and their overall goals for the project.