

The Moon has been an object of great interest throughout the history of mankind. Yet it is only now, almost 50 years after the last man walked on the Moon, that humanity once more has set its eyes on Earth's closest neighbour with ambitious plans in mind. The fight against gravity to lift off from Earth constrains the payload capabilities of spacecraft and thereby limits the sustainability and reach of the space industry. The option of refuelling in space would open up the solar system to locations that would be unreachable otherwise while providing more economical transportation options for the space community. The COLD team has therefore been tasked with designing a system that is able to transport cryogenic propellant produced by NASA on the lunar surface to low lunar orbit, where it would be delivered to customers. This all will be achieved within a budget of seven billion US dollars.

A requirement set out for COLD was that the system had to be capable of delivering 250 tonnes of propellant to low lunar orbit per year and be profitable within a lifetime of ten years. In order to fulfil this task, several mission concepts were considered. Through extensive research and preliminary analysis, a proper concept trade-off has been performed, which led to the choice of the universal cryogenic launcher mission concept. This system will consist of four launcher modules, each capable of delivering 25 tonnes of cryogenic propellant from the lunar surface to low lunar orbit and returning back to the lunar surface afterwards.

Each launcher will be equipped with state-of-the-art cryogenic storage and hydrogen peroxide production systems. The cryogenic storage system will have two storage tanks composed of a composite structural layer and multi-layer insulation along with cryocoolers and heaters. These systems will require significant amounts of power to provide the propellants their operating conditions and to limit boil-off, ensuring that the system operates as sustainably as possible. Consequently, solar cells combined with hydrogen fuel cells will be deployed for power generation, where the residue water of these cells can be used for the production of the hydrogen peroxide needed by the reaction control system. To complete the cycle, further water residue can be sold back to NASA for the production of propellant when the mission is accomplished and the module has returned to the lunar surface.

Additionally, a propulsion system will supply the launchers with adequate performance for lunar lift-off. Once the vehicle is docked to the customer, the reaction control system will spin up the launcher to one revolution per minute to make use of centripetal forces for propellant transfer, which will take up to four hours when fully loaded.

In order to size and optimise these four modules, a sustainable design criterion has been created. This criterion is a ratio between the propellant sold to the customer and propellant bought from NASA. Maximising this ratio will lead to the least propellant wasted during the mission. For a range of payload boil-off levels and number of insulation layers, this criterion has been evaluated. Zero percent boil-off and approximately 45 and 25 insulation layers on the cryogenic storage system tanks leads to the highest propellant sold to propellant bought ratio as desired.

The remaining design time will be used for optimisation of the launcher mass, since the fight against gravity never stops. This iterative process will optimise the system integration of the subsystems and stops once a converged solution has been found.

Finally, verification and validation should point out the technology readiness level of the created design and ensure that the requirements set out by the stakeholder are satisfied.