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LOW-COST TECHNOLOGY COMBINATIONS FOR PLANETARY DEFENSE MISSIONS INVOLVING RECONNAISSANCE AND MITIGATIVE ACTIONS

Paul Graham[(1)], **Nathan Going**[(2)], **Nancy C. Wolfson**[(3)], **James Harris**[(4)], **Debi-Lee Wilkinson**[(5)], and **Ashani Dissanayake**[(6)]

[(1)(2)(4)(5)(6)] *Kepler Shipyards, 6805 Crystalbrook Dr. Austin, TX, 78724-3420 – United States, 248 274 0177, Paul@keplershipyards.com (corresponding author); Nate@keplershipyards.com; JHarris@keplershipyards.com; Debi-Lee@keplershipyards.com; adiss010@uottawa.ca*

[(3)] *Vice-Chair of the IAF TC on NEOs, Washington DC - United States, 202 213 2898, lessonsbynancy@gmail.com*

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Extended Abstract - An asteroid impact even though rare, poses a major threat to life on Earth, making Planetary Defense an important aspect of humanity's space presence. Many Near-Earth Asteroids (NEAs) have unknown dimensions, compositions, trajectories, and correspondingly, unknown impact locations should they enter Earth's atmosphere. The Planetary Defense concept includes surveillance, reconnaissance, and mitigation of NEAs, and several technologies have been proposed to deflect asteroids from collision trajectories with Earth. However most if not all Planetary Defense operations to date have been conducted from Earth which impacts the cost and timeliness of reconnaissance and mitigation operations. Thus, ideal scenarios involving NEAs are those where Planetary Defense operations are maintained in space leading to more timely and direct reconnaissance to resolve multiple unknowns and mitigate threats. Therefore, there is a need to keep exploring options with regards to the concepts and technologies to protect Earth from NEAs.

Accordingly, Kepler Shipyards is developing several low-cost technologies that will round out human space capabilities to enhance permanent presence and operations in cis-lunar and deep space. These technologies are considered important because mission profiles to intercept and mitigate NEA threats potentially require different mitigative approaches, sometimes on the same target. Having in-person reconnaissance will allow mission planners or crew to pick the most effective and efficient strategy although these can still result in crew return and recovery times on the order of months to years. Kepler Shipyards' life support and crew systems will allow for their safe return.

In this way, Kepler Shipyards proposes to contribute to the 2021 IAA Conference scenario with the assumption that OpenLuna's second-generation outpost has been completed and is sustainably serving a 30-person crew. This includes supporting communications and data capabilities for local, mid-range, and deep-space exchanges as well as robust supporting infrastructure for water, food, fuel, and power supporting:

- five habitation modules;
- between 14 and 25 aquaponics modules capable of sustainable bioregenerative life support systems for recycling waste, producing food, and generating O_2 in different environments, at least 4 of which would be microgravity capable;
- limited but flexible manufacturing capacity for constructing and reconfiguring supporting material required for the local infrastructure and vehicle maintenance.

In addition, it is assumed that six reconfigurable space vehicle systems such as Kepler Shipyard's Sled-class vehicle designed for continuous in-space operations in combination with the Aethon- class space vehicles with several cargo modules including at minimum one or two full tanker modules and one full crew/service module (described below). Kepler Shipyards is also developing personal space activity suit technologies with common core pressure liners, armor, and portable life support systems for long-duration sustained deep-space operational regimes (not further described here).

Having this outpost and supporting infrastructure will reduce response time and resource expenditure associated with crew

and launch preparation from Earth's surface since all operations will take place from the Lunar surface.

It is proposed that the mission begins once 2021 PDC is first sighted and determined to be a potential threat. To determine its exact orbit, composition, and true threat risk, the following activities will be initiated:

1. an Aethon-class Tanker is immediately dispatched via remote control from the lunar surface to the closest Sled-class vehicle where the Sled in preparation for the mission is refueled, supplied with more fuel tanks, and stripped completely except for mission-critical equipment. The Sled crew and any cargo will return to the outpost with the tanker.
2. Under remote control, the Sled will immediately orient and accelerate towards the predicted location of 2021 PDC for reconnaissance. At this point, the Sled is considered disposable, this reduces the effort of recovery and allows mission planners to consider using it to impact 2021 PDC or change its orbit. The timeframe for this launch is on the scale of hours from the initial discovery. Total flight time will depend on several factors, but contact with 2021 PDC for evaluation could occur within 8 days;
3. Concurrently, preparations for a crewed mission is underway on the lunar surface beginning with the separation of two aquaponics modules from the larger farm;
4. Several Aethon-class Tanker trips to the lunar orbit will convert another Sled-class vehicle into a deep-space transport with the aquaponics modules and equip it with mining explosives, tools, and spare fuel tanks;
5. The deep-space transport, crewed by two volunteer crew members forming the exploration crew (EC) is launched to rendezvous with 2021 PDC using information obtained from the reconnaissance Sled. Fuel load is planned for a fast arrival, but slow return;
6. During this orbital transfer, the initial Sled should have enabled the evaluation of 2021 PDC for precise orbital determination and estimation of composition. If 2021 PDC poses no risk, the EC will be recalled. If a risk is posed, the EC will continue their mission;
7. If the EC continues the mission, upon arrival the EC will work with Earth-based support to determine the composition and determine the most appropriate mitigations using the tools and materials at hand.
8. At the culmination of the mission, the EC will return back to the Moon. It is anticipated that priority use of fuel will have resulted in a small remaining reserve, so the return trip will be longer than the outgoing trip. The aquaponics modules provide sustainable bioregenerative life support, helping to remove waste and provide fresh food and oxygen for the crew during their extended return trip. Alternatively, another Sled can rendezvous with the EC to resupply them with fuel.
9. Regardless of the success of the missions, the information gained from these excursions are expected to dramatically improve the effectiveness of other earth-based damage mitigation strategies.

Kepler Shipyard spacecraft and modules involved:

1. Aethon-class Cis-lunar transport. Designed to be built on the lunar surface from three to four of Kepler Shipyard's "Speck" class lunar landers. An assembled Aethon is designed to carry several different cargo modules and when empty has a dry mass of 540 kg and a wet mass of 3287 kg with a propellant (C2H5OH/H_2O_2) mass of 2749 kg supplying eight 900N rear engines and four 450N vertical takeoff engines supplying a Delta V of 4971 m/s. Aethons are intended for operation in empty space or in proximity with gravity wells no more than 1/6G. It can be crewed by one or two people or operated remotely;
2. Sled-class near- and deep-space transport. Designed similarly to the Aethon with the exception that it is purely a space-based transfer craft with no landing gear and the 450 N vertical takeoff engines are not included in this craft, contributing to significant mass savings, and the Delta V is increased to 5084 m/s. The Sleds are compatible with all modules the Aethon is designed to carry and are designed for special missions including servicing other spacecraft and satellites.
3. Cargo modules. For this mission, two cargo modules are described:
   - Tanker modules are bundled fuel tanks salvaged from Speck-class lunar landers which are plumbed for easy loading/unloading of fuel, which also supports their use as extra long-range tanks for extended operational range.
   - Service modules are designed to support crews of up to two people for

routine orbital and non-routine planetary defense missions. These modules are divided into three sections for living quarters (microgravity sleeping bags, galley, hygiene facilities, communication/data terminal), storage lockers (for consumables, tools, and other smaller cargo), and an open storage bay with elastic mesh tie-downs to move larger arbitrary shaped cargo. A small manipulator arm or a half tanker module may be added as well if the mission demands it.

Aethon, (56 tanks 1:1 ratio) - 28 H2O2 tanks - 28 fuel tanks	**Wet mass** 3287.28 Kg	**Dry Mass** 538.08 Kg **Max △V** 4971 m/s
Sled, UNCREWED (56 tanks 1:1 ratio) - 28 H2O2 tanks - 28 fuel tanks	**Wet mass** 3261.68 Kg	**Dry Mass** 512.48 Kg
Sled, UNCREWED (56 tanks 1:1 ratio) - 28 H2O2 tanks - 28 fuel tanks - 95% fuel	**Burn time** 1049.31 s **Transit time** approx 8 days	**Acceleration(Maximum)** 4.44 m/s2 **Max △V** 5084 m/s