A PRELIMINARY ESTIMATE OF FUTURE POTENTIAL U.S. MILITARY SUPPLY AND DEMAND FOR IN-SPACE WATER-BASED FUEL. Aiden O'Leary[1] and Jason Aspiotis[2], [1, 2] Booz Allen Hamilton Inc., 3509 Shannon Park Drive Suite 115, Fredericksburg, VA 22408, O'Leary_Aiden@bah.com, Aspiotis_Jason@bah.com

Introduction: On February 19th 2019 the world entered an era of impending Space-based military asset proliferation with U.S. Space Policy Directive-4 (SPD-4), which codifies legislative efforts in support of the establishment of the U.S. Space Force. There are currently approximately 81 U.S. military assets in Space, based on information that is publicly available. This study provides a preliminary quantitative assessment of potential U.S. military demand for in-Space water-based fuel in support of future U.S. military assets in Earth's orbit. Our study concludes that if the U.S. military transitioned its future assets to utilization of water-based propulsion, there could be a military market demand for in-Space water-based fuel of 25 metric tons per year (baseline demand). In addition, and more importantly for the evolution of military demand for in-Space water fuel, we determined a parametric relationship between the supply of in-Space water on the Moon, Near-Earth Asteroids (NEAs) and the Asteroid Belt and the potentiality of increased U.S. military assets and increased propulsive capability per asset, thus leading to even further increased military demand for in-Space water in the future.

Note: We make no assertions as to the merit of the establishment of a U.S. Space Force and the militarization of Space. However, increased market demand from civil, commercial and military use cases will all contribute to increased economic viability of Space Resources Utilization (SRU) and investability of associated technological capabilities and SRU value-chain public and private enterprises. The purpose of this preliminary assessment is to provoke holistic thinking on how U.S. military needs for strategic deterrence could drive significant demand for an in-Space water-based fuel supply-chain.

Determination of utilizable in-Space water resources:

Lunar water. For lunar water estimates we used data and analysis from NASA [1] and Paul Spudis [2] which deduce a possible range of 100 million to 1 billion metric tons of water on each Lunar pole. We assumed that the theoretical U.S. global apportionment of Lunar water would be equivalent to the U.S.'s Gross Domestic Product (GDP), extrapolated to 2050 as an exemplar point in the future [3].

NEA water. We utilized several public data and analysis sources, including J.P. Sanchez and C.McInnes [4], M. Murphy [5], S. Ross [6], and the Keck Institute [7], to deduce an estimate of available water in C-type NEAs. By assuming that 20% of NEAs are of C-type and 15% water by mass, and that only asteroids 5-30m in diameter are mined, we deduced 200 million metric tons of NEA water that is accessible and economically comparable to Lunar water in terms of required delta-V.

Asteroid belt water. Assuming the asteroid belt has a total mass of approximately 3^{21} kg, 80% of asteroids in the asteroid belt are of C-type [8], and the asteroids are 20% water by mass, we estimated that the water mass of the asteroid belt could be as high as 4.8^{20} kg, much of it centralized on Ceres.

Methodology for determining water-based fuel demand from U.S. military assets in Earth's orbit: We catalogued all publicly available [9] U.S. military assets by orbit, design life, orbital mass, type of fuel and propulsion utilized, orbit-transfer fuel needs, required lifetime station-keeping fuel, and graveyard or de-orbit fuel needs (assumptions and averaging were used where data was not publicly available). We then estimated the equivalent fuel needs in terms of water required if all assets were to use water engines in the future instead of the mixture of ion, chemical, and/or monopropellant thrusters.

Results and conclusions: Our estimate of U.S. military baseline demand for in-Space water, assuming today's number of U.S. military assets in Earth's orbit, is 25 metric tons, which using ULA's $3,000/kg price point at LEO [10], deduces a total market opportunity of approximately $75M USD per year. This market opportunity is not significant and probably does not warrant in itself significant investment in the realization of in-Space water supply-chain for U.S. military needs. However, given the U.S. military's desire to grow its presence in Earth's orbit, and the proliferation of low-cost, highly maneuverable, and shorter lifetime military assets in LEO (with higher de-orbiting fuel needs), we foresee the $75M market opportunity growing by at least an order of magnitude in the foreseeable future. In addition, on the supply side, the estimated Lunar, NEA and asteroid belt deposits posit a new paradigm for how the U.S. military could deploy, operate, utilize, refuel, repair and retire or repurpose its assets in Earth's orbit (and beyond). The U.S.'s notional apportionment of Lunar water deposits alone could, for example, enable the deployment of 33,000(!) equivalent assets (by mass) in Earth's orbit, with 100X the maneuverability (i.e. station keeping reserves) for 500 years(!). Even though it is not reasonable to assume all of the U.S.'s theoretical Lunar water apportionment would be used for military needs, even a fraction of it would drive significant demand for in-Space water fuel, with a market opportunity in the $Bs/year.

As noted in the introduction, we make no assertions as to the merit of the establishment of a U.S. Space Force and the militarization of Space. The sole purpose of this preliminary assessment is to provoke holistic thinking on how military needs for strategic deterrence could drive significant demand for an in-Space water-based fuel supply-chain, that enhances the value-chain of SRU for civil and commercial needs, and thus enables increased investability of SRU technologies and enterprises at a global scale.

References:

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