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A UBIQUITOUS PROPELLANT SUPPLY CHAIN FOR ENHANCEMENT OF LEO TO GEO TRANSFER SERVICES

Abstract

This paper describes the potential cost savings and mission flexibility enabled by transporting payloads from LEO to GEO using 'refuellable' space tugs. Projected satellite traffic is expected to increase substantially over the next few decades and the cost of delivering payloads from the earth's surface to LEO is projected to decrease.

Three key enablers are driving LEO costs down and increasing mission flexibility;

1. The availability of small, cost effective vehicles (i.e SpaceX, Rocket Labs, Astra etc).
2. The availability of rideshare services (i.e SpaceFlight industries, SpaceX, NG ISS Resupply etc.)
3. The reusability (or planned reusability) of launch vehicle lower stages. (i.e. SpaceX, RocketLabs).

However, current technologies typically do not reuse upper stage vehicles (LV Upper stages). As such, LEO to GEO or GTO insertion remain relatively bespoke processes. Further, ride share opportunities to GEO have been heavily limited in the past due to the small number of missions.

Reusability of upper stage vehicles is limited by the orbits they end their life in, and the fuel that they have left once their primary insertion mission is completed. As such the true enabler of reusability (at first limited, but over time with the movement towards 'immortal' cycling platforms) requires a distributed ubiquitous, technologically validated supply of propellant on orbit. For this reason, along with the other use cases presented in other papers, Orbit Fab is pursuing the design, developed, deployment and operation of such a propellant supply in Earth orbit. This enables the use of a repeated insertion performing LEO to GEO tug vehicles. These vehicles may take the form of a modified and refuellable upper stage vehicle, or a bespoke spacecraft designed for this function. Other limiting factor may prevent the modification of upper stage into space tugs, such as potential short battery life designs and/or a lack of sufficient solar electric power generation capacity. These design issues are not the focus of this paper.

This paper discusses the potential economic benefits of such a LEO to GEO space tug transportation system when refueling comes into play. It includes the cost-benefit analysis based on economic modelling of the LEO to GEO transport use case, resulting in substantial cost savings that ultimately benefit the GEO satellite market, satellite manufacturer, satellite operator and satellite service provider in the commercial and government/national security space.

Orbital mechanics calculations and details are presented where appropriate to allow the reader to understand the assumptions made by the authors. In most cases, a combined electric/chemical propulsion 'tug' vehicle is envisioned, where electric propulsion (Specifically Xenon Hall effect thrusters) are utilized for the orbit raising maneuvers, and chemical propellants are used for rendezvous and proximity operations, which require higher thrusts to make relatively rapid, minute adjustments in spacecraft position and orientation.

The paper continues to show progress on executing against a plan to build orbital propellant depots and the supporting infrastructure required to place a strategically distributed supply of propellant in space. This infrastructure is intended to provide economic benefits to commercial and government entities by enabling satellites and space tugs: - To be refueled. - To extend mission lifetimes. - To reduce launch mass for space missions by refueling in orbit.

The same infrastructure can be used for EOL (End-of-Life) processing in the form of de-orbiting of spacecraft, satellites, and ADR (Active Debris Removal), which is not the focus of this paper, but was previously presented at IAC 2019.