AN EXISTING MARKET FOR LUNAR PROPELLANT - GTO ORBIT RAISING AS A SERVICE. N. J. Bennett, 1School of Electrical Engineering and Telecommunications, University of New South Wales, High St, Kensington, NSW, 2052, Australia. nicholas.j.bennett@student.unsw.edu.au

Introduction: Every year approximately 120 metric tons of geostationary satellites are launched, this represents an existing market that could be serviced immediately by lunar propellant tugs.

A Financial Model: GTO orbit raising has large revenue and cost advantages over LEO orbit raising for a lunar propellant mine.

Earth launch cost per kg to GTO is more than double the cost to LEO, and high Isp lunar LH2/LOX would be replacing a larger mass of low Isp bipropellant. This allows the service to charge more, and insulates the business case from falling Earth launch costs.

Transporting propellant from the lunar surface to GTO requires less than half the propellant per kilogram of transporting to LEO. Orbit raising to GSO requires much less propellant from GTO than from LEO. This allows the lunar mine size to be greatly reduced, requiring a much smaller initial investment.

Higher prices and lower initial investment deliver higher returns and/or lower risk via overcapicity/redundency.

Using a previously published financial model for a lunar polar mine [1] we show that, all else being equal, the GTO orbit raising case will produce rates of return on initial investment that are much higher than the LEO case, we found an internal rate of return around 50%, comparable to the returns for supporting large manned exploration campaigns. We validated delta-v with NASA’s General Mission Analysis Tool and performed sensitivity analyses to vehicle inert mass fraction and GTO apoapsis.

Operational Details: The service could be implemented as follows:

1. No orbital propellant depots. Standby tugs in PSRs form the bulk of the depot.
2. Around when the Moon is crossing Earth equatorial plane a tug launches from the lunar surface to LLO then does a TEI into and a near GTO orbit with inclination matched to a customer launch site.
3. The customer satellite launches to a GTO matching the tug line of apsides. Current launches target the line of apsides for eclipse conditions; the same constraint, different utility function.
4. The tug rendezvous and captures the satellite; either during the initial transit to apogee or on a subsequent orbit, potentially after some perigee raising.
5. The tug raises the satellite orbit and deposits it into its GEO “slot”.
6. The tug returns to the lunar facility. The flight plan is similar to Moon Direct. [2]

Business Advantages:

1. Satellites do not require any modifications, standardizations, or propellant transfer. Launch procedures remain almost unchanged.
2. The service could prove itself by rescuing / disposing of GEO satellites with launch / operational anomalies.
3. Early adopters do not need to trust the service; many can launch as they do now, but agree to pay for a partial orbit raising which will extend useful life.
4. All electric drive satellites can be on station, making revenue, months ahead of schedule, with extended life.
5. As reliability is proven there is an incremental satellite engineering pathway from under fueling through to the complete removal of the apogee propulsion system.
6. The mine can scale incrementally to extend support deeper into Earth gravity well or for large manned campaigns.

Looking Forward: Any water to LH2/LOX mine produces excess O2. Consuming all the LH2/LOX for LOX transportation could supply the excess LOX to GTO like highly eccentric Earth orbits for interplanetary vehicles using other fuels like CH4 or LNG, about 80% of the propellant mass. This provides a modest 20% revenue increase, but the market is potentially much larger.

Conclusion: GTO orbit raising is an existing business that could be serviced from lunar sourced propellant, so a close stepping stone on the way to using lunar resources to support larger endeavors.

References: