Role of small satellites in fast Mars transit

Darrin Taylor
Outer Space Colonization
outerspacecolonization@gmail.com

Thank you

- Thanks to Dr. Alessandra Babuscia
- Thanks to the acceptance committee
- Thanks for listeners patience

Problem Statement

- Space weather and radiation
- Life-support
- Hohmann Transfer- once every 26 months
- Fast transit is expensive even for NASA. Fundamental limitation is economic.
- 5.2 km/s one way and 10.4 km/s round trip

Fuel creates the cost

Space Shuttle Weight (kg)

- Un-Fueled 342,000 kg
- Fueled 1.7 million kg
- Cargo to GTO 3810 kg

- 358kg fuel per 1kg cargo

Rocket Equation

- Each type of fuel has a fuel_const that tells us the ratio of initial mass/final mass needed to increase velocity 1 m/s
- The total mass needed is then ship_mass * Fuel_const^(delta v in m/s)
- Refueling n times changes this equation to n*ship_mass*Fuel_const^(delta v/n)
- Refueling reduces the total fuel mass needed

Specific Impulse (ISP)

- Specific impulse is exhaust velocity/(9.8 m/s^2)
- Rocket Fuel in vacuum: ISP of ~310 seconds
- Ion Propulsion: ISP of 1,000-20,000 seconds
- Cyclotron: 60% c is ISP of 18,000,000 seconds
- Energy limits high ISP acceleration

“Infinite” ISP options

- Fuel and Energy only count if they are from Earth
- Solar Sails use photons from the sun
- Magnetic Sails and E-field sails use charged particles from sun
- Traditional magnet uses Earth, Sun and Jupiter as the “fuel” via magnetic fields
- Electrons fired into space may be able to bond with hydrogen via electronegativity and produce thrust without fuel from Earth
- Photons create momentum from energy

Solar Sail Ballpark numbers

- Density 10 g/m^2
- Peak force 8 uN/m^2
- Peak thrust of 0.8 mN/kg for 100% solar sail by mass
- If average thrust is 47.6% of peak this would give 1 km/s per month of delta v if 100% solar sail by mass.
- A spacecraft would need 20-46% solar sail by mass to reach Mars in 26 months at 200 m/s per month
- The volume of sail to move 1 Metric Ton spacecraft with 20% solar sail by mass requires 141 km by 141 km sail.

Reusable Fuel

Reusable ISP solves the fast transit issue

- Consider a class of small interplanetary satellite named the “brick” with solar sail propulsion capable of infinite delta V at 200 m/s per month.
- 46% sail by mass to account for 1/r^2 at mars
- Consider another spacecraft “Mother ship” attains its thrust by kinetically launching brick class spacecraft to 250m/s (900 km/hr) using a rail gun or a simple lasso type propulsion. 8 g with 400 m rail gun.
- Brick spacecraft return to fueling points at 200 m/s per month after being launched and are reused for the next mission.
- The kinetic thrust is Low ISP, the brick is Infinite ISP and the fuel is re-usable. The result is near infinite ISP capable of high acceleration with a low energy requirement.

Saving 12.3% on fuel forever

- Using 310 ISP a journey of 10.4 km/s requires 30.67 times mother ship dry weight. The return 5.2 km/s requires 5.54 times mother ship dry weight.
- Launch 1 load of brick spacecraft equal to 30.67 times mother ship dry mass
- Position the bricks at Mars where 30.67 times dry weight which is 5.54 times the return craft's mass of 5.54 times the dry mass of "mother ship".
- ISP 25.5 with initial mass of 5.54 times the final mass provides 427 m/s of thrust.
- Shorter 10.0 km/s trip only requires 26.89 times dry weight. Thus saving >12.3% fuel on every Mars return trip.
- Breakeven for 1 brick load is ~7 missions and gives >12.3% reduction on future fuel
- Breakeven if 2 brick loads is ~10 Missions and gives >15.9% reduction on future fuel

Saving 100% fuel forever

- ISP of 25.5 with initial mass of 1.5 times final mass gives >100m/s delta V
- Refueling 52 times on the way to Mars with 0.5 times rest mass of mother ship at each stop provides 5.2 km/s delta V
- This is one load of bricks equal to 26 times rest mass of “mother ship”.
- The bricks would need to return to initial positions prior to return trip or we would need to send two loads of bricks in the initial step
- Breakeven is 2 or 3 missions

Saving 100% fueling twice

- 8 G acceleration 11 km rail gun gives 1300 m/s ISP 132.6 seconds
- Breakeven for 1 load of bricks is 2 missions and saves >51.5% on all future fuel
- Breakeven for 2 loads of bricks is 3 missions and saves >82% on all future fuel
- Breakeven for 4 loads of bricks is 5 missions and saves >100% on all future fuel

Conclusion

- Kinetic Launch/Solar Sail Hybrid Reusable ISP can be competitive with 310 ISP fuel in terms of ISP and acceleration in the near future
- If rendezvous is possible ~52 times on the way to Mars then no rocket fuel is needed for the round trip
- Eliminating rocket fuel changes launched mass from 30.67 times dry mass to 1 times dry mass of mother ship reducing launch mass by 96.7%
- Reusable ISP has much lower supplied energy requirements than ion propulsion allowing high acceleration and fast transit
- Future fast transit at infinite seconds ISP is possible

Questions

- Contact info for Outer Space Colonization
- outerspacecoloniztion@gmail.com
- outerspacecoloniztion.com
- Twitter   @spacecolonize