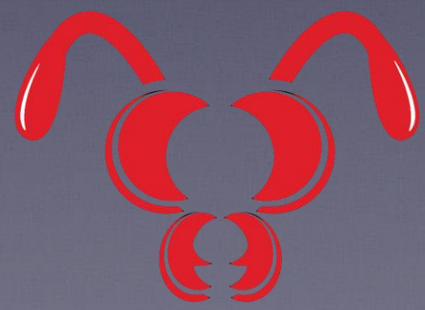
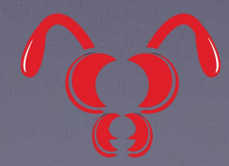
Transferred Momentum Solar Sail Docking

Darrin Taylor
Outer Space Colonization
outerspacecolonization@gmail.com
ISSC 2019



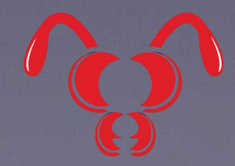
Thank you

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



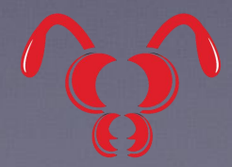
The Problem Statement

- Many in the space community plan on using the water from mining the moon to explore space.
- Is destroying this water via venting it into space a good idea (no)
- Will venting water affect the ultimate upper limit of human colonization of outer space? (yes)
- How can we explore and colonize space better through solar sails and docking in space…



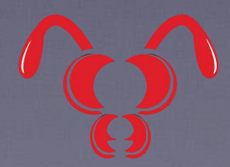
Water on the moon

- The entire moon surface contains ~1.2 E11 kg of water (Shuai Li and Ralph E. Milliken). That is roughly 48000 Olympic Swimming pools. 50 Colonists/pool=2.4M
- Trip from Moon to Mars is ~5.2 km/s and with a 450 Isp engine dissipates 2.25 Kg per 1 Kg transported to Mars.
- Round Trip Moon to Mars to Moon is 10.4 km/s and dissipates 9.57 kg per 1 kg cargo. (two way cargo)
- Bulk of asteroids are 10 km/s (one way) away and mining 1 kg will require about 11 kg of vented water in these cases. (one way cargo)
- Water is the new money. Losing 30-92% is unnecessary
- 2.4 Million colonists vs 1.68 colonists vs 0.192 Million colonists



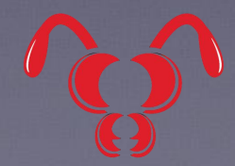
Radiation Pressure of Sun

- Earth receives 5 E 35 photons/second from Sun
- Sun photon pushing on Earth are enough to move 70 Million kg at 1 g (Chad Orzel)
- Solar Sails with a cross section equal to the Earth would have a net dV*kg of 2E16 kg*m/s per year
- > kg m/s per year that lifetime from moon water
- Only uses 1/70,000 of available Sun equator



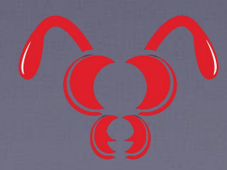
Slow Solar Sails vs Rockets

- Presently 2 Thrust Inefficiencies with rockets, Ion propulsion, Vasmir etc.
- Single Fuel Use is obvious. Jet fuel is ejected as gas never to be reusable by humans. But reuse reaction mass 10 times and the average cost is 10 times less.
- Un-Carried is more powerful but less obvious. The tyranny of the rocket equation is a byproduct of carrying reaction mass.
- If one delta V costs $100/kg delta V 10 times greater isn't $1000/kg but rather $100^10/kg. Thats $100,000,000,000,000,000,000 / kg! Carrying Reaction Mass Costs $
- (Slow) Solar Sail Transportation doesn't consume any reaction mass

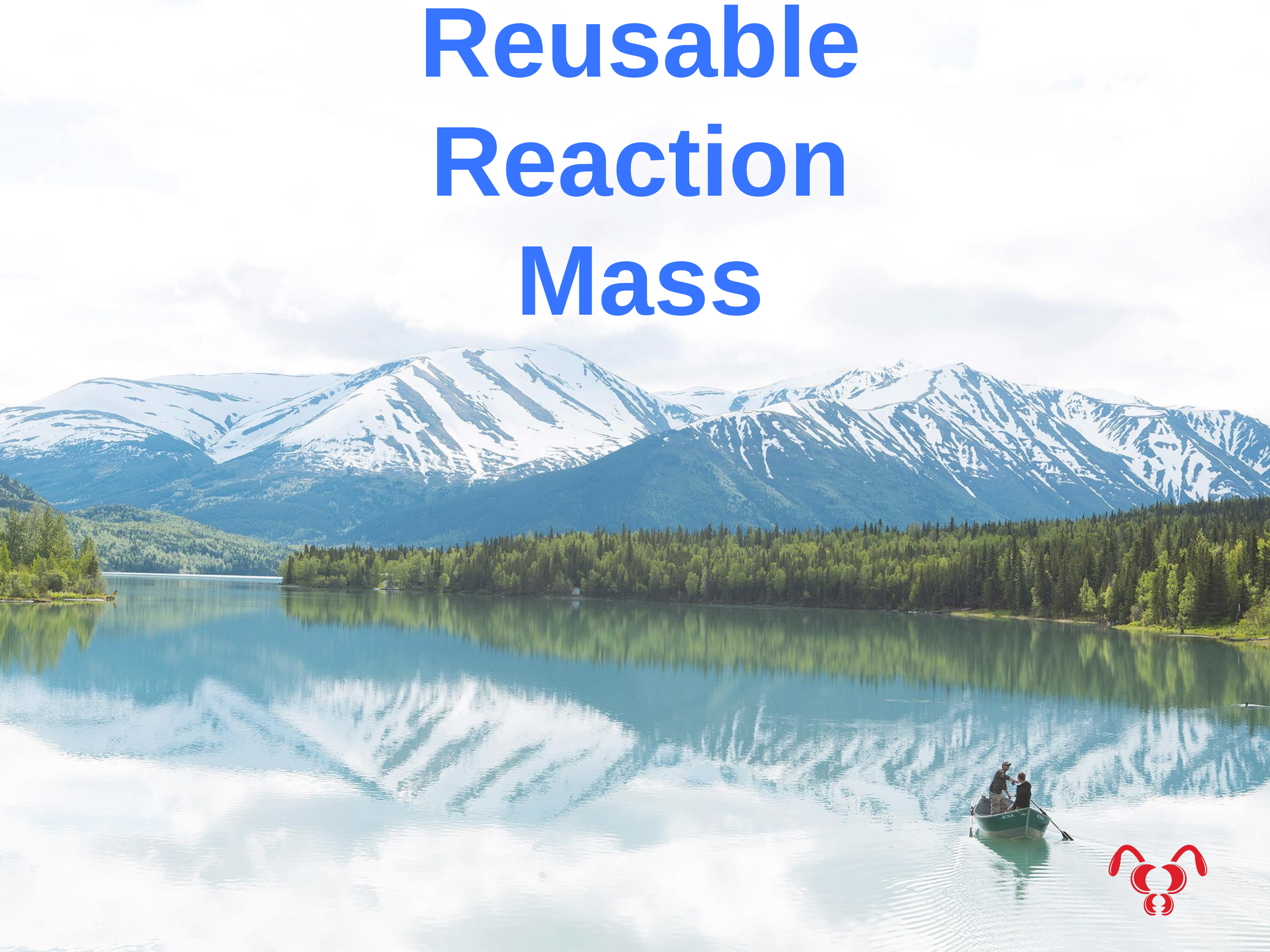


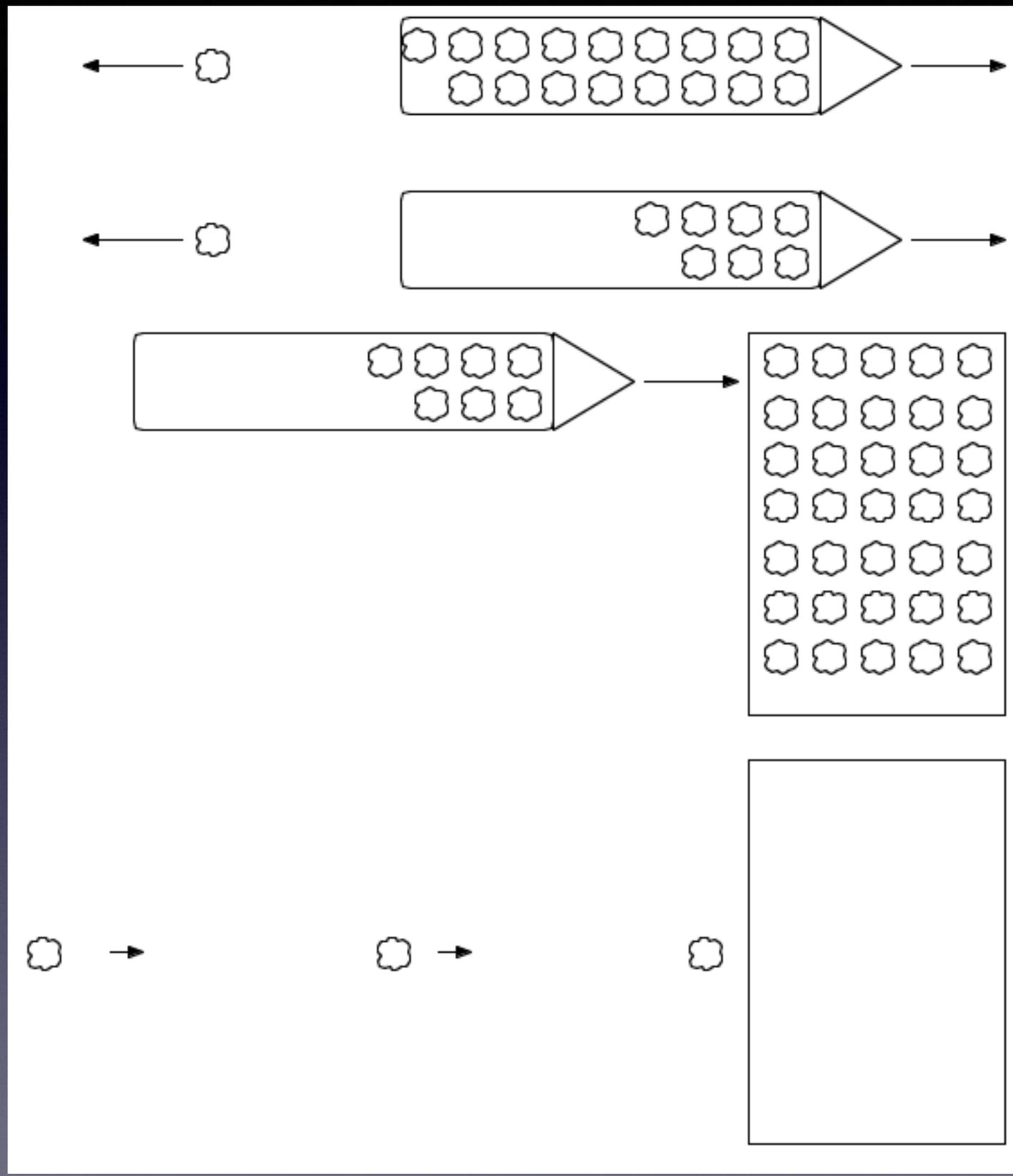
But Solar Sails are slow…

- How can Solar Sails be fastest?
- Faster can be thought of as higher acceleration but nearly all interplanetary rockets spend the majority of their transit with zero acceleration or tiny acceleration
- Solar Sails do not need to match the acceleration of rockets if they can exceed the economic delta V of rockets.
- Need higher Acceleration than ion propulsion and cheaper dv than rocket propulsion



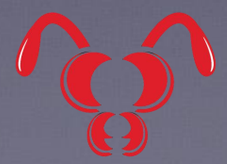
Reusable Reaction Mass





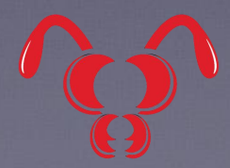
Background Talks

- ISSC 2016 Proposed Transferred Momentum Technique using Solar Sail Spacecraft as “fuel” for 2nd Space craft so Fuel is reusable and never consumed.
- ISSC 2017 Using transferred momentum it is possible to transit to Mars outside the Hohman Transit window on any arbitrary day at similar “fuel consumption” although with massive start up mass requirements. ~E15 less fuel.
- Mars Society 2017 Free Shipping with your order. Exploring free and low cost shipping from Mars surface to Earth using Transferred Momentum and coilguns.
- ISSC2018 Essentially Free: Shipping from Asteroids, Moons and Planets to Earth focused on Coilguns and Merry-go round on moon



“Refueling” Base

- Start with the concept of a large refueling station that will collect many “balls” and package them for a visiting “Pitcher”
- The “Pitcher” will use excess “Balls” to provide docking delta velocity maneuvers similar to docking with ISS
- A relative short docking will transfer a large mass of “Balls” to the “Pitcher” quickly (10 minutes)
- The “thrown” “Balls” will then over months or years navigate to another Base and be packaged for another transit of a “Pitcher”
- “Ball” is only used once per transit For reusable ISP of 200s

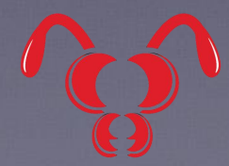


Consider Magnetic Docking

- The “Base” will emit a Periodic wave such as a sign wave with a Period of say 1 second and a duty cycle of 100% so 100 cycles per 100 seconds.

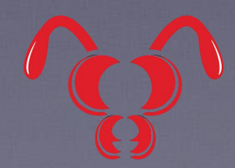
- Consider a single “Ball” with its own periodic 1 Hz wave which is either attracted to or repelled from the Base depending on the relative phasing of the two waveforms.

- Average magnetic field can be zero



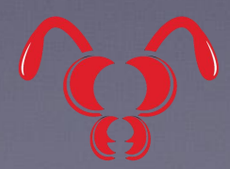
Magnetic flipping

- Consider now 6 magnet emitters (+x,-x,+y,-y,+z,-z) on the Mother ship which are pulsed at 1 Hz cycles but only at 1/6 duty cycle so that each emitter has only 1 cycle per 6 seconds.
- If the “Ball” has a similar setup then there will be a repulsion and rotation at point A, then a repulsion and counter rotation at point B…..The rotations can be canceled leaving only the repulsion provided the angular momentum is large enough to prevent large rotation within the 1 second time frame.
- Phasing can give fractional pushes so A and B can experience different pushes.



Docking

- Before starting docking Solar sails will over months achieve an orbit similar in delta velocity and similar in location to the Base orbit. Group can take a month to dock with base (1 min ea)
- Magnetic forces will provide the attractive force and to some degree a limited repulsive force
- Acceptable docking time is measured in days and months so smaller forces can be depended on to smooth out small 0-20 m/s velocities.
- Robotic catcher could be employed to smooth out velocity differences of 0-10 m/s for fixed refueling station



Aggregate Docking

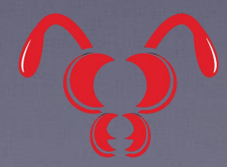
- Now lets imagine instead of 1 “Ball” docking with 1 “Base” consider a cloud of “Balls” that are docking with each other

- The same magnetic methods apply but there are now many more emitters that need to be coordinated.

- Some form of Solar Sail fold up is needed prior docking.

Technical Challenges

- Complex: Orbit generation for thousands or millions of Space Craft to make up a single Transit
- Technical Readiness: The entire system has not been prototyped
- Expensive: Initial reaction mass is equivalent to 200 ISP
- Possible: The potential kg*m/s for Solar exceeds all known forms of space thrust using accepted physics.
- Linear: Transferred Momentum system mass is linear with increased dV.



Questions

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