PROPELLANT-LESS LAUNCH PLATFORM FOR MOTHER SHIPS. G. A. Robertson, Marshall Space Flight Center, Huntsville, AL 35812,256-544-7102; glen.a.robertson@nasa.gov

Challenge Area 2: Innovative Exploration Approaches. (Example 11) Lightweight, low-cost, probes or platforms, suitable to be carried by larger orbital or landed vehicles ("mother-ships"). A new probe launching concept from a Mars orbiting "Mother Ship" for either orbit insertion or descent trajectories (Mars or its moons) is discussed.

Introduction: To reduce the penalties (*i.e.*, cost) for carrying large amounts of propellant on "Mother Ships" and probes, propellant-less launch platforms similar to gas catapults could be developed to deliver the initial trajectory and delta-velocity to the probes to reduce or eliminate onboard propellants. However for in-space applications, the use of traditional gas catapults would suffer from the loss of the gas requiring continued servicing, which could be a greater penalty (*i.e.*, earth launch and delivery cost) than just carry traditional propellants on the probe to begin with.

A new launch concept using the *Pressure-Driven Magnetically-Coupled Conveyance* (PDMCC) [1] is discussed, which allows for the reuse of the gas for future launches.

PDMCC: The PDMCC was conceived to use small cross sectional area gas guns to launch large cross sectional area spacecraft through magnetically coupling to the projectile sealed inside the gas gun and decoupling it upon reaching the desired acceleration. Whereby, all the benefits of the gas gun can be utilized without the loss of the pressurized gas to the atmosphere or space. The PDMCC concept is

- Not an incremental change, but a major leap forward for in-space launch assist as it does not require conventional propellants (liquids or solids) or the direct use of electrical power (e.g., MagLev) for the launch assist. The uniqueness of the concept is that the launcher takes on the weight and efficiency advantages of small gas guns to launch spacecrafts or probes without putting them in the gas gun.
- Based on the simple application of magnetically coupling to a projectile being accelerated by gas expansion in a tube verse the spacecraft or probe being in the tube and accelerated by the gas expansion. This fact allows the gas guns to be very small in comparison to the spacecraft or probe. In general terms, the physics is no different than launching an aircraft from an aircraft carrier.

The PDMCC concept was conceived by the author, but was never officially studied beyond a small summer student demo in 2005 that was not reported outside NASA-MSFC literature. (The demo and the report have since been lost.) The patent [1] concept drawing is shown in FIG 1. As shown the carriage and spacecraft or probe are not in the gas gun tube as is done with typical gas gun launcher concepts. The carriage may not be necessary except to save weight as the magnetic coupling/decoupling device can be placed directly on the spacecraft or probe.

The basic PDMCC concept uses the pressure in a gas gun composed of a (round or square) nonmagnetic tube to push a projectile (not shown, see [1] for more detail) inside the tube. By either making the projectile of a magnetic material (permanent magnet, steel or a combination) with some standoff material to protect the tube and seal the pressure, a carriage or the spacecraft or probe can be magnetically coupled to the projectile inside the gas gun. Dependent on the situation, the vehicle or probe may need to be supported using skids, rollers, magnetic levitation, or etc. Distribution of both the weight and force on the gas gun tube can be accomplished by using multiple gas guns about the vehicle or probe (see [1] for some multiple gas gun configurations).

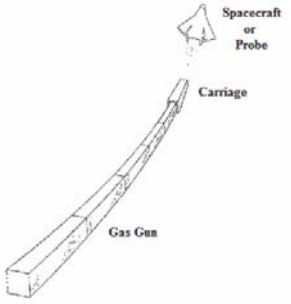

Figure 1. Patent Concept Drawing of the PDMCC.

Gas Guns: Gas guns, which use pressurized gas to accelerate projectiles, are well known. However, gas guns work better and are simply more practical on a small scale (*e.g.*, with small bullet-sized projectiles) than on a large scale (*i.e.*, with large spacecraft-sized projectiles). Consequently, the design and operation of a gas gun that could be used for large spacecraft or other large transportation systems would be very unwieldy. To fix this problem, the PDMCC concept utilizes the small-scale gas gun technology in combination with a magnetic coupling scheme with the internal gas gun projectile to achieve a novel conveyance for propelling larger objects than normally associated with small gas gun technology.

PPMT[1]: The proposed magnetic coupling/decoupling scheme would utilize parallel path magnet technology (PPMT) (see *Methods for controlling the path of magnetic flux from a permanent mag-*

[1] PPMT is a pending trademark of QM Power [3]. Used with permission from QM Power per email date 05/02/2012.

net and devices incorporating the same [2]). PPMT is a technology where the direction of the magnetic flux in a magnet material from a permanent magnet can be redirected by control coils placed about the magnet material.

This technology has been investigated by the author and has been shown to work efficiently as only momentary power is required to redirect the magnetic flux, *i.e.*, only short power impulses to the control coils are needed to redirect the magnetic flux in the magnet material. This is similar to a transistor were a small amount of current opens a gate to allow the flow of a larger amount of current. The difference being that if not properly designed, the magnetic flux can revert to its natural magnetic flux paths after the power impulse. However, this is not a problem if the impulse time is long enough to allow a larger air gap to be produced between the projectile and the coupler/decoupler PPMT device; *i.e.*, considerably reducing the magnetic attraction force.

Due to the short power impulse requirement, the control coils and thus a PPMT based coupling/decoupling device can be made smaller than would be required with conventional electromagnet technology. Plus the use of permanent magnets with high magnetic residual flux densities (Br) can produce high magnetic coupling forces in smaller size than conventional electromagnet technology.

FIG 2 shows the basic design of the PPMT with one permanent magnet, but other designs are possible that may be more suited to the magnetic flux coupler/decoupler in the PDMCC launcher concept. The PPMT of FIG 2 uses two control coil pairs (red and black) to redirect the magnetic flux (green lines) from the permanent magnet to the left or right end plate, whereby a magnetic end plate in the direction of the magnetic flux imposed in the magnet material of the poles by the control coils is attracted to close the magnetic circuit, *i.e.*, reduce the air gap to zero between the poles of the PPMT and the end plate.

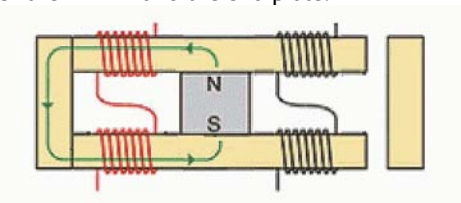

Figure 2. Basic PPMT design.

As shown the magnetic circuit (green lines) is closed on the left side by the application of the impulse power to the left control coils (red) at which time the power is turned off. Application of the impulse power to the right control coils (black) will attract the right end plate to cause the magnetic circuit to close through the right control coils (black) and the right end plate.

It is noted that both control coil pairs can be energized in the proper manner to better control the direction of the magnetic flux in the magnetic pole material. Further, in some designs, mechanism like springs may need to be used to push the end plates toward or away from the poles of the PPMT for better efficiency of use.

PDMCC Launcher Platform: The basic PDMCC launcher platform on the "Mother Ship" would consist of one or more small gas guns as required to give a spacecraft or probe the needed delta-velocity. The projectile inside the gas gun or the coupling/decoupling device can hold the permanent magnets. It is preferred that the spacecraft or probe does not carry away the permanent magnets and the control coils of the PPMT coupler/decoupler circuit, so they can be reused.

Using the PDMCC launcher concept does not necessarily mean that the "Mother Ship" will not need propellants for orbit station keeping. However, if probe launches are properly conducted, part of the probe launch energy could help to correct orbital decay of the "Mother Ship."

Further, it is expected that the advantages of using small gas guns allow the launch platform to be smaller than using conventional means to accomplish the same mission goals, which in turn reduces the earth launch mass requirement of the "Mother ship" and also the probes.

TRL: The proposed paper will discuss in more detail the PDMCC, PPMT and "Mother Ship." It is noted that the PDMCC and PPMT technologies combined are at TRL 1 - Basic principles observed and reported. Although both have been demonstrated independently to at least TRL 4 - Component and/or breadboard validation in laboratory environment. The PPMT has also been implemented into motors and generators to near production [3], *i.e.*, > TRL 6. This paper will bring them together to TRL 2 - Technology concept and/or application formulated. Noting that component and/or breadboard validation in laboratory environment (TRL 4 to 5) could be easily accomplished in one year followed closely by a vacuum test (*i.e.*, TRL 6 System/subsystem model or prototype demonstration in a relevant environment - ground only). With proper funding, a three year program toward a flight test either on a satellite or the space station (*i.e.*, mother ships) could bring the technology to TRL 8 - Actual system completed and "flight qualified" through test and demonstration (space). I.e., could be ready for Mars application in less than 10 years.

References:

[1] Robertson, G. A. (2001) MSFC, US patent #6,170,404. [2] Flynn, J. (2001), US patent #6246,561. [3] www.qmpower.com