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Research Article

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A Space Propulsion System without Mass Ejection

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Abstract

Flight performance of long-range spacecraft is limited by the need to lift large amounts of fuel into orbit; thus, a propulsion system which will not depend on mass- ejection will be a most welcome development. Various past proposals which attempted to achieve this were rejected because it was thought that they contradicted basic laws of physics. An experimental mechanical device which operates without mass-ejection, (or interaction with the environment), and which can serve as a spacecraft propulsion system, was constructed and successfully tested. It is based on manipulating centrifugal forces, internally generated by rotating masses, and is not size or scale dependent. Full explanation, with photos and movies of its construction and operation, is presented. When fully developed, this technology will enable constant long-duration acceleration of spacecraft (decreasing flight times), permit novel physics research, or enable hovering with or without the presence of atmosphere.

Keywords: Ejection-Less Propulsion, Reactionless Space Drive, Space Propulsion Systems, Space Travel, Long-Range Spacecraft

1. Introduction

Currently, spacecraft designed for long missions are lifted into orbit, accelerated to the desired speed (usually by mass ejecting chemical rockets which have Isp of up to 450 seconds, depending on type) and then "coast" to their destination. Since the fuel for such journeys must be lifted too into orbit, long range spacecraft are limited in their maximum velocity, and this bears directly on transit times with all attendant problems of long space voyages. If such a spacecraft is to orbit another celestial body, more fuel is required for deceleration, when it approaches its destination.

Nuclear-powered rockets which work by heating and ejecting stored Hydrogen were investigated too. Although more efficient than chemical rockets, (Isp of 1400 to 2000 seconds) they too eject consumables.

Various electric thrusters, which eject high-velocity particles, are currently studied. Compared to chemical and nuclear-powered rockets their specific impulse is high, 2500 to 4000 seconds, but the weight of the ejected mass is small and consequently the forces they produce are minute, on the order of fractions of Newtons. This suffices for station-keeping of satellites and similar applications but not for long distance travel. Obviously, a propulsion system, which will not depend on mass discharge, will be a most desirable development for future space applications.

2. Previous Work

In the past, many inventors attempted to design devices which will create a lifting force, essentially a form of "anti-gravity", without the ejection of mass, and without utilizing propellers. These devices were usually based on asymmetric pulses of oscillating or rotating masses. With the advent of spaceflight, there were many attempts to adapt such concepts to space flight. Just writing "Reactionless Space Drive" in google brings up many such.

There are also hundreds of patents, patent applications and other proposals for such devices, from all over the world [1]. Some of them are conceptually similar to the current work. Perusal of these designs shows that all suffer from two deficiencies: They are based on overly complicated mechanisms or on arrays of gears, pulleys and cables, both of which will make them difficult to construct and unreliable to operate. Furthermore, none of these publications present or depict actual working models - only drawings and explanations of the concepts [2]. What's more, even in publications which analyze most advanced (albeit theoretical) propulsion concepts, there is little discussion of such simpler, down to earth, technologies [3]. A few papers on various aspects of this subject were presented at scientific meetings and journals [4-6]. In view of these technologies' importance and potential, especially for space travel and research, it is surprising that it was not further developed, at least to a prototype or proof-of- concept level. Part of the reason for this lack might be the resistance of part of the scientific community, which claims that it is impossible to achieve a propulsive force without mass ejection or interaction with the environment. It is stated that tests which claim to achieve this were carelessly conducted [7]. Others insist that such ideas violate basic laws of physics [8-10]. Also, some non-technical objections were raised regarding work in this field [9]. It is possible that this attitude dissuaded researchers from further work on such concepts.

3. Current Work

3.1 Explanation of the System's Design and Operation

Despite such objections, a working model of such a system was designed, constructed and successfully tested. This paper

describes the device's construction, operation and test results.

Nomenclature: (See also Figure 1)

• F – Centrifugal force exerted by masses m on the wall A-B-C-D-A

• R_1 – Longer radius, defined between points A and B.

• R_2 – Shorter radius, defined between points C and D.

• F_1 – Centrifugal force along wall from A to B.

• F_{T1} – "North"-pointing integral of F_1 along wall from A to B.

• F_2 – Centrifugal force along wall from C to D.

• F_{T2} - "South"-pointing integral of F_2 along wall from C to D.

• Fnet - (F_{T1}- F_{T2}); net force acting to the "North" (in the two-armed configuration).

• m – Lead masses mounted on arms. (See Figure. 1 and Images1, 3,4 and 5.)

• V - Linear velocity of the masses along the wall.

• ω – Angular velocity of the masses

• (The length of the arms carrying m varies with their angular positions)

The basic idea was that the magnitude of a centrifugal force could be manipulated along its trajectory, to generate a unidirectional, controllable force. See Figure 1. The system consists of lead masses (m) mounted at the ends of telescoping (free to slide in and out) arms. The momentary length of these arms, and hence the masses' orbits and linear velocity along the wall are defined by the shape of the limiting wall and their angular position. See Image 1. The concept of the limiting wall was described in although without delving into design details [2].

Basic equations for a twin-armed model (see Figure. 1).

3.2 Centrifugal Force Equation

$$F = mv^2/R \quad (1)$$

And

$$V = 2\omega\Pi R \quad (2)$$

resulting in

$$F = m4\Pi^2\omega^2R \quad (3)$$

and thus

$$F_1 = m4\Pi^2\omega^2R_1 \quad (4)$$

$$F_2 = m4\Pi^2\omega^2R_2 \quad (5)$$

F_{T1} and F_{T2} are integrals of F_1 and F_2 along respective sections of the wall; see the Nomenclature and Figure 1.

$$\text{Fnet (acting "North")} = F_{T1} - F_{T2} \quad (6)$$

(Forces between BC and DA are essentially cancelled by the symmetry of the system.)

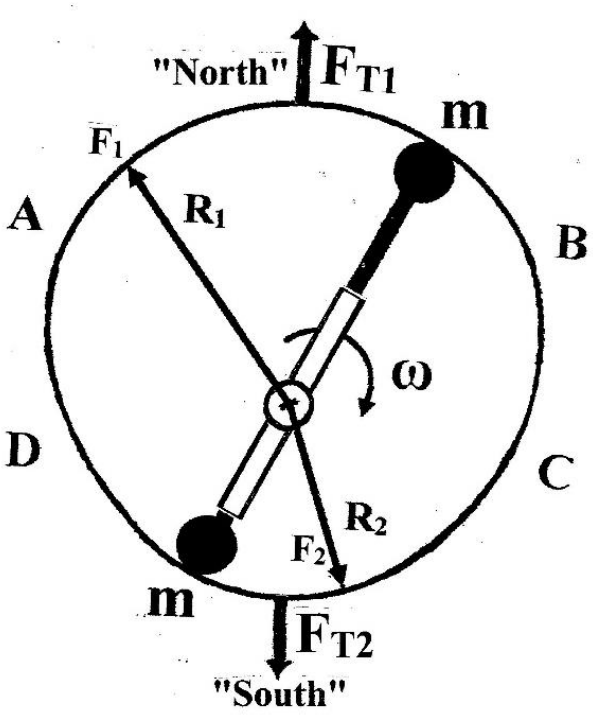


Figure 1: A Schematic of a Twin-Armed System

3.3 The Test Model

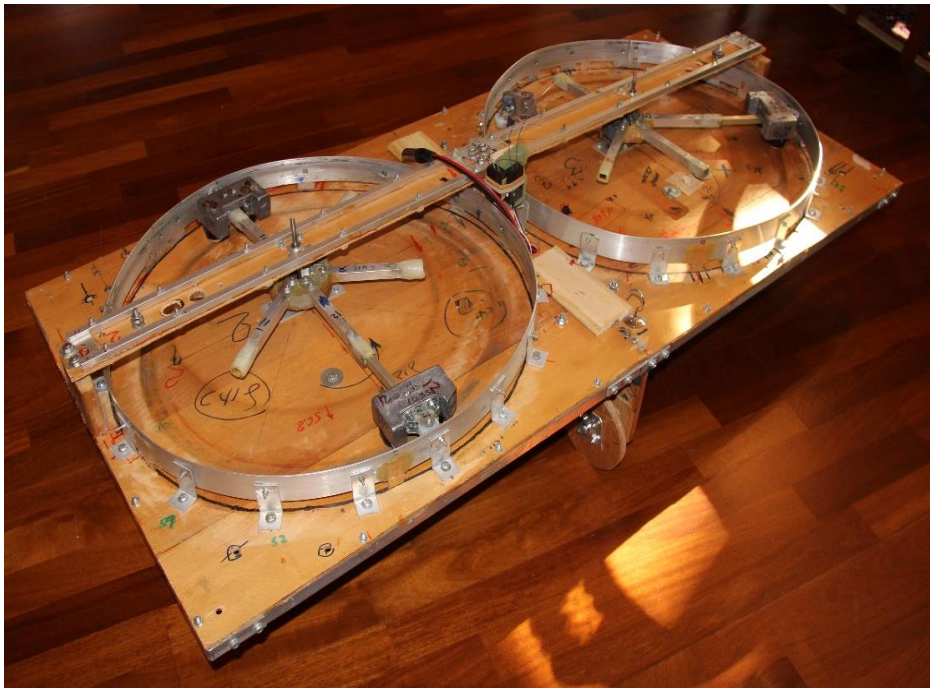


Image 1: Layout of a Twin Armed Test Model

To eliminate rotational moments of the motors the system consists of two similar devices rotating in opposite directions. Initially it was planned to operate with lead masses on all six arms. Turned out that the motors couldn't handle more than two of the masses. The model shown is the latest of several design improvements.

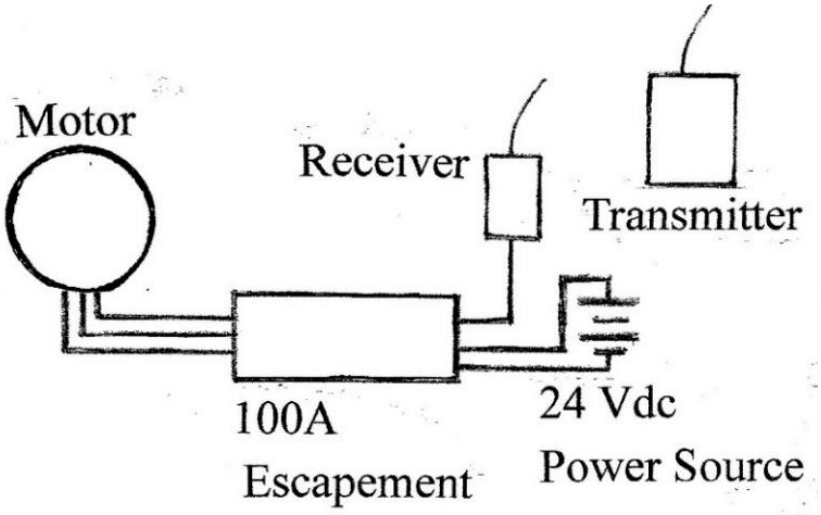


Figure 2: A Schematic of the Model's Electrical System for Each Side

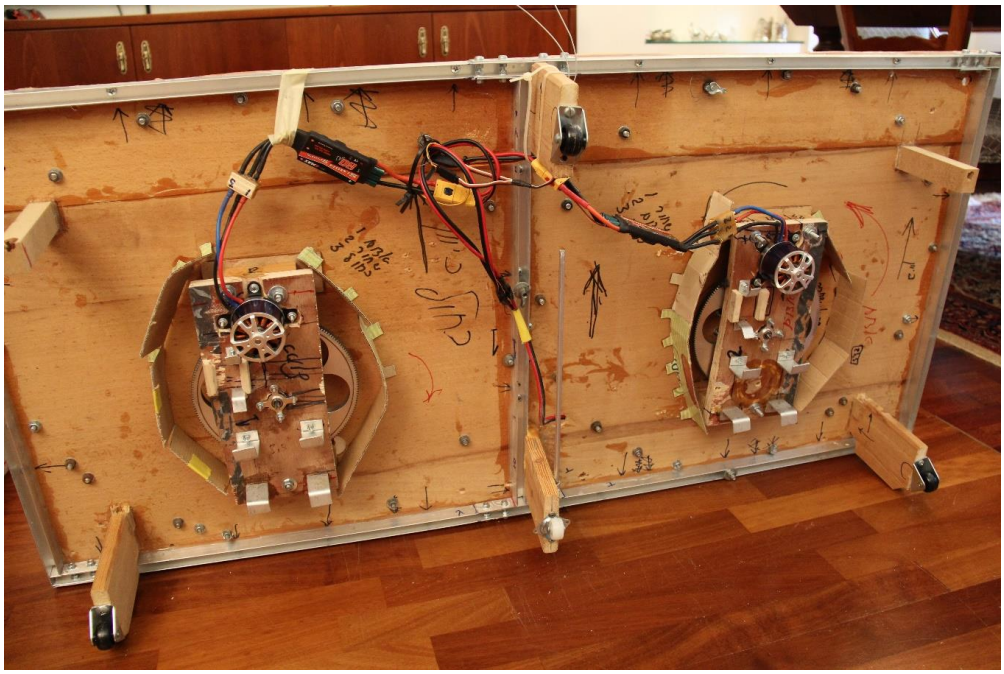


Image 2: An Underside View of the Test Model
(The wheels in this photo were later replaced by better ones, as in image 1) The large gears serve to reduce the motors' angular velocity. See also Image 6.

3.4 The System's Data

(The test article was built in a home-workshop using only basic tools.)
Motors---------- Brushless, Tomcat G90 5625-KV330
Gear ratio, motors to rotating arms ---------- 11.
Control system ---------- 2.4 GHz Futaba transmitters and receivers with RC models 100A escapements; see Figure 2.
Digital Force Gauge ---------- ALIYIQI Instrument Co. Ltd. Model AMF-100
Photo/Contact Tachometer ----------Model DT-2268, Lutron (USA).
Platform's weight without batteries ---------- 15.040 Kgs (Single lead mass on each side.)
Power for motors ----------24VDC (two 12V batteries)
Weight of battery pack ---------- 5.285 Kgs
Total weight of platform ---------- 20.325 Kgs (Single lead mass on each side.)
R_1 of the wall between A and B ---------- 0.315 meter in the current model.
R_2 of the wall between C and D ---------- 0.225 meter in the current model.
R_1m – rotation radius of mass ---------- 0.26 meter*
R_2m - rotation radius of mass ---------- 0.17 meter*
Individual lead masses' (m) weights ---------- 1.1± 0.1Kg each.**
ω Angular velocity in current tests ---------- 200 – 750 RPM

Platform's length (in direction of movement) ---------- 0.6 meter
Platform's width ---------- 1.25 meter

*These values are for the rotation radii of the centers of the masses along sections A-B and C- D, respectively.
** These numbers are for the latest configuration, performance of which is given in Table and Figure 5.

3.5 Test Results

The movement tests (recorded in the supplementary movies) were performed with either one operating arm (a mass at its end) or with two. With one arm the force F_1 is larger than F_2 (see Figure 3a) but the result is a more pronounced periodicity of the system's movement. (Movie-clips 1 & 2) With two arms the "North" pointing net force (F_1-F_2) is smaller, twice as frequent (see Figure 3b) but more stable. (Movie-clip 3).

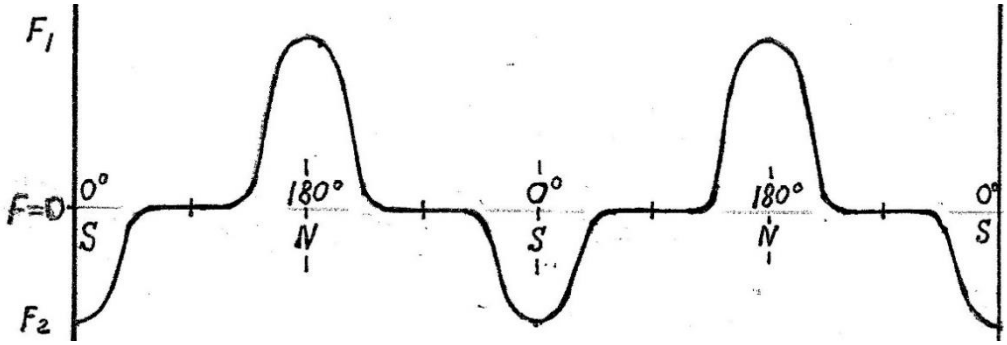


Figure 3a: Forces Along the Circumference of the Device for the One-Armed Configuration
Starting point for this drawing is at the "South" point. F_1 points "North" and F_2 points "South".

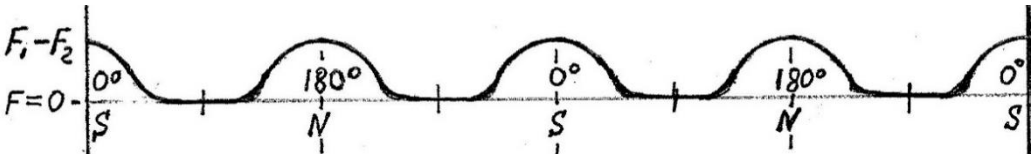


Figure 3b: Forces Along the Circumference of the Device for the Twin-Armed Configuration

Starting point is at the "South". F_1-F_2 points "North".

These forces, F_1 and F_2, were measured (see Figure. 4) and calculated, and the results are presented, separately for F_1 and F_2, in Table and Figure. 5.

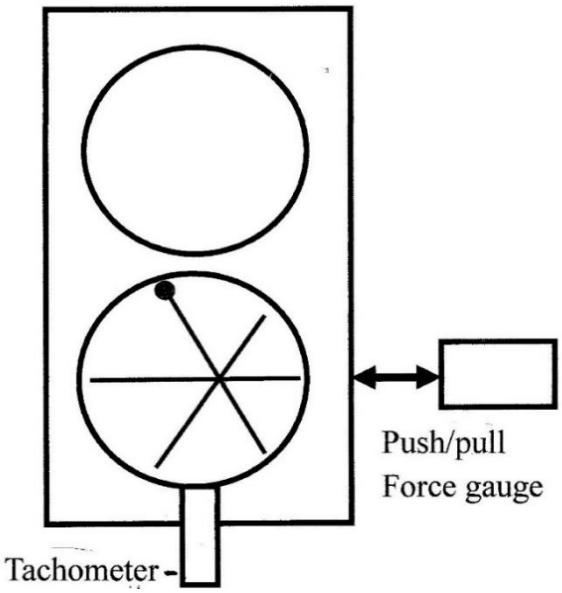


Figure 4: F_1 and F_2 Measurements Set-Up

(F_1 was measured pulling to the left, as in this figure; For F_2 measurements the platform was turned around and F_2 too was measured pulling to the left; This because pushing measurements posed some difficulties and because this procedure avoided calibration differences (in the force gauge) between pull and push.)

RPM	F_1 calculated Kgs	F_1 measured Kgs	RPM	F_2 calculated Kgs	F_2 measured Kgs
220	0.421	0.4	250	0.355	0.26
320	0.890	1.1	340	0.657	0.65
380	1.250	1.5	440	1.10	1.3
420	1.530	1.9	610	2.11	2.0
490	2.090	2.3	620	2.18	2.4
520	2.350	2.7			
600	3.130	3.45			
620	3.350	3.65			
650	3.750	---			
750	4.900	4.88			

Table: F_1 and F_2 Calculated and Measured Test Results as Function of RPM

See also Figure 3a and 5.

The calculated results were obtained using equation 3 from section III. The procedure used was as follows:

1. The measured RPM was divided by 360. (The Tachometer counted all 6 arms.) This gave RPS.

2. The resultant RPS was squared and multiplied by $m4\Pi^2R$. (m was derived from the masses' average weight of 1.1 Kg. See System's Data.) This multiplier was 1.13 for F_1 and 0.737 for F_2. These gave the calculated results.

3. The measured F_1 and F_2 were read manually from the force gauge; see Figure. 4.

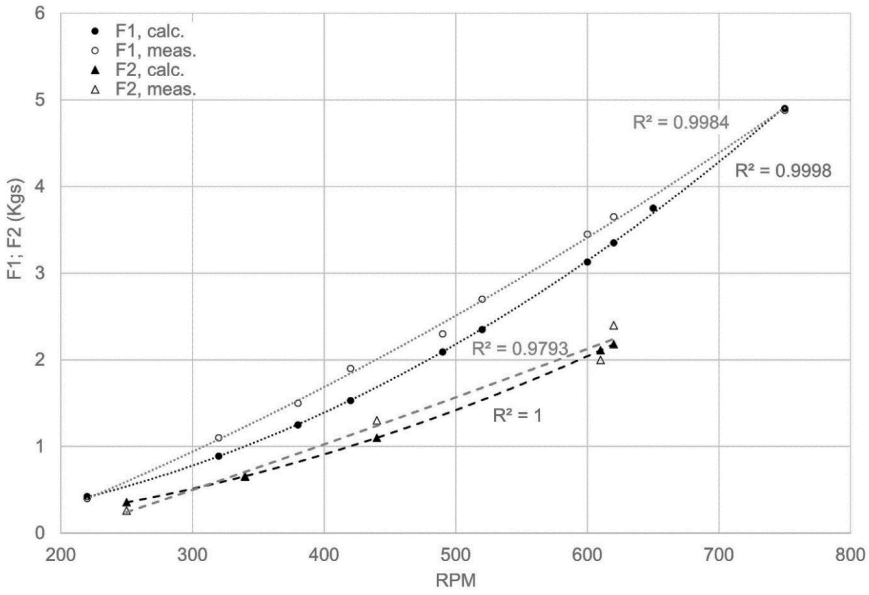


Figure 5: Measured and Calculated F_1 and F_2 Peak Forces. (See also Figure 4)

4. Discussion

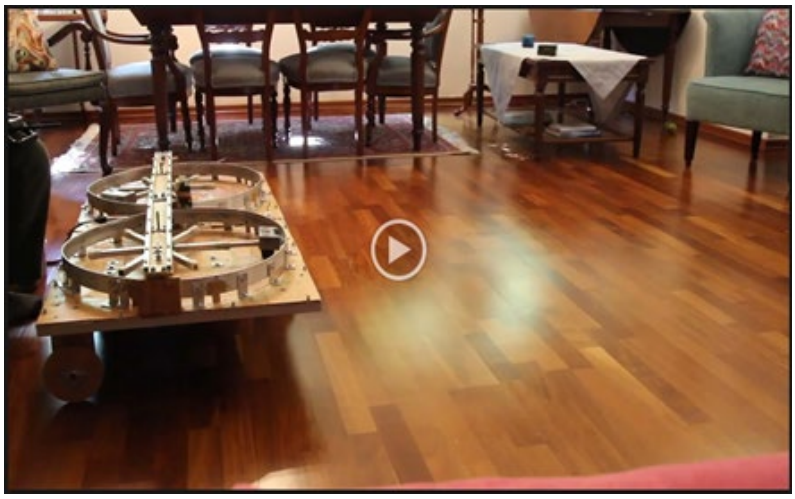
1. This work shows that an object can be accelerated without mass ejection (like in rockets) and no interaction with the environment. The force to achieve this is generated by internal electrical motors. A physical model was constructed and tested for this purpose.

2. The movement of the object – the platform – which can be seen in the supplementary movies, was achieved by either a unidirectional force, F_{T1} (which overcomes F_{T2} in the one-armed configuration – see paragraph 5 below) or Fnet, in the two-armed configuration. These forces act in the desired "North" direction and are generated by the rotating masses. The difference in the temporal magnitude of these forces, generated by one or two operating arms (on both sides of the model) is shown in Figure. 3a and 3b. This difference affects the dynamics of the platform's motion, as demonstrated in the supplementary movies.

3. A common argument against the presented concept is that it violates the Law of Conservation of Momentum, though without explaining in what way it does so. The rotating masses (m) and the electrical system powering them, are a closed system. These

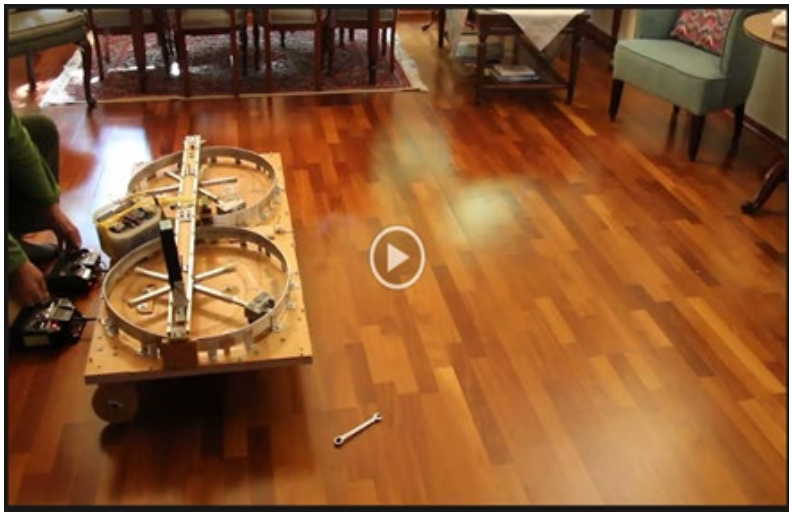
masses, when rotating, possess angular momentum, which is converted into a linear one (attested to by the movement of the platform) by manipulating the magnitude of the centrifugal forces created by these masses. No place to introduce here more sources of momentum.

4. Another argument against the validity of such concepts, and tests intended to prove them, is that the platform's movement is impossible without ground friction. [7]. Newton's Second Law states that if a force is acting on a body, the body will accelerate. Such forces, F_1 and F_2, are generated on the platform. Since F_1 is always bigger than F_2 (see Table and Figure. 5) the result is a net force in the "North" direction, which moves the platform in the same direction. (See also supplementary movies 1 and 2.) It should be remembered that Newton's law is valid without the help of ground friction.



Supplementary Movie 1: Test of a One-Armed System

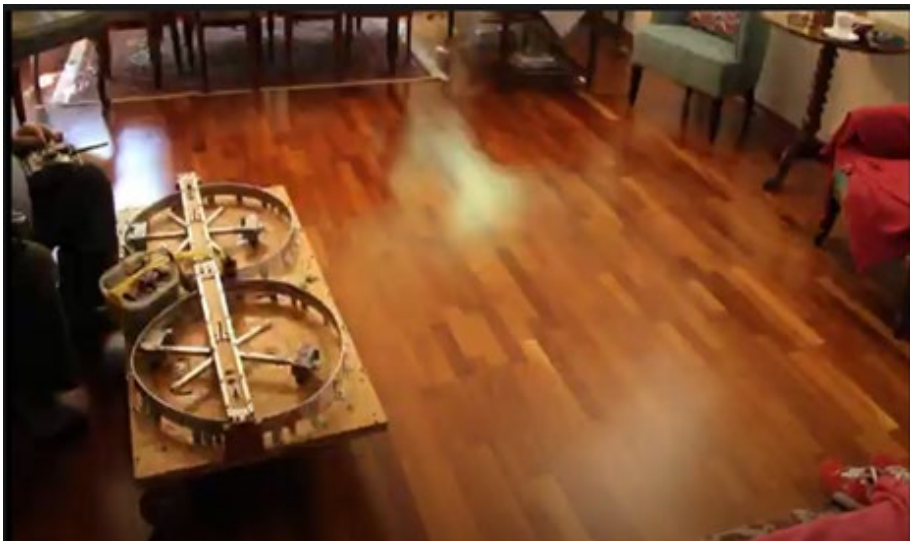
Supplementary Data: The Supplementary data for this article can be accessed using the following link: https://www.opastpublishers.com/assets/videos/space-science-journal-video.mov



Supplementary Movie 2: Another Test of a One-Armed System

Supplementary Data: The Supplementary data for this article can be accessed using the following link: https://www.opastpublishers.com/assets/videos/space-science-journal3.MOV

5. Furthermore, for the argument about the ground friction to be true, this friction must act as a one-way ratchet, blocking backward movement, and allowing it in one direction only. [7]. Clearly, this is not the case. In the one-arm operation, the platform initially reacts to the forces generated in both directions, but because the force in the "North" direction is bigger than the one to the "South" (see also Figure. 3a) then shortly the platform's direction of movement is stabilized, and it moves steadily "North". (Supplementary movies 1 & 2). In the twin-armed configuration the force Fnet acts from the start only in the "north" direction (see Figure. 3b) and the platform moves immediately in that direction, without seesawing. (Supplementary movie 3.) This has nothing to do with the earth acting as a reaction mass, [10] and according to Newton's Second Law this will be true also in orbit or in interplanetary space.



Supplementary Movie 3: Test of a Twin-Armed System

Supplementary Data: The Supplementary data for this article can be accessed using the following link: https://www.opastpublishers.com/assets/videos/space-science-journal1.MOV

6. According to Newton's Third Law, for every action there is a reaction. It was claimed that such a reaction is absent here, and hence, the proposed concept is invalid. When the lead masses push against the wall and generate a force (see Table, Figure 5 and Images 4 and 5) the wall pushes back against them, or to be exact, against the little wheels at their ends. (see image 3 and 5). This is Third Law in Action. But the wall's pushback exerts this force only on the lead masses, and because they are free-standing (they can freely slide in and out of the arms) this reaction force (the pushback) does not affect the rest of the system. The wall's pushback would have been obvious if these masses, or the wheels, were soft.
7. Due to the strong effect of the masses' angular velocity on the system's performance (see equation 3 in section 3.2) increasing this velocity to the likes of internal combustion engines, even with one operating arm, will produce forces of thousands of Newtons, without the extreme temperatures common in rocketry.

5. Conclusions

A prototype mechanical device which produces a unidirectional controllable force without mass ejection, and with no interaction with its environment, was designed, constructed, and successfully tested. The current work is a feasibility study, intended to serve only as a proof of concept, but it proves conclusively that a Reaction-Less-Space-Drive is possible. More development work is needed to fully realize this technology's potential, future applications of which include:

• Constant acceleration of space vehicles for extended times to reach higher velocities. This will shorten flight durations to far destinations.
• Constant acceleration for very long time will enable research in novel fields of physics.
• Directed upward this technology will enable hovering with or without atmosphere. This can also be used to design more survivable, rotor-free helicopters.

6. Future Work

Figures 1 and 2, and Images 1 – 5 give enough details for a technically competent person to be able to copy the design and perform the tests. For high rotational speeds, it might be necessary to enclose the system in a reduced-pressure box.

The first step in further developing this technology will be to professionally design and construct a model of the system (or a set of such) capable of withstanding constant rotational speeds of several thousand RPM and forces of hundreds, possibly thousands of Newtons. This, in order to test and optimize various design parameters, such as overall size, the number of operating arms, (including suitable motors), best wall's geometry, ratio of R_1/R_2 and optimum weights of masses, all of these vs. forces (F) generated and power requirements. The next step can be the testing of such a device hanging from a Helium balloon. Further testing may be done in a true gravity-less environment. For such tests a carefully balanced system should be built.

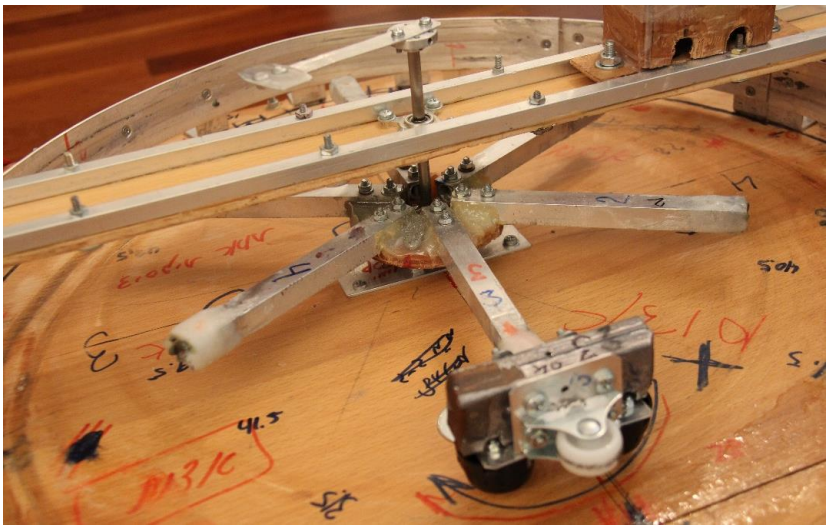


Image 3: A Detail of Image 1

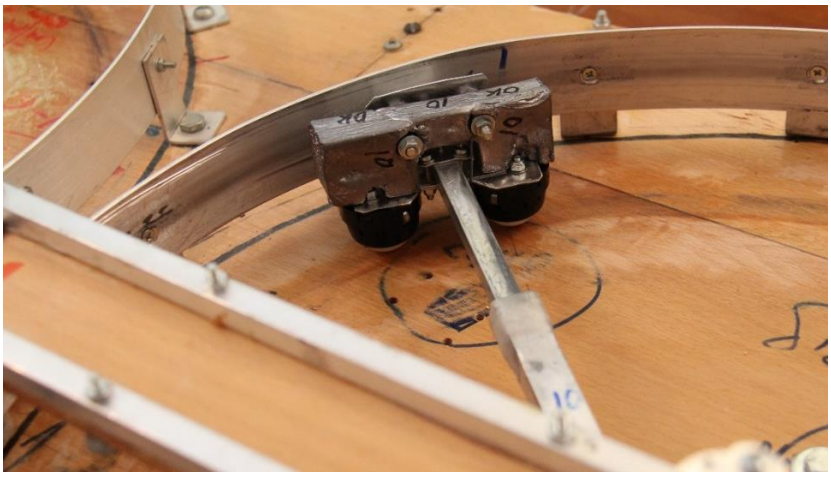


Image 4: Another Detail of Image 1

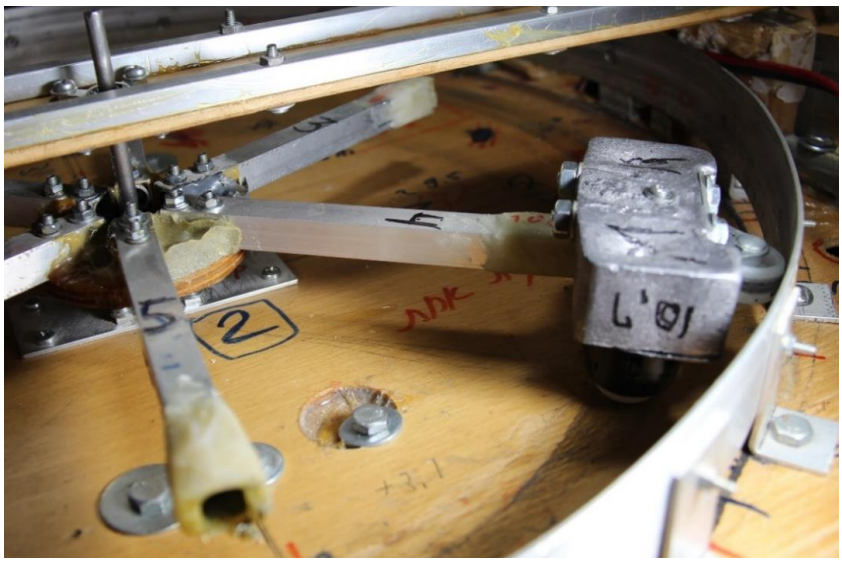


Image 5: Another Detail of Image 1

(The photos were taken from successive designs of the platform, hence the different shapes of the lead masses)

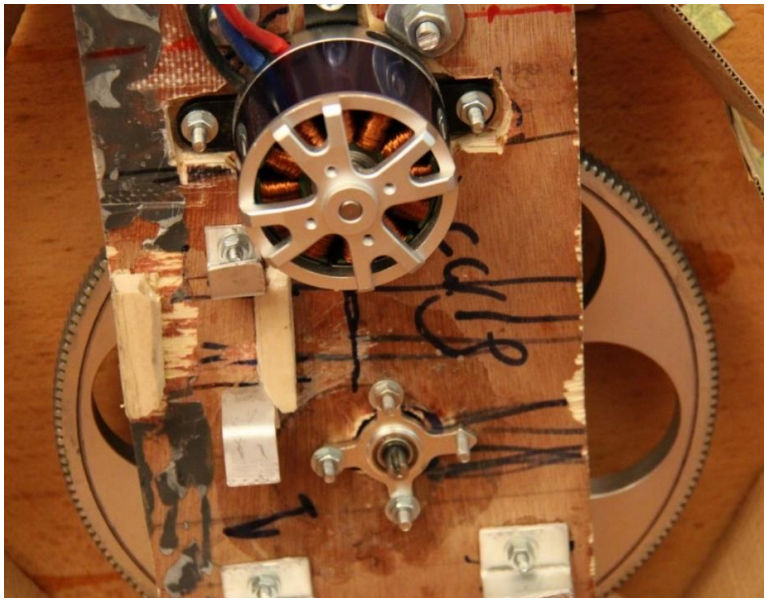


Image 6: A Detail of Image 2

Thanks

The author wishes to thank his children, Dana and Itai, and his wife Nurit, for their advice and practical help in various aspects of this work's development.

References

1. It will be impossible to list here all the patents in this field. A partial list of relevant ones can be accessed at "US Propulsion Patents 1974 – 1989", which also quotes previous works, and in addition lists several foreign patents in this field. A more recent one is [2] below and some are listed at the end of [7].
2. See US Patent 20150314868A1, filed in 2013, A Device for the Generation of Lift, by Angelo Raffaele Alterio. This patent application was singled out because it proposed an idea similar to the one in the current paper, but without any design details, which makes it impossible to analyze or duplicate. (This patent however was abandoned.)
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