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Inertial frames and breakthrough propulsion physics

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ABSTRACT

The term "Breakthrough Propulsion Physics" comes from the NASA project by that name which examined non-rocket space drives, gravity control, and faster-than-light travel. The focus here is on space drives and the related unsolved physics of inertial frames. A "space drive" is a generic term encompassing any concept for using as-yet undiscovered physics to move a spacecraft instead of existing rockets, sails, or tethers. The collective state of the art spans mostly steps 1–3 of the scientific method: defining the problem, collecting data, and forming hypotheses. The key issues include (1) conservation of momentum, (2) absence of obvious reaction mass, and (3) the net-external thrusting requirement. Relevant open problems in physics include: (1) the sources and mechanisms of inertial frames, (2) coupling of gravitation to the other fundamental forces, and (3) the nature of the quantum vacuum. Rather than following the assumption that inertial frames are an immutable, intrinsic property of space, this paper revisits Mach's Principle, where it is posited that inertia is relative to the distant surrounding matter. This perspective allows conjectures that a space drive could impart reaction forces to that matter, via some as-yet undiscovered interaction with the inertial frame properties of space. Thought experiments are offered to begin a process to derive new hypotheses. It is unknown if this line of inquiry will be fruitful, but it is hoped that, by revisiting unsolved physics from a propulsion point of view, new insights will be gained.

1. Introduction

A "space drive" is a notional device for propelling a spacecraft using only the interactions between the spacecraft and its surrounding space, without needing to transport and expel propellant. While the scientific principles from which to engineer such effects have not been discovered, the presumed benefit, when compared to rockets, is that such a device could deliver a greater total mission Δv for a given amount of energy. For interstellar missions the performance gain is about 100 orders of magnitude. The potential benefit when compared to space sails, is that the spacecraft can maneuver independently without any dependency on incoming photons. Another possible benefit is that the physics discoveries necessary to enable such devices would have other utilities – perhaps providing an acceleration field inside a spacecraft (mimicking a gravitational field) for long-duration crew health.

Perhaps the earliest space drive concept to appear in scientific journals was "negative matter" propulsion in 1957 [1]. Other concepts and analysis followed. The most substantive of these were assessed by comparing their critical make-break issues to open questions in physics to determine next-step research questions [2]. Thereafter, 24 examples of space drive concepts were categorized by their physics discipline and then compared in terms of their development status, key issues, and inferred reaction mass [3]. A key table from that publication is included at the end of this report, as Table 1, with updates based on recent progress on the "Mach Effect Thruster" [4] and recent publications on the "EmDrive" [5,6].

From this prior work, it was found that a common ambiguity to most space drive concepts is ensuring conservation of momentum relative to inertial frames. Inertial frames are the reference frames upon which the laws of motion and the conservation laws are defined, yet it is still unknown what causes inertial frames to exist and if they have any deeper properties that might prove useful [7].

Given its key relevance and unknowns, this paper focuses on the physics of inertial frames. First, the main findings of the preceding space-drive work are reviewed, including: the anticipated energy benefit, problem statement, general lines of inquiry, and a review of inertial frame physics. A series of thought experiments are then offered, using a Machian perspective of inertial frames, to illustrate a process to develop new hypotheses. Several different mathematical representations could be posited from this exercise, whose consistency with physical observables could be checked afterwards.

2. Anticipated energy benefit

In principle, the potential benefit of a space drive can be shown by

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Table 1
Compilation and comparison of space drive inquiries, reprinted and updated from Ref. [3] with permission. The shaded cells represents nonviable concepts.

Line of Inquiry		Form	Key Issue or Next Step	Reaction Mass	Net External Thrust	Since (Yr)	Literature Search Author Suggestion	Starting Reference
Common Misinterpretations	Stiction Drives	Devices	Misinterpreting the effect of static and dynamic friction	Floor	–	1959	"Dean Drive"	[2]: p. 249–254
	Gyroscopic Antigravity	Devices	Misinterpreting torques as linear forces	–	No	1973	Laithwaite	[2]: p. 254–259
	Lifters et al.	Devices	Misinterpreting ion wind as and an antigravity effect	Air	–	1920s	Biefeld–Brown	[2]: Ch. 8–9
	Enhanced Photon Momentum	Theory + Experiment	Incorrect combination of incompatible formalisms	–	No	1949	Slepian, Corum, Brito	[2]: Ch. 10
Fundamental Forces	"Antigravity"	Slang	Clarifying semantics	–	–	1900?1932?	Mader, Greg, Walsh	[51,52]
	"EmDrive"	Experiment	Improve fidelity of experimental data	?	?	2002	Shawyer	[5,6]
	Gravity-Shielding Superconductor	Experiment	Misinterpretation of observations	–	–	1992	Podkletnov	[2]: p. 140–242 [53,54]
	Electro-Gravitation	Experiment	Improve statistical significance of data	?	?	1991	Yamashita	[2]: Ch. 7
	Atomic Gravity	Anecdotal experiment	Advance to assessable equations with derivations	?	?	1950s	Alzofon	[2]: p. 221
	"Graviphoton"	Speculation	Derive testable equations	?	?	1996	Heim, Dröscher	[2]: p. 218–221
	Tachyon Drive	Speculation	Requires neutrinos to become tachyons	Neutrinos	Yes	1996	John Cramer	[55]
Inertial Reference	Higgs Mechanism	Theory	Apply theory & experimental data to propulsion	?	?	1962	P. W. Anderson, Higgs	[15,16]
	Modified Inertia Rockets	Speculation	Assess energy conservation and time-rate changes	Propellant	Yes	2009	Millis	[2]: p.138–143
	Negative Mass Propulsion	Speculation, Theory	Seek theoretical and experimental evidence for/against negative inertia	(internal)	Yes	1957	Bondi, Forward	[2]: p. 160–162, 180–184
	Mach-Effect Thrusters of Woodward	Theory + Experiment	Increase magnitude of effect and publish more detailed experimental data	Inertial frame	Being tested	1990	Woodward	[2]: p. 156 [2]: Ch. 11 [4,8,56–58]
	Anomalous Frame Dragging	Experiment	Subsequent experiments found no effect	–	–	2001	Tajmar	[2]: p.243 [59,60]
	Frame Coupling Propulsion	Speculation	Derive testable equations	Inertial frame	?	1996	Millis	[2]: p. 134–137, 160–165
Quantum Spacetime	Quantum Energy Sail	Speculation	Derive testable equations	Quantum energy	If flux sustained	1996	Millis	[2]: p. 152–154
	Vibrating Mirror Propulsion	Theory + Experiment	Explore variations having greater effect	Photons	Yes	2004	Maclay & Forward	[2]: Ch. 12 [21–23]
	Gravity/Curvature & Quantum Vacuum	Theory	Confirm & configure into propulsive embodiment	–	–		Maclay, Pinto, Calloni	[2]: p. 213–218 [30,42]
	Inertia by Vacuum or Unruh Effect	Speculation	Derive testable equations	–	–	1994, 2008	Haisch, McCulloch	[2]: Ch. 13 [37,61]
Riemannian Spacetime	Gravitational Dipole Generator	Theory	Explore variations for greater effect	Mass of Generator?	Yes	1963	Forward	[2]: p. 185
	Levi-Civita Effect	Theory	Rearrange into propulsive embodiment and explore variations for greater effect	–	–	1917	Levi-Civita	[2]: p. 198
	Space Strain, Metric Engineering	Theory	Explore variations, Examine time-rate-of-changes	Spacetime	–	1988 1994	Minami, Puthoff	[2]: Ch. 15 [20,62,63]
	Gravitational Wave Propulsion	Theory	Less efficient than a photon rocket, at best	Gravitons	Yes	1973 1997	Bekenstein, Bonner	[2]: p. 201