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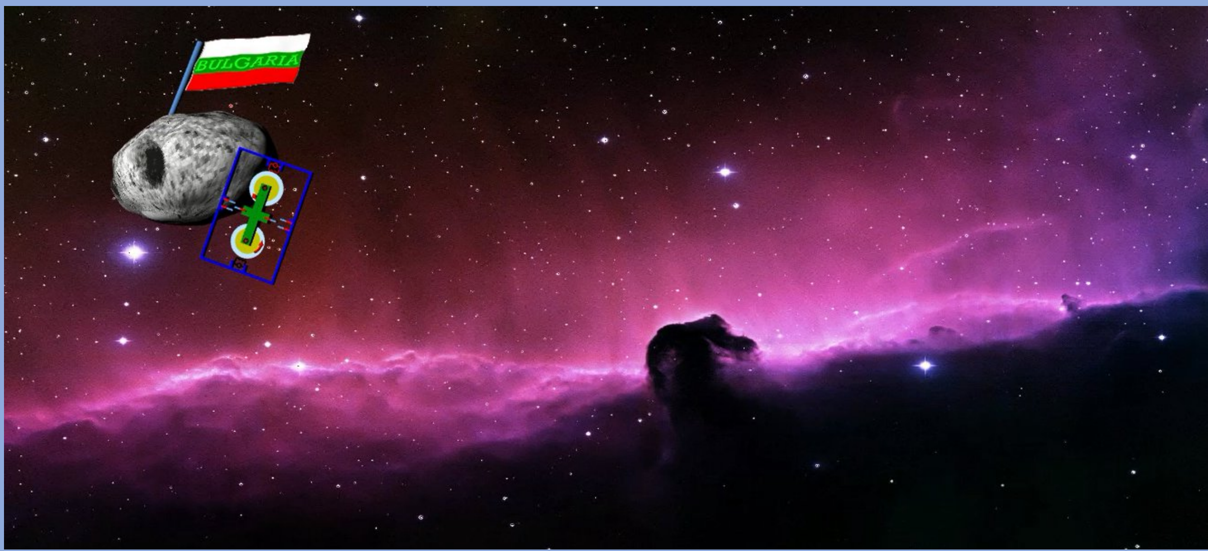


# Propulsion in Space Without Propellant

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(June 2026)

The more thoroughly we understand the laws of physics laws, the more precisely we understand what they prohibit and what they allow.

Contents

# Abbreviations:

UCM – Uncompensated Momentum
DTB – Device of Two Bodies
TCA – Two Cyclic Accelerators
ICS – Inverse Compton Scattering
CM – Center of Mass.
PWP – Propulsion Without Propellant
SC – Spacecraft
CS – Coordinate System
Be- – Bunch of electrons
RA – Resonance Accelerator
CA – Cyclic Accelerator
MXRM – Modified X-ray machine
ISS – International Space Station
LLS – Lunar Lagrangian Station
LEO – Low Earth Orbit
MOS – Mars Orbital Station

# FOREWORD

**What this book discusses.** This book should be viewed as a scientific communication on the possibility of obtaining an Uncompensated Momentum (UCM) for one of the bodies within a closed inertial system involving a Device of Two Bodies (DTB). (Or in a system of Two Cyclic Accelerators (TCA) system for elementary particles utilizing the quantum process of Inverse Compton Scattering (ICS)). As a result of this UCM, obtained only for a portion of the time of the cyclic, interrelated motions performed by the two separate bodies (also considered as two hulls) of the devices in question, we can achieve specific propulsion in space without propellant, via the so-called "3-to-2" method. Thus, we have a special case of the law of conservation of the motion of the Center of Mass (CM) of the closed inertial system DTB (or TCA), as well as the possibility of propulsion without propellant consumption. Despite the shortcomings of such specific propulsion for the devices under consideration, it is the only possible method of Propulsion Without Propellant (PWP) in space.

*(Note that, for the reader's convenience, frequently recurring terms and their abbreviations are listed at the beginning of the book. For ease of use, established abbreviations are used wherever possible, described in both English and Bulgarian. Accordingly, the reader should not be too strict regarding the newly introduced terminology, which may not align with their expectations. As in the text of the entire book, explanatory notes are provided in parentheses and italics, explaining the specific principles, conditions, and requirements for the devices under consideration.)*

*(Note that, in this case, we are considering the generation of UCM and PWP using a device consisting of two bodies (also referred to, for convenience, as a two-hull device). We treat the so-called first body of the DTB as a classical rigid body. Meanwhile, the second body of the DTB, as considered here, consists of two disks that can rotate independently relative to it. Thus, when we apply Newton's third law [1] is applied between the two hulls of the DTB, utilizing the inertia of the disks, the two disks rotate and distribute the kinetic energy of the second hull—for both rotational and translational motions—resulting in the UCM for the first hull. Accordingly, in this way, using the DTB and the defined rules and conditions discussed below, we can obtain UCM for the so-called first body of the DTB without violating the three laws of mechanics.*

*While Newton, in The Principia: Mathematical Principles of Natural Philosophy [1], examines the laws governing two classical bodies (see Corollary 4, page 421), for which UCM cannot be derived, since it would violate the laws of conservation of energy and momentum; in this case, the law of conservation of the CM's motion of the closed system applies, i.e., p=0. Consequently, the questions of where Newton went wrong and whether he was wrong at all lose their meaning, since [1] examines the laws only for classical bodies, not for a DTB device.)*

**The problem of continuous propellant consumption.** The propulsion of a Spacecraft (SC) in space is provided by a rocket engine. The operation of the rocket engine follows Newton's third law [1]. As the propellant flows out of the nozzle under pressure, it creates thrust in the opposite direction according to the law: *every action has an equal and opposite reaction*. Thus, the propulsion of a spacecraft is associated with constant propellant consumption, which makes them inefficient in terms of propellant usage. Consequently, the problem is that the propellant to be used at a later stage must be carried as payload on the SC, which accelerates each time along with the actual payload, yet is used only once at a specific point in the space mission. This is extremely inefficient and fundamentally limits long-distance space missions in two ways. The same applies to geostationary satellites used for communication, which consume propellant for orientation and orbit correction when their orbits are disrupted by solar wind particles and the gravitational influences of the Moon and planets. Consequently, once the allocated propellant is depleted, these complex and expensive geostationary satellites can no longer perform their functions, necessitating their complete replacement. This increases costs and leads to an increase in space debris and challenges for future space activities. A clear example of propellant consumption and the associated technical difficulties is manned missions and landing on the Moon's surface. For instance, the Saturn V launch vehicle has a mass of 3,038,500 kg, while the capsule returned to Earth (in this case, to the ocean surface) has a mass of only a few tons (5,806 kg). NASA's achievement of landing humans on the Moon and bringing them back (a total of 12 astronauts from 6 missions) has yet to be repeated, even though more than 50 years have passed since then.

**Solution to the problem of propellant consumption.** The main idea in this book is to demonstrate that we can achieve specific propulsion in space, within a closed inertial system DTB (or TCA), without consuming propellant, but solely by expending electrical energy.

A solution to the problem of propellant consumption can be achieved when, in a closed inertial system consisting of two bodies, we obtain UCM for one of the bodies, as discussed in Chapter 1. As discussed in Chapter 2, the UCM in question can be "obtained" repeatedly, since the DTB is now implemented as a mechanical pendulum with two springs (referred to for convenience as a "space pendulum"). In this way, periodic specific propulsion in space can be achieved without propellant consumption, using the "3-to-2" method discussed here. This specific propulsion differs from classical propulsion according to Newton's third law. Despite the shortcomings of the "3-to-2" method, it is currently the only feasible way to achieve propulsion without consuming propellant, relying solely on electrical energy generated by photovoltaic cells or a nuclear source.

**The laws of classical mechanics are not violated when the UCM is obtained.** Note that, according to the law of conservation of the motion of the center of mass of a closed inertial system, see [1] (Corollary 4, p. 421), considered as a consequence of the three laws of classical mechanics, propulsion without propellant consumption is impossible. But in fact, when we use DTB and obtain UCM (as discussed in Chapter 1, Section 1.2.2), the laws of classical mechanics are not violated. Because, as already noted, in [1] Newton examines and proves the laws governing two classical bodies, where the law of conservation of the motion of the center of mass holds (is valid). Whereas, when we use DTB and obtain UCM, there is a distribution of energy in the second body under consideration, both for the translational motion of the second body and for the rotation of the two disks (attached to the second body, which are part of the second body's mass). Therefore, for the closed DTB system, we have a special case of the law of conservation of the motion of the center of mass.

It should be noted that the single-shot UCM, as discussed in Chapter 1, Section 1.2.2, can be demonstrated experimentally in a simpler way. This is because the distances traveled, L1 and L2, for each of the two bodies (the two hulls) can be measured with high precision.

Accordingly, in Chapter 2, we can now “obtain” the UCM repeatedly, because the DTB is now constructed as a “space pendulum” with two springs, and in this case we utilize the periodicity of the pendulum according to the discussed rules. This increases efficiency and minimizes some of the undesirable effects of the “3-to-2” method (as discussed in Section 2.4).

It should also be noted that Chapter 3 discusses the production of UCM using the quantum process ICS, generated in two cyclic particle accelerators operating in sync. In this way, we obtain multiple UCMs per unit time, since the particle bunches under consideration perform multiple cycles (revolutions) per unit time in the TCA accelerators.

*(In fact, the concept of UCM and PWP first arose during an examination of the quantum process ICS and the law of conservation of energy. The ICS process strictly contextually must be executed within the TCA framework according to specific rules and conditions so that no angular momentum arises for the TCA and in accordance with the principle of superposition. Subsequently, the possibility of obtaining UCM in the DTB mechanical system was also examined. As with DTB, the same conditions are observed: no torque is generated, and the resultant vector (principle of superposition) is directed only in the specified spatial direction; in this case, we have conditionally chosen the y-axis of the right-handed coordinate system (CS) Oxyz.*

*As in this case, when deriving the UCM for DTB, the laws of classical mechanics are not violated, as discussed in section 1.3. Accordingly, both the resulting UCM and the specific case of the* law of conservation of the motion of the center of mass *for the closed system DTB do not call into question Newton’s genius as both a physicist and a mathematician, since he considers the laws only for classical bodies. Whereas in the DTB, the second body (second hull) considered in this way is comprised of two independent disks that distribute energy within the closed inertial system DTB according to the specified rules (for both translational and rotational motions).*

**Other ideas proposed to date** for achieving PWP are discussed in Section 3.5. Since propellant consumption is a major drawback of propulsion in space, various ideas for achieving propulsion without propellant consumption have been proposed and examined. As shown in Section 3.5, the main “reasons” for some of these ideas, which prevent the achievement of PWP, are outlined.

For example, no one doubts the validity of the paradigm that the literary character Baron Munchausen, by pulling on his own hair, cannot pull himself out of the swamp. This is mainly due to the fact that inertial motion (of the baron) relative to the mud of the swamp is impossible. Since friction in the mud of the swamp will stop any motion of the baron. Whereas a closed inertial system DTB (or TCA), located in space, may be at rest relative to CS, but may also be in translational motion relative to CS, since in this case there is no “friction” between “space” and DTB. Consequently, even the smallest impulse (or UCM, when conditions permit) can change rest into translational motion relative to CS.

**Chapter 4 examines** the drawbacks, optimization, advantages, and applications of propellant-free propulsion in space. It highlights the disadvantages and advantages of using UCM and PWP. It also discusses the potential to solve certain problems, such as space debris, protection against Earth-threatening asteroids, and the construction of space bases and orbital stations that could also be used for deep-space missions. As well as the author's specific idea for the terraforming of Mars. This can be achieved by initially heating its surface. This would utilize the potential energy of falling meteorites resulting from a head-on collision between the natural satellite Phobos and asteroids, which have been pre-positioned via the PWP method into orbits suitable for such a collision.

It should be noted that through UCM and PWP, we also have the opportunity to exploit space resources and extract rare and valuable minerals from asteroids and comets. Such extraction ideas have been considered to this day, due to the problem of dwindling Earth resources and pollution on Earth. Since the exploitation of such space resources offers a high return on investment and is economically very profitable. Because "space transport" will no longer require propellant; instead, it will rely solely on energy from photovoltaics, or nuclear energy where solar intensity is low.

**It should be noted that, for the reader's convenience,** since we are examining a new paradigm for propulsion in space, we are considering the most intuitive technical solutions—those that are easiest to analyze and demonstrate—rather than the best technical solutions that could actually be implemented. Such is the case, for example, with the application of the third law, which is, so to speak, the basis of the devices through which we obtain UCM.

As in the case of the DTB mechanical system, the third law is implemented through the interaction of electromagnets (attached to the first body) and permanent magnets (attached to the disks of the second body). In this case, it is necessary to clarify that the angular position of the permanent magnets in question, attached to the disks (for example, via optocouplers), must also be known (accounted for) in order for the DTB to function correctly. There is also the mandatory condition that, in this case, the electromagnets to which an electrical pulse of precisely defined duration is applied are coils without magnetic cores. In this way, the condition is achieved that once the disks are set in motion, they remain in that state. Consequently, stopping the rotation of the disks, necessary for a new cycle (as discussed in Chapter 2), must be performed by the second body (second hull) under consideration.

However, the application of the third law between the two bodies of the DTB and the generation of the UCM can also be achieved in other ways. For example, the electromagnets attached to the first body could serve as the stator of a multiphase electric motor. Accordingly, the disks of the second body could serve as the rotor of the electric motor. In this way, the requirement for permanent magnets to be attached to the disks under specific conditions is eliminated. However, explaining the operation of such an electric motor, which requires specific conditions and time periods, would be quite lengthy and complex, which is not desirable in our case.

In fact, applying Newton's third law between the two bodies of the DTB and generating the UCM can also be achieved by replacing the electromagnets with mechanical "triggers" (micro-flywheels or similar devices) that deliver a single, synchronized burst of energy to the disks to set them in motion. However, in reality, synchronizing such a mechanical system in practice would be extremely difficult. On the other hand, when using electromagnetic interactions, strict synchronization is achieved more easily. For example, the two coils attached to the first body (acting as electromagnets or stator coils), when connected in parallel to their "power source," are already strictly synchronized in time. Furthermore, the two coils have the same "power," since they are, by definition, manufactured identically. Any minimal difference in the coils themselves (or difference in the mass of the disks) can easily be corrected electronically via a microcontroller and a suitable algorithm, so that the actual operation of the DTB is fully consistent with the theoretical requirements and analysis.

It should be noted that the mathematical apparatus in this book is kept to a minimum. Instead, the emphasis is on the engineering and practical nature of the devices. The aim in using these devices is to demonstrate that they do not conflict with the laws of classical mechanics, and that they are intuitive and easy to explain and understand, rather than presenting the most optimal technical solutions (which are often cumbersome and difficult to explain). A complete mathematical framework, as well as specific technical solutions and devices, can be examined in a separate book. However, in this case, it must be noted that a complete mathematical framework cannot be examined until the exact laws governing certain nonlinear coefficients of the dynamic processes are empirically determined (and proven) using a real model. These coefficients are unknown to the authors, and likely to the entire scientific community as well, since the case of UCM and PWP has not been examined to date.

*(Note that, for the reader's convenience, the book includes computer animations illustrating the dynamics of the processes that cannot be shown in the figures. These animations are included in the References section (listed as links) and can be viewed on the authors' website https://ldg2.com/en/anim-all/*
*as well as on the authors' YouTube channel*
*https://www.youtube.com/playlist?list=PL5qXXi67lS_ezvZMtzTT49s36eK2LZoGU*
*As with each individual animation, of the seven shown, the focus is on a specific process (or effect), which in some cases has been intentionally magnified for the purpose of visual demonstration.*

*Note that for the sake of continuity, the drawings and animations also show components that do not participate (are not used) in the specific case under consideration, but are a key component in the next case under consideration. For example, in [7] VARIANT-1, the bearings are locked and therefore not used, but they are shown. Conversely, in [7] VARIANT-2, the bearings are now used and serve as a key component of the processes under consideration.)*

It should be noted that, since we are examining a new paradigm for UCM and PWP in this case, the explanations are quite extensive. This raises the question of where to begin and what to describe first, so that the explanations are coherent and understandable. This is because, regardless of the approach used, some of the described processes and patterns will always be explained last. Although various approaches were considered for the initial introduction and description, no universal solution was found. Even in this preface, preliminary conclusions are drawn, which are later examined and proven in the individual chapters, for which the authors apologize to the readers. Therefore, it is recommended that each reader, after a preliminary review, determine for themselves, according to their own interests and knowledge, the preferred order and approach for examining the individual cases.

It should also be noted that, for a fuller understanding of the nature of the cases under consideration, it is not always appropriate to use new terms. Since this would complicate the explanations as a whole. Therefore, in many cases, words from everyday language are used, but placed in quotation marks, making it clear that the meaning of the word or the action described should not be taken literally. For example, the following example is used: *The use of liquid hydrogen and oxygen in booster rockets as propellant offers the best mass-to-thrust efficiency, and the end product of the "combustion" is environmentally friendly water.* In this case, *"combustion"* is used to describe the chemical reaction between oxygen and hydrogen, in which a significant amount of heat is released and water is produced.

# CHAPTER ONE

# A Special Case of the Law of Conservation of the Motion of the Center of Mass of a Closed System—A Device of Two Bodies (Two Hulls), Uncompensated Momentum and Propulsion in Space Without Propellant

## 1.1. Introduction

The propulsion of a Spacecraft (SC) in space is achieved by a rocket engine. The operation of the a rocket engine follows Newton's third law [1]. As the propellant exits the nozzle under pressure, it creates thrust in the opposite direction of the escaping gases, according to the law: *for every action, there is an equal and opposite reaction*. Thus, SC propulsion involves a constant consumption of propellant, making them inefficient in terms of propellant consumption. The problem is that the propellant to be used at a later stage must be carried as payload on the SC, which is accelerated each time along with the actual payload, yet it is used only once during a specific phase of the space mission. This is extremely inefficient and limits long-distance space missions in two ways, as well as all SCs that consume propellant for orientation and orbit correction.

To increase efficiency and reduce propellant consumption, so-called electric propulsion systems for SCs have been developed. The various types of electric propulsion, their basic principles of operation, advantages, and disadvantages are presented in [2–6]. Ion accelerators are considered the most promising; in these, ions are accelerated by electric and magnetic fields to a velocity greater than that achieved by thermochemical rocket engines, which reduces propellant consumption by several times. Disadvantages of electric propulsion include: propellant consumption, low thrust, the need for a powerful power source, erosion of the discharge chamber during prolonged operation, as well as the requirement to "eject" ions and electrons into space in a specific manner to prevent the SC from becoming electrically charged. The T6 ion engine, used on the BepiColombo mission to Mercury [6], is considered the best solution for an ion engine still in operation today.

The problem of continuous propellant consumption can be solved by utilizing the Device of Two Bodies (DTB), also described as a two-hull device. (Or through Two Cyclic Accelerators (TCA), which utilize the quantum process of Inverse Compton Scattering (ICS), discussed in a separate chapter.) In this chapter, we will examine and prove the attainment of Uncompensated Momentum (UCM) for one of the DTB's hulls. As a result of this UCM, we have a special case of the law of conservation of the motion of the center of mass of the closed DTB system. This creates the possibility of specific DTB propulsion in space without propellant consumption, obtained only during certain time periods of the cyclic motions of the two hulls. Although the specific propulsion obtained in this way has its shortcomings, for now, this is one of the ways in which we can achieve Propulsion Without Propellant (PWP) in space.

## 1.2. Obtaining and Verifying Uncompensated Momentum and a Special Case of the Law of Conservation of Center of Mass Motion for a Closed System: A Two-Hull Device

Fig. 1.1 illustrates the Device of Two Bodies (DTB), conceptualized as a closed inertial system in a weightless space environment. Note that, for the sake of consistency, the figures show all DTB components required for the various examples and variants under consideration. For example, the four bearings shown as 10 and 10', see Fig. 1.1(b), are not included in the analysis of the so-called first variant; in this case, we consider these bearings to be locked (stuck, non-operational). In contrast, in the second variant under consideration, the bearings play a key role, as they ensure that the two disks can rotate and remain in a rotating state.

Fig. 1.1 shows the design of the closed inertial system DTB, consisting of two bodies, referred to for convenience as two hulls. The first body, designated in the figures by the number 1, is hull H1. And, respectively, the second body, designated in the figures by the number 2, is the hull H2, to which two disks are attached. For the sake of convenience, let us assume that the masses of hulls H1 and H2, together with the additional components attached to each of them, are equal to $m_{H1}$ = $m_{H2}$. Note that if hulls H1 and H2 are considered independently, their geometric centers (GCH1 and GCH2) coincide with the Center of Mass (CM) for each hull. In this case, the hulls are positioned such that the geometric centers of each hull coincide with the CM of the DTB, as illustrated in the figures as GC.

A pair of additional components is always mounted on hulls H1 and H2, symmetrically with respect to CM for each. Mounted on hull H1 are two electromagnets, 5 and 6, referred to in the text as EM1 and EM2. As well as a power source and control electronics, which are not shown in the drawings. *(There are various technical solutions for EM1 and EM2. For this specific case, we assume that the coils of EM1 and EM2 have no magnetic cores, and the angular position of the permanent magnets—discussed further below in the text (Fig. 1.2)—mounted on the disks is monitored via optocouplers.)*

Four bearings 10 and 10' are mounted on the H2 hull at equal distances from CM; see Fig. 1.1(b). The outer ring of each bearing is secured to the H2 hull, and the inner rings of the bearings are secured to shafts 9 and 9', to which disks 7 and 7'—referred to in the text as D1 and D2—are attached. This allows D1 and D2 to rotate independently and freely along with their shafts relative to the hull H2.

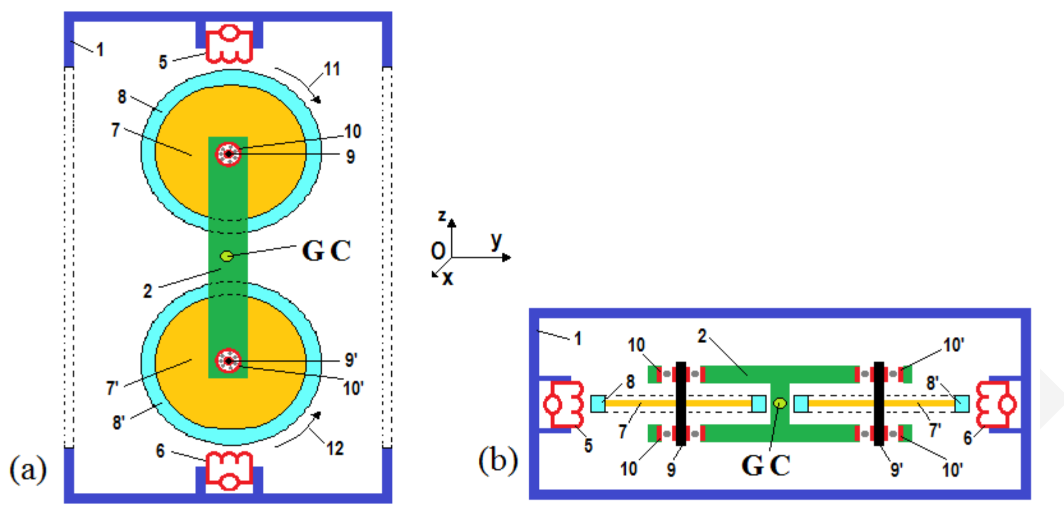


Fig. 1.1 (color) (a) DTB structure, view along the z-axis; (b) DTB structure, view along the y-axis:

(a) 1 – hull H1; 2 – hull H2; 5 and 6 – electromagnets EM1 and EM2; 7 and 7‘ – disk D1 and disk D2; 8 and 8‘ – periphery of D1 and D2 (made of permanent magnets visible only in Fig. 1.2); 9 and 9‘ – axes to which D1 and D2 are attached; 10 and 10‘ – bearings, with axes 9 and 9‘ attached to the inner ring and the outer ring attached to hull H2; 11 and 12 – direction of rotation of D1 and D2; GC – geometric center of H1 and H2;

(b) 1 – hull H1; 2 – hull H2; 5 and 6 – electromagnets EM1 and EM2; 7 and 7′ – disk D1 and disk D2; 8 and 8′ – the periphery of D1 and D2 consisting of permanent magnets; 9 and 9‘– shafts to which D1 and D2 are attached; 10 and 10‘– bearings; shafts 9 and 9‘ are attached to the inner ring, and the outer ring is attached to hull H2; GC – geometric center of H1 and H2

The H2 hull is positioned in the center of H1 (see Fig. 1.1), and this state, with coinciding GCs, is maintained for the closed DTB system in space as long as no force is applied, i.e., as long as no electrical power is supplied to EM1 and EM2. Disks D1 and D2 have identical dimensions and equal masses, and their peripheries 8 and 8’ consist of a set of permanent magnets arranged in a suitable manner (Fig. 1.2 shows only one magnet per disk, numbered 13 and 13’). Since the majority of the mass of D1 and D2 (and consequently of H2) is concentrated in the periphery under consideration, the goal is to achieve maximum moment of inertia. When an electrical pulse is applied to EM1 and EM2 (once, for a “short” interval of time, referred to as time $t_{EM}$ later in the text), the magnetic fields of EM1 and EM2 will interact with the permanent magnets on the disks. If the poles of the permanent magnets 13 and 13’ are oriented as shown in Fig. 1.2, and the start and end of the coils of EM1 and EM2 are aligned with this orientation, respectively, then the magnetic fields of EM1 and EM2 and the permanent magnets on the disks will repel each other, in accordance with Newton's third law. And since all acting forces are equal and symmetric with respect to the CM of the DTB, then according to the principle of superposition and vector addition, the hulls H1 and H2 do not experience torque, but only translational motion along the y-axis. Accordingly, the two hulls will move away from each other along the y-axis without restriction. This is because, in this case, the design of the DTB allows for this (as clearly shown by the dashed lines on the vertical edges of body H1; see Fig. 1.1, Fig. 1.2, and ANIMATION-1 in [7]). We track the motions of the two bodies relative to the Oxyz Coordinate System (CS) or alternatively, relative to the initial position of the DTB's CM, since in this case, for the sake of convenience, we assume that the DTB initially has zero velocity relative to the CS (see Fig. 1.3 and [7]).

### 1.2.1. Variant 1

Let's first consider the case where bearings 10 and 10' on the disks are not functioning (they are rigidly locked); see Fig. 1.2(a). In this case, the hull H2 represents a single body (a classical rigid body) on which the two electromagnets EM1 and EM2, through their magnetic fields and the rule for vector addition, can act on the permanent magnets attached to the disks. In this analysis, we have a classical formulation and application of Newton's third law for the closed system of the two bodies (hulls H1 and H2). Since a single application of an electrical pulse to EM1 and EM2 will result in equal actions and reactions, bodies H1 and H2 will acquire equal kinetic energies $E_{H1} = E_{H2}$. Consequently, H1 and H2 will have equal translational velocities $V_{H1} = V_{H2}$, equal momenta $P_{H1} = P_{H2}$, and consequently, the two bodies will travel equal distances L1 = L2 relative to CS during the time we consider as a "unit of time" (see Fig. 1.3, [7] VARIANT-1). That is, the geometric centers of the two bodies (GCH1 and GCH2), at every moment in time, will have traveled equal distances along the y-axis and, accordingly, will be located at equal distances relative to CM, in accordance with the law of conservation of the motion of the center of mass of a closed system (see [1] Corollary 4, page 421). Since, in this case, the entire kinetic energy of each of the two bodies is in the form of translational motion (see Fig. 1.3, [7] VARIANT-1).

Note that, since the magnetic forces from EM1 and EM2 to the permanent magnets on D1 and D2 are equal and symmetrical with respect to CM, no torque is exerted on H1 or H2. Accordingly, the vectors from each electromagnet, see Fig. 1.2(a), shown as ½ $P_{H1}$, according to the rule for vector addition, give a resultant vector directed along the y-axis. And accordingly, the vectors from each permanent magnet, shown as ½ $P_{H2}$, give a resultant vector directed along the y-axis, but in the opposite direction to the translation vector of hull H1.

In this case, Newton's third law is satisfied,

$$\vec{F}_{12} = -\vec{F}_{21}, \tag{1.1}$$

where $F_{12}$ is the force with which EM1 and EM2 act on D1 and D2, and $F_{21}$ is the force with which D1 and D2 act on EM1 and EM2.

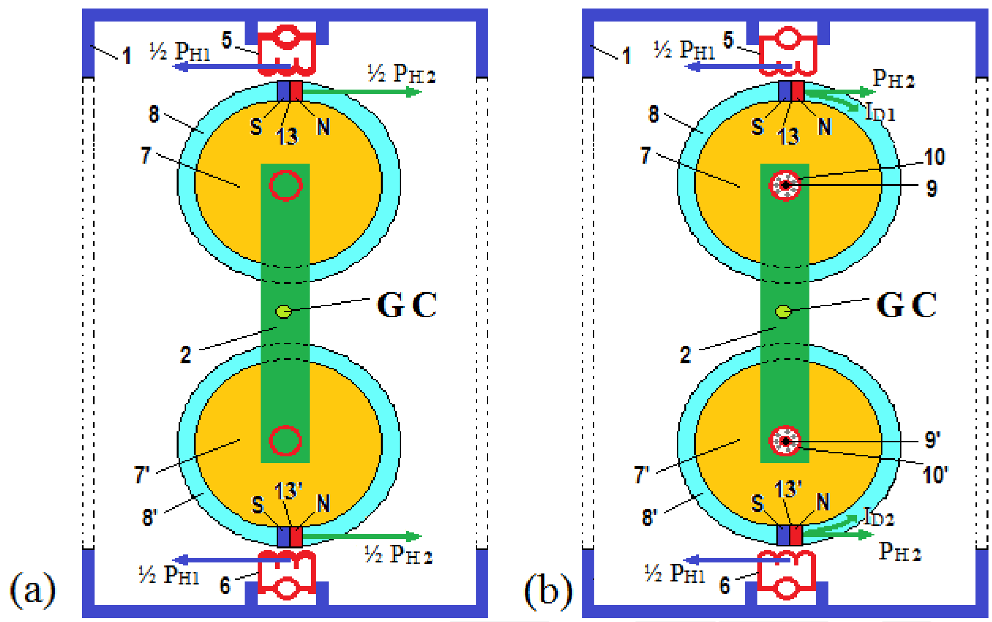


Fig. 1.2 (color) The interaction vectors between the two hulls are shown when an electrical pulse is applied to EM1 and EM2; (a) when the bearings are not operating (locked-bearing configuration); (b) when the bearings are operating (are not locked):

(a) 13 and 13’ – permanent magnets comprising the periphery 8 and 8’ of D1 and D2, positioned symmetrically about the axis of each disk; in this case, only one is shown with a specific orientation of the magnetic poles; the interaction vectors (½ $P_{H1}$ , ½ $P_{H2}$ ) between EM1, EM2, and the permanent magnets attached to the disks are shown when an electrical pulse is applied to EM1 and EM2 and the bearings are not operating (locked-bearing configuration); GC – geometric center of H1 and H2; for the remaining components, the numerical numbering is as in Fig. 1.1;

(b) the interaction and torque vectors ($I_{D1}$ , $I_{D2}$ ) between EM1 and EM2 and the permanent magnets 13 and 13’ when an electrical pulse is applied to EM1 and EM2 and the bearings are operational (not locked), GC – geometric center of H1 and H2; component numbering for all remaining structural elements is identical to Fig. 1.1

*(Note that, forces acting along a single axis can be written without vectors; for convenience, the arrow for the vectors is omitted throughout the text, since the resultant vector is always directed along the y-axis.*

*Furthermore, Newton’s third law (1.1), rather than through the interaction of magnetic forces between EM1, EM2, and the permanent magnets 13, 13’, can also be achieved (fulfilled) in other ways. For example, the periphery of D1 and D2 (8 and 8’), instead of being composed of multiple permanent magnets (shown as 13 and 13’), could be formed by a magnetically conductive material, and accordingly, the electromagnets EM1 and EM2 could be constructed from several coils, as is the* *case with multiphase electric motors. Or EM1 and EM2 could be replaced by mechanical micro-flywheels. The energy previously stored in the mechanical flywheels would be "released" simultaneously and "transmitted" to the two disks (via appropriate mechanical transmissions and triggers). Accordingly, in all the methods discussed above, rotation of the two hulls will not occur, and the resultant vector will always be "directed" along the y-axis.*

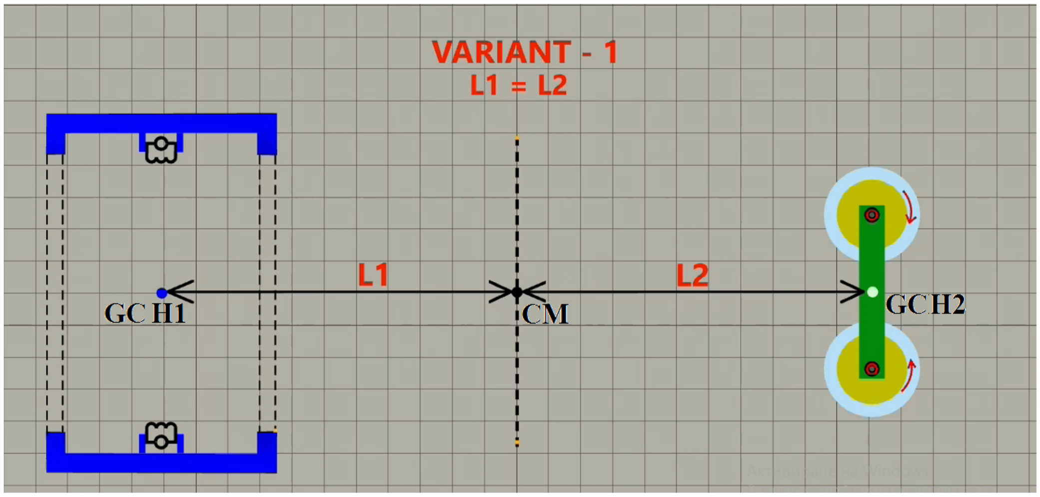


Fig. 1.3 (color) Location of the geometric centers of the hulls H1 and H2 (GCH1 and GCH2) and CM of the DTB relative to CS. In this "snapshot," after the third law has been applied and the specified time has elapsed (referred to, for convenience, as a "unit of time"). Accordingly, we have equality of the distances traveled *L1 = L2*, in accordance with the law of conservation of the motion of the center of mass, as discussed in [1]

## 1.2.2. Variant 2

Let us now consider a second variant, where the disk bearings are operational (not locked); see Fig. 1.2(b), as is actually the case with the DTB device. As in this case, the two hulls again experience equal forces and reactions according to (1.1), as well as equal kinetic energies $E_{H1} = E_{H2}$ , when a single electrical pulse is applied to EM1 and EM2 over the time $t_{EM}$. Since the total kinetic energy $E_{H1}$ of body H1 is in the form of translational motion,

$$E_{H1} = \frac{1}{2}\, m_{H1}\ V^2{}_{H1}\,, \tag{1.2}$$

where $m_{H1}$ is the mass of body H1, and $V_{H1}$ is the velocity of H1.

Accordingly, body H1 has momentum $P_{H1}$,

$$P_{H1} = m_{H1}\ V_{H1}\ . \tag{1.3}$$

However, in this case, the forces from EM1 and EM2 acting on H2 are mediated by the inertia of D1 and D2 and the moment of inertia $I_{D1D2}$,

$$I_{D1D2} = (m_{D1} +\ m_{D2}) *\ R^2, \tag{1.4}$$

where $m_{D1}$ and $m_{D2}$ are the masses of D1 and D2, and R is the radius of the disks. *(Note that, the moment of inertia of each disk depends not only on its mass and radius, but also on how the mass is distributed across the disk. This is usually given by a coefficient for a specific mass distribution on the disk itself. For a disk where the mass is distributed in a thin periphery, the coefficient is 1; for a solid disk, the coefficient is 0.5, and so on. In our case, we are considering an idealized disk with a coefficient of 1.)* And through the axes of D1 and D2 (according to the rule for vector addition), part of $E_{H2}$is converted into translational motion of H2 along the y-axis. In this case, since kinetic energy is an additive quantity, the body H2 can perform both translational and rotational motions on D1 and D2 simultaneously. And the total kinetic energy $E_{H2}$ of the body H2 is the sum of the kinetic energy of the rotational motions $E_{H2R}$ of D1 and D2, plus the kinetic energy of the translational motion $E_{H2M}$ of the body H2,

$$E_{H2} =\ E_{H2R}\ +\ E_{H2M}. \tag{1.5}$$

$$E_{H2R}\ =\ \frac{1}{2}\ I_{D1D2}\ \omega^2, \tag{1.6}$$

where ω is the angular velocity of D1 and D2.

$$E_{H2M} = \frac{1}{2}\ m_{H2}\ V^2{}_{H2}\,, \tag{1.7}$$

where $m_{H2}$ is the mass of body H2, and $V_{H2}$ is the translational velocity of body H2. Therefore, body H2 has a momentum $P_{H2}$,

$$P_{H2} = m_{H2}\ V_{H2}. \tag{1.8}$$

Accordingly, due to the distribution of the kinetic energy $E_{H2}$ of body H2, for the rotational motions $E_{H2R}$ of D1 and D2 and the translational motion $E_{H2M}$, we also have the different velocities of the translational motions of bodies H1 and H2, $V_{H1} > V_{H2}$. Consequently, body H1 has greater momentum than body H2, $P_{H1} > P_{H2}$, and the difference between the momenta in this case is the uncompensated momentum for H1 in the closed system DTB. Consequently, per "unit of time" relative to CS, body H1 will travel a greater distance L1 along the *y*-axis compared to the distance L2 traveled by body H2, L1 > L2 (see Fig. 1.4, [7] VARIANT-2).

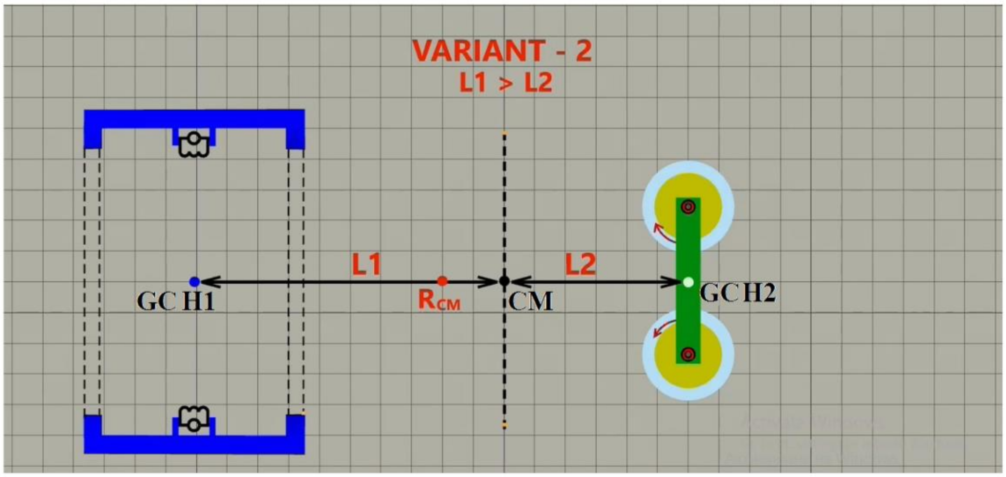


Fig. 1.4 (color) Location of the geometric centers of the H1 and H2 hulls (GCH1 and GCH2) and the resulting center of mass $R_{CM}$ of the DTB relative to CS, with the bearings in operation. In this "snapshot," after the third law has been applied and the specified time—considered as a "unit of time"—has elapsed. The distances of the geometric centers GCH1 and GCH2 relative to the initial position of CM of the DTB are now different: L1 > L2.

What is important in this case is that $E_{H1} = E_{H2}$ according to (1.1), but $E_{H2}$ is the sum of the kinetic energy of the rotational and translational motions (1.5). Meanwhile, the entire kinetic energy $E_{H1}$ (1.2) of the body H1 is in translational motion. Consequently, the kinetic energy and momentum of H2, with which the translational motion $E_{H2M}$ (1.7) is performed, is less than $E_{H1}$ (1.2); accordingly, the momentum and the distance traveled by H2 are also less, L1 > L2. However, since the CM of the closed system DTB is determined by the mass of the two bodies comprising the system itself (bodies H1 and H2, $m_{H1} = m_{H2}$), the CM is located at the center of the two bodies at every moment in time. Shown as the resultant center of mass $R_{CM}$ of the DTB and displaced relative to the initial position of CM, see Fig. 1.4, [7] VARIANT-2. Therefore, the law of conservation of motion of the CM of the closed system DTB does not hold in this case (variant).

*(Note that, by definition, the masses of the two bodies are equal: $m_{H1} = m_{H2}$, the resultant center of mass $R_{CM}$ of the DTB is always located midway between the geometric centers GCH1 and GCH2 of the two bodies. In this case, the introduced term "resultant center of mass $R_{CM}$ of the DTB" helps us visually demonstrate and distinguish the CM of the DTB from its initial position. Since, for convenience, in the "snapshot" shown here, the location of $R_{CM}$ and the initial location of the CM of the DTB relative to CS can be "shown" on the drawing, even though neither CM nor $R_{CM}$ are actual physical points. The convenience of actually "showing" CM and $R_{CM}$ is only possible when the DTB has zero initial velocity relative to the CS, as shown (and discussed) in Fig. 1.4, [7] VARIANT-2)*

## 1.3. On Some Theoretical Questions Regarding the Case of Obtaining Uncompensated Momentum and a Special Case of the Law of Conservation of the Motion of the Center of Mass of a Closed System – a Two-Hull Device

The considered special case of the law of conservation of the motion of the center of mass of the closed system DTB and the possibility of propulsion without propellant consumption will likely raise a number of theoretical questions. As a brief summary, we will clarify the questions raised by the case, obtaining the UCM for one of the hulls (one of the bodies) of the closed inertial system DTB. As a result of this UCM, we also have a special case of the law of conservation of the motion of the center of mass of the closed system DTB.

The paradigm that propulsion in space without propellant consumption is impossible is linked to the law of conservation of the motion of the center of mass of a closed system. This law is regarded as a consequence of the three laws of classical mechanics; see [1] Corollary 4, page 421. But in fact, as we have already seen, the derivation of UCM does not violate any of the three laws of classical mechanics. This leads us to answer the question: Was Newton wrong, and if so, where did he go wrong?

It should be noted that in *The Principia*: *Mathematical Principles of Natural Philosophy*, Newton examines and proves the classical laws of mechanics, as well as the gravitational forces acting between bodies. Furthermore, all examples discussed in [1] are correct, including the example discussed in Corollary 3 on page 420 of [1]. There, Newton considers a case where two bodies in a closed inertial system, upon interaction between the bodies (when the third law is applied), each of the bodies, in addition to translational motion, may also acquire rotation about its own center of mass. As in this case, the law of conservation of the motion of the center of mass of the closed system is true (holds), despite the brief explanation of this case considered only in the last two sentences of Corollary 3. Because, as a consequence of the third law, the two interacting bodies always receive equal and opposite actions (motions), as well as equal and opposite rotational motions (when conditions permit), which always mutually compensate each other. Thus, the momentum in the closed system is always equal to zero, $p = 0$, as is usually presented in textbooks. The fact that all examples discussed in [1] are correct, as well as Newton's authority, likely played a role in the post-Newtonian acceptance of the indisputable fact that propulsion in space without propellant consumption is impossible, and thus any consideration contrary to this is deemed meaningless.

For example, when we have two "standard" bodies (as in the first case) and the interaction between them is governed by Newton's third law, the law of conservation of the motion of the center of mass of a closed system holds true. But when there is interaction between the bodies (the hulls) via Newton's third law and the inertia of the two disks (as we consider in the second variant). Since these disks are part of the H2 body of the DTB, the energy of the H2 body is now distributed between the translational motion and the rotational motions of the two disks. Accordingly, we obtain UCM for the H1 body without violating any of the three laws of classical mechanics. From this, we can conclude that the law of conservation of the motion of the center of mass of a closed system holds true for all cases considered in [1], i.e., according to [1], Newton was not mistaken. However, [1] does not consider special cases such as: the possibility of obtaining UCM in devices such as DTB, or in devices using the Inverse Compton Scattering process. *(In fact, [1] also does not consider the motions of three gravitationally interacting bodies, nor the intermediate axis theorem [8].)* Since these cases were not known at the time, they were not on the "agenda" and were therefore not considered.

What is new in the UCM formulation is that the two bodies do not undergo rotational motion about their own CM during the time interval $t_{EM}$(as shown and discussed in [1], Corollary 3, page 420). This is because all components and acting forces occur in pairs, with equal masses, operating synchronously, and are symmetrically positioned relative to the CM. As in the case of the second variant, rotational motions, but in opposite directions, are experienced by D1 and D2, because the action and reaction between the two bodies are determined by the inertia of D1 and D2. Accordingly, due to the design of the DTB, the resulting vector for both bodies is always directed along the y-axis, but in opposite directions. Because at time $t_{EM}$ (1.1), bodies H1 and H2 experience equal actions and reactions, as well as equal kinetic energies $E_{H1} = E_{H2}$. Since the total kinetic energy $E_{H1}$ (1.2) of body H1 is in translational motion. Meanwhile, the kinetic energy of body H2, $E_{H2}$ (1.5), is distributed both to the rotational motions of disks D1 and D2, $E_{H2R}$ (1.6), and to the translational motion of body H2, $E_{H2M}$ (1.7). Consequently, we obtain UCM for body H1, respectively $V_{H1} > V_{H2,}$ $PH_1 > P_{H2M}$ and L1 > L2. As in a real experiment demonstrating UCM, it is most convenient to measure the distances L.

If we assume that the law of conservation of the motion of the center of mass also holds true for the second variant, then the law of conservation of energy within the closed system will be violated, because it requires $V_{H1}= V_{H2}$, $P_{H1} = P_{H2M}$ and L1 = L2. But this requirement cannot be met, since at time $t_{EM}$ both bodies receive equal forces and energies $E_{H1} = E_{H2}$, but $E_{H2}$ (1.5) is the sum of $E_{H2R}$ (1.6) and $E_{H2M}$ (1.7). Accordingly, in the closed DTB system, there is no other way for D1 and D2 to "acquire" energy for their rotational motions except from the distribution of $E_{H2}$ (1.5); in all other cases, the law of conservation of energy would be violated. Consequently, the derived UCM and the special case of the law of conservation of motion of the CM in the closed system DTB can also be proven via the law of conservation of energy, since the energy for the rotation of D1 and D2, $E_{H2R}$ (1.6), simply has nowhere else to "come from" except from the distribution of kinetic energy $E_{H2}$ (1.5).

## 1.4. Conclusions

The capability to obtain UCM through a DTB (or TCA) opens up new possibilities for the PWP of SC in space. In this chapter, we have considered only the single-instance generation of UCM. As we have also proven, this special case of the law of conservation of the motion of the CM of the DTB has no contradictions with the law of conservation of the motion of the CM of classical bodies, as discussed in [1]. Accordingly, in the following chapters, the DTB is considered (constructed) as a cyclic device, thereby allowing us to obtain UCM multiple times. Despite the optimizations discussed below, the PWP also has some drawbacks.

However, despite these shortcomings, through the resulting UCM and PWP, a number of problems associated with modern space activities and missions can be solved, such as protection from Earth-threatening asteroids, the problem of space debris, and the construction of space bases and orbital stations. Furthermore, it unlocks the economic feasibility of deep-space resource harvesting, enabling the automated extraction and transport of high-value minerals from asteroids and comets. Such ideas are still being considered today, a consequence of dwindling Earth resources and pollution on Earth. This is because the exploitation of such space resources offers a high return on investment and is economically very profitable. Since “space transport” will no longer require propellant, but will rely solely on energy generated by photovoltaics or nuclear power [9–11].

synchronously. Because both motion-stopping processes are independent of each other and do not induce torque on the DTB, they must be performed at precisely defined moments of the cycle (see Fig. 2.3 and ANIMATION-3 [14]).

Note that, at the beginning of the time interval $t_{EM}$ , when the two bodies are in equilibrium (with coinciding GCs, as shown in Fig. 2.2(a) ), the resultant vectors of the magnetic fields through which EM1 and EM2 act on the periphery of disks D1 and D2 are maximal. However, at the end of the time interval $t_{EM}$ , since the bodies H1 and H2 are now displaced relative to each other (as shown in Fig. 2.5), the action of the magnetic field vectors is correspondingly reduced (albeit to a minimal value). Because these reduced magnetic field vectors mutually cancel each other out, we do not obtain any torque or other effects for the DTB, except that the efficiency of the resulting UCM deteriorates by a factor proportional to the displacement between the hulls. Therefore, the requirement for DTB operation is that the time interval $t_{EM}$ be several times shorter than the time interval $t_1$ , $t_1 > t_{EM}$ (see the timing diagram in Fig. 2.3).

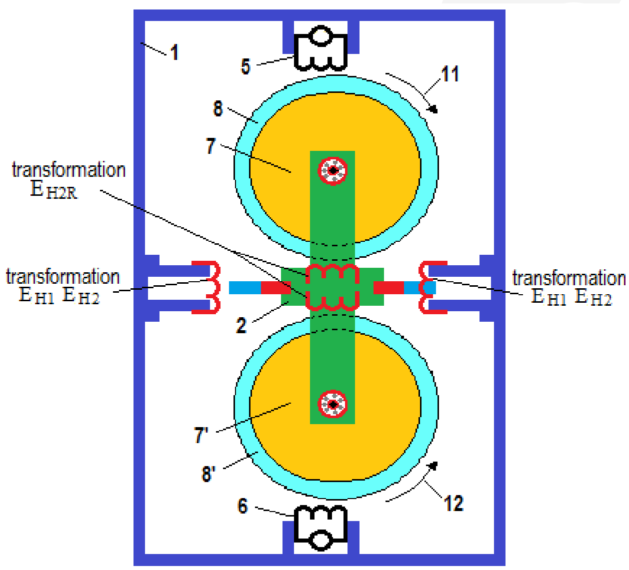


Fig. 2.5. (color) The positions of hulls H1 and H2 relative to the CM are shown when spring 4 (not shown in this drawing) has energy Umax. The coils used to stop the rotational motions are shown—transformation $E_{H2R}$ on disks D1 and D2. Also shown are the coils—transformation $E_{H1}$, $EH_2$—through which the translational motions of hulls H1 and H2 are stopped. EM1 and EM2 are turned off after the time period $t_{EM}$ (shown in black) while the coils transformation $E_{H2R}$, $E_{H1}$ and $E_{H2}$ are active (on, shown in red).

## 2.4. Optimization of the Propellantless Propulsion Method

Propulsion without propellant consumption using the “3-to-2” method can be achieved when the specified conditions are met in a suitable device and UCM is achieved. The design of the DTB, as well as the coordinated operation of pairs and groups of DTBs mounted on the common SC hull (see Fig. 2.6), can significantly improve efficiency and mitigate the shortcomings of the “3-to-2” method.

**Minimizing the shortcomings of the "3-to-2" method**. Figure 2.6 shows two pairs of DTBs, numbered sequentially as 1 and 2. The hull H1 of each DTB is attached to the hull of the SC, shown in the drawing as HULL of SC. Each of the numbered DTB pairs is positioned symmetrically with respect to the axis on which the CM of the SC lies (shown in the drawing as Line of CM).

When all DTBs operate synchronously, there is no torque on the SC. There will also be no torque on the SC when each of the numbered pairs of DTBs operates with a phase shift in the cycle relative to the other pair, i.e., the two parts of the cycle $t_1$and $t_2$considered here are out of phase and do not coincide in time for the two pairs of DTBs.

However, what is important in this case is that such out-of-phase operation of the two DTB pairs leads to a reduction (minimization) of the "3-to-2" method vibrations under consideration, which are an undesirable effect (accelerations) in the propulsion process; see Fig. 2.4. This is because for the DTB pair, which we conditionally consider as the first (numbered 1 in the drawing), at time $t_1$, the resultant vector coincides with the direction of motion of SC, i.e., the H1 bodies (and consequently SC) increase their speed relative to CS at time $t_1$. Whereas at time $t_2$, the H1 bodies of the first DTB pair considered in this way tend to decrease their current velocity relative to CS, see Fig. 2.4. But at the same time $t_2$, for the second DTB pair under consideration, which operates out of phase, the resultant vector of H1 bodies "will strive" to increase their velocity relative to CS. Thus, the resulting velocity of SC relative to CS, derived from each successive cycle, is the difference in the velocities of H1 for the two parts of the cycle $t_1$and $t_2$under consideration, see Fig. 2.4. Furthermore, we can use multiple pairs of DTBs, with each DTB pair being appropriately phase-shifted relative to the other pairs. This will significantly reduce the "magnitude" of the "3-to-2" vibrations of the SC hull under consideration. In this way, the vibrations (or unwanted accelerations) considered in this manner will no longer be a problem for the crew or the equipment located on the SC. It should be noted that the "3-to-2" vibrations considered in this way can be reduced significantly, but 100% elimination of the vibrations is impossible.

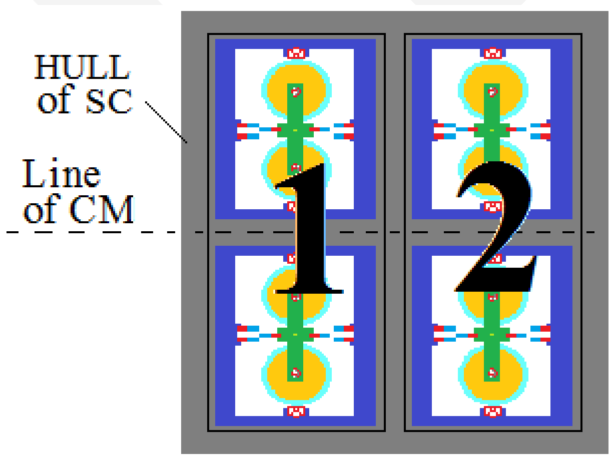


Fig. 2.6. (color) The figure shows the configuration of the SC and two pairs of DTBs, numbered sequentially 1 and 2, as viewed along the z-axis. The H1 hull of each DTB is attached to the SC hull, shown in the drawing as the HULL of SC. Each of the numbered pairs of DTBs is positioned symmetrically with respect to the axis on which the CM of the SC lies (Line of CM), coinciding with the y-axis of the coordinate system

**This facilitates the rotation of the DTB**. In the discussion so far, it has been emphasized that when both disks are simultaneously rotated in opposite directions, there is no torque on the DTB. Therefore, if we want to rotate the DTB (and consequently the SC) in the plane of the disks, we must cut off the power supply to one of the disks for the duration of one or several cycles of the DTB. Consequently, if we want to stop the rotation of the DTB, we must cut off the power supply to the other disk for the same number of cycles (see [15]). Alternatively, when we have an even number of DTB pairs arranged symmetrically in different planes (relative to the Line of CM), we can rotate the SC in any direction in space by using a suitable algorithm to turn the power supply to specific disks from the different DTB pairs on and off (see ANIMATION-4 [15].

**The thrust direction can be reversed by 180 degrees during each successive DTB cycle**. In this case, we also have the option to change the thrust direction by 180 degrees simply by changing the rotation direction of disks D1 and D2 (see Fig. 2.2 and the shown rotation directions 11 and 12). This can be done without any mechanical modification of the DTB, but simply by changing the algorithm for the energy supplied to EM1 and EM2, i.e., by changing the direction of the current via software. This provides the advantage of a rapid change in thrust direction during each successive cycle of the DTB; Consequently, it enables the effective use of the DTB during approach, landing, and takeoff on asteroids, comets, and other celestial bodies. This is an extremely promising technical solution that can be used in the exploration and exploitation of so-called space resources.

In conventional SCs, changing the direction of thrust is a complex process that requires additional engines and significantly more time. This makes the use of thrust direction reversal in DTB during each cycle an exceptionally effective technical solution. This is because it facilitates landing and takeoff on celestial bodies with surface gravity that can be overcome by the thrust of the SC used for the task. Such celestial bodies in practice include asteroids, comets, as well as the less massive moons in the solar system (see [15]).

*(Note that, when considering only the linear propulsion of the DTB, the resultant vectors are always directed along the y-axis, and consequently there are no forces that would displace the two hulls into different planes. Thus, the DTB design can have only two springs, as shown in Fig. 2.1. However, in a real DTB, which will "have to" rotate in space while changing both its direction and thrust (see [15]). Such a DTB must have a four-spring design, as shown in Fig. 2.2(b). Furthermore, in a real DTB, there must also be mechanical limiters (not shown in the drawings). These limit the maximum rotation between the planes of the hulls, as well as the maximum "amplitude" of the translational movements between hulls H1 and H2 along the y-axis, in order to prevent potential mechanical damage.)*

## 2.5. Conclusions

The new method of propulsion in space discussed here, which requires no propellant consumption, has a number of advantages and possibilities. For the operation of the DTB, we can use solar energy via photovoltaics [9], as well as nuclear energy [10,11], for deep-space missions where solar intensity is low. The velocity of an SC using the "3-to-2" method and PWP can theoretically reach relativistic speeds, though in this case the limitations stem from the need for a powerful and compact energy source capable of sustained operation. But even at speeds of hundreds of kilometers per second, for low-mass SCs using DTB, reconnaissance missions within the Solar System—and beyond—will be accomplished in much less time than with SCs using chemical propulsion.

This will facilitate research and exploration, as well as the development and delivery to Earth of the space resources and valuable minerals in question. This is because Earth's reserves of certain minerals are limited, and their extraction is becoming increasingly difficult and polluting. Meanwhile, using the PWP method, such "deliveries" will be highly cost-effective, as no propellant will be used for the cargo—only electricity. However, the PWP method cannot be used solely for launching the SC into low Earth orbit; instead, the use of established powerful chemical boosters is required. It should be noted that during the SC's return to Earth's surface (as in this case, where we actually have the return of a capsule with a payload), propellant is consumed in minimal quantities. This is because, when the SC enters the atmosphere at a certain angle and speed, the Earth's atmosphere is already used to reduce the SC's speed.

MXRM is located in space, there is no need for a vacuum tube, as shown graphically for simplicity in Fig. 3.3.

However, when the lasers L1 and L2 are active and the ICS process takes place, a net UCM is established, enabling PWP. This is because, during the acceleration of the Be- from RA, according to (1.1), both the hull and the Be- acquire equal momenta. Following the ICS interaction at the interaction point (*), the momentum of the Be- bunch becomes smaller than the momentum transferred to the hull, successfully yielding a net UCM for the MXRM body. In this case, the escape angle of the scattered photons must be chosen so that they can "leave" the body through the open $EXIT_{PF\text{-}ICS}$ section. At an angle of a few degrees between the Be- and laser pulses, the maximum energy according to (3.1) changes insignificantly.

Note that, in MXRM, each successive Be- bunch reaching the anode must be reformed for each successive cycle. This complicates the system and increases energy consumption. However, this allows for a "simplified" mode, which is required according to (3.2), and consequently higher energy consumption for both the Be- and the scattered photons following the ICS process. Accordingly, MXRM, along with its disadvantages, also has advantages, such as miniaturization and less stringent requirements for the parameters of individual processes and components.

## 3.4. Optimization on of the Propellantless Propulsion Method in Inverse Compton Scattering

Section 2.4 of Chapter 2 discusses the optimization of DTB, which minimizes certain undesirable effects. In this section, we will examine the possibility of optimizing and minimizing certain undesirable effects in the TCA (and, accordingly, the MXRM). The rules and conditions discussed in Section 2.4 can, in most cases, also be applied to TCA. Accordingly, the previously discussed minimization of the shortcomings of the "3-to-2" method can be achieved when TCA pairs and groups operate with a phase-shifted cycle. Furthermore, the attitude control of TCA devices in space can be achieved by selectively switching the appropriate resonant accelerators on and off.

Note that while in DTB, a 180-degree change in thrust direction can be performed on every consecutive cycle without requiring a mechanical modification of the device. In TCA, however, a change in thrust direction on every cycle is impossible. This is because it would require a second set of resonant accelerators, adjacent to the first bending magnets M1 (see Fig. 3.2), to accelerate the Be- in the opposite direction; however this would increase the mass and complicate the TCA. Alternatively, the resonant accelerators RA1 and RA2 could change their positions for each successive cycle, which is a significant technical challenge; that is, it also alters and complicates the device, as well as increasing the mass of the TCA.

Note that, to compensate for the torque, CA1 and CA2 must lie in the same plane, with the directions of rotation of Be- being opposite (see Fig. 3.2). However, in this configuration, the TCA (and consequently the SC) has a large width (body area, since we are considering translational motion along the u-axis). Accordingly, to reduce the area of the TCA, we can place CA1 and CA2 in different planes, such that their geometric centers (see Fig. 3.4(a)) and the indicated common

GC coincide (lie on the same axis). To resolve this situation, we must use a set of four independent accelerators (or a multiple of this set), arranged as shown in Fig. 3.4(b) (in this case, for simplicity, we consider only four cyclic accelerators). Consequently, there is now symmetry for each pair of accelerators with respect to the CM (the common GC); see Fig. 3.4(b). In this case, no torque is generated for the SC, and the area is minimized.

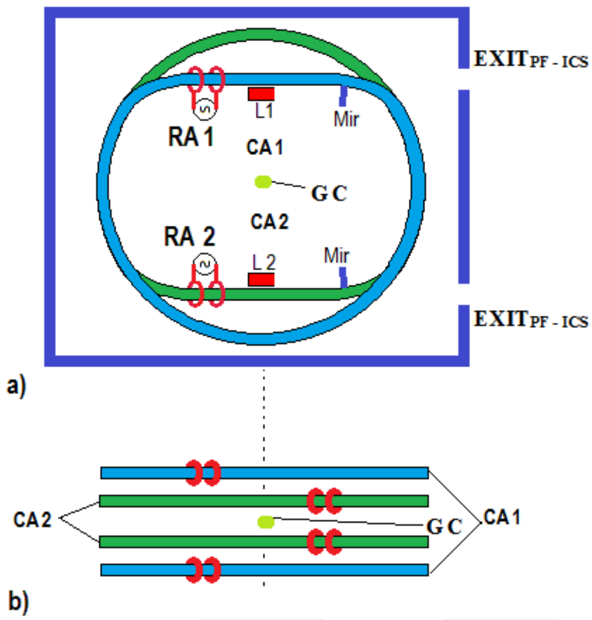


Fig. 3.4 (color) A TCA design with reduced footprint is shown: (a) view along the z-axis; (b) view along the y-axis: (To avoid complicating the drawing, the bending magnets, the hull, and other components are not shown.)

(a) A general configuration of two pairs of TCAs is shown, with coincident geometric centers GC along the z-axis, located in different planes;

(b) Two pairs of TCA (or four individual cyclic accelerators) are shown, with each pair of accelerators being symmetric with respect to the GC, as viewed along the y-axis;

In this way, the resultant vector of the four cyclic accelerators is symmetric about the geometric center GC shown in Fig. 3.4(b). Consequently, even with the resulting minimum area, when all cyclic accelerators operate synchronously, the torque on the SC is completely compensated. Accordingly, when it is necessary to rotate SC in space, we can turn the cyclic accelerators on and off according to a specific algorithm; *see ANIMATION-7 [31]. (To avoid complicating the drawing, in Fig. 3.4 and [31], the hull to which the four cyclic accelerators are attached, the bending magnets, as well as the other components attached to each cyclic accelerator, are not shown.)*

## 3.5. Other Ideas Proposed to Date for Achieving Propulsion in Space Without Propellant

Regarding the issue of achieving propulsion in space without propellant, a natural question arises. Why not use the well-known and previously discussed photon engine? Since, in this case as well, the photons emitted by the SC have no mass, but according to $E = m\,c^2$ , photons have momentum. In this case, the force F of the resulting thrust is,

$$F = \frac{P}{c}, \tag{3.3}$$

where P is the power of the light beam and c is the speed of light. To generate a thrust of 1 N according to (3.3), 300 MJ/s of light energy is required. This is completely unacceptable, since such an energy source would add significant mass to the SC, even with 100% efficiency in the generation and utilization of light energy. Even if we use the Sun's intensity as a source of photons and 100% efficient reflective "light sails," as is being considered. In Earth orbit, the mass of the sails would be significant if we want to generate thrust that can actually be used, and for more distant orbits, the intensity decreases significantly. This is because the area of the sails required to generate just one N of thrust would be more than 300,000 square meters. Furthermore, the direction of the sun's rays determines maximum thrust only when moving away from the Sun, and any movement at an angle to the sun's rays automatically leads to a reduction in the thrust obtained. Whereas, when using the ICS process, with one MJ of energy we can obtain tens of N of thrust, or orders of magnitude more if we use DTB, and in both cases there are no restrictions on the direction of motion.

In fact, if we have an unlimited amount of energy and a source of such energy with minimal mass, we can "transform" the energy into elementary particles and antiparticles with rest mass, which we can accelerate and use for thrust in a variety of ways using (1.1). However, to produce a particle and an antiparticle with rest mass, energy will always be required according to Einstein's formula $E = m\,c^2$ , which also makes the idea unacceptable.

The concept of generating UCM and PWP is discussed in [32] using the so-called Helical Engine. As in the case of [32], a beam of ions moving in a spiral is accelerated in one direction of the accelerator and decelerated in the opposite direction, which increases the relative mass in one direction and decreases it in the opposite direction. However, in this case, it is not taken into account that the increased (or decreased) relative mass is achieved by the ion accelerator, which is fixed to the casing of the Helical Engine under consideration, with the third law (1.1) in effect. Consequently, both the casing and the ion beam experience equal actions and reactions, even though the ion beam has a relative velocity. Thus, UCM and PWP cannot be achieved with the proposed device. Because the ion beam is not free, but is always accelerated, guided, and "held" by the electric and magnetic fields of the accelerator, which is part of the closed system; therefore, UCM cannot be achieved. The same conditions and principles apply to a conventional X-ray machine, where the electrons are not free (since the Be- electrons are accelerated by the potential difference between the cathode and anode), and therefore UCM and PWP cannot be achieved. In contrast, in MXRM, the Be- electron beam, after being accelerated in the RA, is free, and the ICS process proceeds without the Be- electrons and photons exchanging energy with the MXRM hull; consequently, we can obtain UCM for the MXRM hull.

Another method, widely discussed in many articles in recent years [33], which explores the possibility of propulsion without propellant consumption, is the so-called EmDrive. In a slanted resonator, electromagnetic waves propagating within the resonator are believed, for reasons that remain unclear, to generate thrust in one direction of the resonator. Not only are there no clear theoretical explanations for such an effect, but the experimental data from the various groups "measuring" the effect are highly contradictory.

It should be noted that there are numerous videos on the internet of mechanical devices showing "movements" claimed to be propulsion without propellant consumption. In some of these, there is also rotation of flywheels, but without the two hulls being free or quasi-free relative to each other, and consequently, there are no springs (metal or magnetic) as described. Consequently, there is a possibility that "clearances" in the rotating systems, or certain components of the systems, "perform" the role of springs, albeit partially. And consequently, "apparent" synchronization may result from friction, since friction on the Earth's surface cannot be ignored in any way. Through these "properties" ("play" and "apparent" synchronization), some of the devices shown may indeed perform "apparent" propulsion, but only on the Earth's surface. This can easily be proven (verified) by testing the device in microgravity, where friction is absent. In this case, if the device achieves UCM, periodic forward impulses should be observed in only one direction, with the current velocity adding to each successive impulse. And any chaotic jerks of the device under investigation, in different directions, will be proof that UCM has not been achieved, since in this case, synchronization without friction cannot be achieved.

It should be noted that external friction is the primary physical obstacle to the famed exploit of the literary character Baron Munchausen, who claimed to pull himself out of a swamp by his own hair. This feat is impossible because inertial motion of the Baron relative to the viscous mud of the swamp cannot occur, as the friction within the mud immediately dampens and halts any internal mechanical displacement. In contrast, a closed inertial system operating in open space may remain at rest or maintain uniform translational motion relative to the reference coordinate system (CS), since there is no external friction between space itself and the vehicle structure. Consequently, any impulse—such as the UCM generated to achieve PWP—is fully capable of converting a state of rest into translational motion, or actively altering the pre-existing translational velocity relative to the CS.

## 3.6. Conclusions

Ever since the launch of the first artificial satellite into Earth's orbit in 1957, SCs have found real-world applications that, in many cases, cannot be replaced by any other means. In the ensuing space race, in 1961 the first human, Yuri Gagarin, flew into space, and in 1969, Neil Armstrong took the first step on the surface of the Moon.

Modern human civilization is unthinkable without the capabilities provided by SC, such as: communication, GPS, mapping and monitoring of the Earth's surface, scientific research in microgravity, exploration of the planets in the solar system, astronomical observations, and many others, including, unfortunately, military applications. This explains the enormous costs invested over the years in improving space technologies and applying them to ever-new uses. However, the fundamental challenge—propellant consumption—remains unresolved. This severely limits the scope of deep-space exploration, while also restricting the operational lifespans of geostationary satellites, space stations, and any SC that requires propellant for orbital corrections and attitude control. This limitation exists because every kilogram of propellant consumed at a later stage of a mission must be launched as passive mass initially, requiring additional energy to accelerate it alongside the actual functional payload, only to be expended a single time.

It should be noted that when launching a spacecraft into Low Earth Orbit (LEO), the first cosmic velocity of 7.9 km/s must be achieved, in addition to overcoming the resistance of the Earth's atmosphere. Therefore, launching a spacecraft into LEO is currently only possible using boosters that rely on the energy from the chemical reaction of propellant. These boosters have high thrust but, in practice, operate for only a few minutes. Therefore, future space missions must combine both powerful chemical boosters and the PWP method, using the most appropriate propulsion for each specific part of the mission. However, once the spacecraft has reached LEO, the PWP method has the advantage, as propulsion is achieved without consuming propellant, using solar [9] or nuclear energy [10,11] for long-distance missions.

and Tuttle show approximately twice as much deuterium as in ocean water. Using the measured D/H ratios, models predict that less than 10% of Earth's water was delivered by comets.

**Asteroids** are composed almost entirely of solid material, and therefore do not change in size or mass over time. Asteroids are found in the asteroid belt (2.7 and 3.1 AU) between the orbits of Mars and Jupiter, but there are also many in other orbits. Over half a million have been mapped, ranging in size from hundreds of kilometers to a single meter. They are composed of silicate fragments and various minerals.

Of interest as future sources of resources are the so-called M-type asteroids, which contain a high percentage of metals. Asteroids are relatively well-studied because they fall to Earth's surface and are then called meteorites. About 11,000 Earth-approaching asteroids have been discovered, most of which are small and pose no danger to Earth. For larger asteroids, deep beneath their surface, where solar heat cannot penetrate, it is believed that there may be frozen water and gases that have ended up there in various ways.

NASA's Lucy mission, launched in October 2021, is currently executing a 12-year primary reconnaissance itinerary designed to explore the main asteroid belt and Jupiter's co-orbital Trojan asteroid swarms. Over its operational timeline, Lucy will perform close-range flybys of a main-belt asteroid and multiple Trojan targets, closing to distances between 400 and 950 kilometers. Utilizing its onboard suite of high-resolution remote sensing instruments, the mission is systematically mapping the surface geology, mineralogical composition, and volumetric mass densities of these primordial bodies. The data recovered from these Trojan swarms will provide vital constraints for models explaining planetary migration and the early structural evolution of the Solar System.

### 4.4.3. Lunar Station on an Asteroid at a Lagrange Point

The International Space Station (ISS) operates in Low Earth Orbit at an altitude of approximately 450 km above the Earth's surface. Although the station's operational lifecycle was initially projected to phase out closer to 2024, its service timeline has been formally extended to 2030 through international consensus. This extended utilization is heavily dictated by the shifting geopolitical landscape of the partner nations, alongside capital stagnation in the development of a commercial replacement of the same scale. Concurrently, China, operating independently from the ISS framework, has successfully assembled and is now fully operating its own modular space station, Tiangong.

To advance space exploration to a higher level, there have long been ideas for establishing a lunar base on the surface or a lunar orbital station similar to the ISS. The advantages of a lunar base are that it has constant gravity, and when modules are buried in the ground, we have biological protection from radiation and protection from micrometeorites, as well as the potential extraction of water and other resources. Over the past few decades, NASA has crashed a series of probes into the lunar surface to determine, through spectroscopic measurements, the amount of water in the rocks and beneath them. What they discovered was surprising: there is much more water present than previously thought. Furthermore, it is believed that there is hidden ice in the craters near the poles, where sunlight does not reach. However, it is not yet clear whether the amount of this water is sufficient for cost-effective extraction and use.

The problem with a lunar base is that its construction requires a significant amount of cargo in the initial phase. This is because new technologies must be developed and tested due to the complex geology of the terrain in the craters and the extremely low temperatures in the permanent shadow; see [35]. Furthermore, the first cosmic velocity of the Moon is 1.68 km/s, and this velocity must be reduced to zero during every landing, consuming propellant due to the lack of an atmosphere. *(Note that, friction in Earth's atmosphere reduces the velocity of returning* spacecraft. *In this way, they land with minimal propellant consumption.)* Accordingly, for both landing and takeoff, the first cosmic velocity of the Moon is included in the propellant consumption calculation. This necessitates a reevaluation of a potential lunar base, as it would be more prudent to first build a lunar orbital station, analogous to the ISS. In addition to the activities carried out on the ISS, this station should be used to accumulate experience and technologies, as well as a starting point for exploring both the Moon and deep space. However, despite these shortcomings, from an energy and propellant consumption standpoint, it is more cost-effective for the water at the lunar orbital station (provided that lunar resources are utilized) to be supplied from the Moon. This lunar orbital station could also serve as a refueling station for SCs using liquid hydrogen and oxygen propellant. In fact, even for the ISS, it is more cost-effective to have water delivered from the Moon rather than from Earth, since the first cosmic velocity from the Earth's surface is 7.91 km/s, plus atmospheric drag during takeoff.

From an energy and propellant consumption standpoint, it is far more cost-effective for a future lunar station to be "built" on an asteroid at one of the stable Lagrange points of the Earth–Moon system. With this Lunar Lagrange Station (LLS), we have the advantages of a solid foundation. In 1772, the French mathematician and astronomer Joseph-Louis Lagrange, using his mathematical calculations, predicted the locations of the stable Lagrange points L4 and L5. There, the gravitational pull of the two larger objects keeps a small object, such as an asteroid, in a stable orbit 60 degrees ahead of or behind the orbit of the massive body. The asteroids discovered in 1906 in the Sun–Jupiter system at the Lagrange points L4 and L5 confirm Lagrange's predictions. They were named after characters from the Trojan epic, a tradition that continues to this day. In a broader sense, Trojan asteroids are defined as asteroids located at the Lagrange points L4 or L5 of any planet, or even a moon of a large planet. Over 15500 Trojan asteroids have been discovered at Jupiter's L4 and L5 Lagrange points, with the large number attributed to the close proximity to the asteroid belt and Jupiter's massive mass. Trojans have been discovered around Venus, Earth, Mars, Uranus, and Neptune. Nine Trojan asteroids have been confirmed on Mars, eight of which are located at L5 and one at L4 [39]. *(It should be noted that due to their specific location and solar glare, observations and detection of Earth Trojans are more difficult than those of the Martian Trojans. This is why the Martian Trojans were discovered earlier than the Earth Trojans.)*

In 2010, the first Trojan asteroid, 2010 $TK_7$, was discovered at the L4 Lagrange point [40]. It has a diameter of about 300 meters and exhibits a specific cyclic libration around L4, which ensures its stability for thousands of years. For now, there is no data on its chemical composition. Its mass can be estimated at about $50 \times 10^9$ kg, with a diameter of 300 m and an average density of about 3 g/cm³. Given this mass, 2010 $TK_7$ can be transferred from Earth's Lagrange point L4 to one of the Moon's stable Lagrange points, since the orbital velocities of Earth, 2010 $TK_7$, and the Moon coincide. This can be accomplished using a space elevator (SC) that combines the "3-to-2" method with conventional rocket boosters. A sui table phase of its libration should be selected to minimize the required thrust and reduce the duration of the process.

**The advantages of an LLS at the Trojan asteroid 2010 $TK_7$ are:**

1. An LLS located at one of the Moon's stable Lagrange points can remain at that point for many years without needing to correct its orbit; that is, in this case, the required propellant or other form of thrust will be minimal. In contrast, a lunar orbital station would require periodic orbital adjustments due to gravitational influences and the solar wind.

2. On 2010 TK7, the advantage of a solid geological foundation—similar to that of the lunar surface—can be leveraged to provide robust radiation and micrometeorite protection for subsurface modules designed to house astronauts and equipment. Solar panels for electricity generation, as well as radiators for cooling, can be installed on the surface of 2010 $TK_7$. In space at the distance of Earth's orbit, each square meter receives 1,361 W of solar energy [35]. Given the 300-meter diameter of 2010 $TK_7$, we have over 70,000 m² of directly illuminated area, comparable to daytime sunlight, and the potential to generate up to 20 MW of electrical energy (taking into account the efficiency of modern photovoltaics [9]). Accordingly, on the unlit side of 2010 $TK_7$, cooling radiators can operate, as well as telescopes and other instruments that must not be "blinded" or heated by the Sun.

3. At a later stage, 2010 $TK_7$ can be rotated around one of its axes, thereby creating a gyroscope effect. This also ensures a precisely defined duration of sunlight (day and night) for one half of the LLS.

The rotation of the LLS and the centrifugal forces along the "equator" will generate artificial gravity, which will vary depending on the distance from the center of 2010 $TK_7$. In this way, astronauts located in a module docked to the LLS will feel comfortable, as the problem of weightlessness that accompanies every SC will be eliminated. This will allow for longer stays by astronauts, activities and production requiring gravity, as well as facilitated cultivation (production) of food products in a closed-loop system. *(Note that, to prevent the disintegration of 2010 $TK_7$ due to centrifugal forces, which are strongest at the equator, it must be "secured with a sturdy" belt. In this case, the space debris accumulated over the years in LEO can be recycled and used for this "sturdy" belt. In this way, the problem of space debris is solved and the construction of the LLS is facilitated.)*

4. Take, for example, the problem of space debris, which someone will eventually have to clean up. Instead of burning it up in the Earth's atmosphere—which is one possible solution—it could be "transported," recycled, and used to build the LLS. Since a large amount of propellant has already been expended to launch even this current debris into LEO, solar energy and PWP can be used for an orbit to LLS. It is well known that "retired" SCs are constructed from high-quality materials and metals. A major problem for geostationary satellites is that they end their missions primarily due to the depletion of the propellant used for orientation and orbit correction, while the complex and expensive components can still be used for many years.

5. The LLS will conduct the usual research, observations, and experiments, just as they are currently carried out on the ISS. In addition, the LLS can serve as an observation, communication, and coordination center, as well as a base for micro-SC reconnaissance missions targeting Earth-

threatening asteroids, the so-called “city-killer” meteorites. The famous Chelyabinsk meteorite, for example, which fell over Russia in 2013, originated from an asteroid with a diameter of about 20 meters. It exploded about 23 km up in the sky, yet still caused massive destruction. The shockwave from the explosion, many times stronger than a nuclear blast, shattered the windows of a large number of buildings, damaging the eyesight of many people who were watching the powerful light “phenomenon.” Even with modern space technologies, it is possible to influence and prevent the consequences of asteroids like the Chelyabinsk one, and even larger ones, provided they are detected early and countermeasures are ready in appropriate orbits.

Another possibility for the LLS is that the material removed from the interior of 2010 $TK_7$ could be used to create embedded modules. It could serve as a kinetic impactor (kinetic impact element), a method being developed by the Double Asteroid Redirection Test (DART) Mission, which launched in November 2021 [41]. The initial plan for the DART mission was to test technologies that could prevent dangerous asteroids from colliding with Earth. DART, with a mass of 610 kg, is scheduled to impact the second asteroid in the Didymos system between September 26 and October 2, 2022, at a speed of approximately 6.6 km/s. Consequently, the impact will destroy DART and reduce the orbital velocity of the smaller asteroid by approximately 0.4 m/s. The impact will be observed by the Italian LICIA CubeSat, which will be deployed by the DART spacecraft itself 10 days before the impact. On September 26, 2022, at 11:14 p.m., the collision between DART and the second asteroid in the Didymos system was successfully carried out. It should be noted that DART technology could be implemented at a higher level in the coming years for protection against dangerous asteroids, utilizing the capabilities of the “3-to-2” method combined with the modern potential of conventional chemical boosters.

The advantages of LLS as a base for micro-SCs, which will orbit in suitable orbits around Earth and the Sun, are that they will observe, detect, study, and provide information, including on hazardous asteroids (see [15]). And SC boosters (powerful accelerators), pre-positioned in suitable orbits, will be “on standby” to deploy the DART technology as quickly as possible. They can use the material from the “mining” operations during the construction of the buried LLS modules as a kinetic impactor for DART. Given that 2010 $TK_7$ has a diameter of 300 m, an inner sphere with a diameter of up to 200 m can be removed, leaving an outer shell 50 m thick, which will be sufficient to provide protection against radiation and micrometeorites. Accordingly, the mass of the removed portion that we can use could be tens of millions of tons. For this mass, not a single gram of propellant will be used, aside from self-generated electricity and the operation of robotic “excavation” machines. Even if it turns out that 2010 $TK_7$ consists of a large percentage of valuable resources, such as water, valuable minerals, and metals, there will still be millions of tons of unnecessary mass that can be used for a kinetic impact. Furthermore, the principles of kinetic impact can be used to correct the trajectory and guide asteroids and comets containing valuable resources toward the LLS or other suitable orbits. In this case, the fragmented waste material from “mining” operations, used as a kinetic impactor, would be dispersed into a suitable cloud of “shrapnel” immediately before the collision, which would alter the celestial body’s orbit without destroying it.

Historically, pioneering private enterprises (such as Planetary Resources) initiated commercial interest in capturing and transporting volatile-rich asteroids into Earth-Moon space to secure high returns on investment. A highly viable target for such operations is the co-orbital quasi-satellite

2016 HO3, which measures 40–100 meters in diameter. The China National Space Administration (CNSA) plans to send the ZhengHe (Tianwen-2) spacecraft to 2016 HO3 to fly by and land on the asteroid, collect samples, and deliver them to Earth via a return module.

It should be noted that it is extremely profitable to use even the “ordinary” minerals found on asteroids. These “ordinary” minerals (such as nickel and iron) have been definitively identified in so-called M-type asteroids (metallic asteroids). Furthermore, it is claimed that some asteroids consist almost entirely of valuable metals and minerals. Iron-nickel asteroids, for example, account for about 8 percent of all asteroids. For example, an iron-nickel asteroid with a diameter of about 150 meters has a volume of over one million cubic meters. Since the average density of iron-nickel asteroids is over 7–8 tons per cubic meter, the total mass of the asteroid is over 10 million tons. Consequently, we have about 9 million tons of iron, as well as about 1 million tons of nickel content, and likely millions of kilograms of other valuable metals. Since nickel in asteroids typically ranges from 6 to 12 percent, and in some asteroids reaches up to 60 percent. Accordingly, the price of nickel is 15 euros per kg (source: Wikipedia, for 2025). Therefore, the 1 billion kg of nickel in the asteroid in question is worth 15 billion euros, plus several billion euros for the iron. These two elements form the basis of so-called stainless steel, which has good properties for building SCs, properties that were unjustifiably ignored until recently. Furthermore, nickel and iron are already in space, so no propellant is needed to transport them to LEO. As for processing asteroid materials in Earth orbit, we have 24 hours a day with 1,361 W of solar energy per square meter [35].

6. Modules with normal living conditions, protection against radiation and micrometeorites, and breathable air can be built within the resulting cavity of the LLS. And when the LLS is rotated around its axis, there will also be artificial gravity, ranging from zero g at the center to the desired level at an optimal distance from the center toward the “equator.” In these modules, food can be grown in a closed-loop system, and a space industry requiring gravity can be developed—an industry that will clearly be different from Earth’s. Scrap in Earth orbit can be utilized in this emerging “space industry,” as obsolete spacecraft contain high-quality materials and metals. In recent years, 3D printing technology has advanced to the point where components for SCs are now being produced. This technology is particularly well-suited for “manufacturing” products and consumables for which delivery from Earth would not be cost-effective.

And although the construction of the LLS, as a new space station, requires significant initial resources, the investment is justified because it solves a number of fundamental problems, such as:

- The advantages of a solid foundation for the buried modules, with protection against radiation and micrometeorites.
- Generating up to 20 MW of electrical power via photovoltaic panels attached to the solid surface of the LLS. The structure for the photovoltaic panels can also serve as a “sturdy belt” encircling the asteroid.
- Millions of tons of excavated material, which is suitable for use as a kinetic impactor [41]. This material can be used to protect Earth from asteroids, as well as to correct the orbits of asteroids containing valuable minerals.
- A solution to the problem of space debris. This material can be used for recycling and the construction of the LLS.

- “Artificial” gravity when 2010 $TK_7$ is rotated around its axis. A solution to the problem of weightlessness and long-term human activity in space. The advantage is that at the center of 2010 $TK_7$ we have microgravity, while at the equator we have maximum gravity.
- Local production of food and technical components requiring gravity.
- Opportunity to exploit space resources and extract valuable minerals, both from 2010 $TK_7$and from celestial bodies “brought” to 2010 $TK_7$, via the kinetic impactor under consideration [41].
- A base for the exploration and development of deep space, as well as for the terraforming of Mars. As a resupply station for water, food, and propellant.
- Space tourism.

## 4.5. Terraforming of Mars

In 1942, American science fiction writer Jack Williamson first formulated the concept of terraforming, a term still in use today. Its proximity in terms of astronomical distance, geology, topography, and atmosphere makes Mars [42] the most suitable candidate for terraforming and colonization. Furthermore, Mars is closer to the asteroid belt than Earth, has nine Trojan asteroids, and numerous asteroids cross its orbit. The idea is to use asteroids that can be “brought” into suitable orbits for a synchronized head-on collision with Mars’s natural satellite, Phobos. Consequently, the fragmented material from the collision, falling onto the surface as meteors, would use its kinetic energy to heat the surface of Mars. In this way, the carbon dioxide, which is in the form of dry ice on the surface, as well as some of the frozen water, will evaporate. And the newly formed atmosphere, which has good greenhouse gas properties, will trap infrared radiation from the surface, thereby increasing the effect of the Sun’s natural warming of Mars. This determines the use of asteroids both for the future terraforming of Mars and for the extraction of valuable resources to be used on Mars as well as transported to Earth.

Mars is the fourth terrestrial planet in the Solar System. Because of its distinctive color, which is due to the presence of iron oxide, it is also known as the Red Planet [42]. Of all the planets, Mars is the best studied; it has been mapped by orbital satellites, and dozens of space probes and rovers have landed on its surface, where they continue to explore the planet. Mars has two natural satellites, Phobos and Deimos; they are small and irregularly shaped. It is believed that they are former asteroids captured by the planet’s gravitational field and remaining in orbit around it. Mars completes one rotation on its axis in 24.6 hours and one orbit around the Sun in 686.9 days (1.88 Earth years). The tilt of its axis, as well as its full orbit around the Sun, determine the seasons on Mars, which are observed as changes in the polar caps. Mars’ diameter is 6,804.9 km, which is nearly half that of Earth’s (0.533). Its average density is 3.934 $g/cm^3$, and its mass is $6.4185 \times 10^{23}$ kg (0.107 Earth masses); accordingly, the escape velocity from the surface is 5.027 km/s, and the equatorial gravity is 3.69 $m/s^2$ (0.376 g, relative to Earth’s). Mars has a thin atmosphere; its surface resembles Earth’s polar caps, deserts, valleys, and volcanic features, as well as numerous impact craters on its surface. It has been proven that there was once flowing water on Mars, and water in

### 4.5.4. Status of Terraformed Mars

Any planet on which a terrestrial spacecraft has landed can be considered a contaminated planet, given that there is no absolute guarantee that Earth microorganisms have been completely removed from the spacecraft and its modules. It has been proven that microorganisms remain alive in microgravity, high radiation, vacuum, and at various temperatures. In the case of Mars, there are already dozens of Earth-based spacecraft, so we can consider Mars a likely contaminated planet. But despite the possibility that Earth microorganisms have reached Mars, they have hardly developed into living colonies capable of exerting any significant influence. In fact, the main ethical question here is whether there are living microorganisms on Mars now, and whether we have the right to interfere with its terraforming in this case. A primary objective of NASA's Mars 2020 mission, which landed in 2021, was to confirm or rule out the presence of such microorganisms, past or present.

Another question is what the status of Mars will be once it has been terraformed. It stands to reason that whoever carried out the terraforming would have, if not full rights to Mars, then at least some priority. After all, the surface area of Mars is equal to that of all the Earth's continents combined, which offers enormous opportunities. This necessitates that all these issues be addressed in advance and receive the status of international agreement, similar to what currently exists regarding the Moon and space. Another issue is the ownership of MOS, since they will be built and, accordingly, owned by an organization in which many countries and associations will most likely participate. Furthermore, MOS will be highly desirable as a source of valuable resources and minerals for Earth, both in the initial period and after the terraforming of Mars, while also serving as bases to facilitate the exploration and development of Mars, the asteroid belt, and deep space. A number of questions also arise, such as: Who will govern Mars? What form of government will be established, and how planetary jurisdiction will be managed?

## 4.6. Conclusion

In this book, we have primarily examined two important questions. The first question is whether we can obtain the UCM for one of the bodies in the closed inertial system DTB (or in the case of TCA). The first question is strictly theoretical, since in this case we are examining and proving the special case of the law of conservation of the motion of the CM of DTB. The second issue, however, concerns the practical possibility of solving the problem of constant propellant consumption, which accompanies standard rocket engines during their propulsion in space.

The essence of the first question is that, according to the classical laws of mechanics [1], the momentum in a closed inertial system is always zero: P = 0. This holds true for all examples considered in [1], since Newton examines the laws only for classical bodies. We consider such an example in Section 1.2.1, when the bearings under consideration are locked (not operating). The essence of this analysis can most easily be understood and analyzed in the following way. Fig. 1.2(a) (see also Fig. 1.3 and [7] VARIANT-1) shows a configuration where the bearings are locked (not operating). As in the case of this considered variant, the two hulls have (so to speak) identical classical properties. Accordingly, when we apply the third law (1.1) to the two bodies of the DTB, the bodies receive equal forces, equal kinetic energies, equal velocities, and opposite momenta, i.e., P = 0. Consequently, both bodies will travel equal distances per unit time, in accordance with the law of conservation of the motion of the CM, as discussed in [1].

However, when the bearings are operational (not locked), as shown in Fig. 1.2(b) (see also Fig. 1.4 and [7] VARIANT-2), the H1 hull still exhibits classical properties. In this configuration, body H2 now has properties different from those of body H1. Under the action of the third law (1.1) within the DTB system, the H1 hull receives and utilizes the entirety of the input energy solely for translational motion. Conversely, the H2 body distributes its received energy between the rotational motion of its two internal disks and its own translational motion. In other words, body H1 can "convert" the action of the third law (1.1) solely into translational motion. Accordingly, body H2 converts and distributes the action of the third law (1.1) both for the rotational motions of the two disks and for the translational motion of body H2. This is because the effect of the third law (1.1), in this case, is achieved through the moment of inertia $I_{D1D2}$ (1.4) of the two disks, and the two disks are fixed to the H2 body via their axes.

The possibility of obtaining UCM for the H1 shell of the closed DTB system can also be viewed through the different properties that the H1 and H2 shells "acquire" under the third law (1.1). Accordingly, the various properties of the shells—so named for convenience—should be understood as a way of avoiding the introduction of new terminology, i.e., in this case, avoiding unnecessary complexity. In this way, we make things easier for readers who are not interested in the theoretical question, but for whom only the applied methods and possibilities are important.

By addressing the so-called second issue, we resolve the problem of the constant propellant consumption, which must always be carried along with the payload but is used only once at a later stage. Therefore, in this case, it is important that we can obtain UCM and PWP using the "3-to-2" method. In this way, the problem of constant propellant consumption is solved. Accordingly, it must be noted that such propulsion is not the best way to travel in space, but for now it is the only possible method by which propulsion can be achieved without propellant, using only electrical energy. In this way, celestial bodies such as asteroids and comets can now be explored for so-called space resources and valuable minerals. While such ideas were previously constrained by Earth's finite resources and the ecological damage caused by terrestrial mining, the exploitation of these space assets is now highly profitable and offers a substantial return on investment. This is because "space transport" will no longer require propellant; instead, it will rely solely on energy from photovoltaics or nuclear power where solar intensity is low [9–11]. Robotic extraction and transport technologies for resources from celestial bodies prove to be the most suitable in this case. Furthermore, during the terminal phase of the spacecraft's return, the Earth's atmosphere can be utilized for aerobraking to safely reduce the velocity of incoming payloads, precisely as is currently done for re-entry capsules entering the atmosphere at calculated angles and velocities. This approach fundamentally shifts the entire paradigm of space technology and exploration capabilities.

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