Title: Ground Effect Machine System

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Inventors: Adam B. Suppes
Galen Suppes

Abstract

A ground effect machine GEM) system emphasizes a vehicle capable of ground effect flight with a means to control flight above the ground. Induced drag is reduced by “Lift Span Tech” which comprises an upper-surface trailing propulsor that pushes air above a trailing high-pitch surface to overcome boundary layer separation and promote air flow generating a trailing edge stagnation point due to air’s interaction with the ground. Lift Span Tech in combination with a lower cavity both reduces drag and provide aerodynamic lift. Efficiency of the GEM may be increased both due to reduced drag and reduced mechanical resistance, depending on application. Applications include but are not limited to railcars, box trucks, buses, aircraft, automobiles, and boats.

TITLE: Ground Effect Machine System

CROSS REFERENCE TO RELATED APPLICATIONS

[1] This application claims priority on PCT/US24/35242 (24-JUN-2024); the content is incorporated herein by reference. Pre-prints were published after respective applications as summarized by illustrative examples at the end of this document.

FIELD

[2] The present invention relates to generation of aerodynamic lift and reduction of drag using air flow around lifting bodies including trucks, railcars, and aircraft.

BACKGROUND

[3] For over a century, the aircraft industry has been without an accurate simple explanation of aerodynamic lift that explains how air flow is transformed into lift pressures. Instant inventors have identified and verified a correct simple explanation, and that explanation enables the accurate extrapolation of observations to new inventions.

[4] Drag reduction devices such a deflectors, skirts, and rear diffusers are designed to reduce drag; but they have minimal impact on reducing rolling losses and do not reduce drag to the extent possible. Compared to alternative methods, the transit system of this invention reduces drag further than alternative art and replaces when or float suspension with aerodynamic suspension resulting in increased reductions in drag losses and reductions in other resistances such as rolling losses.

SUMMARY OF THE INVENTION

[5] Instant invention consists of a system comprised of ground effect machines (GEM) and a control means based on clearance with the ground. The term “ground’ is applied broadly, as is typical for ground effect machine literature, and includes the ground, water’s surface, roadways, waterways, railways, and other coverings of Earth’s surface.

[6] The base case ground-effect flight **vehicle** consists of a *lower surface cavity* configured to contain pressure, an upper-surface propulsor, and a forward upper surface configured to generate induced thrust. The lower surface cavity is comprised of a port fence, a starboard fence, and a trailing edge flap said trailing edge flap having a trailing flap edge. The ground-effect aircraft is configured to operate with the chord connecting the forward stagnation point to the trailing flap edge at a pitch between 0° and 3°. The base case lifting body (**Fig. 1**) is the base case vehicle absent the propulsor.

[7] An upper surface propulsor pushes air behind the vehicle toward eliminating boundary layer separation with flow downward and rearward along a high-pitch discharge surface extending from the propulsor discharge to a trailing edge where the flow impacts underbody air flow and the ground to create a trailing-edge stagnation point. A stagnation region having a pressure higher than surrounding pressure extends from the ground to the trailing edge. Preferably, the stagnation region extends forward through the lower surface cavity from the trailing edge to a leading edge.

[8] GEM of the system may take free flight including takeoff in a ground-effect flight mode. The invention includes a wing gimble able to transform a laterally-extending wing in a free-flight configuration to a fence on the lower cavity of a GEM in a GEM configuration. The GEM configuration provides a high lift-drag efficiency at a low aspect ratio enabling travel on highways and railways including takeoff and landing on highways and railways.

FIGURES

[9] **Fig. 1** illustrates a GEM 5 on tracks from: a) below and b) above.

[10] **Fig. 2** illustrates a GEM 5 with fences and mid-chord flap.

[11] **Fig. 3** illustrates GEM 5 railcar.

[12] **Fig. 4** illustrates a GEM 5 with a pair of gimbal wings that folds fences.

[13] **Fig. 5** illustrates a GEM 5 with two pairs of gimbal wings that fold fences.

[14] **Fig. 6** illustrates a thin cambered airfoil with a crossover propulsor.

[15] **Fig. 7** illustrates a towed platform aircraft with crossover propulsor and solar panels.

[16] **Fig. 8** illustrates GEM 5 with wings that fold down with wings extended.

[17] **Fig. 9** illustrates GEM 5 with wings that fold down with wings folded down.

[18] **Fig. 10** illustrates vehicle with center fuselage and lateral wings with slats: a) extended and b) retracted.

[19] **Fig. 11** illustrates GEM 5 with thick fence designed to create induced thrust.

[20] **Fig. 12** illustrates a golf cart with Lift Span Tech and cavity.

[21] **Fig. 13** illustrates a thin airfoil GEM 5 with wings that fold down.

[22] **Fig. 14** illustrates fences that pivot back and up as configured: a) on an aircraft, b) with a wheel, c) as a ski, and d) with a wheel on a rail.

[23] **Fig. 15** illustrates a catamaran boat designed for ground-effect flight with extendable slats and flaps where: a) is slat extended and b) is slat retracted.

[24] **Fig. 16** illustrates a passively-adjusting lift span.

[25] **Fig. 17** illustrates a lead aircraft option for towing a platform. CG is center of gravity, CP is center of pressure, CT is center of tow force, and S is propulsion thrust.

[26] **Fig. 18** illustrates an alternative pivot connection of a lead aircraft.

[27] **Fig. 19** illustrates distributed propulsion for forming jet discharges.

[28] **Fig. 20** illustrates a thin cambered lifting body aircraft with wings.

[29] **Fig. 21** illustrates a propulsion assembly for single-sheet construction.

[30] **Fig. 22** illustrates railway side walls to enhance railcar L/D efficiency.

[31] **Fig. 23** illustrates a ground-effect aircraft in a tunnel with overhead LIM.

[32] **Fig. 24** illustrates a towed glider aircraft with crossover propulsors.

[33] **Fig. 25** illustrates Bernoulli Loops 70 using vehicle traffic to reduce tunnel pressure.

[34] **Fig. 26** shows pressure profiles in a sequence of Bernoulli Loops 70.

[35] **Fig. 27** shows an algorithm for controlling vertical fence actuation..

[36] **Fig. 28** Single sheet construction showing frame with and without fuselage.

[37] **Fig. 29** is an algorithm for ground-effect takeoff in GEM 5 with wings in fence positions.

[38] **Fig. 30** illustrates stagnation points of GEM without (b) and with (a) propulsor power.

[39] **Fig. 31** compares: a) a cross-over propulsor to b) a Lift Span propulsor..

[40] **Fig. 32** illustrates a GEM with wing shoulder joints in a wings as fences configuration.

[41] **Fig. 33** illustrates a trailing cavity surface as a flap and as a spoiler in various position.

[42] **Fig. 34** illustrates a GEM in a) free flight configuration, b) transition configuration, and c) ground-effect flight configuration.

DEFINITIONS

This document uses definitions and abbreviations of patent application PCT/US24/35242. The embodiments range from trucks that travel mostly on highways to wing-in-ground maritime aircraft; and due to this range, a range of terms are commonly used which generally refer to the same vehicle features. Also, for ground effect machines, the ground refers to Earth's surface and surface features such as a highway, a railway, and a waterway. With applications ranging from trucks to aircraft and with founding of an alternative fundamental's foundation there is a wide range of terms referring to devises that are fundamentally the same. The last paragraph of this document cross-references terms to facilitate relating terms over the range of applications.

DETAILED EMBODIMENT

[43] The instant invention is a transit system comprising a ground effect machine (GEM 5) and a means to control the path along a path surface broadly referred to as the ground.

[44] The instant invention comprises a GEM 5 (e.g., Fig. 1) having a lower surface extending lengthwise along an underside of the vehicle from a forward stagnation point to a trailing edge flap,

the lower surface bounded on a portside by a portside fence, and the lower surface bounded on a starboard side by a starboard side fence. The portside fence extends downward from the lower surface along the portside of the lower surface and abuts against a portside edge of the trailing edge, and the starboard fence extends downward from the lower surface along the starboard side of the lower surface and abuts against a starboard edge of the trailing edge. The lower surfaces, the portside fence, the starboard fence, and the trailing edge flap are configured to form a cavity underneath the vehicle and contain pressure during flight.

[45] The GEM 5 has an upper surface extending lengthwise along an upper side of the vehicle from the forward stagnation point to the trailing edge flap and further comprising an upper-surface propulsor operably connected to the upper surface. The upper surface has a forward upper surface portion proximal the stagnation point, wherein the forward upper surface is configured to generate induced thrust.

[46] The GEM's 5 lower surface can be substantially flat surface with a pitch of 0° to 3°, relative to a horizontal pitch of 0°. A key feature to maximize L/D is a trailing edge flap having a lower surface than the vehicle's lower surface.

[47] In an alternative sequence of limitations, the instant invention includes a GEM 5 having a lower surface 8 cavity 1 configured to contain pressure, an upper-surface propulsor 2, and a forward upper surface 3 configured to generate induced thrust. The lower surface 8 cavity 1 comprises a starboard side fence 4, a portside fence 4, and a trailing edge flap 6; the trailing edge flap 6 has a trailing flap edge 7. To achieve higher efficiencies, the vehicle is designed to operate with a lower surface 8 having an average surface pitch between 0° and 3°.

[48] An approximate design criterion is for the pitch angle of the straight line 9 (or chord) connecting the leading edge of the vehicle to the trailing flap edge 7 at an angle between 0° and 3°. A more-rigorous design criterion is a flap and leading section designed with a straight line 9 of pitch between 0° and 3° connecting the forward stagnation point 10 to the trailing flap edge 7.

[49] Preferred fence 4 positions are on the port and starboard sides of the cavity 1 at a height between 5% and 100% of the thickness of the lifting body, more preferably 10% to 50% of the lifting body thickness. The fences are preferably a vertical longitudinally-extending surface which may be augmented by vertical structures extending from the ground, such as railway tracks 11. Fences may deviate from vertical such as at an angle, curved, or formed as spaced from vertical surface extensions.

[50] Preferably, the fence includes a forward surface designed, such as a deflector, to create induced thrust with a leading edge near the fence's inner surface with a fence-deflecting surface extending from the leading edge to the fence's outer surface. The design is configured to enable a

higher pressure along the inner surface to promote oncoming air to deflect outward and over the fence-deflecting surface to create induced thrust. A trailing section of the fence includes a taper to promote higher pressures on the inner surface and overall neutral pressures (average pressure similar to free stream pressures) along the taper's surface.

[51] Preferably, the longitudinally extending fence 4 is a sequence of fence sections 12 with each section configured to move vertically as a control surface. At a given sequence of vertical heights of fences, the vehicle will assume a steady-state flight position including a vehicle pitch and an angle in the roll dimension. When a fence section is moved upward, more lift pressures disperse laterally at a greater rate at that position, resulting in lower lift and a lowering of the vehicle at that position and any positions having lift pressure indirectly impacted. The vehicle will lower at the positions of lower lift leading to a new steady state vehicle pitch and roll angle; hence, the fence is preferably a vertically moving control surface. Thinner lower fence sections may slide in and out of thicker upper fence sections.

[52] Preferably, the trailing flap 6 pivots or extends from a position on the lifting body by methods known in the art. The flap extends between a pair of fences. A lowering of the trailing flap edge 7 creates higher pressures in the cavity 1 and more lift. In the absence of vertical ground structures 11 augmenting fence functionality (e.g., a railway track), a good operating position is the trailing flap edge 7 at 70% of the vertical distance between the lifting body's trailing edge and the fence at that chord position. The trailing flap position is a results-driven parameter of vehicle operation. The trailing flap may be a laterally extending sequence of flap sections 12 between a pair of fences 4 5. Optionally, the trailing flap may extend from a contiguous connection with the underbody to form a spoiler which is a non-contiguous connection. The spoiler is preferably positions so air flow from both the trailing taper and the underbody impacts the spoiler creating a spoiler trailing stagnation region with orientations which increase lift and substantially cancel induced drag of forward spoiler surfaces with induced thrust of trailing spoiler surface.

[53] Any fence or flap section may optionally have independent control actuation 27 and independent shock-absorbing function by moving in response to contact with an outside surface. Fig. 14a illustrates a fence with sections 12 in sequence in vertical and longitudinal dimensions with boards connecting vertical sequences with pivoting contact 14 to allow the fence sections 12 to pivot back and up in control actuation 27 or shock absorbing action. Wheels (Fig. 14b) or ski configurations (Fig. 14c) may be used to assist in absorbing the shock or to sustain contact with a surface in close clearance. The fence is configured to move up and back while blocking loss of lift pressures. For example, adjacent faces of fences in close proximity can move while providing resistance to air flow.

[54] GEM 5 may use a wheel assembly connected to the vehicle body where the wheel assembly consists of wheels connected to a portside fence section to create a clearance between the portside fence section and a path where vertical movement of the wheels creates a similar vertical movement of the portside fence. A bearing may be used in this connection.

[55] A key factor to achieve higher L/D efficiency is induced thrust on a frontal surface 3; lower pressures and respective induced thrust are created by expansion of higher pressure along the stagnation line 9 upward. Lower pressure forms when air flow diverges from a surface such as a curved surface (Fig. 2) or when a transition occurs from a lower pitch surface (i.e., more negative) to a higher pitch surface as illustrated by the frontal section lower surface 8 regions of Fig. 1c. Induced thrust 3 subtracts from drag in L/D performance; hence, as drag decreases from small values of induced thrust 3 there can be large increases in L/D.

[56] The most-preferred embodiment is configured to form a higher-pressure region extending from a trailing-edge stagnation point 60, through the cavity, and to the leading-edge stagnation point 10. The formation of this continuous underbody stagnation region is consistent with the trailing edge stagnation region extending from the ground to the vehicle underbody and a fence-ground clearance sufficiently low to prevent lateral dissipation of pressure from significantly depleting the pressure in the cavity.

[57] The frontal section 3 induced thrust may be enhanced by an upper-surface propulsor 2 where the propulsor intake 15 creates a lower pressure on the upper surface which increases the rate of expansion from the stagnation line which causes greater velocities of divergence from frontal surfaces having shapes to enhance this propensity.

[58] Preferably the upper surface propulsor is configured and operated with the Lift Span surface and trailing taper to overcome boundary layer separation, direct flow along the trailing taper, and impact with the ground and undercarriage flow to create the trailing edge stagnation region extending from the ground to the vehicle underbody.

[59] The transit system comprises a ground effect machine (GEM 5) said GEM 5 comprising a vehicle underbody surface, an upper-surface propulsor, a low-pitch intake surface, a high-pitch discharge surface, a forward deflecting surface, a control means, and a vehicle body extending from a leading edge to a trailing cavity surface; the GEM 5 further comprises a lower cavity bound by a) a portside fence, b) a starboard side fence, c) the vehicle underbody surface, and d) the trailing cavity surface; the high-pitch discharge surface is below an air flow discharge of the propulsor and consists of an average surface pitch of 15° and 50° degrees; the control means is configured to detect and maintain a GEM 5 minimum clearance with a path. Preferably, the high-pitch discharge surface is configured to generate a higher-pressure stagnation region extending from the trailing

cavity surface to the ground, the higher-pressure stagnation region's pressure between 50% and 150% of free-stream-air's dynamic gauge pressure relative to the GEM 5.

[60] More preferably, the transit system also comprises of a low-pitch surface located below the air flow intake of the propulsor and extends forward at least 0.3 chord lengths from the propulsor; and the high-pitch discharge surface is located below an air flow discharge of the propulsor and extending over at least 60% of the vehicle body thickness.

[61] More preferably: the trailing cavity surface is a flap, the low-pitch intake surface has an average surface pitch between -1° and 1°, the propulsor is a ducted fan having an upper surface extending less than 20% of the vehicle body's length (chord), the low-pitch intake surface is contiguously connected to a lower surface of the ducted fan, and the high-pitch discharge surface: a) extends rearward over at least 80% of the vehicle body thickness, b) has a pitch variance less than 5°, and c) is contiguously connected to a lower surface of the ducted fan.

[62] Devices that enhance the performance of the base case ground-effect lifting body include: a) Trailing-edge flap comprising a sequence of laterally-extending flap sections, b) an upper surface comprised of a sequence of flat surfaces 16, c) a variable-pitch lift-span 17, d) a crossover propulsor 18, e) a panel surface 19 extending at least half the vehicle chord and at least one third the vehicle width, f) a towed platform 20, g) a trailing taper 21, h) laterally-extending wings 22 with optional ailerons 23, i) slats 24 configured to increase the camber of a lifting body when extended, j) a mid-chord cavity flap 25, k) a mid-chord cavity morphing surface 26, l) vertical control actuation 27 of fence sections 12, m) forward-extending fences 28, n) a second pair of fences 29, o) an aerial tail 30, p) a hydrofoil tail 31, q) a fence hydrofoil 32, r) the fence comprised of a plurality of sequential fence sections 12, s) a fence air or water ski 33, t) a fence wheeled ski 34, u) a ductless focusing fan 35, v) an inboard chambered panel 36 comprising an inboard cambered panel between two outboard lifting body fuselage 37, w) shock-absorbing fence sections 38, slats 39, and flaps which optionally include shock-absorbing embodiments in retraction/extension track assemblies 44 45. Here, the chamber 53 is a space below a concave downward panel which has sides that may or may not be fences.

[63] Vehicle categories of this invention include but are not limited to: a) A marine aircraft, b) A railway car 40, c) A subway car, d) A roadway vehicle, e) A piecewise flat platform vehicle 41, f) An all-terrain vehicle, g) A ship, h) A boat with boat hulls 42 43, i) a guideways system (tracks, terraced guideway, overhead electric assembly), j) trucks, k) cars, l) propulsion-assist trailers, and m) specialty agricultural vehicles like crop sprayers and aerial seeders.

[64] For GEM 5 versions operating on paths designed for wheeled vehicles, the weight is preferably suspended by both aerodynamic lift (from the cavity) and wheel suspension with

sufficient wheel suspension to provide traction (steering and/or thrust) and regenerative braking. Preferably, the GEM 5 is designed to increase wheel suspension as part of braking to enhance braking traction; increased wheel suspension would result from reduced aerodynamic lift and could be used to increase weight on existing wheels or engage additional wheels or tracks in the braking process.

[65] Extra braking 54 preferably engages with a reduction of lift suspension such as a wheel or track that contacts the ground for braking as part of a braking sequence consisting of reducing aerodynamic lift followed by contacting the extra braking 54 with a manifestation of the ground.

[66] Intermodal Embodiments – Lateral control on highways preferably includes tire traction augmented with aerial yaw control devices such as rudders, especially rudders incorporated on fences. Hi-wheel embodiments may be used to provide yaw path control in intermodal operation between roadways and railways. Fence rudders using aerodynamic forces to engage rails are most-preferred for yaw-path control over rails.

[67] Configured to Generate Induced Thrust – For instant invention, a leading section (i.e., leading 25% of the lifting body) configured to generate induced thrust has a leading edge on the lower 25%, preferably 15% of the surface and a surface that continuously, or stepwise continuously, has decreasing pitch as the surface proceeds upward and rearward from the leading edge. Preferably, greater than 80% (more preferably, greater than 90%) of oncoming air flows upward from the stagnation surface (i.e., stagnation line in 3D) and over the leading section including diverging flow from the surface which creates lower pressures on some upper surfaces having pitches less than 0° (more preferably, from 45° to 0°). Lower leading-edge stagnation points can promote more leading section induced thrust where a continuous underbody stagnation region deflects more oncoming air flow upward with more diverging flow from a deflector surface area.

[68] Shock-Absorbing Extendable Slats – Slats, fences, and flaps are downward extensions of a lifting body; they offer the following advantages: a) enabling the lifting body, slats, fences, and flaps to operate at different clearances; b) enabling fast-actuating vertical movement of fences, slats, and flaps to avoid hitting the ground (i.e., the use the momentum of the lifting body to counter the momentum of fast actuation), c) reducing shear at low clearance relative to the entire lower surface of the lifting body being at that clearance, d) enabling shock-absorbing mechanisms to allow contact with the surface as a mode of operation or as a minor versus major perturbation, and e) enabling the vehicle to change aerodynamics for free flight versus ground-effect flight.

[69] An advantageous change in surfaces to change aerodynamics is to increase the camber of a wing, fuselage, or other lifting body for ground-effect flight. Highly concave (e.g., a camber

greater than 0.03) lower surfaces rely on the expansion of higher pressures from the lower surfaces of the trailing section to the lower surfaces of the leading section to create lift throughout the entire lower surface. In free flight, those lift pressures dissipate before reaching the lower surfaces of the leading section with resulting low L/D efficiency. In ground effect flight with fences and ground block losses of lower surface lift pressure and higher L/D are attainable. The general description of this embodiment is a vehicle having surfaces configured to operate at high-camber lower surface concave-downward surfaces when close to the ground and a lower-camber lower surfaces when flying distant from the ground. Flaps and slats can be used to increase the lower surface camber.

[70] Preferred embodiments have slats that extend or pivot to increase camber of lower surfaces from less than 0.02 (concave downward) to greater than 0.03 (concave downward. Figure 15 illustrates a curved track assembly 44 with two roller connections that allow the slat 24 to provide an extended configuration (Fig. 15a) with increased camber for ground-effect flight and a retracted position (Fig. 15b) with lower camber for free flight. Methods known in the art can provide shock-absorbing capabilities along the track travel path or at the connection between the track assembly 44 and the hull 42 43.

[71] Fence Control Actuation – Efficiency of GEM 5 increases as the clearance ratio (CR) decreases. The preferred actuation is active fast vertical movement of fence sections with an algorithm consisting of the steps: a) detection on oncoming bump/wave, b) calculation of timing to move fence section upward to avoid the bump/wave, c) return of fence section, and d) repeat of process for subsequent fence sections encountering the wave/bump. Preferably, superimposed over this algorithm is a control algorithm adjusting other control surfaces (e.g. ailerons, other fence sections) to maintain a smooth ride.

[72] A preferred fence includes a lower surface characterized as a ski with upward force provided by wheels, air, or water on the lower surface of the ski. Wheels, air, or water on the lower surface of the ski, which are attached to the fence, sustain from 0% to 20% (preferably 0.5% to 4%) of the vehicle weight with most of the vehicle weight supported by lift pressures (from aerodynamic forces) on the vehicle. The advantage being that the close clearance ratios are maintained with a low Ski drag due to the low weight supported by the Ski. Methods known in the art may be used to design fences with wheels, skis on snow, skis on water, and skis on water with air injection. Fences are designed to restrict air from flowing through the fence and the fence-vehicle interfaces. The ski may have a narrow long cavity 1 to create aerodynamic lift below the ski to buffer impact and reduce drag.

[73] Fences with lower ski surfaces may be designed for a preferred state with the ski engaging the surface or with the ski as an approach to better absorb inadvertent contact with the surface; in

either case, performance can be improved with high-speed controlled actuation of the extent of vertical extension of fence sections. A fence control inner algorithm is comprised of the following sequence: a) detection of on-coming ground level, b) calculation of timing for raising or lowering fence sections to maintain a set point clearance above the ground level, and c) movement of fence sections to match ground level. Superimposed over this inner algorithm is a second-tier algorithm to move the lifting body up and down in the case of severe changes in ground level. Superimposed over both of these algorithms is a third algorithm that inputs available input into an AI calculation algorithm designed with the objective function of creating a smooth ride. The second and third algorithms use additional control surfaces of flaps, slats, and ailerons to move the lifting body up or down per Fig. 33.

[74] Lift Span Tech – An upper-surface propulsor 2 intake 15 creates low pressures on upper surfaces which create lift; those same lower pressures can create form drag or induced thrust 3. For a trailing section propulsor, at about 0.75c, higher pitches are preferred at low propulsor power to reduce boundary layer separation when gliding. At higher propulsor power, the propulsor dominates boundary layer phenomena and a lower pitch surface at the intake (e.g., -0.1°) is preferred. The lower pitch surface at the intake reduces or eliminates form drag and reduces the amount of resistance the surface has on air flow into the propulsor. Preferred is an intake surface that exhibits decreasing pitch with increasing propulsor power. The term “Lift Span” 17 is used to refer to the surface afore an upper surface trailing section propulsor intake 15 which experiences lower pressures due to the propulsor, and the term “Lift Span Tech” is used to refer to embodiments that reduce the pitch of the surfaces afore propulsor intakes 15 with increasing propulsor power.

[75] The related invention embodiment is an aircraft comprising a variable pitch Lift Span 17 afore an upper-surface propulsor 2 where the variable pitch Lift Span 17 is an upper surface configured to operate at decreasing average surface pitch with increasing thrust of the upper-surface propulsor 2. It is not uncommon for the pitch of the entire aircraft to decrease with increasing speed. The preferred aircraft is configured for the average surface pitch of the variable pitch Lift Span 17 to decrease relative to the aircraft chord pitch with increasing thrust of the upper-surface propulsor 2.

[76] A passively-adjusting Lift Span 17 device is illustrated by Fig. 16 and is comprised of a contiguous connected sequence of a) a forward connection to the aircraft 46, b) a Lift Span surface 47, c) an upper-surface propulsor 2, d) a pivotable connection 48, e) a trailing taper panel 49, and f) a contiguous sliding contact 50 with the trailing section of the aircraft. The passively adjusting Lift Span 17 device includes a spring or similar elastic device 51 connecting the passively-adjusting Lift Span surface 47 device to the aircraft. For active control, the spring may be replaced with active

control actuators. Also, the elastic aspect of the device may be incorporated into the Lift Span 17 surface such that lower pressures stretch the surface upward toward overall lower pitch; such elastic surfaces may be referred to as morphing surfaces.

[77] Single-Sheet Planform, Folding Wing, and Cross-Over Propulsor Embodiments– Air may be forced into the cavity 1 to increase pressure beyond that expressed by oncoming air's dynamic pressure relative to vehicle velocity. This can be achieved with a cross-over propulsor 18, where a lifting body comprising a propulsor, an upper surface afore the propulsor, and a panel 19 aft the propulsor is configured with the propulsor intake 15 above the upper surface and the discharge below the panel 19 as illustrated by Fig. 5. The preferred propulsor is a ducted fan and the panel 19 is a rearward extension of the upper surface of the ducted fan.

[78] Preferably, the panel 19 is a convex upward cambered panel 19 consisting of thickness to chord ratio less than 0.1 [preferably between 0.005 and 0.02] and a camber between 0.02 and 0.12 [more preferably between 0.04 and 0.08]; this is referred to as a high-cambered span 52. Preferably, the high-cambered span is an inboard panel 19 span between two outboard fuselage spans 37.

[79] The cross-over propulsor 18 is an effective method to extend a platform surface of an aircraft. Fig. 7 illustrates a lead aircraft 56 and a towed platform 20 connected through a pivotable connection 55 where a cross-over propulsor 18 is part of the transition from the lead aircraft to a towed platform 20. The lead aircraft comprises of the propulsor and the towed platform 20 comprises of the panel 19. Said panel 19 has a camber greater than 0.02. The towed platform 20 is configured to operate with a balance of lift and panel 19 center of gravity coupled with the leading lifting body by a pulling force acting through the pivotable connection. When the panel is a bifacial solar panel 57, the towed platform 20 may be configured to collect considerably more energy than is needed to sustain the flight of the towed platform 20.

[80] Single sheet construction is advanced with the crossover configurations of Fig. 17, Fig. 18, and Fig. 28. The single-sheet construction embodiment comprises a lateral device such as a humerus spar 76 or propulsor assembly. Quill ribs 64 extend longitudinally from the lateral device to provide semi-rigidity. Single sheets attach to the quill ribs 64 and to a contiguous connection on the lateral device. Example contiguous connections include a clamp, rivets, bolts, screws, and surfaces fastened with adhesive. Actuators 78 provide control and transition.

[81] Fig. 31 provides over-under comparisons of a crossover propulsor (31a) to a Lift-Span propulsor (31b). The upper surface of the crossover propulsor may provide a contiguous connection to a trailing bifacial sheet with a connecting bracket connected to a pivot connection toward enhancing stability and ease of manufacturing. The Lift Span propulsor provide provides a

contiguous connection to a trailing taper surface toward via a connection, that may be under actuation, toward providing a truncated chord length to reduce fuselage height. The Lift Span Tech may be configured to increase the change of surface pitch from the surface in front of the propulsor to the trailing taper surface to increase left or to reduce drag, often consistent with the passive configuration of Fig. 16.

[82] The most-preferred GEM 5 obtaining substantial operation in free flight are comprised of gimbal wings that transform to form fences. In the transformation horizontal laterally-extending surfaces are re-aligned to form vertical longitudinally-extending surfaces.

[83] Fig. 4 illustrates wings attached to a trailing high-pitch surface with a leading connection to a leading pivot joint with the body and side shoulder joints 77 to wings extending laterally and forwardly at a 45° angle (in horizontal plane). Fig. 4b illustrates a transformation with the trailing high-pitch surface at 45°, while Fig. 4c illustrates a transformation with the trailing high-pitch surface at 22.5°. Variations of the Fig. 4 illustration may include but are not limited to: a) an upper surface propulsor at the leading pivot joint and respective trailing high-pitch discharge surface, b) variations in the location of the side shoulder joints which impact the fence-body and fence-high-pitch discharge surface interface, c) overlap of the high-pitch discharge surface with the wings so as to extend the fence past the trailing edge of any trailing cavity surface, and d) incorporation of other joint sections and spar sections such as elbow joints and radius spars. Analogy is made with names and gimbal action (positioning, not flapping) of bird wings where elbow transformation may be forward or backward so as to provide a fence along an underbody.

[84] Herein, parts of a wing are referred to by terms common on bird anatomy, but the terms refer to GEM 5 embodiment parts which may have gimbal action but do not flap. The terms spar and rib refer to structural frame embodiments along the wing span for spar. A rib is typically perpendicular to a spar. Typically, a shoulder joint is a wing root.

[85] The Fig.4 orientation may be longitudinally reversed where the wing is attached to a forward slat and extends spanwise and rearward. Fig. 5 illustrates an embodiment with spanwise extensions at leading and trailing positions. A fuselage may be a part of the body, preferably under the flat surface body illustration of Fig. 4 and Fig. 5.

[86] The invention includes a gimbal wing extending outward said gimbal wing comprises a humerus spar configured to pivot about a shoulder joint from a spanwise extension to a cavity fence position. The shoulder joint may be configured to rotate in a wing pitch control actuation. A wing propulsor may be located below a wing root section located between the vehicle body and a shoulder joint, and the wing propulsor may be configured as a crossover propulsor with discharge in a side cavity 63 comprising a vehicle body side and a gimbal wing section in a fence position.

Wings may use quill ribs 64 extending from the humerus spars 76 rearward wherein lift surfaces extend laterally between adjacent quill ribs 64; design features of a quill rib may be similar to design features of a feature's quill.

[87] Folding and gimbal wing embodiments may use bifacial photovoltaic cells as sheet lift surfaces. The gimbal joints may include an elbow joint connecting the humerus spar to a radius spar where the GEM 5 is configured to move the radius spar from an outward-extending radius wing position to a longitudinally-extending radius fence position. Gimbal wing roots may be connected to a high-pitch discharge surface with a taper pivot connecting the body to the high-pitch discharge surface; the shoulder joint 77 may connect the humerus spar to the high-pitch discharge surface; the cavity fence position may extend spanwise longitudinally from the shoulder joint with a fence lower edge near 0° pitch; and the high-pitch discharge surface may pivot from a free flight position to the GEM 5 configuration.

[88] Fig. 8, Fig. 9, Fig 11, and Fig. 13 illustrate lower wingspan configurations where the wing folds down via shoulder joints. Fig. 13 has particular utility for single-sheet construction such as low aspect ratio aircraft using single-sheet bifacial photovoltaic sheets to collect solar power. Fig. 11 illustrates a fence of thicker construction using induced thrust to reduce drag. The GEM 5 may include a portside fence configured to generate induced thrust on at least one third the leading surface of the fence with a trailing fence taper surface extending from the side fence surface rearward and outward.

[89] GEM 5 Folded Wing Configuration and Algorithms – Fig. 29 summarizes the algorithm for GEM 5 takeoff. Preferably, a locking mechanism locks the wing tip in a vertical position next to the body to reduce vibration and decrease air leaks between the fence and body. The vehicle may be lowed with the wings extended, and so, prior to takeoff the wings are placed and locked into the GEM 5 position. Velocity is increased until the wheels clear the ground; whereby, optionally, a hovercraft mode may be used to avoid use of wheels. Wheels may be on the fences and wheels may be on the body. After takeoff the wings are unlocked from the fence position and wingtips are lowered no lower than a minimum pre-determined ground clearance. The wings are spread in a controlled manner.

[90] The controlled manner avoids boundary layer separation by keeping the air divergence (i.e., air angle of attack) below a minimum value and avoids the sudden increase in drag. The controlled algorithm be a statical control function based on the specific aircraft and operating conditions. The controlled algorithm may be a feedback control based on sensor input such as pressure measurements at locations known to correlate with the onset of boundary layer separation. When wings are fully extended they may be locked in position with affirmation of control by ailerons or

flaps. For the Fig. 5 configuration with leading and trailing wings, the smaller wings may function as ailerons using their respective shoulder joints as actuators. To function as ailerons, the shoulder joints must have a rotating gimbal action such as is possible with ball and socket shoulder joints; however, hinge-type joints are sufficient. If a hinge joint is used for the shoulder joint, the Fig. 4b axis of a shoulder hinge joint is aligned with the edge of the trailing taper 22 while axis of the hinge joint for Fig. 4c is not aligned.

[91] A method for operating the GEM 5 with an upper surface propulsor includes takeoff to free flight may comprise the steps: (a) placing wing sections in a fence position configured for , (b) accelerating to takeoff velocity and attaining of ground effect flight, (c) lowering wing section wing tips as elevation increases and while maintaining a minimum ground clearance, and (d) extending wings to a lateral wing position configured for efficient free flight. This free-flight GEM 5 has a lower cavity defined by two fences in the fence position, a vehicle body lower surface, and a trailing flap.

[92] An additional method for transit comprises the GEM 5 configured to transition from transit on a railway path to transit on a roadway where the GEM 5 comprises an upper surface propulsor and a lower cavity; the lower cavity preferably comprises side fences and a trailing flap where the flap configuration is changed from a vertical distance of at lead one half inch above the wheels on a highway to a vertical distance of at least one inch below the wheels on a railway track. The GEM 5 travels at a speed greater than 60 mph on the railway to attain better efficiencies.

[93] The control algorithm for wing transition from take-off ground effect to free-flight may consist of a dynamic sub-algorithm controlling trailing flaps, ailerons, fence sections, and morphing upper cavity surface for maintaining moment coefficient for stability. This sub-algorithm designed to modify listed surfaces to prevent pitch deviation dependent on changes in ground conditions, wind speeds, and weight distribution. The algorithm is designed to distribute lift forces along the cavity upper surface to maintain smooth and safe flight during wing and elevation transitions.

[94] Railcar Embodiment – The ground-effect railcar embodiment has particularly good performance due to the ability to travel at low clearance gap ratios resulting in high L/D efficiency. At locations where traffic is high, additional blocking of lateral losses, from upper and lower surfaces, can be achieved with railway side walls 58 along the sides of the tracks positioned for preferred lateral vehicle clearances of 0.3 to 1.5 feet. An overhead LIM 59 may be used as a safeguard against derailment and may be part of a guideway separate from the tracks.

[95] Typically, a clearance is a vertical distance, however, over rails the fence may extend over the side of the rail. Fig. 3a illustrates a fence 4 beside a rail 11 with a horizontal clearance ratio. Fig. 3b illustrates a fence curved in the vertical dimension.

[96] Fig. 1c illustrates a hi-rail embodiment which engages a flanged wheel with the rail when an intermodal GEM 5 transfers from roadway operation to railway operation.

[97] Transit in tunnels enables enhanced blocking of vertical and lateral losses of lift pressures. For operation in tunnels, the preferred vehicle is powered by fans and a non-aerodynamic method such as wheel traction or LIM propulsion. Preferred operating conditions are with enough non-aerodynamic propulsion so as to create a slightly higher pressure afore the vehicle which pushes air through the tunnel in the direction of vehicle travel and enhances system efficiency with the created "tailwind". Preferably, the non-aerodynamic propulsion is 5% to 30% of the vehicle's propulsion needs.

[98] The transit system of this invention may comprise GEM 5 with side propulsors connected to the vehicle body and configured to increase the velocity of air along the side of the vehicle from a first leading tunnel section 68 to a first trailing tunnel section 69. A duct sequence 70 preferably connects a first leading tunnel section 68 to a second trailing tunnel section 71 where the duct sequence 70 are configured to use air's dynamic pressure create an air flow from the second trailing section to the first leading section. This is most useful for operation with open vehicle entrances to and from tunnel sections designed to operate at lower pressures where the leading section extends to a first leading section tunnel exit 72 and the second trailing section extends from a second trailing section tunnel entrance 73. A GEM 5 and a transit path the transit system preferably comprises a tunnel, a tunnel entrance section and a tunnel exit section; the tunnel entrance section being connected to said tunnel exit section by a sequence of air passages configured to convert entrance air's relative dynamic pressure into flow through the sequence of air passages from the tunnel entrance section to the tunnel exit section.

[99] A LIM is able to provide non-contact propulsion with the preferred LIM 59 being overhead a vehicle and also providing: a) energy transfer, b) partial suspension, and c) tractor-type guidance along a LIM cable. More preferably, an overhead electrical assembly consists of an upper LIM cable and a lower contact cable; the contact cable configured to transfer electrical power to conventional trains which may operate on the same tracks.

[100] Bernoulli Loops 70 at entrance-exit locations can reduce pressures in tunnels to further reduce drag and increase efficiency. Bernoulli Loops 70 are ducts configured (see Fig. 25 and Fig. 26) to convert air's dynamic pressure into a driving force for the transfer of air from entrance sections to exit sections.

[101] The pressure profiles of Figure 26 were created by air flow with pressures in the loops increasing from right to left. In each instance air flow of the tunnel connected to the entrance increases when approaching the Bernoulli loop surface ahead of the air flow. That increased

pressure persists to the air in the tunnel connected to the exit. Air mass is transferred from the entrance section to the exit section with the result of tunnel in the tube becoming progressively lower as path progresses from the entrance further into the tube. The driving force for transfer of air from entrance tunnel sections to exit tunnel sections is air flow in the tunnel which can be created by vehicles pushing the air or by blowers 75 in ducts designed to push air through the tunnel.

[102] Free Flight – Free flight is away from ground effects. In free flight the fences are typically retracted and the flap set at a lower setting.

[103] The transit system of this invention may or may not include a path 74 of ground-effect flight. The transit system includes a means to interact with the path 74 which may be on the GEM 5 in part or in whole. The path 74 is a manifestation of the ground surface such as a railway, roadway, or water surface.

[104] Fig. 32 illustrates a GEM with shoulder joints to fold wing from free flight to fence positions. The fence-position wings are contiguous with a GEFT fuselage consistent with transition on rails and roadways including roads blocked off to allow the GEM to takeoff and land. The Fig. 32 GEM embodiment is capable of high-lift high-L/D-efficiency ground-effect flight in the GEM configuration consistent with the many pre-print papers of the Illustrative Example section, including L/D efficiency in excess of 30. Also, the Fig. 32 GEM is capable of extending wings, with gimbal action similar to that illustrated by Fig. 4 to achieve wing of good span and high aspect ratio with commonly attainable L/D efficiencies in excess of 12.

[105] Preferably, a GEM 5 designed for extended free flight comprises a wing section and a shoulder joint connecting the wing section to the vehicle body where the wing section pivots about the shoulder joint longitudinally and vertically from a lateral wing position to a longitudinal fence position. More preferably, the wing section comprises a long-chord section extending spanwise outward from the vehicle body and a short-chord section extending spanwise inward over the vehicle body such as illustrated by Fig. 34.

[106] Latches may be used to secure the wing sections in fence positions, such as a magnetic latch. Overlap of section may be used to provide contiguous air flow or to increase structural strength, such as a section of a wing section resting on a fuselage upper surface when the wing section is expanded in span for free flight.

[107] The GEM 5 may be configured as an electric vehicle for operation on a highway wherein at least half the weight is supported by aerodynamic lift and, optionally, with solar panels on a payload compartment providing at least half the propulsion power at a cruising speed greater than 50 mph.

[108] The GEM 5 may comprise a lead vehicle pulling a trailer with regenerative braking and electric wheel propulsion where at least half the trailer weight suspension in air-based ground effect flight suspension, and optionally an upper surface propulsor 2 on said trailer precedes a trailing taper 22 having a surface pitch between 15 and 70 degrees. Preferably, photovoltaic cells on the ground effect machine provide more than 25% of the power required to transport a cargo-less system; more preferably, more than 50% of the power.

[109] The GEM 5 may be configured as an agricultural vehicle where the agricultural vehicle interacts with farm ground in a ground effect flight mode of operation. The agricultural GEM may be used for crop spray, aerial seeding, and other operations.

[110] Fig. 34 illustrates a GEM similar to that of Fig.32 except the wing extensions have sections that are primarily fence section to avoid interference in free flight. The flat wing sections with rectangular sections removed is one of many shapes which can be optimized specific to application. Morphing shapes are an option.

[111] Supersonic flight may be achieved in ground effect where the shock wave bounces off the ground and back onto the lower surface. For supersonic aircraft, the about of fuselage above the leading edge is reduced, preferably with a near-horizontal apex near the leading edge and a convex upper surface camber. Crossover propulsors may be used to reduce accumulation of shock wave near the leading edge.

[112] Illustrative Example of Folding Wing Embodiment – Figure 4 illustrates two examples of how an extended wing may fold into fence positions for ground-effect flight, takeoff, and landing.

[113] Parametric Ranges – Parametric ranges are identified for ground-effect flight with free flight or floating in water optionally operating outside the preferred ranges for ground-effect flight. Important design parameters include the following:

a. Trailing taper is important. The trailing taper 22 reduces vehicle length whereby shorter vehicle length makes it easier for higher cavity pressures to expand forward and increase induced thrust where: a) for free flight preferred trailing tapers are between 3° and 20° with 15° to 20° range most preferred for cruising and b) in ground-effect flight preferred trailing tapers are between 15° and 50° with 25° to 40° range most preferred for cruising. Variable pitch is preferred to allow optimal performance as dependent on propulsor power. The trailing taper extends over at least 60% of the body height, and preferably, from the upper surface of the body to the lower surface with contiguous connection to a flap that extends below the vehicle lower surface. Most-preferred in ground-effect is a flat taper surface which translates to a pitch consisting of a variance of less than 2°. Variances less than 5° allows camber as may be preferred for certain applications.

b. A typical good flap percent is 70% of the gap between the lifting body's trailing edge and the lower part of the fence at the flap location, and preferably for ground effect flight, the flap percent is able to vary between about 20% and to about a clearance about twice that of the fence. Note that if the fence is above railway tracks, the flap may extend below the tracks in the space between tracks. In free flight, a zero percent flap or upward deflection may be preferred.

c. Fences extend downward from the body 37 with the body height defined independently of the fence's downward extension from the body's lower surface. The clearance ratio is the minimum clearance from the ground divided by the fence height (from lower fence edge to the lower surface of the lifting body). Preferably: a) fence heights are typically 5% to 100% of the body height, b) the fence extends forward to at least the leading edge of the body, and c) the fence extends backward to at least the flap. Fence geometry parameters are subject to results-driven optimization. In steady-level ground-effect flight, the fence is preferably a constant clearance value (e.g. 0.01 clearance ratio for railcar) for both fences throughout the length. As a control method, the fence clearance may be increased resulting in local cavity pressure reduction and a change in roll or pitch, depending upon location and coordination of changes in clearance ratio. By example, a GEM railcar may be designed to operate at a clearance ratio of 0.01 at 70 mph to generate a lift pressure that is 80% of air's oncoming dynamic pressure; where, as the velocity increases the clearance ratio increases to keep the average lift pressure about the same since the railcar weight is relatively constant during a trip.

d. The pressure in the cavity increases with increasing GEM velocity and decreasing clearance ratio; and so, at a constant vehicle weight and preferred near-constant pressure throughout the cavity the clearance ratio will increase with increasing velocity after the desired aerodynamic lift force is attained. A typical design point is for full aerodynamic lift at about 70 mph at a clearance ratio of 0.02. Example "desired aerodynamic lift" are: a) 100% of the weight for takeoff to free flight, b) 90% of weight for GEM operation with wheel traction, and c) 90% of weight for GEM operation with water ski traction.

e. Control surfaces vary considerably between a GEM truck, a GEM aircraft designed for free flight, and a GEM boat. For a truck, the preferred control surfaces are wheels with conventional steering mechanisms and braking mechanisms. Ailerons, flaps, vertical stabilizers, and horizontal stabilizers may be added as deemed optimal for GEM designed for free flight; and specific to inventions herein, GEM with a lead body pulling a towed platform have good passive stability characteristics. For GEM boats, ski orientation is a control surface for steering as is the weight on the ski for braking. For GEM railcars, hi-rails may be used as well as: a) ailerons, b) rudders on fences, c) sections of the flap, and d) fence clearance. Rapid vertical movement of fence sections may be used to avoid hitting upward perturbations from an otherwise flat surface (e.g. such as speed humps, carrion, rocks, and wave crests).

f. Lift Span surfaces in front of a Lift Span propulsor preferably have a pitch that varies with propulsor power, where for cruising speeds, the preferred average pitch of the 30% of body chord length in front of the propulsor is -1° and 1°.

g. Tunnel pressures are a degree of freedom with optimal tunnel operating pressures depending on the distance of travel in the tunnels and the traffic density; more Bernoulli Loops lead to lower tunnel pressures.

[114] Illustrative examples are contained in the following series of pre-print materials published after priority documents and before instant application, but after stated provisional applications. These documents contain multiple illustrative examples, calculations, and explanations of underlying theory and design approaches.

[115] The preprint https://doi.org/10.33774/coe-2024-76mzx entitled “Critical Data and Thinking in Ground Effect Vehicle Design” illustrates the importance of adjustable fences and control on attaining L/D efficiencies exceeding 40. Said preprint illustrates the improvement from these compared to patent No. GB1347352 GEM with L/D of 11 to 17.

[116] The preprint https://doi.org/10.33774/coe-2024-w4qtp entitled “An Airfoil Science Including Causality” illustrates the importance of developing leading and trailing edge stagnation points 10 60 for the development of strong lift forces and induced thrust without significant irreversible energy losses.

[117] The preprint https://doi.org/10.31224/4224 entitled “Overcoming Boundary Layer Separation” illustrates the importance of the trailing stagnation region 60 reaching from the path to the cavity trailing surface for the formation of ground effect efficiencies of L/D exceeding 25, and readily between 15 and 25 for digital prototypes. Said preprint illustrates the importance of upper-surface propulsor in increasing efficiency through the mitigation of boundary layer separation turbulence losses over the trailing taper, increasing L/D efficiency by 100-200%. Said preprint illustrates effective use of trailing taper pitch surfaces higher than 30 degrees pitch. Example energy savings exceed 50% energy consumption due to drag reduction and reduced wheel suspension using technologies of this invention with example loads up to 277 lb/ft at 50 mph.

[118] The preprint https://doi.org/10.21203/rs.3.rs-4670250/v2, “Computational Analysis of Towed Solar platforms" illustrates the importance of the -1 to 1 degree pitch for the low-pitch upper surface of claim 2 for achieving high L/D efficiency. The preprint also illustrates the importance of developing the trailing stagnation point 60 to develop lift pressures through the use of a spoiler as the cavity trailing surface. The preprint illustrates the excess energy capabilities of trailing sections (i.e., towed platforms) of aero vehicles, with estimates of power generation over 150 times the power needed to sustain flight of the towed section.

[119] The preprint https://doi.org/10.31224/4136 entitled “Thin Cambered Lifting Bodies in Ground-Effect Flight” illustrates that GEM consisting partially of thin cambered sheet sections generate the same or better lift forces per surface area with readily increasing aspect ratios than GEFT GEM. L/D of said thin camber inboard sectional GEFT exceed 40, readily attaining L/D of 20-35, and wing sections of thin camber in ground effect exceed 80 L/D with upper-surface trailing propulsors. This work illustrates how a low aspect ratio boat can be expanded spanwise by expanding an inboard thin-cambered section; this expansion increases lift while preserving L/D efficiency toward allowing a ship to attain free flight. Example changes in aspect ratios are from a range of 0.2 to 0.4 to a range of 0.5 to 2.0; where the chord remains approximately constant..

[120] The preprint https://doi.org/10.33774/coe-2024-2c87q entitled “Ground Effect Flight Transit (GEFT) – Approaches to Design” illustrates the importance of induced thrust on the leading section of the cavity’s upper surface. Said preprint illustrates GEFT with L/D greater than 60 with upper surface trailing propulsors.

[121] The preprint https://doi.org/10.33774/coe-2024-prxvr “Ground Effect Flight Transit (GEFT) – Towards Trans-Modal Sustainability” illustrates the importance of adjustable portside fences, starboard fences, and trailing flaps on propagating trailing edge stagnation point 60 dynamic pressures through the cavity for improved lift. The paper illustrates the capabilities of wing sections of the transport system of claim 13 to function on roads, railways, and canals with L/D 40-60 readily attained.

[122] The preprint https://doi.org/10.33774/coe-2024-6w0lw entitled “Ground Effect Flight Transit (GEFT) in Subways” illustrates the importance of maintaining the pressure before a GEM at a pressure equal to or less than the pressure behind a GEM to attain wing section L/D efficiencies 20-30 within enclosed spaces. Ground effect is subways is one type of tunnel transit which include inventions of Fig. 25 with example performance of Fig. 26. Diameters of the Bernoulli loops 60 are typically 20% to 100% the average diameter of the tunnel. This work estimates GEFT technology to provide btu/passenger-mile less than 650 for GEFT technologies, over 10 times more efficient than multicopters and over twice as efficient as bus and rail systems.

[123] The conference paper referenced Suppes, A., and Suppes, G., "Highly-Efficient Low-AR aerial vehicles in urban transit," Proceedings of the 2014 Transportation Research Board Annual Meeting, January, 2024, hs-drone.com illustrates the design of Bernoulli loops to efficiently link multiple transit tunnels to maintain the favorable pressure differentials of said preprint entitled Ground Effect Flight Transit (GEFT) in Subways."

[124] The following is a summary of devices or terms that are different manifestations of the same thing: a) a deflector surface 1 may be configured to provide "induced thrust" on forward surface, b) a trailing cavity surface 6 is a surface designed to create pressure, and optionally, control the amount of pressure created and flow through a cavity. A flap 6 and a spoiler 6 are types of trailing cavity surfaces, c) a truck underbody 8 implicitly includes a truck lower surface 8, d) the lower-pitch intake surface 16 in front of a Lift Span propulsor may be referred to as a Lift Span 16 or flat intake surface 16, e) the crossover propulsors 18 of this invention may be thin plate crossover propulsors 18 when used with thin plate construction or a side propulsor 66 crossover propulsor when on the side of a vehicle with intake on an upper surface and discharge in a side cavity 63, f) a panel surface 19 includes more-specific options such as a sheet surface 19, a thin cambered surface 19, and single sheet bifacial photovoltaic surfaces 19, g) . laterally extending wings 22 may be referred to as wing sections 22, h) an aerial tail 30 may be referred to as a boattail 30 or diffuser 30, i) a wheeled ski 34 may be referred to as a wheel assembly 34, and j) A curved track assembly 44 may be referred to as an extension track 44 for a slat.

Fig. 1

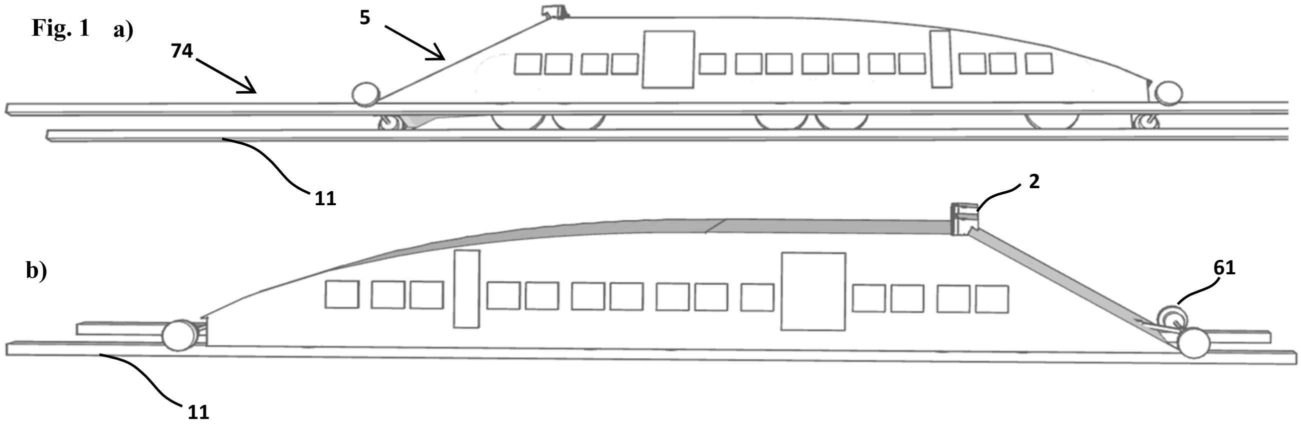


Fig. 2

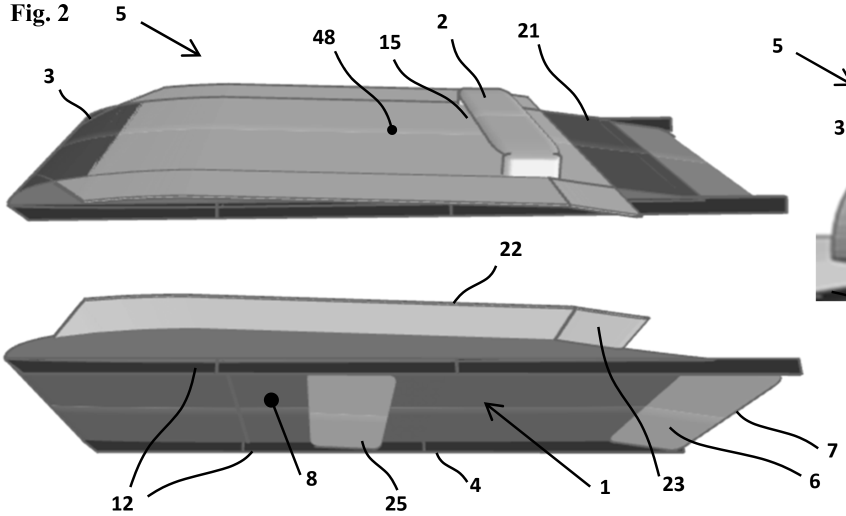


Fig. 3

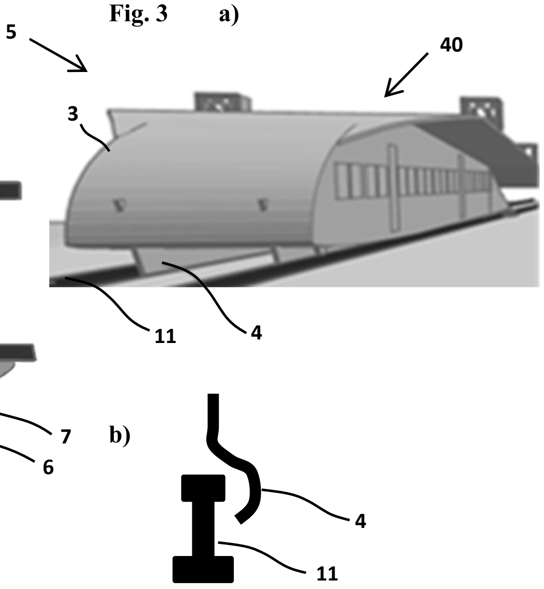


Fig. 4

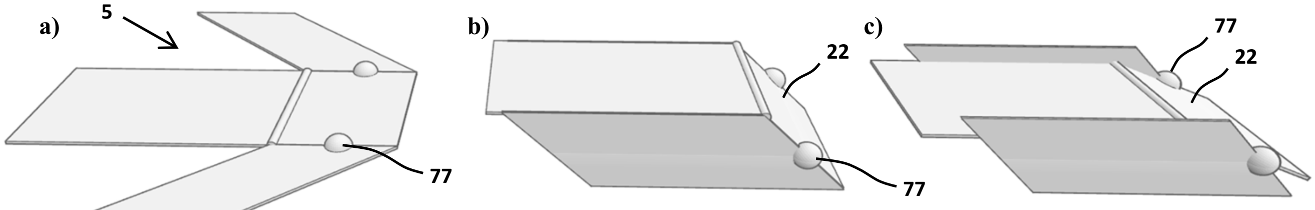


Fig. 5

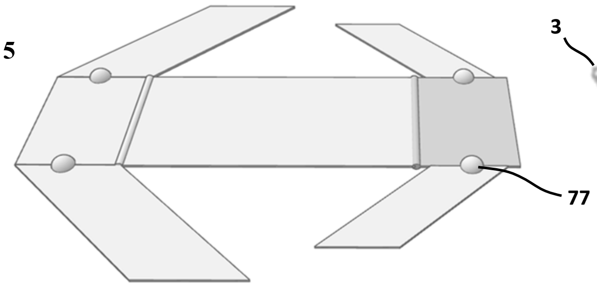


Fig. 6

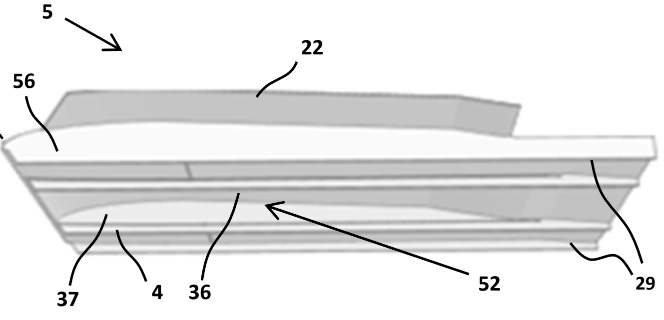
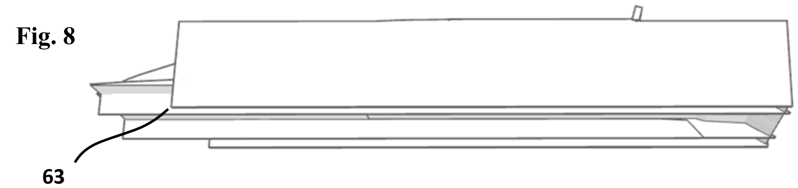


Fig. 8



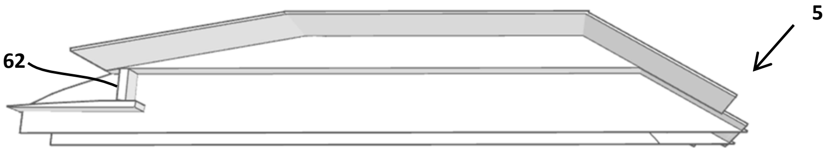


Fig. 9

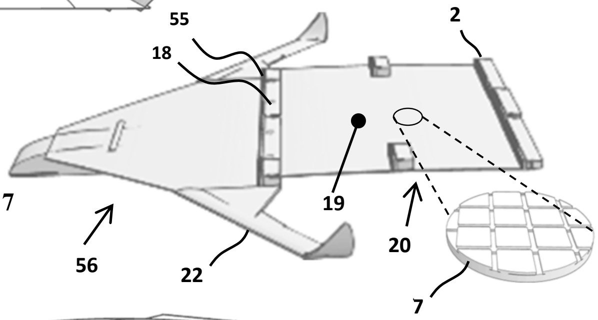


Fig. 7

Fig 10

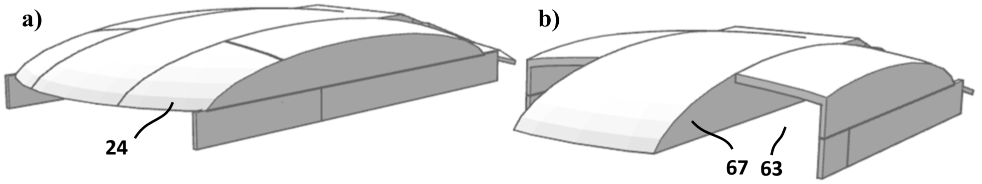


Fig 12

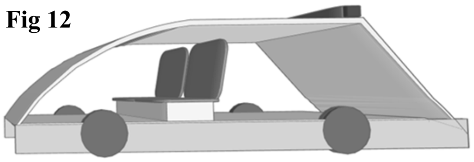


Fig. 13

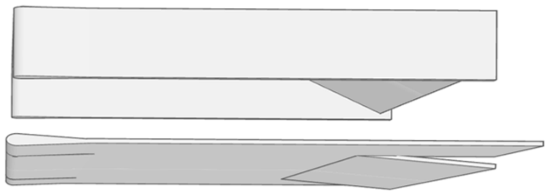


Fig 11

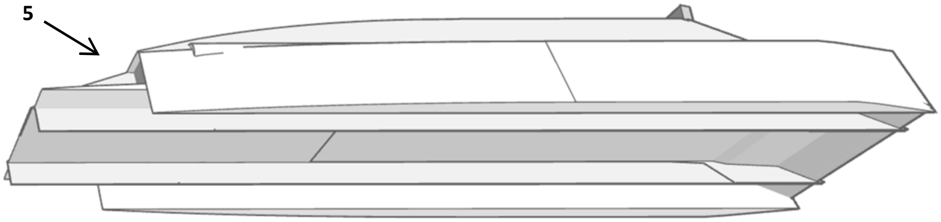


Fig. 14

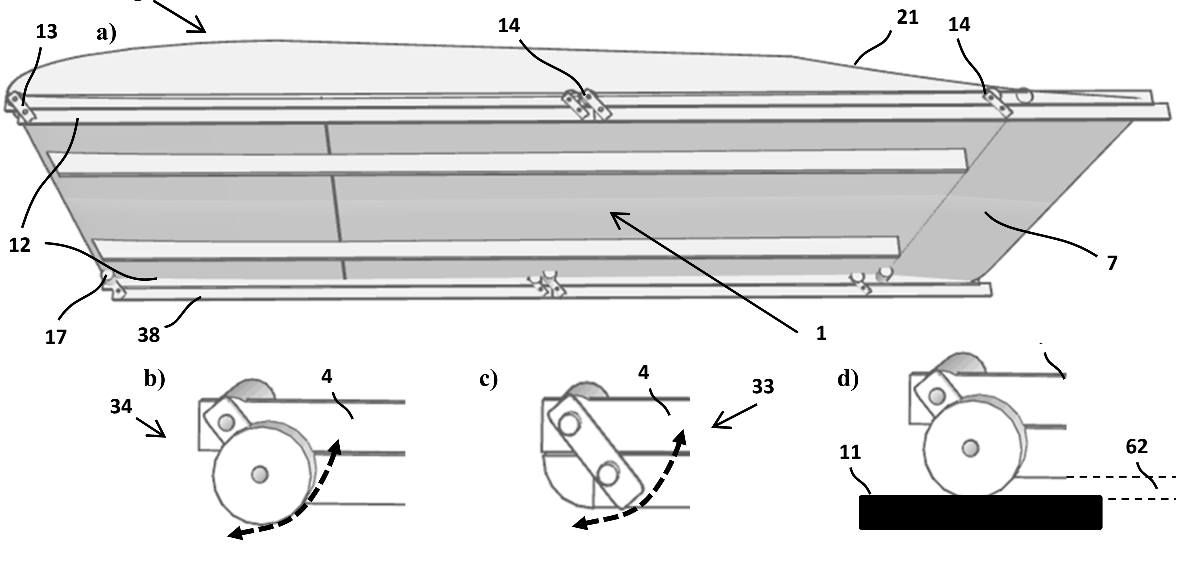


Fig. 15

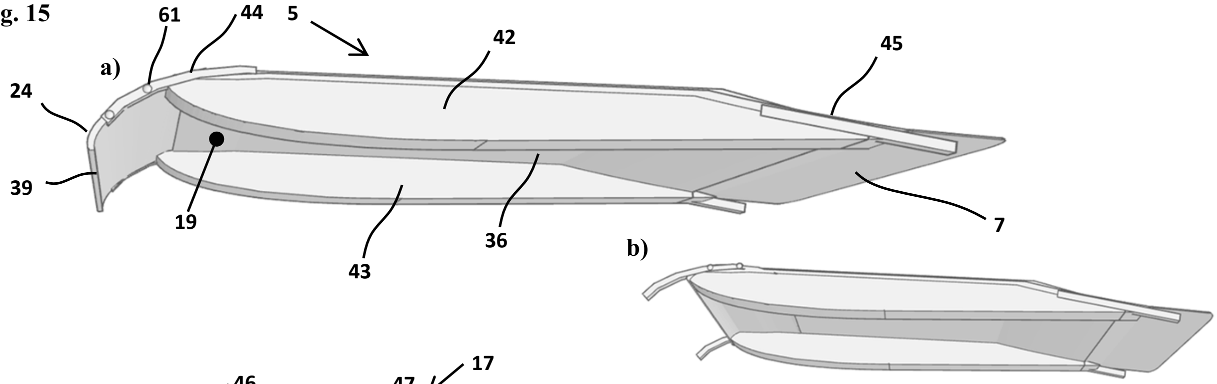


Fig. 16

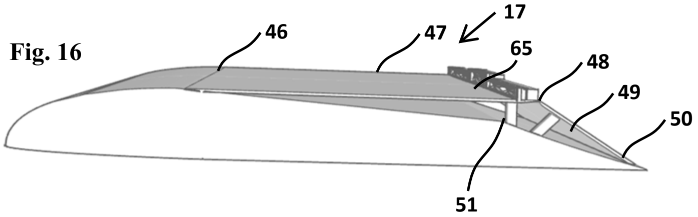


Fig. 17

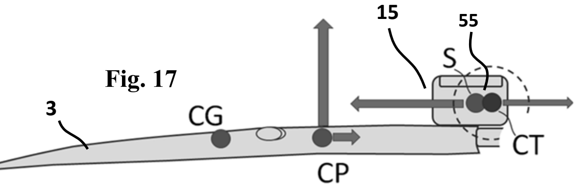


Fig. 18

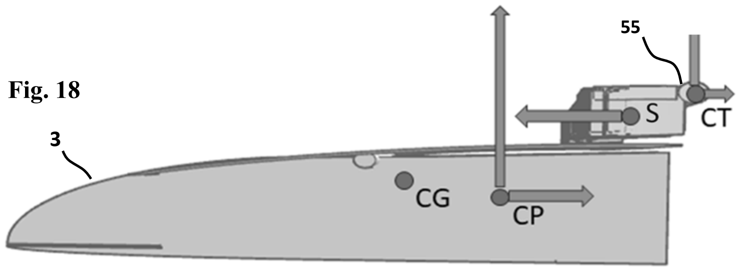


Fig. 21

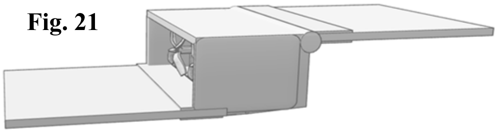


Fig. 19

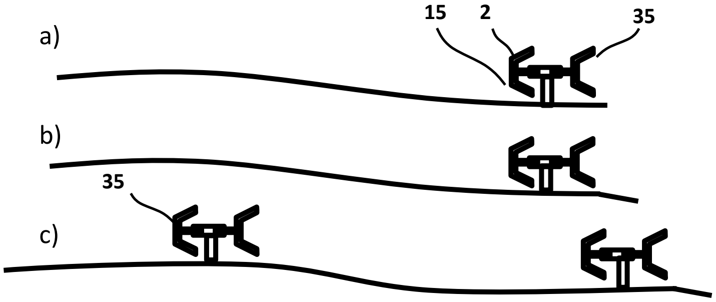


Fig. 20

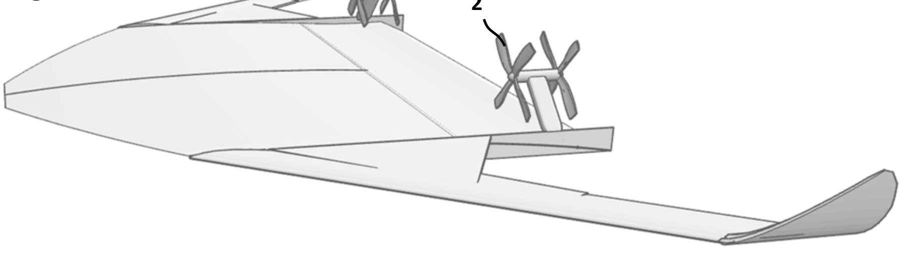


Fig. 23

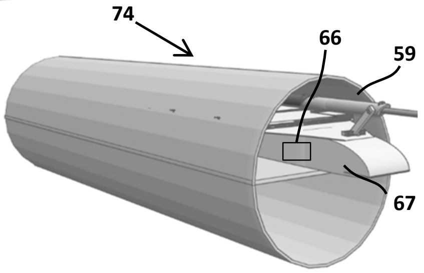


Fig. 22

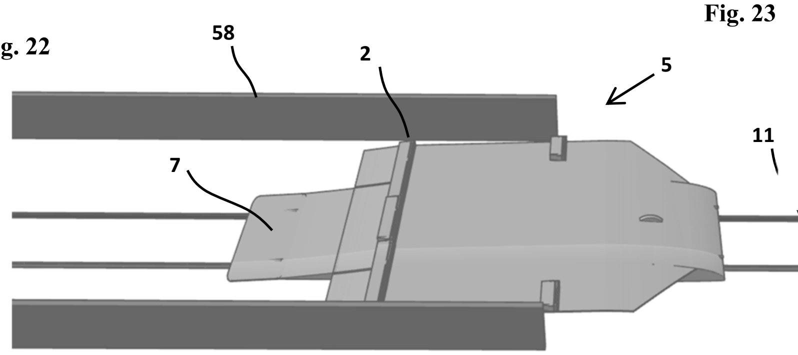
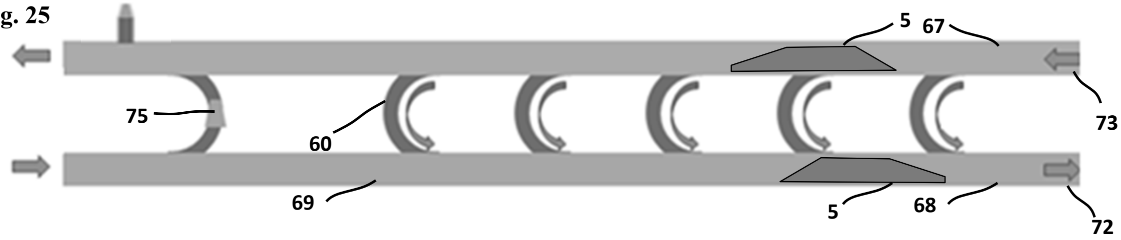


Fig. 25



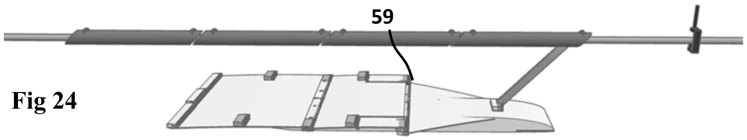


Fig 24

Fig. 27

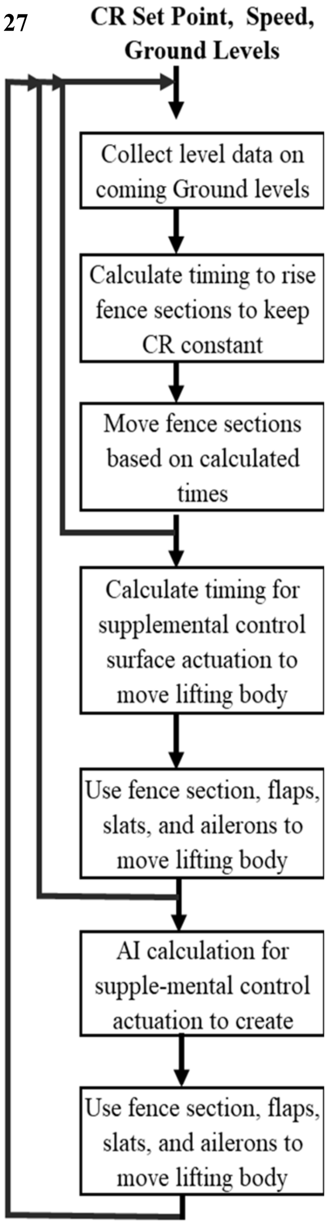


Fig. 29

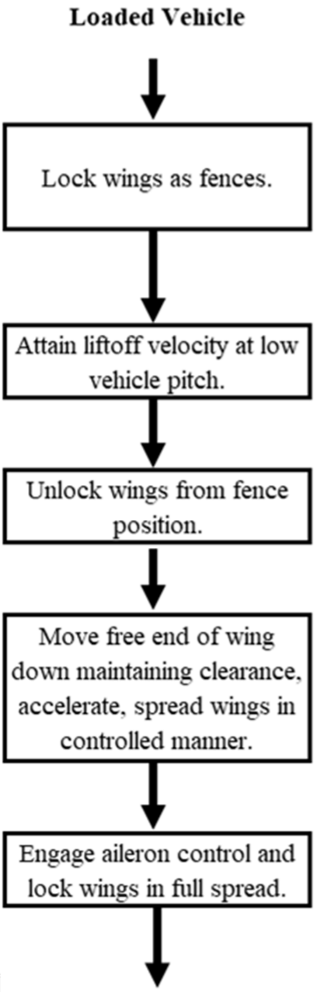


Fig 26

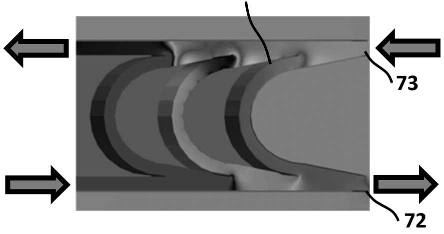
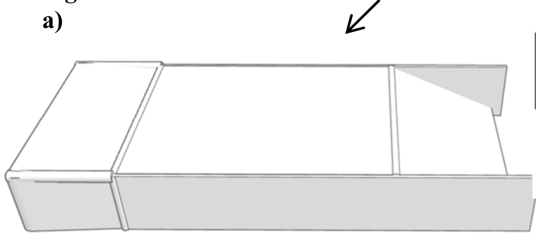
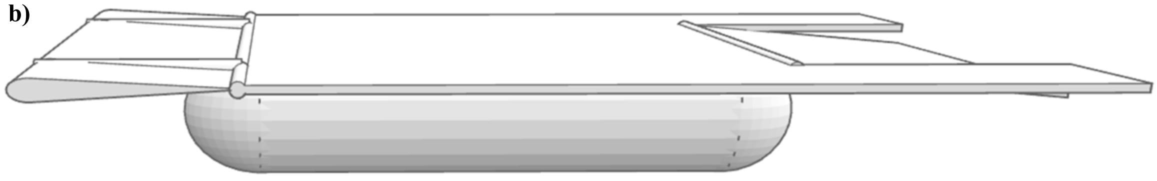


Fig. 28

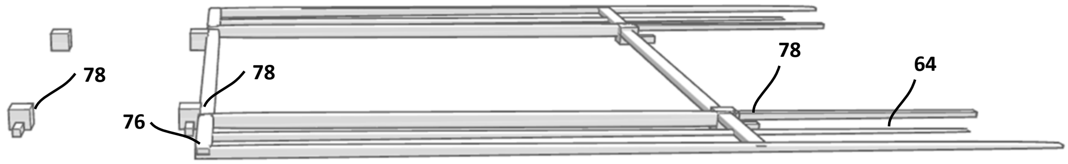
a)



b)



c)



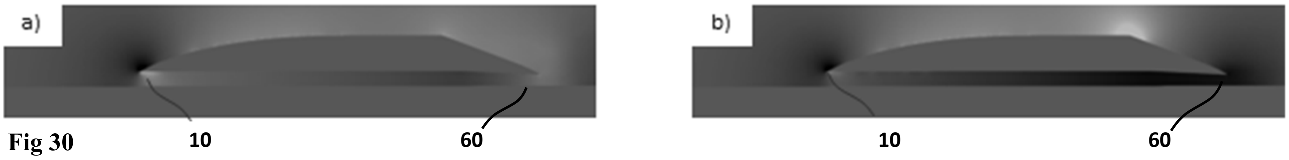


Fig 30

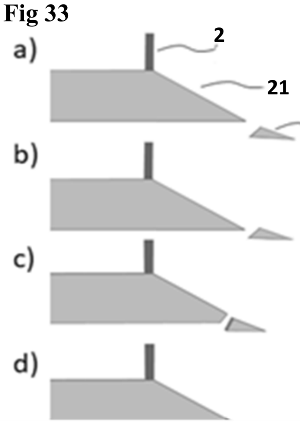
Fig 33


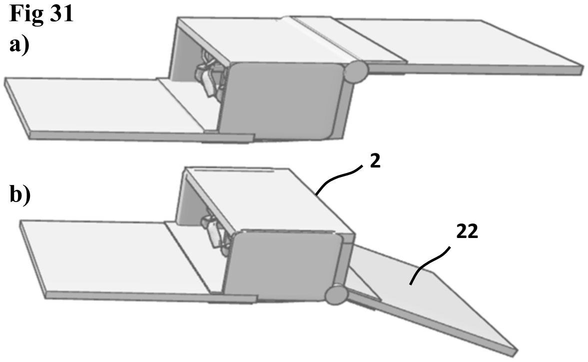
Fig 31


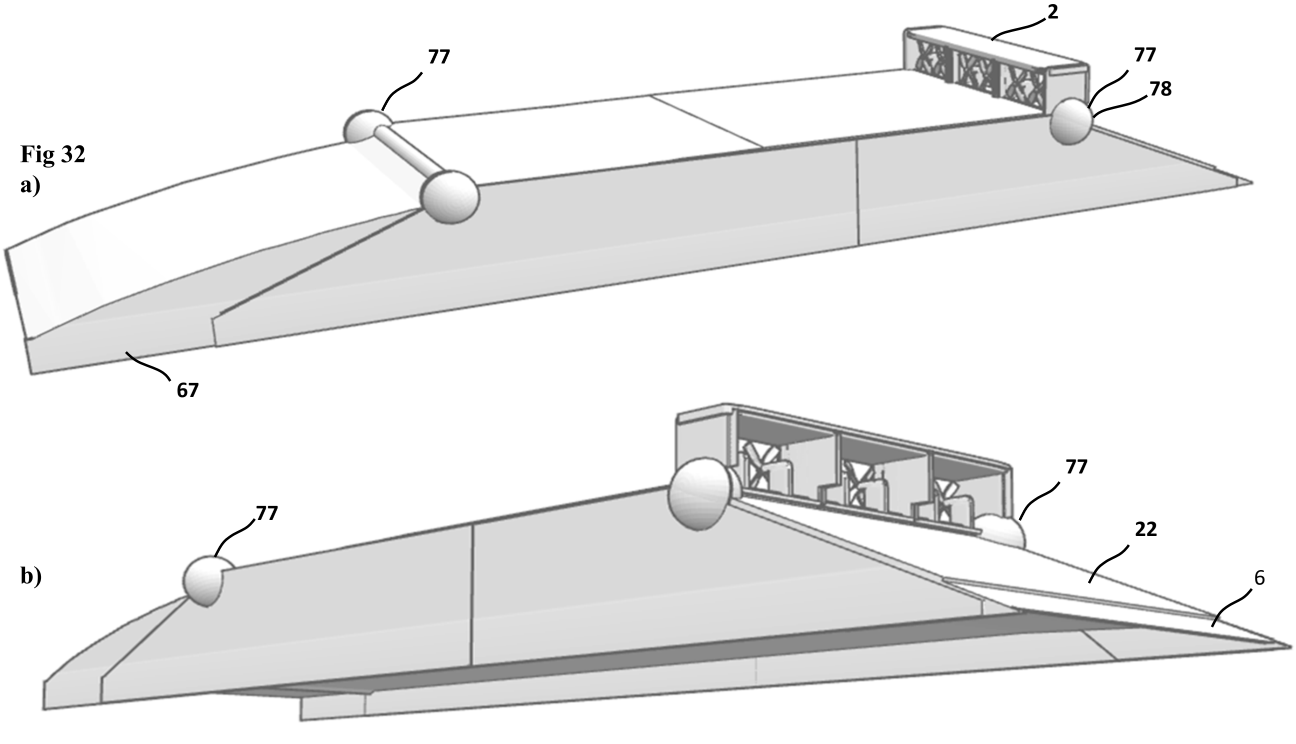
Fig 32


Fig 34