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(54) EMERGENCY RUNWAY

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(57) ABSTRACT

An apparatus is provided to support aircraft with disabled landing gears. The apparatus comprises a support assembly, a hub, a shock absorber and a transport mechanism. The support assembly includes a contact component. The support assembly is rotatably connected to the hub. The shock absorber includes a first end to which the hub is rigidly connected. The transport mechanism is to move the apparatus along a ground surface. The contact component is to contact with and to support an aircraft fuselage during landing.

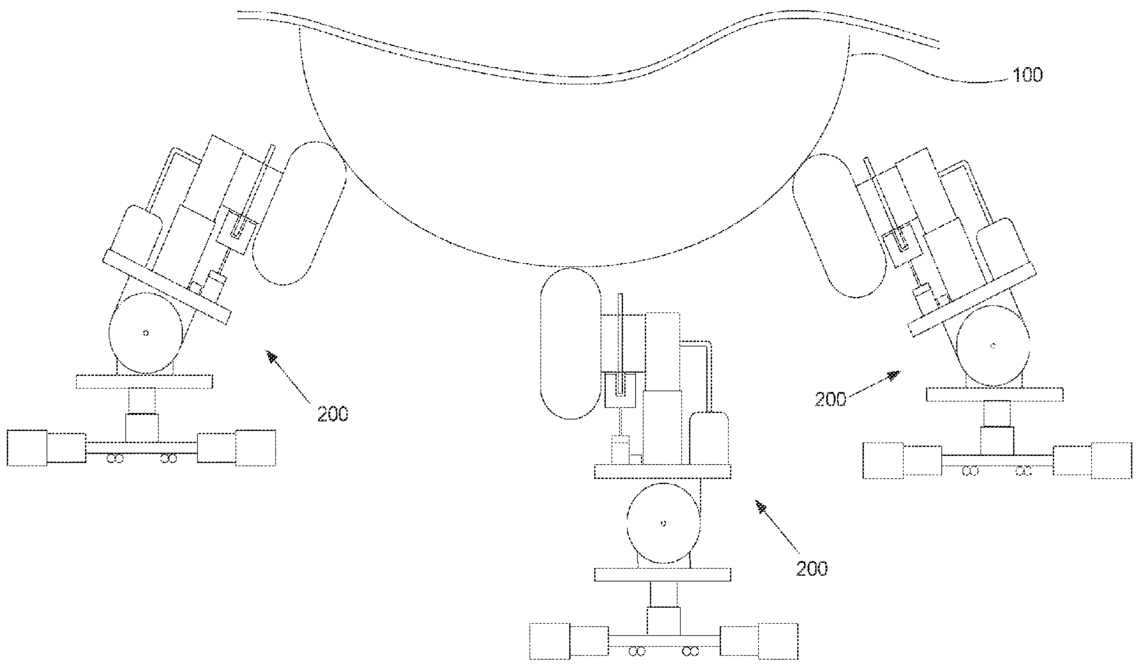


FIG. 1A

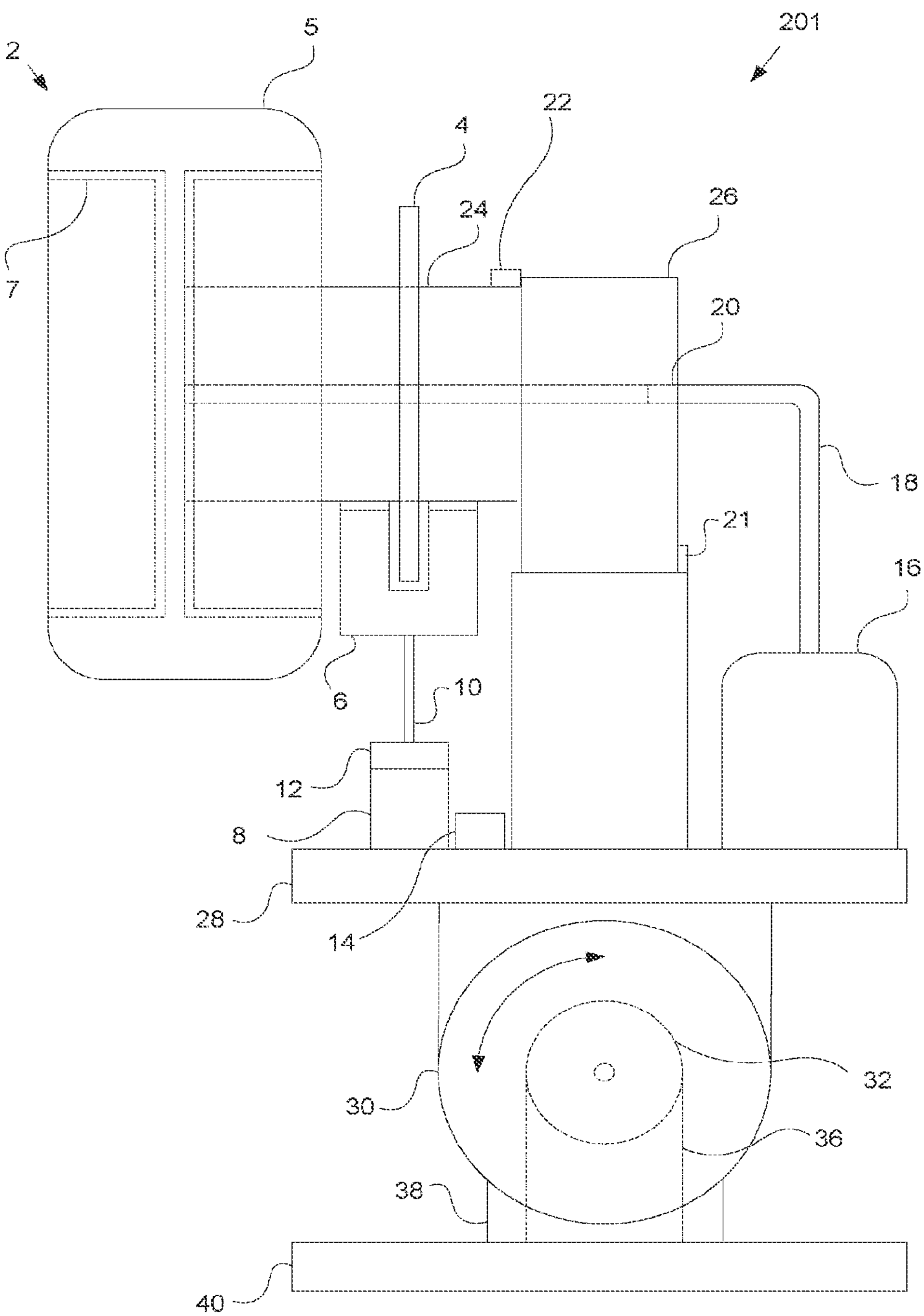
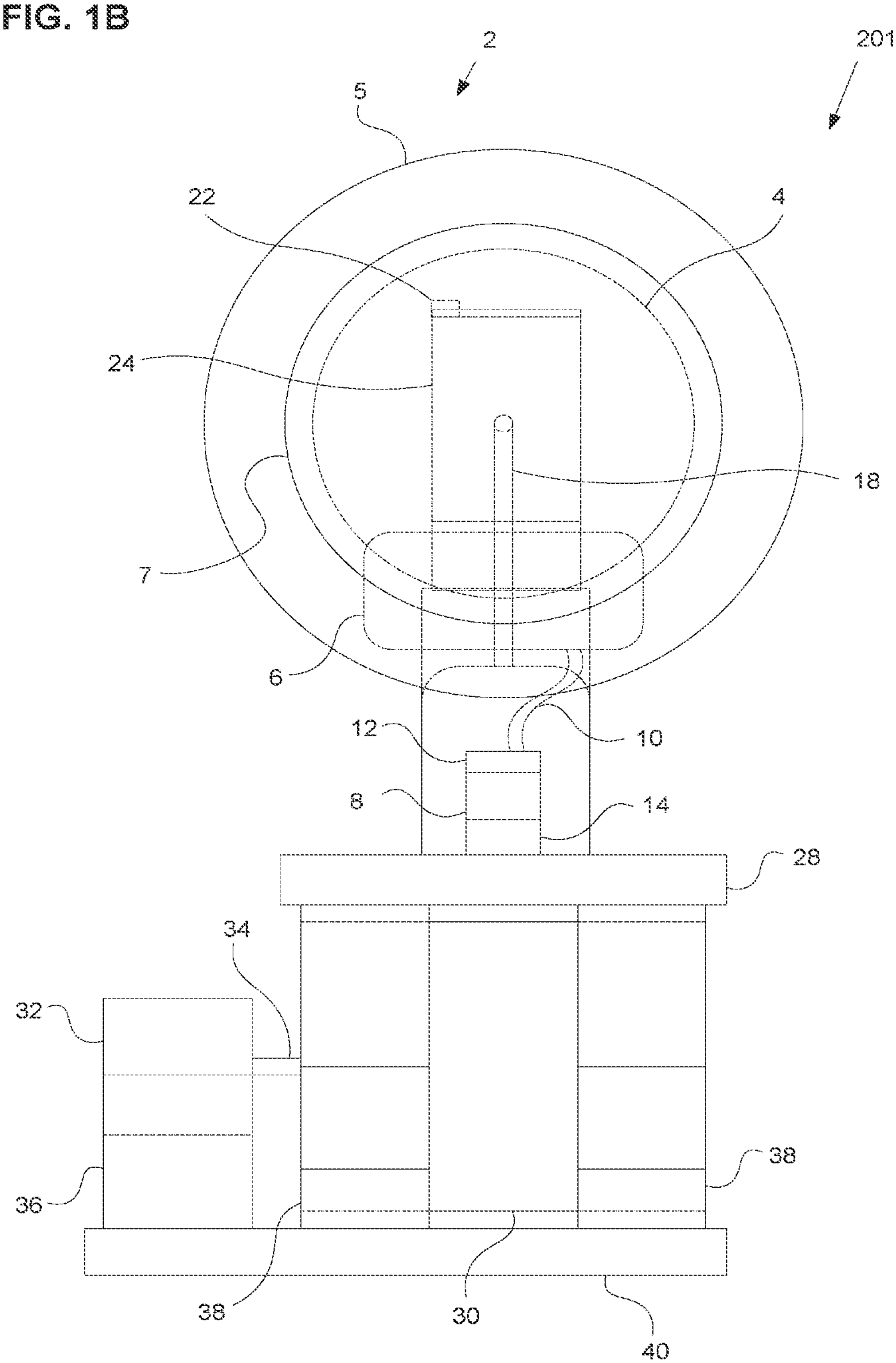


FIG. 1B



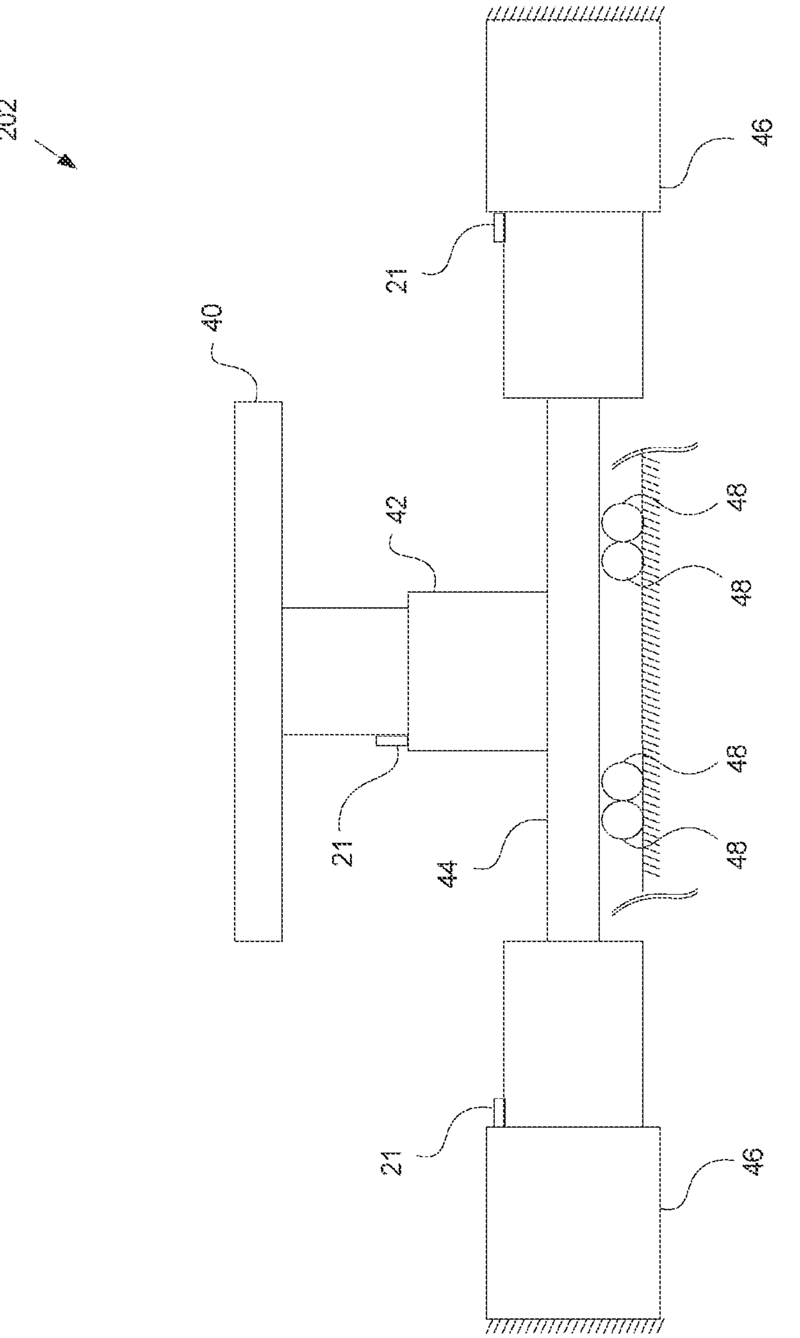



FIG. 2A

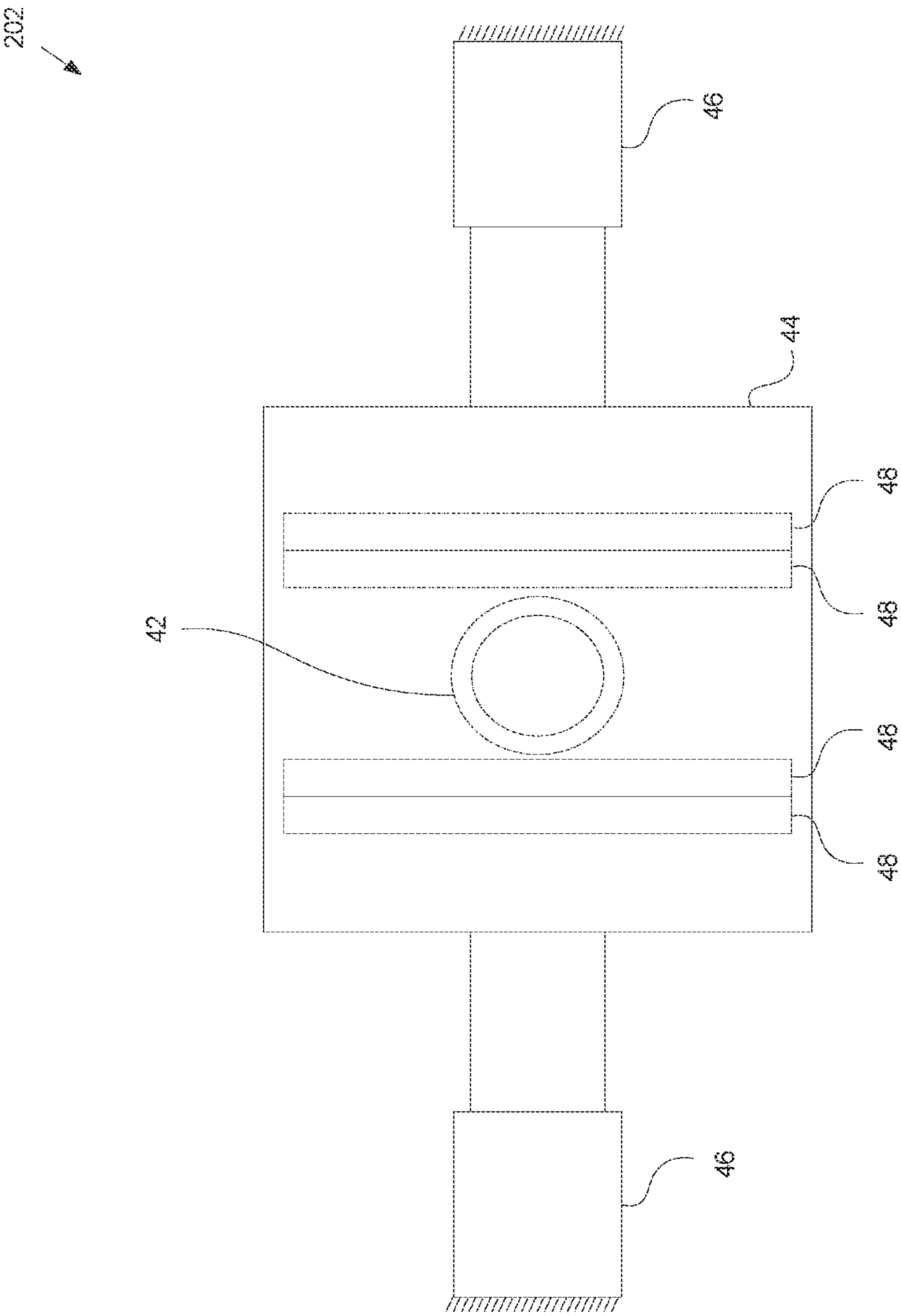
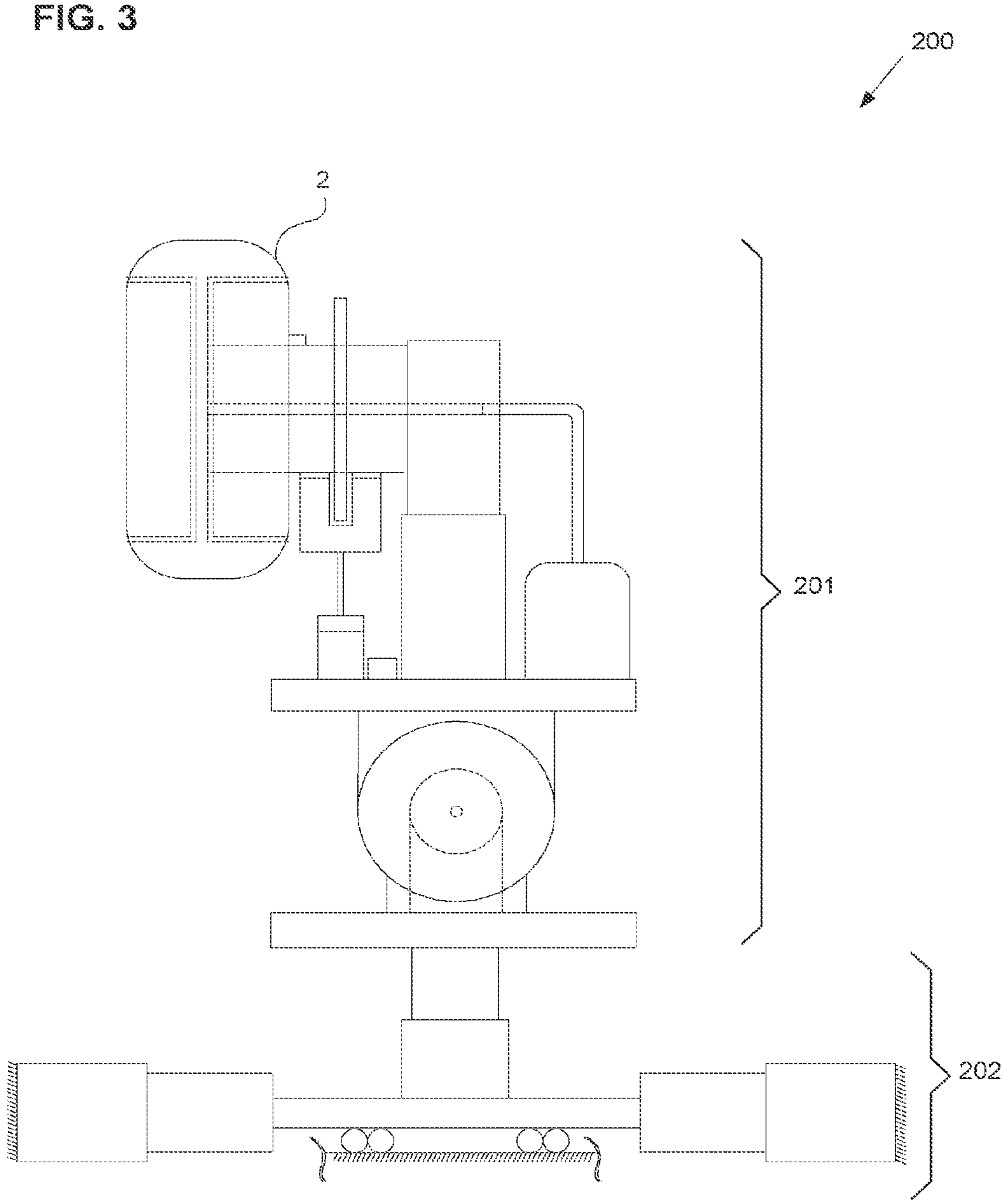



FIG. 2B

FIG. 3



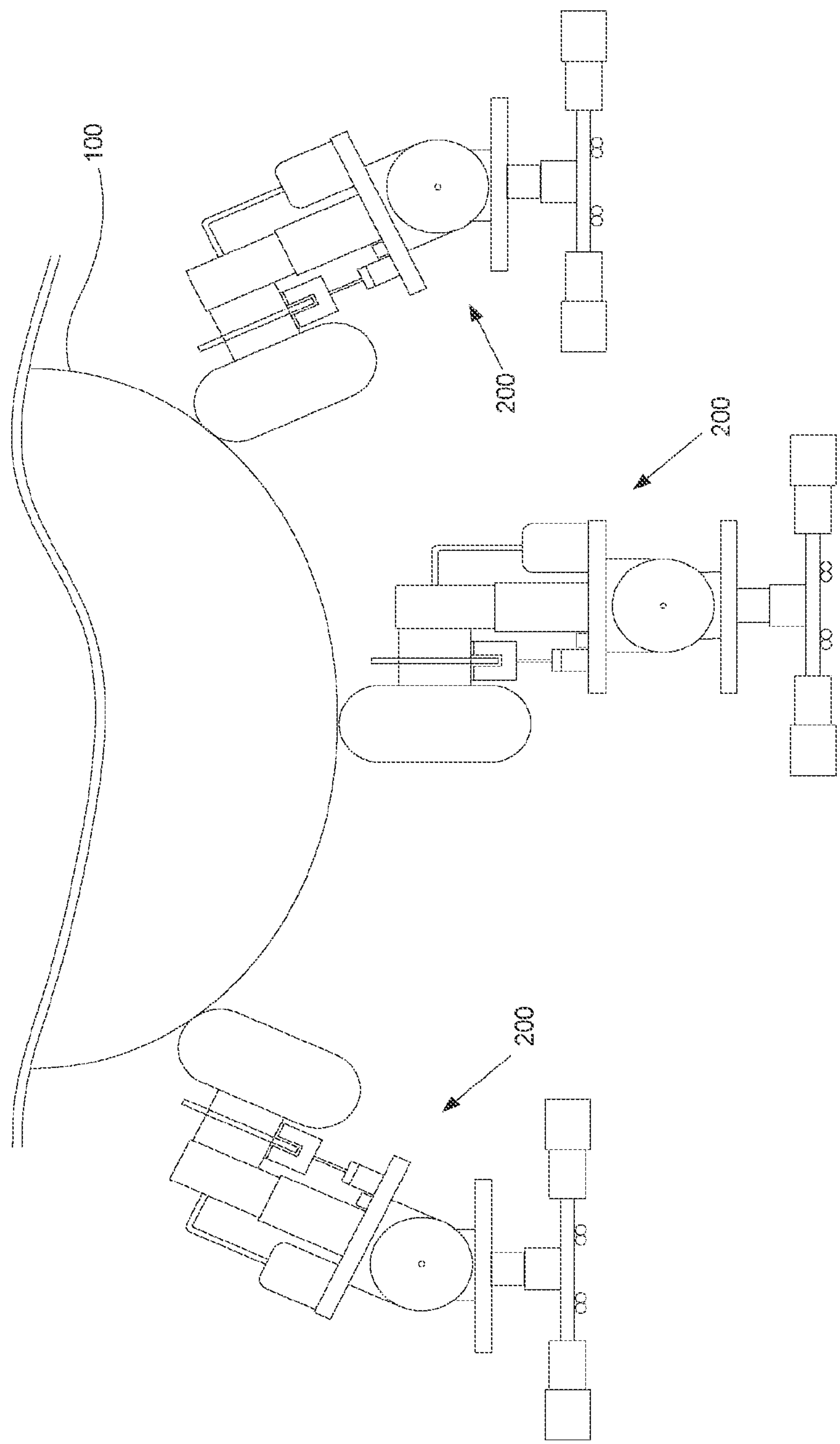
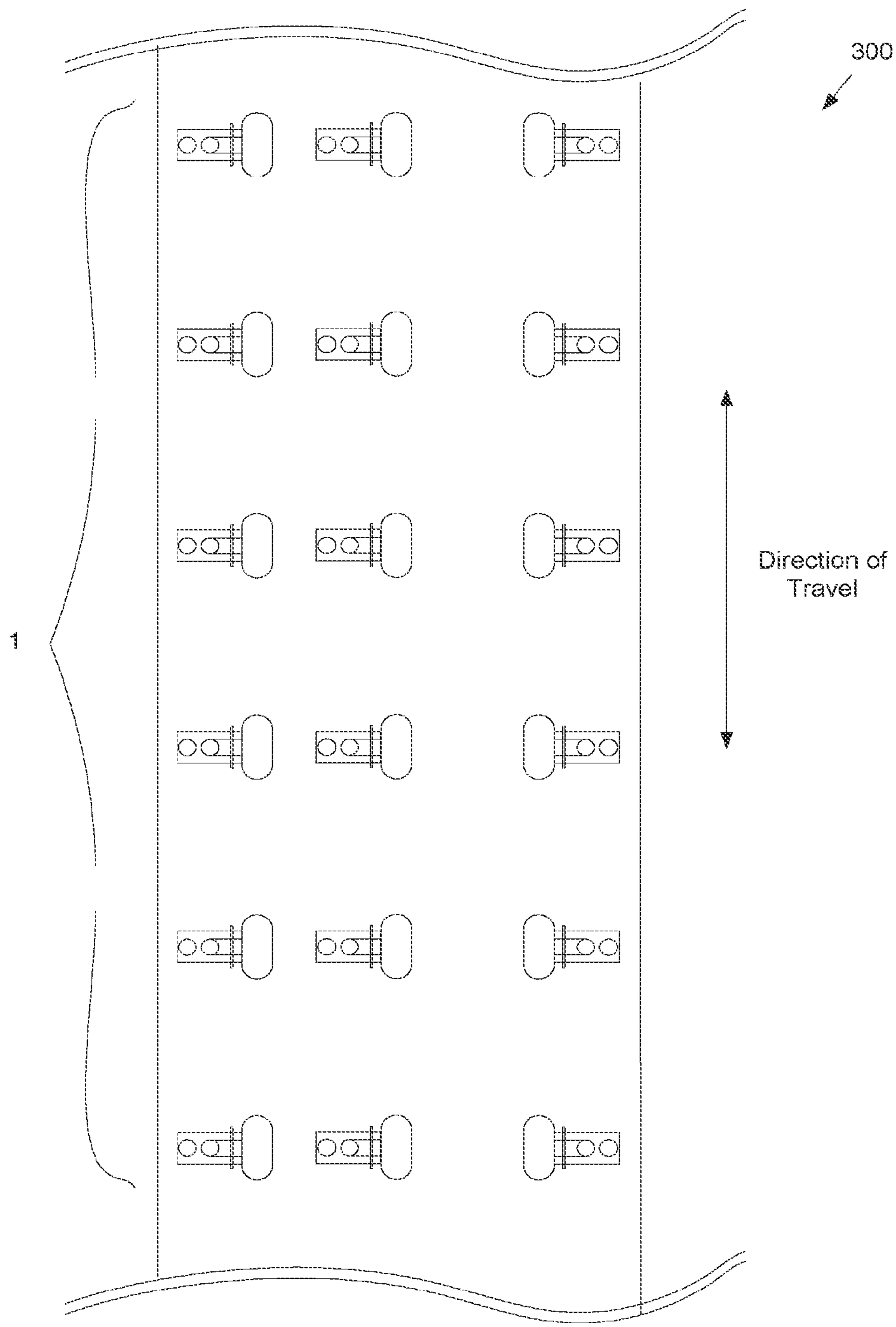



FIG. 4

FIG. 5



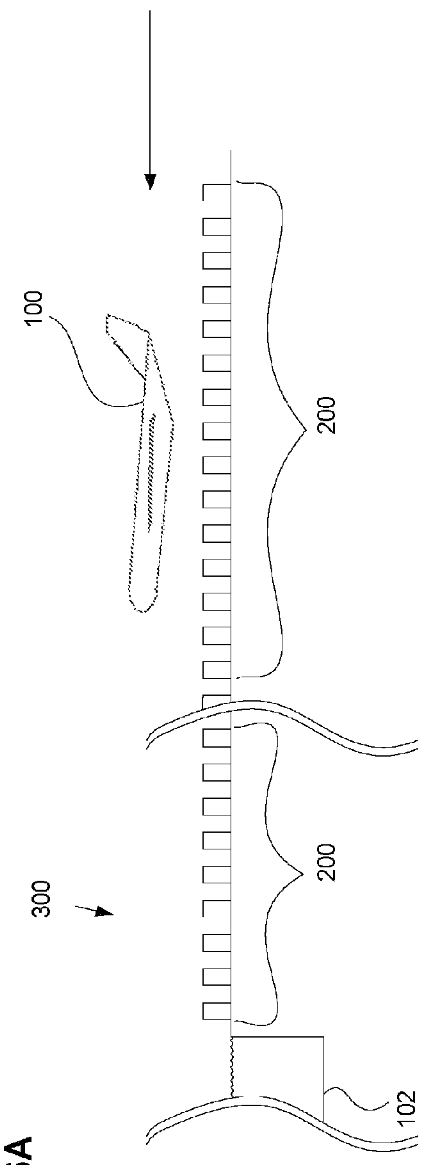



FIG. 6A

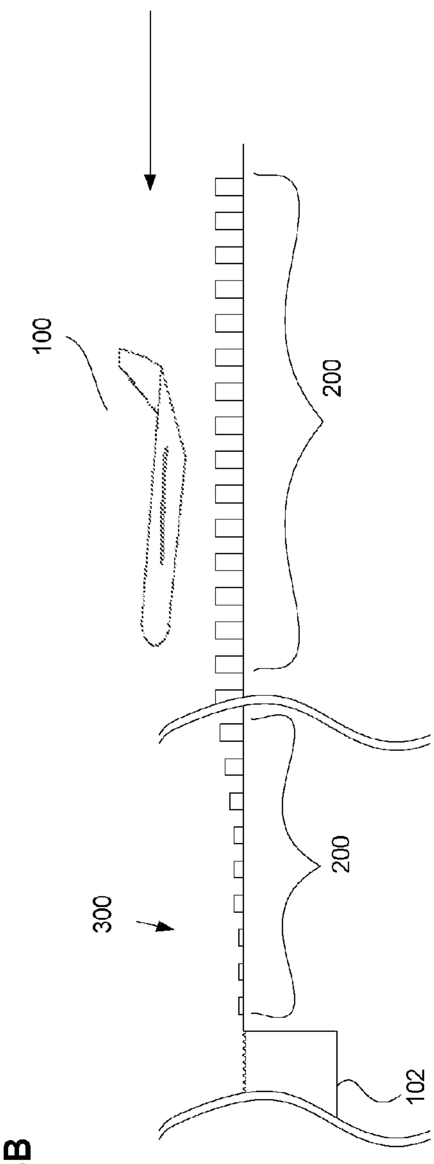
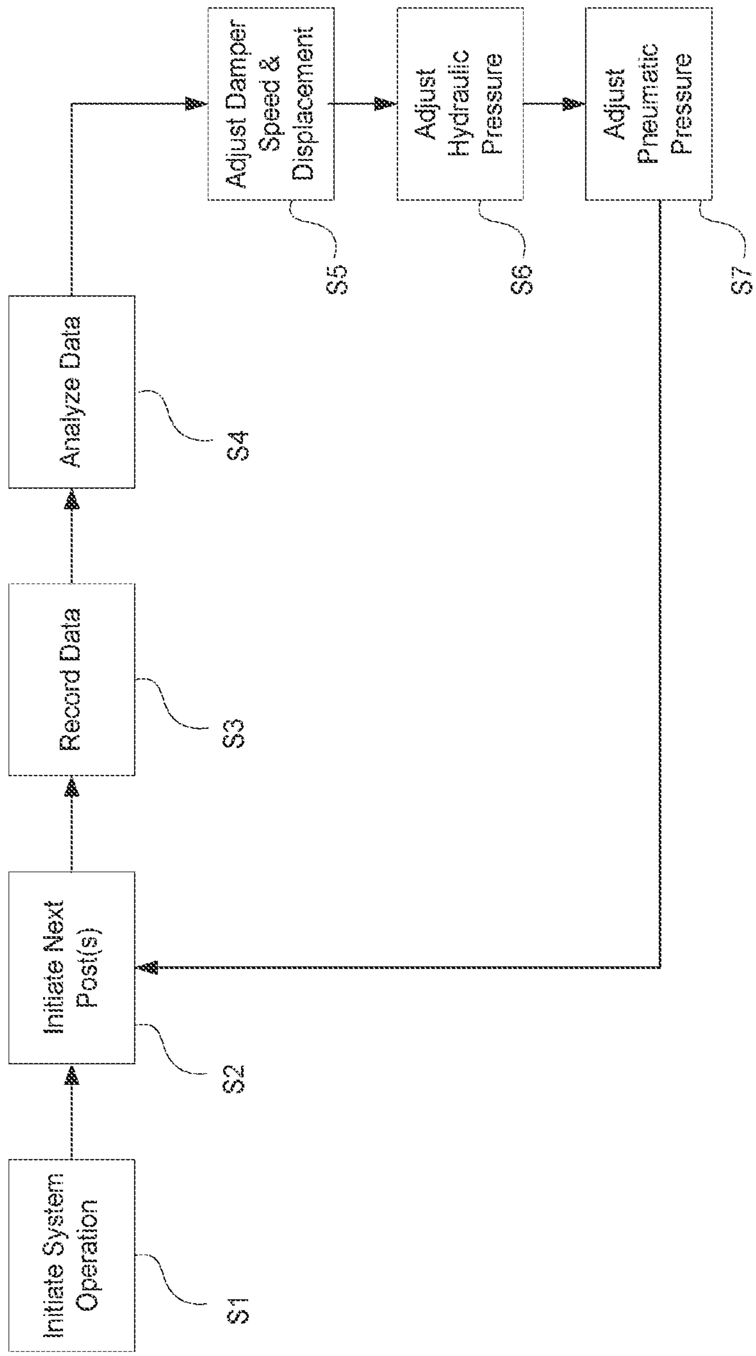



FIG. 6B

FIG. 7


Initiate System Operation
S1
Initiate Next Post(s)
S2
Record Data
S3
Analyze Data
S4
Adjust Damper Speed & Displacement
S5
Adjust Hydraulic Pressure
S6
Adjust Pneumatic Pressure
S7

# EMERGENCY RUNWAY

## BACKGROUND

**[0001]** Field of the Disclosure

**[0002]** The present disclosure is directed toward a method and apparatus to conduct emergency aircraft landings.

**[0003]** Description of the Related Art

**[0004]** The risk of aircraft fire, explosion, and catastrophic failure when landing with a mechanical or technical problem, and the attendant safety issues, have been addressed by a number of disclosures in the related art.

**[0005]** However, while aviation safety continues to improve, it continues to be a concern due to the potential severity of any serious failure, whatever the cause. Failures occur as the result of a wide variety of possibilities, but often arise from either accidents originating from pilot error, equipment malfunction due to manufacturing or maintenance failures, or outside interference such as unexpected weather or operating conditions, or terrorist attacks.

**[0006]** Equipment malfunction can occur in a variety of ways including, for example, failures and leaks from hydraulic equipment that operates landing gears, interference inside the landing gear wheel well, such as from debris or the presence of stowaways. For these reasons, methods and apparatus for safely landing aircraft with disabled landing gear mechanisms continue to be developed with the aim of reducing the extent of the damage when such incidents occur.

## SUMMARY

**[0007]** In one example aspect, an apparatus is provided to support aircraft with disabled landing gears. The apparatus comprises a support assembly, a hub, a shock absorber and a transport mechanism. The support assembly includes a contact component. The support assembly is rotatably connected to the hub. The shock absorber includes a first end to which the hub is rigidly connected. The transport mechanism is to move the apparatus along a ground surface. The contact component is to contact with and to support an aircraft fuselage during landing.

**[0008]** In another example aspect, a system is provided to support aircraft landing with malfunctioning landing gears. The system comprises a plurality of landing struts and a control system. Each landing strut includes a support assembly and a tilt platform. The tilt platform is to adjust an angular position of the support assembly. The control system is to adjust a position of the landing strut. The plurality of rows of the landing struts is configured along a ground surface to form an emergency runway. Each support assembly is disposed with an axis of rotation perpendicular to a forward path of an aircraft in a plan view. Each row of the landing struts includes three landing struts adjusted laterally by the control system with respect to the emergency runway and the support assembly of the landing struts is angularly adjusted by the tilt platform to follow a cross section of an aircraft fuselage, for the fuselage of an aircraft to land and stop.

**[0009]** In yet another example aspect, a method is provided to land an aircraft with malfunctioning landing gears. The method uses a plurality of landing struts. Each landing strut includes a support assembly and a brake. A position of the support assembly is adjustable. The method comprises identifying information relating to an aircraft including a type and dimensions, adjusting a position of the support assembly of the plurality of landing struts on an emergency runway based on the information so as to accommodate a landing of the aircraft, and applying the brake system of each support assembly as the aircraft traverses each of the landing struts.

**[0010]** The foregoing general description of the illustrative implementations and the following detailed description thereof are merely exemplary aspects of the teachings of this disclosure, and are not restrictive.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0011]** A more complete appreciation of the disclosure and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

**[0012]** FIG. **1**A and **1**B are front and side views, respectively, of an example embodiment of a landing strut mechanism;

**[0013]** FIG. **2**A and **2**B are side and plan views, respectively, of an example embodiment of a landing strut platform;

**[0014]** FIG. **3** is a front view of an example embodiment of a landing strut;

**[0015]** FIG. **4** is a front view of an example array of the landing struts supporting an aircraft;

**[0016]** FIG. **5** is a plan view of a section of an example embodiment of an emergency runway;

**[0017]** FIG. **6**A and **6**B are side views of sections of different embodiments of the emergency runway;

**[0018]** FIG. **7** is a diagram of an embodiment of a process for controlling the operation of a plurality of landing struts.

## DETAILED DESCRIPTION OF THE EMBODIMENTS

**[0019]** In the drawings, like reference numerals designate identical or corresponding parts throughout the several views. Further, as used herein, the words “a”, “an” and the like generally carry a meaning of “one or more”, unless stated otherwise. The drawings are generally not drawn to scale unless specified otherwise or illustrating schematic structures or flowcharts.

**[0020]** Referring now to the drawings, wherein like reference numerals designate identical or corresponding parts throughout the several views.

**[0021]** FIG. **1**A and FIG. **1**B are front and side views, respectively, of a landing strut **201** including a support assembly **2**, and a plurality of contact components **5**, where the contact components **5** may make contact with and support a fuselage of an aircraft **100** during landing. The contact components **5** may make contact with and absorb the impact of the aircraft **100** as the aircraft **100** lands. The contact components **5** may include apparatus such as pneumatic pressurized tires and wheels, inflatable bladders, and various types of continuous track assemblies such as those found on tanks and earthmoving machinery.

**[0022]** In one embodiment, the support assembly **2** has a contact component **5** that may be a pressurized pneumatic tire that is connected to a wheel **7**, and a hub **24** to which the support assembly **2** is rotatably connected. A shock absorber **26** includes a first end to which the hub **24** is rigidly connected. The shock absorber **26** also includes a second end which is connected to or supported by a tilt platform **28**. The support assembly **2** is connected to a compressed air tank **16** by a pneumatic line **18** and a brake system **3**. The brake system **3** includes a brake rotor **4**, a brake caliper **6**, a brake cylinder **8**, and a hydraulic brake line **10**. The brake rotor **4** is connected to the hub **24** and the brake caliper **6** is also connected to the hub **24**. The brake caliper **6** is further connected to the brake cylinder **8** which is supported by the tilt platform **28** and an Anti-lock Brake System (ABS) controller **12** by the hydraulic brake line **10**. The operation of the landing strut **201** is controlled by a controller **14** that is connected to the tilt platform **28** and, wired or wirelessly, to an air pressure controller **20**, including an air pressure sensor **20***a* and an air pressure relief valve **20***b*, a position sensor **21**, a wheel speed sensor **22**, the brake cylinder **8**, the ABS controller **12**, and the compressed air tank **16**. The support assembly **2** is a contact component hollow wheel and tire combination with internal passages for supplying the chamber with air. The support assembly **2** is connected to and rotates freely relative to the hub **24**, which is rigidly connected to the shock absorber **26**. The shock absorber **26** supports the force transmitted by an aircraft **100** (FIG. **4**) upon landing, and absorbs the impact from the support assembly **2** and the hub **24**. The compressed air tank **16** supplies air pressure to the support assembly **2** via the pneumatic line **18** to vary pressure within the support assembly **2** to account for load differences from various types and conditions of aircraft **100**, while the air pressure controller relieves air pressure in the support assembly **2** and automatically adjusts pressure as needed. The compressed air tank **16** is supplied by one or more separate compressed air sources (not shown), for example a compressor or air pressure reservoir. The brake caliper **6** provides braking force on the brake rotor **4** which rotates with the hub **24**. The wheel speed sensor **22** detects rotational speed of the support assembly **2**. The controller **14** uses that data to adjust the ABS controller **12** as needed.

**[0023]** In one embodiment, the controller **14** adjusts damping characteristics of the shock absorber **26** based on signals received from the position sensor **21**. The tilt platform **28** is supported by a tilt drum **30**, which is connected to at least one drum support **38**. The tilt drum **30** is connected to the drum support **38** and an elevator platform **40** which is disposed on a ground surface and underneath the drum support **38**. A servo motor **32** is connected to a motor support **36** which is supported by the elevator platform **40**. The tilt drum **30** rotates about its center and is connected to the servo motor **32** by a coupling **34**. The angular position of the landing strut **201** is determined by the position of the tilt platform **28** on the tilt drum **30**. The tilt drum **30** rotates due to rotation of the servo motor **32** and the coupling **34** (FIG. **1**B).

**[0024]** In a one embodiment, the ABS controller **12** is connected between the brake cylinder **8** and a hydraulic brake line **10** to provide ABS functionality for the landing strut **201**. The controller **14** controls the functions of the landing strut **201**, receives signals from various on-board sensors as well as from external networks and sources.

**[0025]** FIG. **2**A and FIG. **2**B are side and plan views, respectively, describing a transport mechanism **210** to move the landing strut along a ground surface. In one embodiment, the transport mechanism **210** is a landing strut platform **202** having an elevator platform **40** (same as shown in FIG. **1**A and FIG. **1**B), connected to a first hydraulic piston **42**, a lateral platform **44**, four rollers **48**, and a second and a third hydraulic piston **46**. In one embodiment the first hydraulic piston **42** may be positioned vertically, and the second and the third hydraulic pistons **46** may be positioned laterally. The elevator platform **40** is supported at its center from beneath by the first hydraulic piston **42**, which is supported underneath by the lateral platform **44**, which rests on the rollers **48**. The axes of the rollers **48** may be parallel to that of the tilt drum **30**. The lateral platform **44** includes a first end and a second, opposite end which are connected to the second and the third hydraulic pistons **46** respectively. The first hydraulic piston **42** moves vertically and adjusts the height of the elevator platform **40** above it. The lateral platform **44** supporting the first hydraulic piston **42** moves laterally based on the rollers **48** beneath it. The lateral movement of the lateral platform **44** is controlled by the inputs of the second and the third hydraulic pistons **46**, each secured to a rigid surface at one end while the other end is connected to the lateral platform **44** and able to extend and retract in horizontal directions that are perpendicular to the axes of the two rollers **48**. The operation of the first hydraulic piston **42** and second and the third hydraulic pistons **46**, each of which is connected to a position sensor **21**, are also monitored and controlled by the controller **14** (FIG. **1**A and FIG. **1**B).

**[0026]** In another embodiment, the lateral platform **44** has two rollers **48** rather than the four rollers **48** shown in the figure.

**[0027]** FIG. **3** is a front view of the landing strut **200**, the assembly comprising the landing strut **201** and the landing strut platform **202** (described by FIG. **1**A and FIG. **2**A, respectively) to position the apparatus in the lateral, vertical, and angular directions, and to support a load applied to the support assembly **2**.

**[0028]** FIG. **4** is a front view of an array of three landing struts **200** supporting an aircraft **100**, one landing strut **200** at the center **200**, one landing strut **200** toward the right side of the aircraft **100**, and one landing strut **200** toward the left side of the aircraft **100**. The contact component **5** of the support assembly **2** supports a load acting a substantially radial direction with respect to axis of rotation of the support assembly **2**. The landing strut platform **202** (FIG. **2**) allows for lateral adjustment of the position of each landing strut **200** by the controller **14** to accommodate various commercial aircraft fuselage **101** shapes and widths approximately in the range of 15 to 25 feet. The support assembly **2** is also angularly adjusted by the rotation of the tilt platform **28** based on the operation of the tilt drum **30** to follow a cross-section of the aircraft fuselage.

**[0029]** In addition to the vertical adjustment of the position of the support assembly **2** through the use of the first hydraulic piston **42** (FIG. **2**A and FIG. **2**B), the height of each landing strut **200** can also be set during initial installation within a plurality of ground surfaces, for example, the middle column of landing struts **200** can be positioned on a lower ground surface than that of the side positions since the vertical position of the landing strut **200** located on the side positions is higher to make contact with a round aircraft fuselage **101** and tilts to one side, reducing the effective height of the landing strut **200** upon which the support assembly **2** is mounted.

**[0030]** FIG. **5** is a plan view of a section of an emergency runway **300** having a plurality of landing struts **200** configured in three columns along multiple rows in a length-wise pattern, and includes a center column of upright suspended landing struts **200**, and outside columns tilted inwardly toward the center row of upright suspended wheel assemblies **2**. Since each landing strut **200** freewheels and mechanically operates independently of any drive force, it is free to rotate in either direction, allowing the mounting of each landing strut **200** and use of the emergency runway **300** in either direction, providing greater flexibility of use with prevailing weather conditions. Total length of the emergency runway **300** is in the range of between one and three miles, with longitudinal spacing between the landing struts **200** approximately in the range of between five and ten feet, for a total of about 1,500 to 9,500 landing struts **200** per emergency runway **300**.

**[0031]** In another embodiment, each landing strut **200** has two landing strut platforms **202** (FIG. **2**B) one positioned above the other in a side view, and positioned orthogonal to one another in a plan view, allowing for movement of the landing strut **200** in both the lateral and longitudinal directions, therefore allowing longitudinal spacing between the landing struts **200** to be adjusted. The embodiment shown in FIG. **2**A and FIG. **2**B has one landing strut platform **202** and can only move along one axis.

**[0032]** FIG. **6**A and FIG. **6**B are side views of sections of embodiments of an emergency runway **300**, the emergency runway **300** shown as rows of landing strut **200** with a landing pit **102** and an aircraft **100**. An aircraft **100** without properly functioning landing gears is redirected from landing on a runway to an emergency runway **300**, to attempt a safe landing. All landing gears may be retracted prior to landing on the emergency runway **300**. Landing on the emergency runway **300** may be possible even if the landing gears are not retracted depending on the location of the landing gears with respect to the aircraft **100**. For example, landing on the emergency runway may be possible if no landing gears are located below the aircraft fuselage **101**. As with a regular landing, the tail section of the aircraft **100** touches down on the emergency runway **300** first. On each landing strut **200**, the support assembly **2** that makes contact with the aircraft fuselage **101** begins to rotate. Each landing strut **200** in contact with the aircraft **100** begins to slow the aircraft **100** through a small amount of rolling resistance and friction inherent in the support assembly **2** and hub **24**. Further, a modest amount of braking power is provided by the brake caliper **6** applying a force to the brake rotor **4** of each landing strut **200**. Once the aircraft **100** is level and fully supported by the array of landing struts **200**, greater braking power can be supplied by each of the brake calipers **6** on the landing struts **200** in contact with the aircraft **100**. Further, a thrust reverser **104** of an aircraft engine **103** can be engaged to further reduce speed of the aircraft **100**.

**[0033]** While the position of each landing strut **200** remains the same relative to the other two landing struts **200** in a row across the emergency runway **300**, the height of each row can vary with that of other rows along the length of the emergency runway **300**, for example to create an upward or downward slope over the length of the emergency runway **300**. The variation in height between rows of landing struts **200** is adjusted by the first hydraulic piston **42** of each landing strut **200** (FIG. **2**A). An emergency runway **300** with an upward sloping array of landing struts **200** slows the aircraft **100** at a faster rate. An emergency runway **300** with a downward sloping array of landing struts **200** provides a smoother transition for the aircraft **100** to enter the landing pit **102**.

**[0034]** In one embodiment, a landing pit **102** is located at one or both ends of the emergency runway **300** such that the aircraft **100** is slowed by the array of landing struts **200** along the length of the emergency runway **300**, and then comes to a stop before or in the landing pit **102** located at the end of the array of landing struts **200**. The landing pit **102** may be filled with a material or mixture of material, for example, sand, dirt, soft soil or liquid, to retard the forward motion of the aircraft **100**, reduce the risk of fire, and maintain an upright position of the aircraft **100** to ease rescue operations, while minimizing the risk of injury to passengers and ground crew, and of damage to the aircraft **100**.

**[0035]** In one embodiment, the emergency runway **300** has a landing pit **102** at each end, the landing pit **102** is a manmade body of water such as a large pool or canal which may connect to a larger body of water such as a river or lake, providing additional runoff room for the aircraft **100**.

**[0036]** FIG. **7** is a diagram of an embodiment of a process of the controller **14** for controlling the operation of a plurality of landing struts **200** of an emergency runway **300**. Operation of the controller **14** is initiated at Step **S1** when use of the emergency runway **300** is needed.

**[0037]** At Step S**1**, an aircraft **100** that is expected to arrive at the emergency runway **300** is identified and initial data is input, including sources external to the landing strut **200** such as data about the expected aircraft **100**. Example data may include aircraft type, fuselage dimensions, weight, approach speed (generally at a rate of around aircraft 100 to 130 knots), approach angle, wind speed, and ambient weather conditions. The angular, vertical and lateral position of the support assembly **2** of each landing strut **200** is adjusted as needed to accommodate the dimensions of the incoming aircraft fuselage **101**.

**[0038]** At Step S**2**, the controller **14** transmits its available data elements to the controller **14** of at least the next landing strut **200** along the anticipated path of travel of the aircraft **100** on the emergency runway **300**. Available data include those provided by all the sensors described by FIG. **1**A and FIG. **1**B, such as wheel speed, brake pressure, and position and velocity readings of the various hydraulic dampers and pistons.

**[0039]** At Step S**3**, data received from Step S**2** are recorded to memory.

**[0040]** At Step S**4**, system-level analysis of the emergency runway **300** is performed on the data from Step S**3**. Example data of interest include how many and which landing struts **200** have made contact with the aircraft **100**. This can determine if the aircraft **100** has made full contact with the emergency runway **300**, the velocity of the aircraft **100** along the emergency runway **300**, and if the rate of deceleration of the aircraft **100** is sufficient such that the aircraft **100** will come to a stop before the aircraft **100** reaches the end of the emergency runway **300**.

**[0041]** Based on the analysis of Step S**4**, local analysis of the particular landing strut **200** is performed to determine which settings of Steps S**5** through Step S**7** should be adjusted.

**[0042]** At Step S**5**, if applicable, damping stiffness of the shock absorber **26** is adjusted in case the load is out of tolerance relative to the downward load applied.

[0043] At Step S6, hydraulic brake pressure applied is adjusted by the ABS controller **12** based on rotation speed of the support assembly **2** to prevent the support assembly **2** from locking. However, the hydraulic pressure applied can be varied from one end of the emergency runway **300** toward the other to provide optimal brake force once the aircraft **100** has stabilized on the emergency runway **300**. For example, the brake force applied by each subsequent landing strut **200** is gradually increased to maintain a state of threshold braking and maximize effectiveness for each support assembly **2**.

[0044] At Step S7, pneumatic air pressure is adjusted in the support assembly **2** if pressure readings are out of tolerance for the given pressure and load upon the support assembly **2**, primarily a function of the weight of the aircraft **100**.

[0045] The aforementioned adjustments may occur as the aircraft **100** is traversing each landing strut **200**.

[0046] Upon completion of Step S7, the process of FIG. **7** returns to Step S2 and repeats the loop until the aircraft **100** has come to a stop or passed the final landing strut **200** of the emergency runway **300**.

[0047] Thus, the foregoing discussion discloses and describes merely exemplary embodiments of the present invention. As will be understood by those skilled in the art, the present invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. Accordingly, the disclosure of the present invention is intended to be illustrative, but not limiting of the scope of the invention, as well as other claims. The disclosure, including any readily discernable variants of the teachings herein, defines, in part, the scope of the foregoing claim terminology such that no inventive subject matter is dedicated to the public.

What is claimed is:

**1**. An apparatus to support an aircraft with disabled landing gears, the apparatus comprising:
- a support assembly including a contact component;
- a hub to which the support assembly is rotatably connected;
- a shock absorber including a first end to which the hub is rigidly connected; and
- a transport mechanism to move the apparatus along a ground surface,
- wherein the contact component is to contact with and support an aircraft fuselage during landing.

**2**. The apparatus of claim **1**, wherein the contact component is a pressurized pneumatic tire, and the contact component is to support a load acting in a substantially radial direction with respect to the support assembly.

**3**. The apparatus of claim **1**, further comprising:
- a tilt platform,
- wherein a second end of the shock absorber is connected to the tilt platform.

**4**. The apparatus of claim **3**, further comprising:
- a brake caliper;
- a brake rotor;
- a brake cylinder; and
- a hydraulic brake line,
- wherein the at least one brake caliper and the brake rotor are connected to the hub, the brake cylinder is connected to the tilt platform, and the hydraulic brake line connecting the brake cylinder and the at least one brake caliper.

**5**. The apparatus of claim **4**, further comprising an anti-lock brake system controller.

**6**. The apparatus of claim **3**, further comprising:
- a tilt drum;
- a drum support;
- a servo motor; and
- a coupling,
- wherein the tilt platform is supported by the tilt drum and the drum support on a ground surface, the servo motor is connected to the tilt drum by the coupling, and the servo motor is to rotate the tilt drum over a range of motion to adjust an angular position of the tilt platform.

**7**. The apparatus of claim **6**, further comprising:
- an elevator platform;
- a first hydraulic piston; and
- a lateral platform,
- wherein the lateral platform supports the first hydraulic piston that supports the elevator platform, the elevator platform is disposed underneath and connected to the drum support, and operation of the first hydraulic piston changes an elevation of the support assembly.

**8**. The apparatus of claim **7**, further comprising:
- at least two rollers, with axes parallel to that of the tilt drum and disposed underneath the lateral platform,
- a second hydraulic piston; and
- a third hydraulic piston,
- wherein the lateral platform is supported by the at least two rollers, the second hydraulic piston is connected to a first end of the lateral platform, the third hydraulic piston is connected to a second, opposite end of the lateral platform, the second and third hydraulic pistons each with one end fixed to ground such that the position of the lateral platform can be adjusted along the horizontal plane in a direction perpendicular to the axes of the at least two rollers.

**9**. The apparatus of claim **2**, further comprising:
- a compressed air tank;
- a pneumatic line; and
- an air pressure controller;
- wherein a tire pressure of the support assembly is automatically adjustable by the compressed air tank.

**10**. A system to support an aircraft, landing with malfunctioning landing gears, comprising:
- a plurality of landing struts, each including a support assembly and a tilt platform, the tilt platform to adjust an angular position of the support assembly; and
- a controller to adjust a position of the landing strut,
- wherein a plurality of rows of the landing struts are configured along a ground surface to form an emergency runway, each support assembly is disposed with an axis of rotation perpendicular to a forward path of the aircraft in a plan view, each row of the landing struts includes three landing struts adjusted laterally by the control system with respect to the emergency runway, and the support assembly of the landing struts being angularly adjusted by the tilt platform to follow a cross section of an aircraft fuselage, for the aircraft to land and stop.

**11**. The system of claim **10**, further comprising:
- a landing pit,
- wherein the landing pit is filled with a soft material and positioned at an end of the plurality of the landing struts.

**12**. The system of claim **11**, wherein:

the landing pit is filled with sand.

**13**. The system of claim **12**, wherein:

the landing pit is filled with liquid.

**14**. A method for landing aircraft with malfunctioning landing gears using a plurality of landing struts, each of the landing struts including a support assembly and a brake system, a position of the support assembly being adjustable, the method comprising:

identifying information relating to an aircraft including a type and dimensions;

adjusting a position of the support assembly of a plurality of landing struts on an emergency runway based on the information so as to accommodate a landing of the aircraft; and

applying the brake system of each support assembly as the aircraft traverses each of the landing struts.

**15**. The method of claim **14**, further comprising:

applying a thrust reverser once the aircraft is fully supported by the plurality of landing struts.

**16**. The method of claim **14**, the support assembly further including a shock absorber, the method further comprising:

adjusting a stiffness of the shock absorber of each support assembly.

**17**. The method of claim **14**, the support assembly further including a pressurized pneumatic tire, the method further comprising:

adjusting a pressure of the pressurized pneumatic tire of each support assembly.

**18**. The method of claim **14**, wherein:

the position of the support assembly is adjustable angularly, vertically and laterally.

**19**. The method of claim **14**, further comprising:

adjusting a vertical position of the landing struts to form a slope in an emergency runway along the forward path of the aircraft.

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