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(54) **Title:** GROUND EXPLORATION VEHICLE

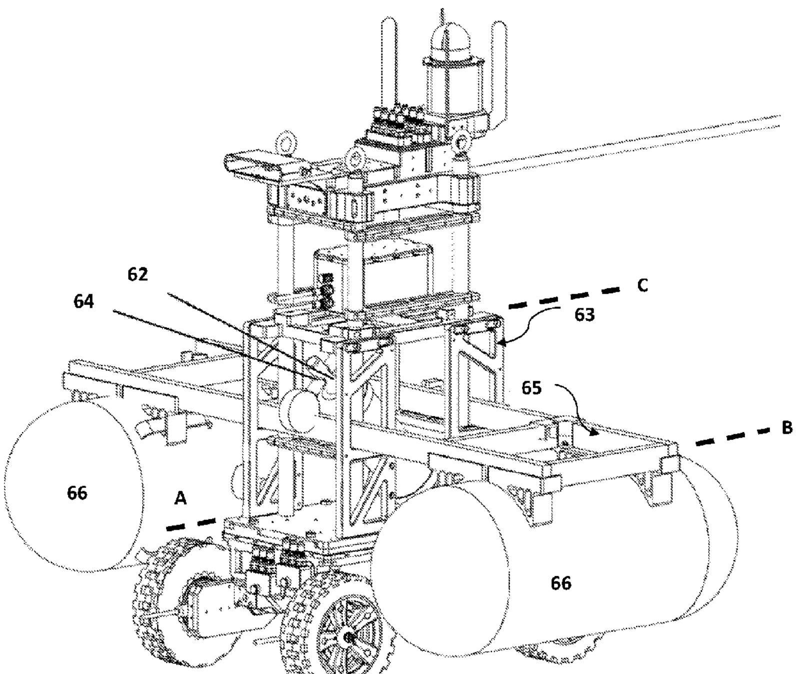

FIGURE 6

(57) **Abstract:** A remotely operated ground exploration vehicle having: a. a platform b. one or more tools mounted on the platform c. and at least one set of opposing wheels mounted to the platform d. a drive means for receiving signals from remote operation controls and for driving the wheels accordingly to move the vehicle Have the one or more tools maintained above water levels by use of: a) Wheel engagement to ride higher in a confined pipe surface b) An extension tower to maintain tools relatively higher than the platform c) A set of buoyancy means to maintain platform at or above water level to maintain tools at least at: (i) A - which is platform height A which is at least equal to but preferably greater than size of wheels and natural platform height; (ii) B - which is buoyancy level B due to automatically activated buoyancy system; or (iii) C - which is a tower height above the platform or (iv) a combination of a plurality one form or different forms thereof.

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[Continued on next page]

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GROUND EXPLORATION VEHICLE

Field of the Invention

[001] The present invention relates to a ground exploration vehicle and in particular to a remotely controlled ground exploration vehicle for use in exploring, surveying, assessing, maintaining and/or repairing waterways and will be described hereinafter with reference to this application. It is particularly related to an adaptable round exploration vehicle for countering variable environments and emergency recovery so as to be usable in confined and hostile environments.

[002] However, it will be appreciated that the invention is not limited to this particular field of use.

Background of the Invention

[003] There is a present difficulty in inspecting confined spaces especially industrial systems such as pipelines, manholes, narrow tunnels, and ductworks.

[004] Due to limited space provided by these industrial systems, maintenance workers do not have the access to conduct consistent inspection of said systems to validate if there are any physical problems occurring within the systems. While current methods exist in solving problems in these confined industrial systems, it is much more advantageous to provide an accessible way of easily inspecting the systems to avoid such problems from occurring.

[005] A remotely operated ground exploration vehicle is usually a car-like vehicle having wheels which are connected to a box-like body by suspensions. There are various remotely operated vehicles already present for performing explorations on hazardous terrains, such as the use of rovers for space exploration. Advantageously, these remotely operated ground exploration vehicles may likewise be deployed in confined industrial systems. Its portability, maneuverability, and accessibility is beneficial in inspecting the confines of pipelines, manholes, and other limited space with a hazardous environment.

[006] Presently, pipeline inspection robots are properly equipped to provide a visual assessment of the innards of the pipelines. However, these pipeline inspection robots lack mobility features and structures for easily traversing the confines of pipelines. There is a probability, due to their lack of adaptive structure and configurability, that these

pipeline inspection robots get stuck inside the confines of the pipelines. Moreover, these pipelines inspection robots do not comprise adaptable safety features to avoid hazardous terrain and substances it may be faced with while traversing the pipelines.

[007] Also, there is a need for a method of easily and safely deploying a remote vehicle into the confines of industrial systems.

[008] Another substantial problem in confined spaces is that the environment is not homogenous. In particular in water supply, sewerage or storm water runoff there is a confined area with a lower water or fluid environment with possible suspension or mixture of solids and an upper air or other gaseous environment. The plurality of environments is also not consistent. In dry times, the water environment could be at a low level in the pipes, while after a storm, the water level could be fast flowing at a high level.

[009] It can be seen that known prior art a remotely operated ground exploration vehicle has the problems of:

a) Mobility through confined spaces;
b) operation in multiple environments
c) effects of change of multiple environments
d) Protecting both structural and electrical components of the remote vehicle;
e) Adaptability to be reconfigured based on the terrain currently traversing through; and
f) Safe and easy deployment of the remote vehicle in to the confined industrial systems;

[0010] Therefore, there is a need to provide a remotely operated vehicle specialized in inspecting confined industrial spaces equipped with:

a) inspecting features for proper remote visual assessment of the confined space;
b) safety features for protecting the remote vehicle from hazardous substances and terrain
c) mobility features for easily traversing the confined spaces of the industrial systems;
d) modular features for restructuring the remote vehicle to adapt to an intended space or terrain it will be deployed in to; and e) a deployment feature to safely and easily deploy the remote vehicle in to the confined industrial spaces.

[0011] The present invention seeks to provide a remotely operated vehicle, which will overcome or substantially ameliorate at least one or more of the deficiencies of the prior art, or to at least provide an alternative.

[0012] It is to be understood that, if any prior art information is referred to herein, such reference does not constitute an admission that the information forms part of the common general knowledge in the art, in Australia or any other country.

Summary of the Invention

[0013] According to a first aspect of the present invention, there is provided a remotely operated ground exploration vehicle having a platform, one or more tools mounted on the platform, and at least one set of opposing wheels mounted to the platform, and a drive means for receiving signals from remote operation controls and for driving the wheels accordingly to move the vehicle. The opposing wheels include tapered external outward surfaces which contact the curved wall of a ride-on surface to provide a driving attitude of the vehicle.

[0014] The interaction of one or more of the component parts of the remotely operated ground exploration vehicle can be adjustable relative to each other to adjust the width and or height of the one or more of the component parts.

[0015] The interaction of the one or more of the component parts provides a change in the attitude of a vehicle with respect to a ride on surface. The ride on surface can be an angular bottom waterway or the lower walls of an enclosed tunnel such as large diameter pipes in sewerage or storm water systems.

[0016] The remotely operated ground exploration vehicle can include one or more tools which include one or more of:

- Panoramic camera
- Secondary camera (pan tilt zoom camera)
- 360 degree Lidar
- 360 degree sonar
- Concrete sensor
- One or more Gas Sensors of type NH_3, O_2, CO, CH_4, NH_3, and/or H_2S.

[0017] Most advantageously the wheels are mountable to the platform in an adjustable manner to allow increasing or decreasing of the relative spacing of the opposing wheels.

[0018] The operative parts of the tools can be mountable adjustably to provide a higher attitude and remain above water level. The tools can be mountable in an adjustable manner to allow increasing or decreasing height relative to the opposing wheels wherein the tools are lifted above a certain desired height which allows the electronics and sensor payload to sit above a higher water flow, and to allow for operation in larger diameter pipes with higher levels of water flow. Thereby the operative parts of the tools are mountable adjustably to provide a higher attitude and remain above water level.

[0019] The operative parts of the tools can be mountable on modular scaffolding on the platform to allow adjustable height of the tools relative to the platform and associated opposed wheels.

[0020] It can be seen that in one form the invention achieves a method of modifying a set of opposing wheels mounted to the platform to including a step of creating a desired taper angle of external outward surfaces of the wheels which allows simultaneous contact of the opposing curved wall of a tunnel. The desired taper can be based on factors including the ovoid invert angle which varies based on the tunnel height.

[0021] The modifying of a set of opposing wheels mounted to the platform can include the step of altering the desired operating height of the platform inside the ovoid tunnel wherein Increasing the width will sit the unit higher in the ovoid. The desired operating height can be adjusted by increasing or decreasing the spacing of the opposing wheels. At higher positions in the tunnel, a sharper taper angle can be required to match the curve of the ovoid.

[0022] Other aspects of the invention are also disclosed.

Brief Description of the Drawings

[0023] Notwithstanding any other forms which may fall within the scope of the present invention, preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Fig. 1 shows a front perspective view of a remotely operated ground exploration vehicle;

Fig. 2 shows a front perspective view of a second embodiment of the remotely operated ground exploration vehicle;

Fig. 3 shows a front perspective view of a third embodiment of the remotely operated ground exploration vehicle;

Fig. 4 shows a left side view of the remotely operated ground exploration vehicle as shown in Fig. 3;

Fig. 5 shows a front view of the remotely operated ground exploration vehicle as it traverses through a tunnel;

Fig. 6 shows a perspective view of an embodiment of the remotely operated ground exploration vehicle used for deploying the buoyancy operated height adjustment of the vehicle; and

Fig. 7 shows a side view of the embodiment of the remotely operated ground exploration vehicle of Fig 6.

Description of Preferred Embodiments

[0024] It should be noted in the following description that like or the same reference numerals in different embodiments denote the same or similar features.

[0025] Referring to the drawings there is shown a remotely operated ground exploration vehicle for use in exploring, assessing, maintaining and/or repairing waterways.

[0026] <u>Remote Vehicle</u>

[0027] Fig. 1 shows a remotely operated ground exploration vehicle 10 comprising a wheelbase 11 and a platform 13, wherein the platform 13 is fixed on top of the wheelbase 11. A plurality of opposing wheels 12 are provided on each side of the wheelbase. An electronics payload is mounted on top of the platform 13, the electronics payload further comprises a plurality of sensors and electronic devices. A panoramic camera 22 is installed proximately on the front side of the electronics payload and protrudes frontwards. Behind the panoramic camera 22, a secondary camera 23 is provided in an upright configuration. The secondary camera 23 may be, but is not limited to, a pan-tilt-zoom (PTZ) camera. At least one lighting device 21 is provided proximately behind the secondary camera 23 and is elevated in height in comparison to the panoramic camera and the secondary camera. Proximately at the rear of the electronics payload and the remotely operated vehicle 10 is a lidar device 25 capable of transmitting and detecting a light source. In addition, a sonar device 24 capable of transmitting and detecting a sound wave.

[0028] The use of a panoramic camera 22, a secondary camera 23, and a lighting device 21 provides a clear digital view of the current location of the vehicle 10 to a remote user. The addition of the lidar device 25 and sonar device 24 further improves the traversing capabilities of the vehicle 10 should there be a need for the vehicle 10 to autonomously traverse a confined space without live commands from a remote user.

[0029] Fig. 2 shows an embodiment of a remotely operated ground exploration vehicle 10 similar to that of Fig. 1. In addition to the components mentioned in the previous embodiment, the remotely operated ground exploration vehicle 10 further comprises a gas sensor situated proximately in between the lighting device 21 and the lidar device 25. Actuator arms 30 are installed proximately in the center right and center left of the platform 13. The actuator arms 30 are modifiable in such a way that various modular components can be installed at the end of each actuator arms. For example, a concrete sensor 31 may be provided on one end of the actuator arm 30 for collecting information and data from the concrete walls of tunnels. In another example, a gripping mechanism 32 may be provided on one end of the actuator arm 30 for grabbing a material of interest in a current terrain or environment.

[0030] It is beneficial to provide the remotely operated ground exploration vehicle with modular capabilities as it expands and broadens the functionalities of the vehicle. For this instance, the gas sensor 26 provides a remote user with a reading of gas levels within an environment without being physically exposed to the same. Furthermore, the concrete sensor 31 provided in the actuator arms 30 allows the remote vehicle 10 to reach and provide readings for structures obstructed by blockades the vehicle 10 would not be able to traverse to.

[0031] <u>Adjustable Platforms</u>

[0032] In another embodiment as shown in Figs. 3 and 4, the remotely operated ground exploration vehicle 10 comprises a wheelbase 11, a plurality of wheels 12 provided on opposing sides of the wheelbase, and a platform 13 fixed on top of the wheelbase. A plurality of vertical rigs 43 are fixed proximately on the corners of the platform 13 in an upright position. A second level platform 41 is fixed to the top ends of the vertical rigs 43 in such a way that, the outer surfaces of the corners of the second level platform are securely joined to the inner surfaces of the vertical rigs 43. A secondary camera 23 is installed on the second level platform 41. A plurality of shafts 44 are provided on the corners of the second level platform 41 in an upright position. To further improve structural integrity, each shaft is connected to an adjacent shaft through bracing members 45. The bracing members 45 are placed on the shafts 44 in such a way that it minimally obstructs the range of view of the secondary camera 23. A third level platform 42 is securely fixed to each top end of the shafts 44. In an example as shown in Figs. 3 and 4, the third level platform 42 includes a plurality of locking members 46 that clamps on a substantial portion of the top ends of the shafts 44. The third level platform 42 serves as the base for other electronics and sensors. A panoramic camera 22 is provided proximately to the front end of the third level platform 42. At least one lighting device 21 is provided proximately behind the panoramic camera 22 and is elevated in height in comparison to the panoramic camera. Proximately at the rear end of the third level platform 42 is a lidar device 25 capable of transmitting and detecting a light source.

[0033] Providing the vehicle 10 with adjustable platforms 41 and 42 allows the electronics payload and sensors payload to be set in a certain height. Due to this, the vehicle 10 can easily traverse terrain flooded with a liquid substance. The electronics and sensors are protected from low-lying floodwaters and sewage waters while still being able to provide a clear view of the terrain from a better vantage point. The shafts are also supported by bracing members in case of high flowing fluids passes through the confined spaces.

[0034] In an embodiment not shown in the figures, actuator arms 30 is provided on opposing sides of the second level platform 41. Similarly, actuator arms 30 may also be provided proximately on the center right end and center left end of the third level platform 42. The actuator arms 30 are modifiable in such a way that various modular components can be installed at the end of each actuator arms. In an example similar to what is shown in Fig. 2, a concrete sensor 31 may be provided on one end of the actuator arm 30 for collecting information and data from the concrete walls of tunnels. In another example, a gripping mechanism 32 may be provided on one end of the actuator arm 30 for grabbing a material of interest in a current terrain or environment.

[0035] <u>Tapered Wheels</u>

[0036] Fig 5. shows the remotely operated ground exploration vehicle 10 traversing through a tunnel. The wheels 12 are shaped as a conical puck and comprises a central hub 51. The wheels 12 are rotatably attached to the wheelbase 11 in such a way that the wide base serves as the rim and is proximately closer to the wheelbase 11, and the central hub 51 protrudes away from the wheelbase 11. The wheels 12 are provided with tread blocks 52 which are raised surfaces on the wheels. The tread blocks 52 extends radially outward from the central hub 51 to the rim in an alternating manner.

[0037] The structure of the wheels 12 allows the vehicle 10 to easily traverse spaces even if the terrain is filled with miniscule obstructions that may cause a poorly designed rover to be stuck. The vehicle 10 is provided with better grip by the tread blocks 52. The spaces between each tread blocks 52 also reduces the miniscule obstructions to be stuck within the wheels. The conical puck shape of the wheels 11 ultimately provides ease of traversing through curved paths such as pipes. The tapered and angled part of the wheels allows traction with the curved surface of the pipes.

[0038] Moreover, a plurality of adjustable axles 53 are provided to rotatably mount the wheels 12 to the wheelbase. The adjustable axles 53 can be remotely controlled to extend outwardly from the wheelbase and retract inwardly towards the wheelbase. The taper angle of the surface of the wheels 12 are likewise adjustable based on the desired operating height of the remotely operated ground exploration vehicle 10 and the ovoid angle of the tunnel.

[0039] The tapered wheel design has been developed to assist with remaining centralized (and stable) inside an “ovoid” tunnel shape.

[0040] The desired taper angle is calculated based on the following factors:

a) Ovoid invert angle (which varies based on the tunnel height)

b) Desired operating height inside the ovoid tunnel.

[0041] The desired operating height will be adjusted by increasing or decreasing the wheelbase width (or wheel to wheel width to be precise). Increasing the width will sit the unit higher in the ovoid. At higher positions in the tunnel, a sharper taper angle will be required to match the curve of the ovoid.

[0042] The remotely operated inspection vehicle is primarily designed for the inspection of confined space areas. The vehicle implements a modular design, to allow for the fit-out of multiple different sensors, and to accommodate different environments.

[0043] <u>Primary Payload</u>

[0044] The primary components of the vehicle unit are as follows:

a) Wheelbase

b) Electronics Payload

c) Wheels

d) Data Acquisition Payload

e) Lights

f) Actuator arms

g) Sensors Payload

[0045] The components of the sensor payload will vary depending on the application. They may include any of the following sensors:

a) Panoramic camera

b) Secondary camera (pan tilt zoom camera)

c) 360 degree Lidar

d) 360 degree sonar

e) Concrete sensor

f) Gas Sensor (NH3, O2, CO, CH4, NH3, H2S)

g) Specific modifications

[0046] The concrete scanner is attached to the end of an actuated robotic arm, to allow it to reach the apex (or crown) of the tunnel, and walls as well.

[0047] The cross-section of the vehicle unit is designed to be fit into a 600mm diameter manhole and can operate in tunnels that range from 600mm up to +3m.

[0048] The addition of the lidar device 25 and sonar device 24 further improves the traversing capabilities of the vehicle 10 should there be a need for the vehicle 10 to autonomously traverse a confined space without live commands from a remote user. As the sonar device 24 is more beneficial in the water

[0049] To cope with multiple environments there is a combination of LIDAR / SONAR / 360 Camera to provide a synergistic control and synergistic analysis of the enclosed environment. Apart from the use of different technologies there is also at the same time an adjustment of position of different technologies relative toi the multiple environments such as lowering into the water or lifting above water. Not only is there a physical difference but there needs to be a digital processing difference so as to match the results of each technology due to their different operation by reason of different permeabilities in the environment, different scopes and different timing of operation.

[0050] • Three datasets are captured from three different data sensors - lidar for pointcloud, sonar for 2D cross-sectional tunnel profiles, 360 camera for panoramic video and imagery. These datasets are married to each other using chainage readings from a cable counter, and a global time reference.

[0051] • Lidar is used to capture in-air 3-dimension reconstruction of a tunnel asset. Sonar is used to create 2D cross-sectional reconstruction of the submerged section of a tunnel. • These three datasets can then be presented in a single interface.

[0052] • The 2D cross-sectional scans from the sonar can be interpolated with respect to chainage data in order to create a 3-dimensional reconstruction of the submerged section of tunnel. Chainage data and sonar data are correlated by the global timestamp.

[0053] ○ E.g. at 0m chainage, a single sonar scan is captured. At 0.5m a second sonar scan is captured. These two scans can be interpolated, or a “loft” created between the two, in order to create a 3-dimensional reconstruction of the tunnel section between 0m and 0.5m.

[0054] • By assessing the gradient of the interface between the lidar and sonar measurements, one can also correlate the point cloud with the interpolated 2-dimensional scans, in order to create a full reconstruction of submerged, and in-air, sections of the tunnel (and thus a full 3D reconstruction of the asset). The sonar data and lidar data can be correlated either by timestamps or by chainage data.

[0055] A localization system, is also provided comprising an inertial navigation system (complemented with Doppler velocity logger) configured to provide localization data; and a prism configured for line-of-sight localization during traverse using external total stations. The combined trajectory data of INS, DVL, and Visual SLAM are used in parallel and input into an extended Kalman filter

[0056] <u>Alteration for multiple environments</u>

[0057] The remotely operated ground exploration vehicle can have the one or more tools mounted on the platform are maintained above a water level by one or more of:

a) Wheel engagement to ride higher in a confined pipe surface

b) An extension tower to maintain tools relatively higher than the platform

c) A set of buoyancy means to maintain platform at or above water level.

[0058] The height of the entire unit can also be adjusted, by using extension modules to lift the electronics payload above a certain desired height. This allows the electronics and sensor payload sit above a higher water flow, to allow for operation in larger diameter pipes, with higher levels of water flow.

[0059] Referring to the drawings the way the device is altered to different environments it encounters can be facilitated by a range or a combination of particular aids.

[0060] As shown in Fig 3 and 5 the wheels 12 can provide the platform to be at a height A. This height A would usually be due to the height of the wheels and the relative height of the platform due to the engagement of the wheels and the platform to the intervening chassis. However as shown by Fig 3 and Fig 5 the wheel shape and its interaction with shaped enclosure can allow for the device to ride higher and therefore the platform height A is substantially higher than the wheel height.

[0061] Further as shown in Figs 3 and 4 the tools can be spaced from the platform by vertical rigs 43 or height modules or extension towers so that the tools are at least at height C which is the tower height above the platform.

[0062] However as shown in Figs 6 and 7, there is a need to ensure that operation is automatically maintained at a high level in case remote operation fails dure to power or communication failures or environmental effects. Therefore an automatic buoyancy system is included. This ensures that even if the water overlies the height A the tools will be ensured to be above the buoyancy level B and thereby above the water level.

[0063] Generally the remote control of the remotely operated ground exploration vehicle by having one or more of:

a) Buoyancy means; and

b) Deadman controls.

[0064] Referring to Figs 6 and 7, the buoyancy modules mounted on the sides of the vehicle to facilitate emergency extraction in the event the platform becomes stuck due to communications loss, power loss, obstructions or other factors.

[0065] The buoyancy means is based on a lateral frame 65 that can be mounted on the platform but preferably on an extension tower 63 so that is above the height of the platform. The frame Two cross beams extending through the center of the vehicle's extension to provide structural support for mounting the buoyancy modules 66. A pressurized gas canister 62 connected to the buoyancy modules 66 via a regulator 64, configured to inflate the buoyancy modules upon activation.

[0066] A deadman switch is operably connected to the pressurized gas canister, wherein the deadman switch automatically activates the inflation of the buoyancy modules in the event of a communications or power failure; and it is controllable during normal operating conditions to selectively activate inflation for additional lift during operational bogging.

[0067] It can therefore be seen that the remotely operated ground exploration vehicle can have the one or more tools maintained above water levels by use of:

a) Wheel engagement to ride higher in a confined pipe surface
b) An extension tower to maintain tools relatively higher than the platform
c) A set of buoyancy means to maintain platform at or above water level

to maintain tools at least at:

(i) A - which is platform height A which is at least equal to but preferably greater than size of wheels and natural platform height;
(ii) B - which is buoyancy level B due to automatically activated buoyancy system; or
(iii) C - which is a tower height above the platform or
(iv) a combination of a plurality one form or different forms thereof.

[0068] Other embodiments understood by a person skilled in the art are included in the scope of this disclosure.

Interpretation

Embodiments:

[0069] Reference throughout this specification to “one embodiment” or “an embodiment” means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases “in one embodiment” or “in an embodiment” in various places throughout this specification are not necessarily all referring to the same embodiment, but may. Furthermore, the particular features, structures or characteristics may be combined in any suitable manner, as would be apparent to one of ordinary skill in the art from this disclosure, in one or more embodiments.

[0070] Similarly it should be appreciated that in the above description of example embodiments of the invention, various features of the invention are sometimes grouped together in a single embodiment, figure, or description thereof for the purpose of streamlining the disclosure and aiding in the understanding of one or more of the various inventive aspects. This method of disclosure, however, is not to be interpreted as reflecting an intention that the claimed invention requires more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive aspects lie in less than all features of a single foregoing disclosed embodiment. Thus, the claims following the Detailed Description of Specific Embodiments are hereby expressly incorporated into this Detailed Description of Specific Embodiments, with each claim standing on its own as a separate embodiment of this invention.

[0071] Furthermore, while some embodiments described herein include some but not other features included in other embodiments, combinations of features of different embodiments are meant to be within the scope of the invention, and form different embodiments, as would be understood by those in the art. For example, in the following claims, any of the claimed embodiments can be used in any combination.

Different Instances of Objects

[0072] As used herein, unless otherwise specified the use of the ordinal adjectives “first”, “second”, “third”, etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

Specific Details

[0073] In the description provided herein, numerous specific details are set forth. However, it is understood that embodiments of the invention may be practiced without these specific details. In other instances, well-known methods, structures and techniques have not been shown in detail in order not to obscure an understanding of this description.

Terminology

[0074] In describing the preferred embodiment of the invention illustrated in the drawings, specific terminology will be resorted to for the sake of clarity. However, the invention is not intended to be limited to the specific terms so selected, and it is to be understood that each specific term includes all technical equivalents which operate in a similar manner to accomplish a similar technical purpose.

[0075] Terms such as "forward", "rearward", "radially", "peripherally", "upwardly", "downwardly", and the like are used as words of convenience to provide reference points and are not to be construed as limiting terms.

[0076] Terms such as “attitude” relate to

Comprising and Including

[0077] In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word “comprise” or variations such as “comprises” or “comprising” are used in an inclusive sense, i.e. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the invention.

[0078] Any one of the terms: including or which includes or that includes as used herein is also an open term that also means including at least the elements/features that follow the term, but not excluding others. Thus, including is synonymous with and means comprising.

Scope of Invention

[0079] Thus, while there has been described what are believed to be the preferred embodiments of the invention, those skilled in the art will recognize that other and further modifications may be made thereto without departing from the spirit of the invention, and it is intended to claim all such changes and modifications as fall within the scope of the invention. For example, any formulas given above are merely representative of procedures that may be used. Functionality may be added or deleted from the block diagrams and operations may be interchanged among functional blocks. Steps may be added or deleted to methods described within the scope of the present invention.

[0080] Although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

Industrial Applicability

[0081] It is apparent from the above, that the arrangements described are applicable to the for use in exploring, assessing, maintaining and/or repairing waterways industries.

Claims

The claims defining the invention are as follows:

1. A remotely operated ground exploration vehicle having:
    a. a platform
    b. one or more tools mounted on the platform
    c. and at least one set of opposing wheels mounted to the platform
    d. a drive means for receiving signals from remote operation controls and for driving the wheels accordingly to move the vehicle
2. A remotely operated ground exploration vehicle according to any one of the preceding claims wherein the tools include one or more of:
    a. Panoramic camera
    b. Secondary camera (pan tilt zoom camera)
    c. 360 degree Lidar
    d. 360 degree sonar
    e. Concrete sensor
    f. One or more Gas Sensors of type NH_3, O_2, CO, CH_4, NH_3, and/or H_2S.
3. A remotely operated ground exploration vehicle according to claim 1 or 2 wherein the one or more tools mounted on the platform are maintained above a water level by one or more of:
    a. Wheel engagement to ride higher in a confined pipe surface
    b. An extension tower to maintain tools relatively higher than the platform
    c. A set of buoyancy means to maintain platform at or above water level.

4. A remotely operated ground exploration vehicle according to claim 1, 2 or 3 wherein the interaction of one or more of the component parts of the remotely operated ground exploration vehicle are adjustable relative to each other to adjust the width and or height of the one or more of the component parts.

5. A remotely operated ground exploration vehicle according to claim 1, 2 or 3 wherein the interaction of the one or more of the component parts provides a change in the attitude of the vehicle with respect to a ride on surface.

6. A remotely operated ground exploration vehicle according to claim 1, 2 or 3 wherein the interaction of the one or more of the component parts provides a

change in the attitude of one or more tools mounted on the platform to the vehicle with respect to a ride on surface.

7. A remotely operated ground exploration vehicle according to claim 4 wherein the ride on surface is an angular bottom waterway.

8. A remotely operated ground exploration vehicle according to claim 4 wherein the ride on surface is the lower walls of an enclosed tunnel such as large diameter pipes in sewerage or storm water systems.

9. A remotely operated ground exploration vehicle according to claim 4 wherein the wheels are mountable to the platform in an adjustable manner to allow increasing or decreasing of the relative spacing of the opposing wheels.

10. A remotely operated ground exploration vehicle according to any one of the preceding claims wherein the operative parts of the tools are mountable adjustably to provide a higher attitude and remain above water level.

11. A remotely operated ground exploration vehicle according to claim 10 wherein the tools are mountable in an adjustable manner to allow increasing or decreasing height relative to the opposing wheels wherein the tools are lifted above a certain desired height which allows the electronics and sensor payload to sit above a higher water flow, and to allow for operation in larger diameter pipes with higher levels of water flow.

12. A remotely operated ground exploration vehicle according to any one of the preceding claims wherein the operative parts of the tools are mountable on modular scaffolding on the platform to allow adjustable height of the tools relative to the platform and associated opposed wheels.

13. A remotely operated ground exploration vehicle according to any one of the preceding claims wherein the system for emergency extraction, comprising buoyancy modules mounted on the sides of the vehicle to facilitate emergency extraction in the event the platform becomes stuck due to communications loss, power loss, obstructions or other factors.

14. A remotely operated ground exploration vehicle according to claim 13 including a set of pressurized gas canisters connected to the buoyancy modules via a regulator, configured to inflate the buoyancy modules upon activation.

15. A remotely operated ground exploration vehicle according to claim 13 or 14 including a deadman switch operably connected to the pressurized gas canister, wherein:
    a. The deadman switch automatically activates the inflation of the buoyancy modules in the event of a communications or power failure; and
    b. The deadman switch is controllable during normal operating conditions to selectively activate inflation for additional lift during operational bogging

16. A remotely operated ground exploration vehicle according to any one of the preceding claims including a localization system, comprising:
    a. an inertial navigation system (complemented with Doppler velocity logger) configured to provide localization data; and
    b. a prism configured for line-of-sight localization during traverse using external total stations

17. A remotely operated ground exploration vehicle according to claim 16 wherein combined trajectory data of INS, DVL, and Visual SLAM are used in parallel and input into an extended Kalman filter.

18. A method of modifying the height of one or more tools mounted on a platform of a remotely operated ground exploration vehicle to maintain ther tools above a water level by one or more of:
    a. Wheel engagement to ride higher in a confined pipe surface
    b. An extension tower to maintain tools relatively higher than the platform
    c. A set of buoyancy means to maintain platform at or above water level.

19. A method of modifying according to claim 18 including the steps of:
    a. modifying a set of opposing ground engaging wheels mounted to the platform; and
    b. Creating a desired taper angle of external outward surfaces of the wheels which allows simultaneous contact of the opposing curved wall of a tunnel

20. A method of modifying a set of opposing wheels according to claim 19 wherein the desired taper is based on factors including the ovoid invert angle which varies based on the tunnel height.

21. A method of modifying a set of opposing wheels according to claim 19 or 20 including the step of:

    Altering the desired operating height of the platform inside the ovoid tunnel wherein Increasing the width will sit the unit higher in the ovoid.

22. A method of modifying a set of opposing wheels according to claim 21 wherein the desired operating height is adjusted by increasing or decreasing the spacing of the opposing wheels.

23. A method of modifying a set of opposing wheels according to claim 21 wherein at higher positions in the tunnel, a sharper taper angle will be required to match the curve of the ovoid.

24. A method of modifying a set of opposing wheels according to claim 21 including providing a set of pressurized gas canisters connected to the buoyancy modules via a regulator, configured to inflate the buoyancy modules upon activation and maintain platform at or above water level.

25. A method of modifying a set of opposing wheels according to claim 21 including providing a modular tower to distance the tools from the ground engaging wheels and maintain platform at or above water level.

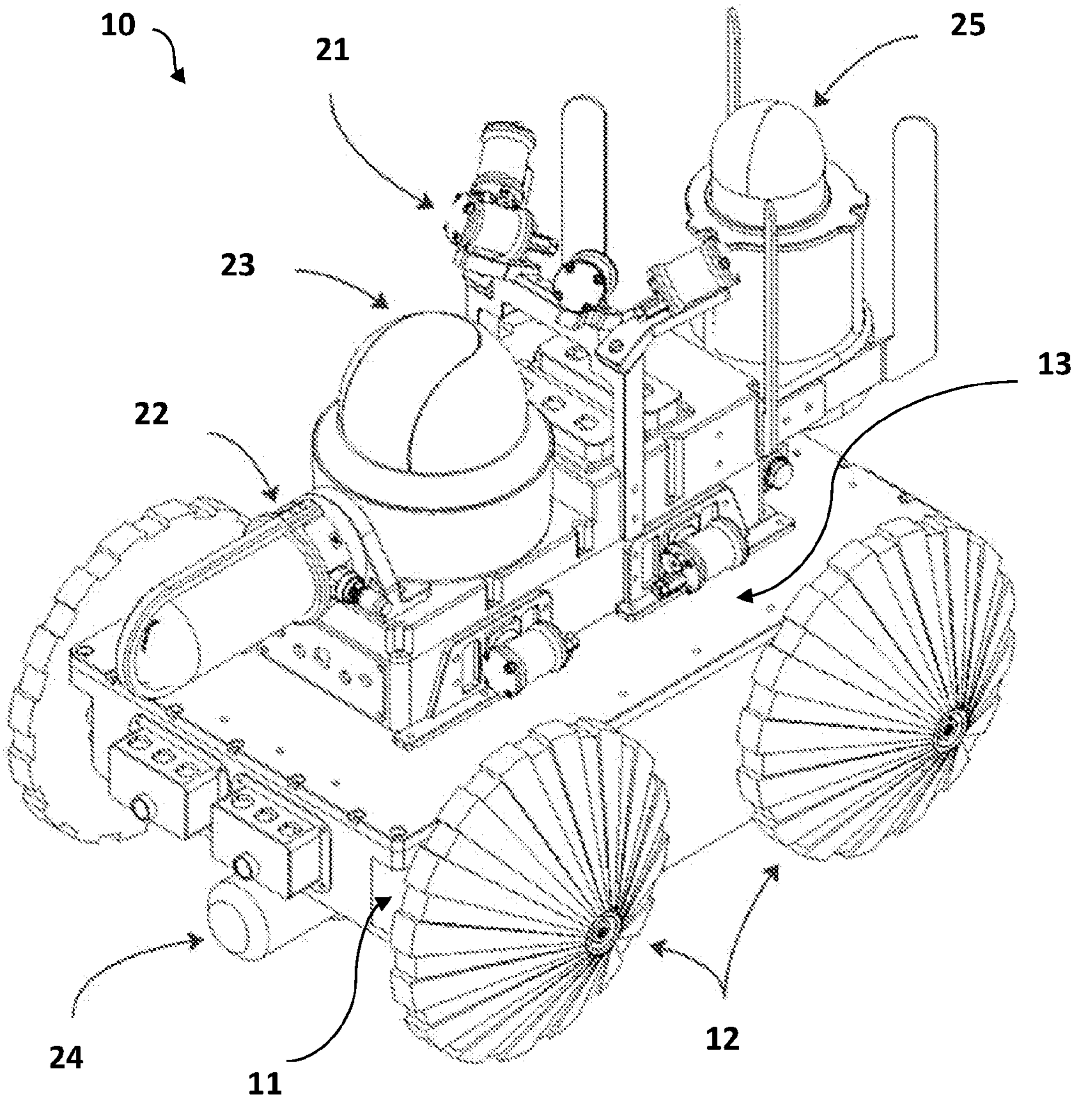

FIGURE 1

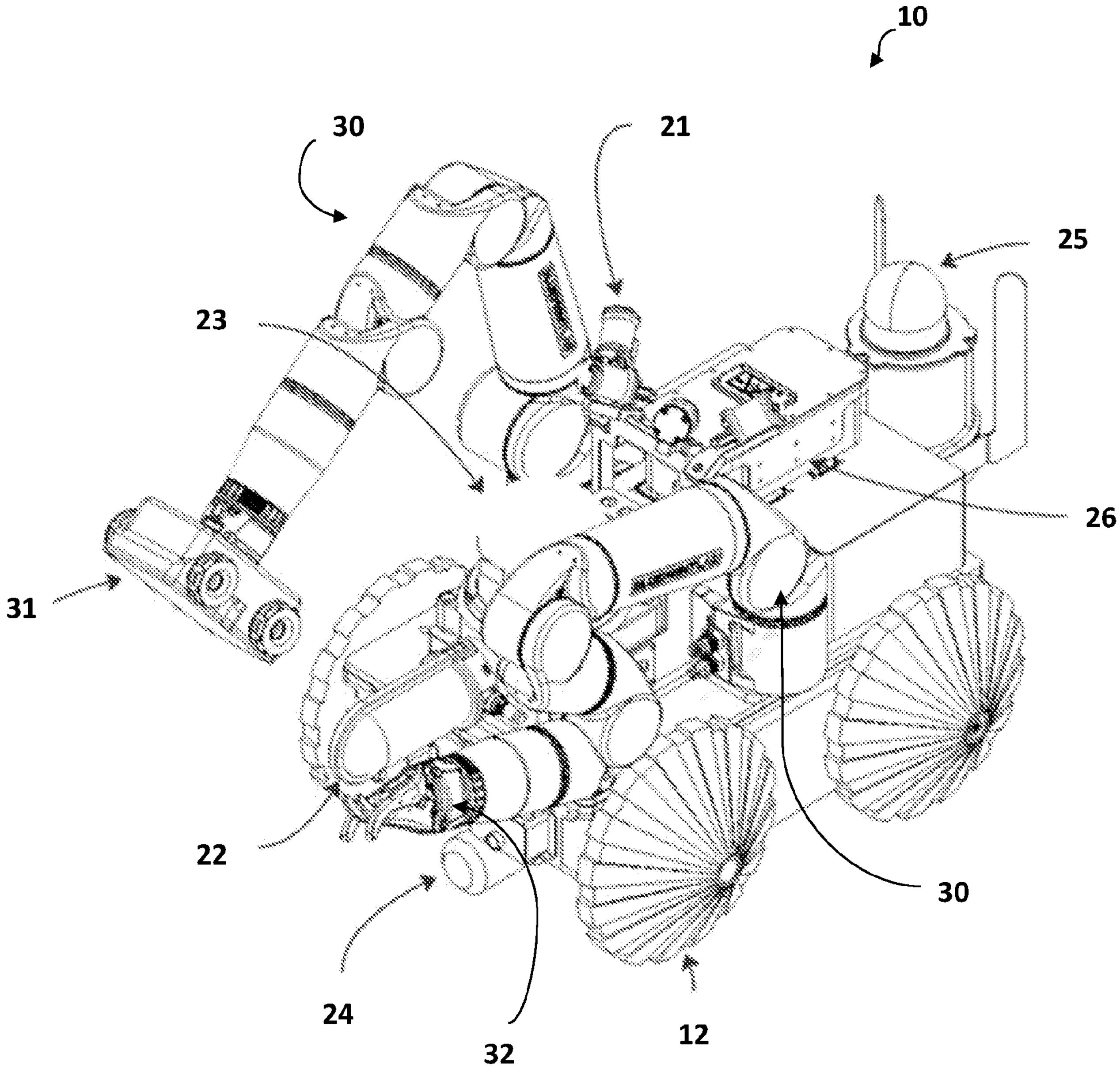

FIGURE 2

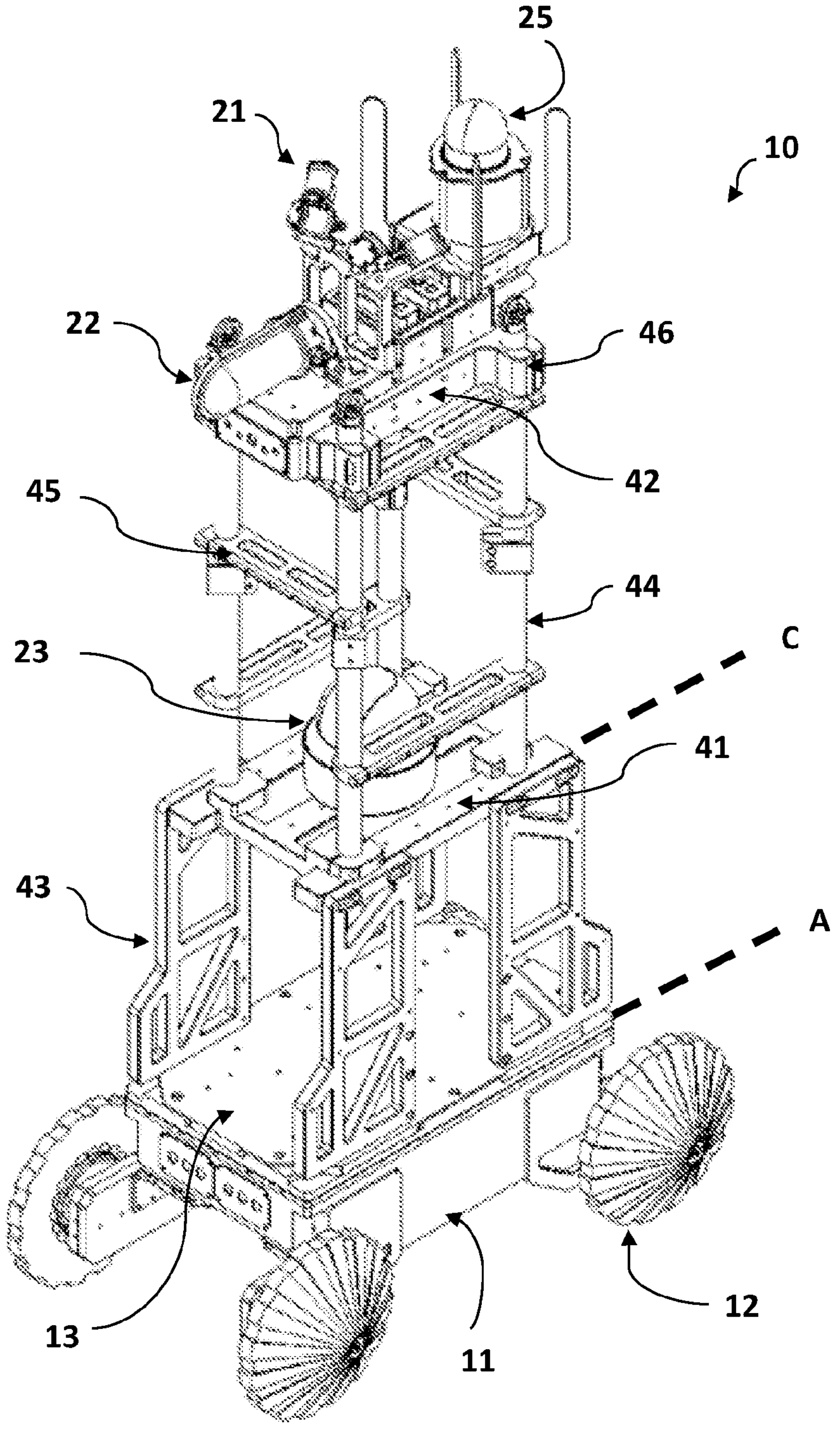

FIGURE 3

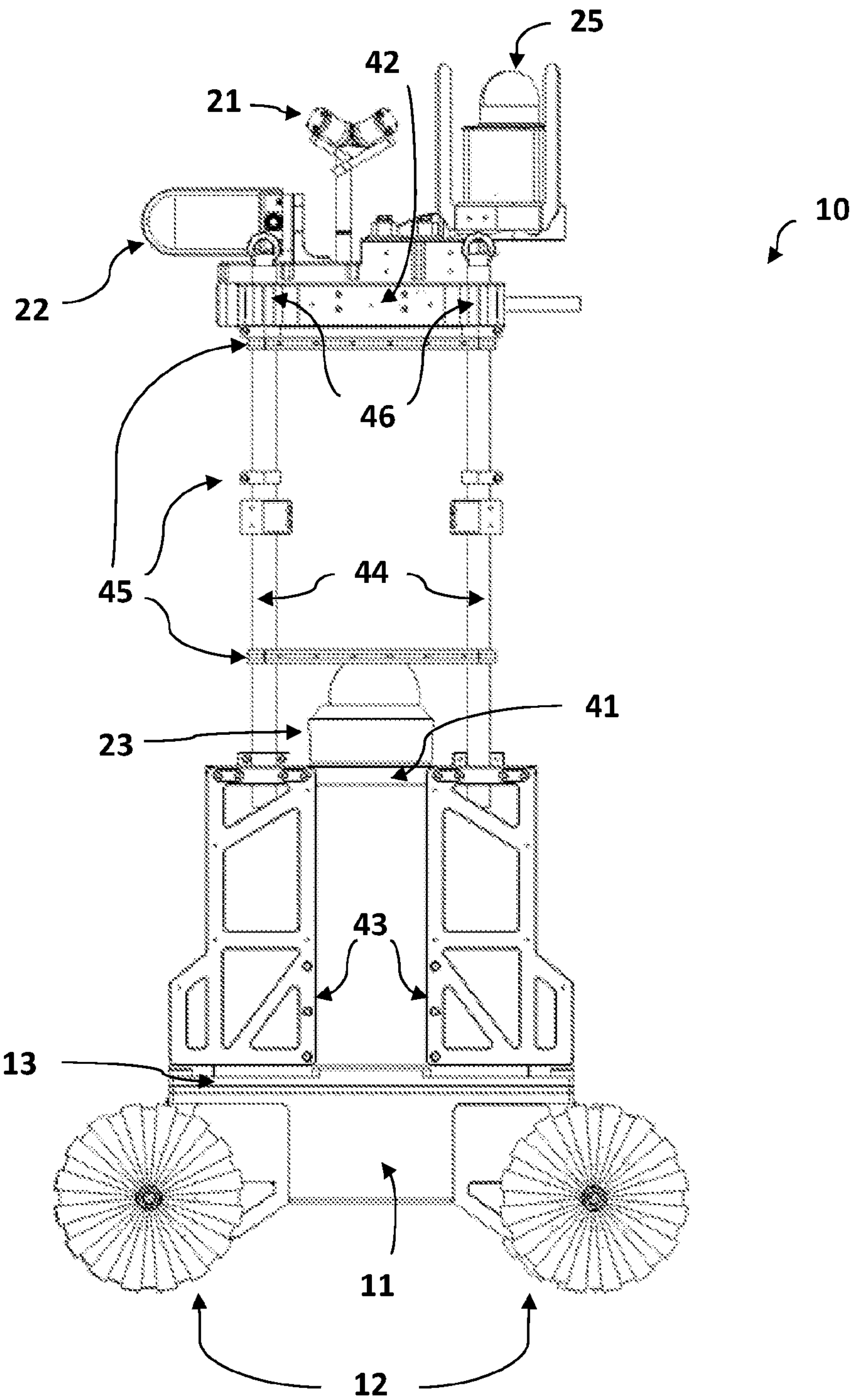

FIGURE 4

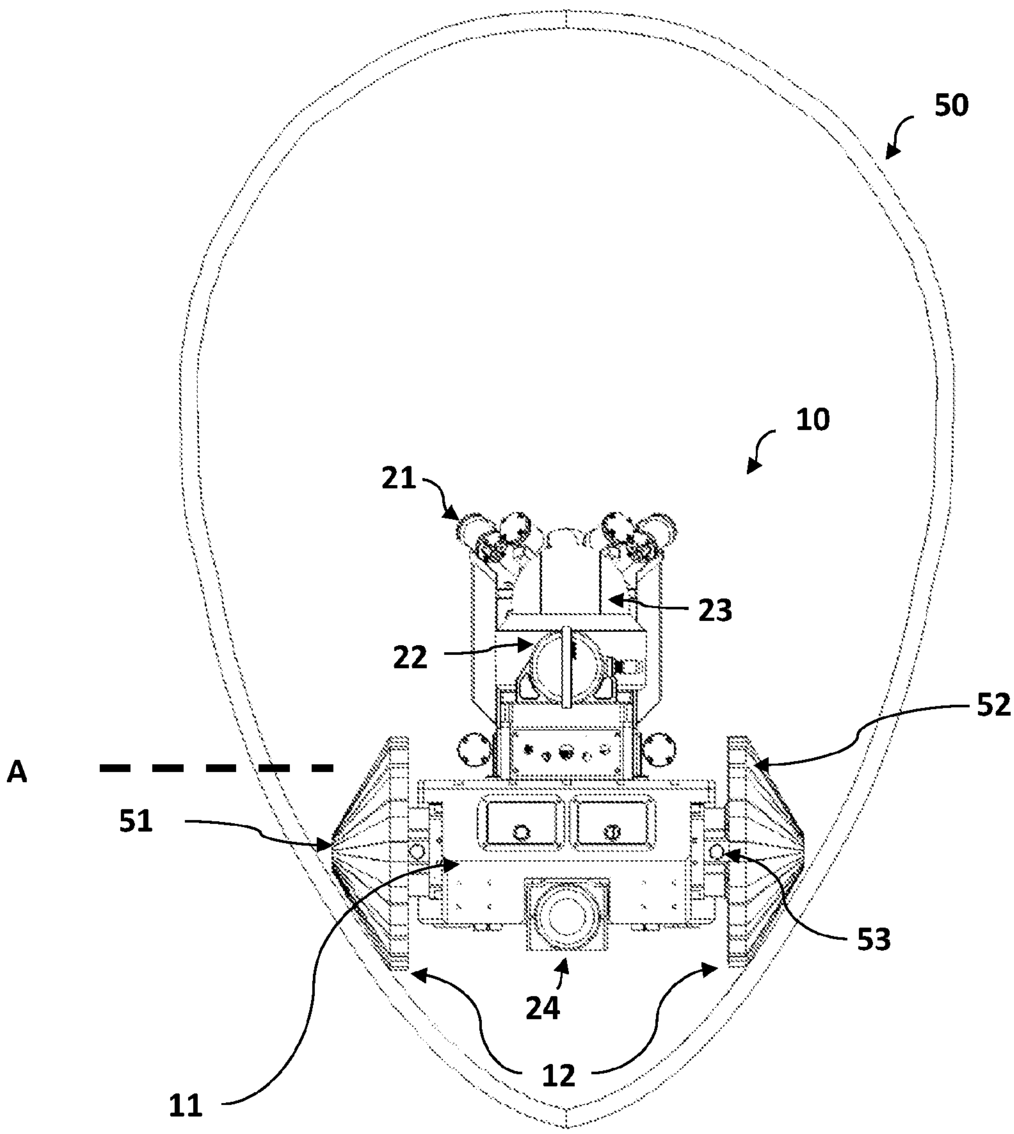

FIGURE 5

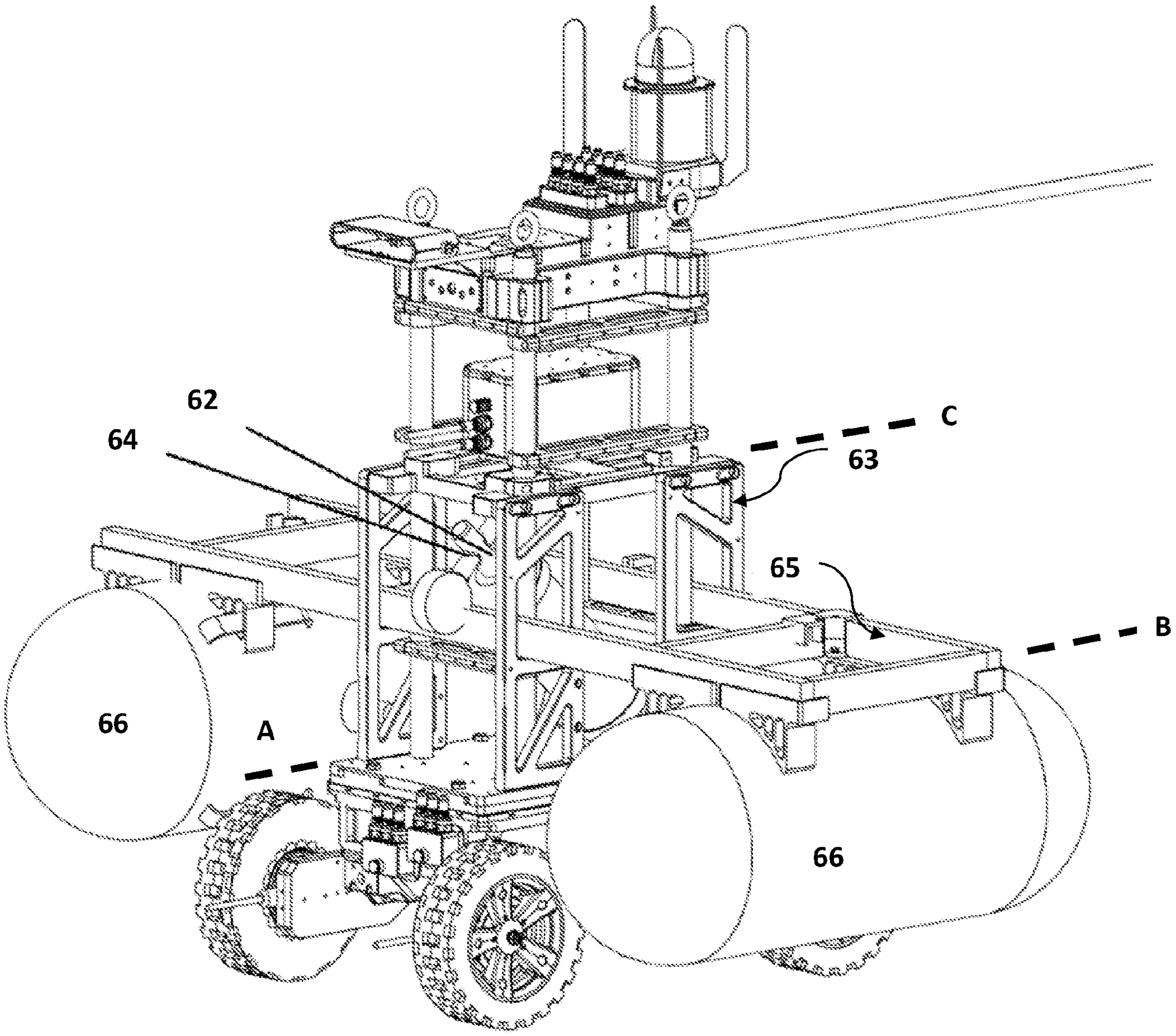

FIGURE 6

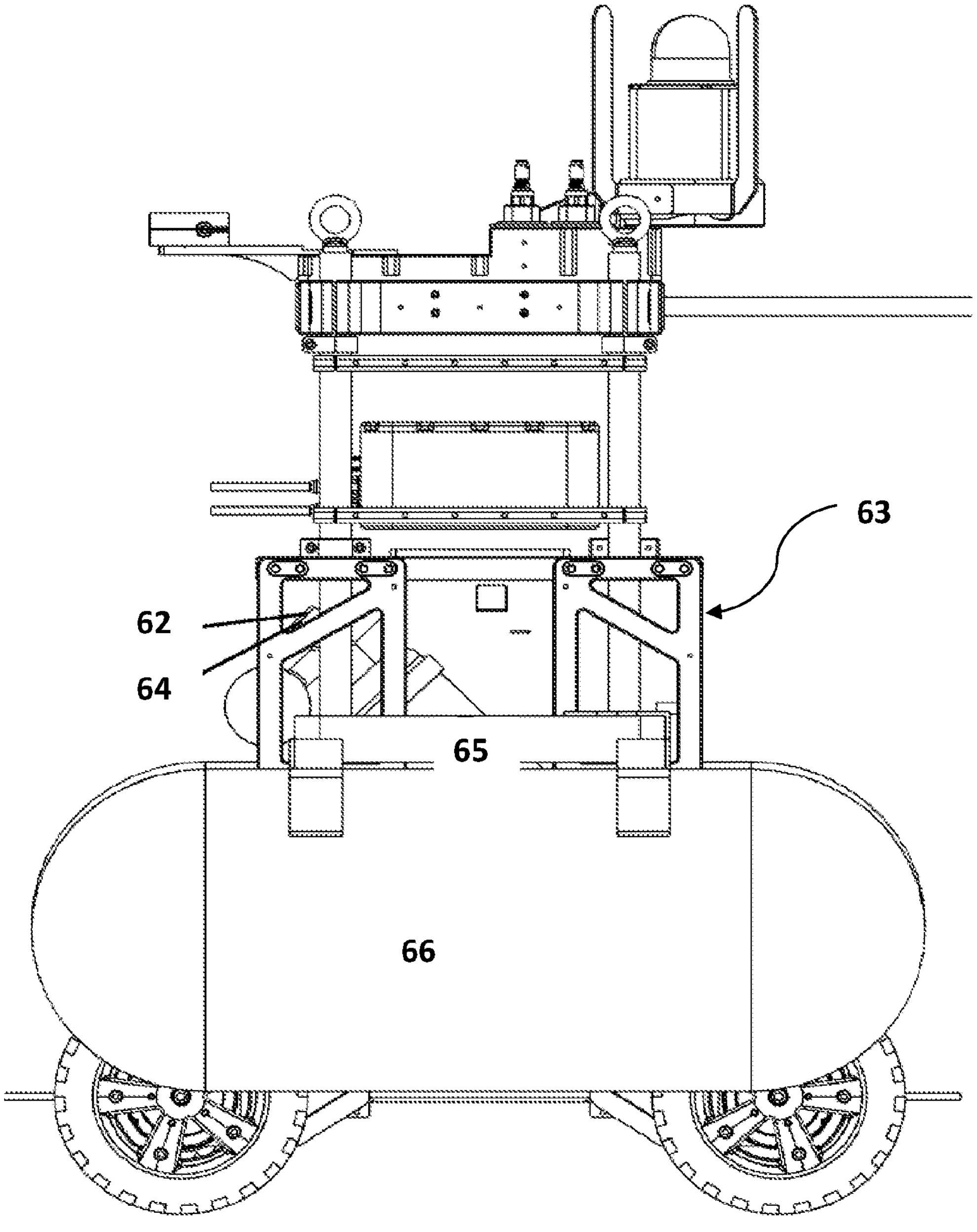

FIGURE 7

INTERNATIONAL SEARCH REPORT	International application No. **PCT/AU2024/051308**

A. CLASSIFICATION OF SUBJECT MATTER

[See Supplemental Sheet]

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Databases: PATENTW, DOCDB, DWPI, Google patents, Google scholar, Google images, Esp@cenet And IP Australia's Internal databases:

CPC/IPC Codes: B60W 60/-, G05D 1/-, G01S 17/-, B60W 2/-, G05D 2/-. Keywords: robot, autonomous, camera, sensor, platform, wheel, taper, tunnel, float, lidar and similar keywords.

Applicant/inventor name (UAM TEC PTY LTD/ CUTRI, Alexander et al.) Keywords: robot, autonomous, camera, sensor, platform, wheel, taper, tunnel, float, lidar etc.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

[X] Further documents are listed in the continuation of Box C   [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 February 2025	28 February 2025
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaustralia.gov.au	**Authorised officer** Riju Jacob AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. +61 2 6283 2220

INTERNATIONAL SEARCH REPORT		International application No.
C (Continuation).	DOCUMENTS CONSIDERED TO BE RELEVANT	PCT/AU2024/051308

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2023/0051111 A1 (LUNAR OUTPOST INC.) 16 February 2023 Paragraphs 0001, 0016, 0023, 0047, 0050, 0051, 0052, 0064, 0073-0075, 0100, Figures 3, 4, 12	1-25
X	US 2022/0331945 A1 (GECKO ROBOTICS, INC.) 20 October 2022 Paragraphs 0199, 0144, 0147, 0150, 0160, Figures 5, 9, 10, 17	1-25
X	US 2023/0236608 A1 (NANYANG TECHNOLOGICAL UNIVERSITY) 27 July 2023 Figures 6, 7, 8B	1-25
X	CN 114484149 A (HARBIN INSTITUTE) 13 May 2022 Paragraphs 0043, 0044, Figures 1-11	1-25
X	Robot Spotlight: Autonomous Inspection of Industrial Facilities & Equipment, Clearpath Robotics by Rockwell Automation, YOUTUBE, 23 September 2022. <URL: https://www.youtube.com/watch?v=YkOhs1QDKdk>. Whole Youtube video	1-25
X	Introducing: Husky Observer | Fully Integrated Inspection System, Clearpath Robotics by Rockwell Automation, YOUTUBE, 13 September 2023. <URL: https://www.youtube.com/watch?v=ADKTxEnSep8>. Whole Youtube video	1-25
X	Robot Spotlight: Fully Loaded & Autonomous Husky UGV with Robotic Arm, Clearpath Robotics by Rockwell Automation, YOUTUBE, 13 July 2022. <URL: https://www.youtube.com/watch?v=8yk0rrYMV3Q>. Whole Youtube video	1-25

INTERNATIONAL SEARCH REPORT	International application No. PCT/AU2024/051308

Supplemental Box – IPC Marks

G05D 1/40 (2024.01)
B60W 60/00 (2020.01)
F16L 55/28 (2006.01)
F16L 101/30 (2006.01)
G01N 29/22 (2006.01)
G01S 17/88 (2006.01)
G05D 1/00 (2024.01)
G05D 1/221 (2024.01)
G05D 1/224 (2024.01)
G05D 1/226 (2024.01)
G05D 1/467 (2024.01)
G05D 1/48 (2024.01)
G05D 1/611 (2024.01)
G05D 105/80 (2024.01)
G05D 109/10 (2024.01)
G05D 109/30 (2024.01)
G05D 109/50 (2024.01)

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/AU2024/051308**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document/s Cited in Search Report		**Patent Family Member/s**	
Publication Number	**Publication Date**	**Publication Number**	**Publication Date**
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		US 12214806 B2	04 Feb 2025
		AU 2022325951 A1	29 Feb 2024
		CA 3228618 A1	16 Feb 2023
		EP 4384421 A2	19 Jun 2024
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Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/AU2024/051308**

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Patent Document/s Cited in Search Report		**Patent Family Member/s**	
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		CN 114484149 B	18 Nov 2022

End of Annex

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.