CLAIMS

1. A robotic vehicle for autonomously calibrating a storage tank without remote input or processing, comprising:

a body having a length;

a drive system coupled to the body and configured to move the robotic vehicle about a surface of the storage tank in the lengthwise direction;

at least two wheels coupled to the body and including magnets, the at least two wheels being configured to contact and magnetically adhere to the surface of the storage tank using the magnets, and turn the robotic vehicle during the movement of the robotic vehicle;

two or more wheel encoders housed within the at least two wheels for measuring the movement and generating movement data of the robotic vehicle when driven by the drive system about the surface of the storage tank;

three or more distance sensors coupled to the body in a linear lengthwise arrangement to measure respective distances from the three or more distance sensors to the surface of the storage tank;

an accelerometer coupled to the body and configured to generate data to capture an orientation of the body relative to the gravity vector; and

a control computing system coupled to the body and comprising:

a non-transitory computer readable storage medium,

one or more processors in electronic communication with the accelerometer, the three or more distance sensors, the two or more wheel encoders, the drive system, and the computer readable storage medium, and

software modules comprising executable instructions stored in the storage medium, in which the software modules are executable by the one or more processors and include:

a movement module that configures the one or more processors to receive the generated movement data from the two or more wheel encoders and the generated

accelerometer data in order to determine the position and orientation of the robotic vehicle with respect to the surface of the storage tank and the gravity vector,

a sensor control module that configures the one or more processors to instruct the three or more distance sensors to transmit a corresponding three or more signals toward the surface of the storage tank at respective impulse times and to detect respective travel times for the corresponding three or more signals to reflect off the surface of the storage tank, and

a profile analysis module that configures the one or more processors to process the received movement data and orientation from the movement module, and to determine a snapshot of the surface of the storage tank by calculating the respective distances from the three or more distance sensors to the surface of the storage tank using the detected respective travel times for the corresponding three or more signals to reflect, the determined orientation, and the processed movement data, and to store the determined snapshot in the non-transitory computer readable storage medium,

in which the robotic vehicle, as controlled by the control computing system, is driven by the drive system to autonomously traverse the surface of the storage tank while the control computing system continuously determines a plurality of snapshots of the surface of the storage tank as the position of the robotic vehicle with respect to the surface of the storage tank changes to autonomously generate a profile of the surface of the storage tank without remote input or processing and to autonomously calibrate the storage tank using the generated surface profile.

2. A robotic vehicle according to Claim 1, in which a first sensor of the three or more distance sensors is mounted on a front portion of the robotic vehicle, and a second sensor of the three or more distance sensors is mounted on a rear portion of the robotic vehicle.

3. A robotic vehicle according to Claim 1, in which the three or more distance sensors are arranged linearly along a longitudinal axis of the robotic vehicle.

4. A robotic vehicle according to Claim 1, in which the three or more distance sensors are arranged linearly along a longitudinal axis of the robotic vehicle, with adjacent such distance sensors being substantially equidistant from one another.

5. A robotic vehicle according to Claim 1, in which the three or more distance sensors are arranged on an outer surface of the robotic vehicle.

6. A robotic vehicle according to Claim 1, in which the three or more distance sensors are arranged within the robotic vehicle.

7. A robotic vehicle according to Claim 1, in which the processed movement data includes a speed of the robotic vehicle or a distance travelled of the robotic vehicle.

8. A robotic vehicle according to Claim 1, in which the profile analysis module further configures the one or more processors to calculate respective times of flight (TOFs) for the corresponding three or more signals traveling between the three or more distance sensors and the surface of the storage tank, to determine the respective distances from the three or more distance sensors to the surface of the storage tank at given points based on the respective TOFs, and to store the respective distances from the three or more distance sensors to the surface of the storage tank at the given points in the non-transitory computer readable storage medium.

9. A robotic vehicle for autonomously calibrating a storage tank without remote input or processing, comprising:

a body having a length and a width;

a drive system coupled to the body and configured to move the robotic vehicle about a surface of the storage tank in the lengthwise direction;

at least two wheels coupled to the body and including magnets, the at least two wheels being configured to contact and magnetically adhere to the surface of the storage tank using the magnets, and turn the robotic vehicle during the movement of the robotic vehicle

two or more wheel encoders housed within the at least two wheels for measuring the movement and generating movement data of the robotic vehicle when driven by the drive system about the surface of the storage tank;

three or more distance sensors coupled to the body in a linear widthwise arrangement to measure respective distances from the three or more distance sensors to the surface of the storage tank

an inertial measurement unit coupled to the body for measuring an angle of the robotic vehicle relative to the direction of gravity; and

a control computing system coupled to the body and comprising:

a non-transitory computer readable storage medium,

one or more processors in electronic communication with the inertial measurement unit, the three or more distance sensors, the two or more wheel encoders, the drive system, and the computer readable storage medium, and

software modules comprising executable instructions stored in the storage medium, in which the software modules are executable by the one or more processors and include:

a movement module that configures the one or more processors to receive the generated movement data from the two or more wheel encoders and the measured angle of the robotic vehicle in order to determine the position of the robotic vehicle with respect to the surface of the storage tank and the direction of gravity,

a sensor control module that configures the one or more processors to instruct the inertial measurement unit to determine a first angle at a first position on the surface of the storage tank relative to gravity, and to determine a second angle at a second position on the surface of the storage tank relative to gravity, and to instruct the three or more distance sensors to transmit a corresponding three or more signals toward the surface of the storage tank at respective impulse times and to detect respective travel times for the corresponding three or more signals to reflect off the surface of the storage tank, and

a profile analysis module that configures the one or more processors to determine an offset relative to the direction of gravity between the first position and the second position, to process the received movement data from the movement module, and to determine a snapshot of the surface of the storage tank between the first position and the second position using the determined offset, the detected respective travel times for the corresponding three or more signals to reflect, and the processed movement data and to store the determined snapshot in the non-transitory computer readable storage medium,

in which the robotic vehicle, as controlled by the control computing system, is driven by the drive system to autonomously traverse the surface of the storage tank while the control computing system continuously determines a plurality of snapshots of the surface of the storage tank as the position of the robotic vehicle with respect to the surface of the storage tank changes to autonomously generate a profile of the surface of the storage tank without remote input or processing and to autonomously calibrate the storage tank using the generated surface profile.

10. A robotic vehicle according to Claim 9, in which the profile analysis module determines the offset by calculating a sine of an average of the first angle and the second angle multiplied by a distance measured by the two or more wheel encoders between the first position and the second position.

11. A robotic vehicle according to Claim m 1, in which the control computing system generates the profile of the surface of the storage tank by solving equations based on the detected respective travel times and the processed movement data to determine how the surface of the storage tank looks.

12. A robotic vehicle according to Claim 1, in which the three or more distance sensors comprise 12 or more distance sensors.

13. A robotic vehicle according to Claim 9, in which the three or more distance sensors are arranged linearly along a horizontal axis of the robotic vehicle.

14. A robotic vehicle according to Claim 9, in which the three or more distance sensors are arranged linearly along a horizontal axis of the robotic vehicle, with adjacent such distance sensors being substantially equidistant from one another.

15. A robotic vehicle according to Claim 9, in which the processed movement data includes a speed of the robotic vehicle or a distance traveled of the robotic vehicle.

16. A robotic vehicle according to Claim 9, in which the profile analysis module further configures the one or more processors to calculate respective times of flight (TOFs) for the corresponding three or more signals traveling between the three or more distance sensors and the surface of the storage tank, to determine the respective distances from the three or more distance sensors to the surface of the storage tank at given points based on the respective TOFs, and to store the respective distances from the three or more distance sensors to the

surface of the storage tank at the given points in the non-transitory computer readable storage medium.

17. A robotic vehicle according to Claim 9, in which the control computing system generates the profile of the surface of the storage tank by solving equations based on the detected respective travel times and the processed movement data to determine how the surface of the storage tank looks.

18. A robotic vehicle according to Claim 9, in which the three or more distance sensors comprise 11 or more distance sensors.