An excavator includes a mobile chassis with a first bucket drum and a second bucket drum coupled thereto. The first bucket drum and second bucket drum are coupled to the chassis for positioning thereof on the surface at opposing ends of the chassis. Each first scoop on the first bucket drum is a mirror image of one second scoop on the second bucket drum when (i) the first bucket drum and second bucket drum are on the surface adjacent opposing ends of the chassis, and (ii) the first bucket drum is rotated in one direction and the second bucket drum is simultaneously rotated in an opposing direction.
Another object of the present invention is to provide an excavator that is small and lightweight.

Still another object of the present invention is to provide an excavator for regolith excavation on extra-terrestrial bodies.

Other objects and advantages of the present invention will become more obvious hereinafter in the specification and drawings.

In accordance with the present invention, an excavator includes a mobile chassis, a first bucket drum, and a second bucket drum. The first bucket drum has a first axis of rotation and is coupled to the chassis. The first bucket drum has at least one first scoop formed thereon that is adapted to dig into a surface when the first bucket drum is placed on the surface and is rotated about its first axis of rotation in a first direction.

The second bucket drum has a second axis of rotation and is coupled to the chassis. The second bucket drum has at least one second scoop formed thereon that is adapted to dig into the surface when the second bucket drum is placed on the surface and is rotated about its second axis of rotation in a second direction that is opposite to the first direction. The first bucket drum and second bucket drum are coupled to the chassis for positioning thereof on the surface at opposing ends of the chassis. Each first scoop on the first bucket drum is a mirror image of one second scoop on the second bucket drum when (i) the first bucket drum and second bucket drum are on the surface adjacent opposing ends of the chassis, and (ii) the first bucket drum is rotated in the first direction and the second bucket drum is simultaneously rotated in the second direction.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features, and advantages of the present invention will become apparent upon reference to the following description of the preferred embodiments and to the drawings, wherein corresponding reference characters indicate corresponding parts throughout the several views of the drawings and wherein:

FIG. 1 is a side schematic view of a zero reaction force excavator in a transport position in accordance with an embodiment of the present invention;

FIG. 2 is a side schematic view of the zero reaction force excavator in its excavation position;

FIG. 3 is a side schematic view of the zero reaction force excavator with one of its bucket drums in a dumping position;

FIG. 4 is an isolated side view of a bucket drum showing the relative scoop positions in accordance with an embodiment of the present invention;

FIG. 5 is an isolated perspective view of the bucket drum shown in FIG. 4;

FIG. 6 is an isolated perspective view of a bucket drum with each scoop having a serrated blade attached thereto in accordance with another embodiment of the present invention;

FIG. 7 is a cross-sectional view of a bucket drum shown in FIG. 5 illustrating a baffle adjacent to each scoop in accordance with an embodiment of the present invention; and

FIG. 8 is a plan view of a scoop's open end and adjacent baffle that is taken along line 8-8 in FIG. 7.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings, simultaneous reference will be made to FIGS. 1-3 where a zero horizontal reaction force excavator 10 in accordance with an embodiment of the present invention is shown in three of its many possible positions. Briefly, FIG. 1 illustrates excavator 10 in a travel or transport position; FIG. 2 illustrates excavator 10 in its dig-
be used to lift one or both ends of vehicle 12 off surface 100 or to be used in combination with track 12A or in place thereof. Thereupon, excavator 10 could also be used on Earth environments. However, excavator 10 could have small and lightweight attributes make it an ideal candidate for use in excavating soft surfaces (e.g., sand) in which conventional heavy excavators would sink.

Excavator 10 includes a mobile chassis or vehicle 12 that could be manned or unmanned without departing from the scope of the present invention. Since excavator 10 produces zero reaction forces during excavation operations, it is well suited for space applications that will generally make use of an unmanned form of vehicle 12. For such unmanned applications, a controller 14 will generally be mounted on vehicle 12. Controller 14 could include stored programs for pre-planned operations of excavator 10, could be responsive to control signals received from a remote source for “on the fly” operations of excavator 10, or could control excavator 10 using a combination of stored programs and remotely-received instructions. The choice of controller 14 and how it achieves its control functions are not limitations of the present invention.

Vehicle 12 can be any suitable structure that can navigate over a surface 100 to include a variety of surface types (e.g., smooth, rocky, hilly, hard, soft, etc.). By way of example vehicle 12 could be outfitted with one or more endless tracks 12A capable of moving and navigating vehicle 12 over a surface as track 12A is driven by a motor 16 (e.g., an electric motor) controlled by controller 14. Single or multi-track type vehicles and their navigation are well understood in the art. It is further to be understood that wheels could be used in combination with track 12A or in place thereof without departing from the scope of the present invention.

As is generally known in the art, the term “bucket drum” refers to a drum-like device/assembly having open-ended scoops formed thereon that communicate with interior region(s) within the drum. When the drum is rotated at a surface region such that each scoop scrapes/digs into the surface, scraped/dug material is deposited into the interior region(s). Accordingly, in the present invention, each bucket drum 22 includes/deline defines an interior volume (or volumes) accessible only via one or more open scoops 22B (two are illustrated) formed on bucket drum 22. In the illustrated embodiment, the interior region of bucket drum 22 is indicated in a general fashion by the region between dashed lines 22D. The number of scoops 22B is not a limitation of the present invention. For clarity of illustration in FIGS. 1-3, only two scoops 22B are shown. More typically, a number of such scoops will be formed on the bucket drum and distributed about the drum’s rotating periphery as will be explained further below. The number, size and position of scoops 22B is duplicated for scoops 32B on bucket drum 32.

Each of scoops 22B is open at one end 22C with open end 22C designed to cut into a surface during excavation. As will be explained further below, open end 22C can be sharp, serrated, etc., to more readily dig into a surface during excavation. A sacrificial edge (not shown in FIGS. 1-3) could be attached to some or all of each open end 22C thereby allowing each scoop 22B to be repaired without replacing bucket drum 22.

When bucket drum 22 is rotated in clockwise direction 28B3 about its longitudinal axis 22A, each open end 22C of a scoop 22B forms the leading edge thereof. Conversely, when bucket drum 32 is rotated in counterclockwise direction 38C about its longitudinal axis 32A, each open end 32C of a scoop 32B forms the leading edge thereof. The significance of this will be explained in an operational description of excavator 10.

With continued reference to FIGS. 1-3, three basic operations of excavator 10 will be explained. In FIG. 1, both bucket drums 22 and 32 are raised off surface 100 by their respective cantilevered assemblies 24 and 34. Such positioning of bucket drums 22 and 32 allows vehicle 12 to move/navigate over surface 100. The particular distance between surface 100 and bucket drums 22 and 32 is not a limitation of the present invention. Further, cantilevered assemblies 24 and 34 could be individually controlled such that the position of bucket drum 22 above surface 100 can be different than the position of bucket drum 32 above surface 100.

In FIG. 2, bucket drum 22 in its excavating position where bucket drums 22 and 32 are positioned on surface 100 (by their respective cantilevered assembly) and where bucket drum 22 is rotated in clockwise direction 28B3 while bucket drum 32 is simultaneously rotated in counterclockwise direction 38C. It is to be understood that the present invention could also be practiced by reversing the drums such that counterclockwise rotation of drum 22 and simultaneous clockwise rotation of drum 32 resulted in surface excavation. In either case, prior to such opposing directional rotation of bucket drums 22 and 32, bucket drums 22 and 32 are synchronized with respect to each other such that each scoop 22B has a mirror image scoop 32B during the opposite-direction rotation of the bucket drums. The respective longitudinal axes 22A and 32A are maintained parallel to one another throughout such opposite-direction rotation of bucket drums 22 and 32.
The advantages of the present invention are numerous. The present invention is directed to a completely new type of excavator capable of overcoming all of the problems associated in space environments on planetary bodies with conventional excavation apparatus. In particular, the present invention is a compact, lightweight, scalable regolith excavator that uses counter-rotating bucket drums mounted on each end of the excavator. During excavation, the excavator generates a zero horizontal reaction force due to the effective self-cancellation of the symmetrical and equal-but-opposing digging forces created by the counter-rotating bucket drums. In addition, the bucket drum design can incorporate multiple small scoops that reduce the digging forces at any given moment in the excavation operation, while being capable of hauling and dumping the regolith load without a separate storage container or dump bin. An improved baffle design reduces clogging and improves material retention.

In addition to the above-described excavation features and advantages, the opposing-end bucket drum placement can be used to manipulate the excavator in a variety of ways. For example, bucket drum positioning and selective rotation thereof can be used to help the excavator perform maneuvers such as climbing stepped surfaces, extracting itself from soft terrain, righting itself if tipped over, raising up the chassis for maintenance purposes, and achieve a wide variety of robotic poses.

Although the invention has been described relative to a specific embodiment thereof, there are numerous variations and modifications that will be readily apparent to those skilled in the art in light of the above teachings. It is therefore to be understood that, within the scope of the appended claims, the invention may be practiced other than as specifically described.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. An excavator, comprising:
   a mobile chassis;
   a first bucket drum having a first axis of rotation, said first bucket drum coupled to said chassis, said first bucket drum having at least one open-ended first scoop formed thereon that provides access to an interior region of said first bucket drum and that is adapted to dig into a surface generally described.

Letters Patent of the United States is:
An excavator, comprising:

1. A mobile chassis;

2. An excavator, comprising:
   - a first bucket drum having a first axis of rotation, said first bucket drum coupled to said chassis, said first bucket drum having at least one first scoop formed thereon that is adapted to dig into the surface when said first bucket drum is placed on the surface and is rotated about said first axis of rotation in a first direction;
   - a second bucket drum having a second axis of rotation, said second bucket drum coupled to said chassis, said second bucket drum having at least one second scoop formed thereon that is adapted to dig into the surface when said second bucket drum is placed on the surface and is rotated about said second axis of rotation in a second direction that is opposite to said first direction;

3. An excavator as in claim 2 further comprising a blade attachable to an outboard edge of each said first scoop and each said second scoop.

4. An excavator as in claim 2, wherein said first bucket drum is coupled to said chassis using at least one rigid support arm pivotally coupled to said chassis for positioning said first bucket drum on the surface, said rigid support arm supporting rotation of said first bucket drum in at least said first direction.

5. An excavator as in claim 2, wherein said second bucket drum is coupled to said chassis using at least one rigid support arm pivotally coupled to said chassis for positioning said second bucket drum on the surface, said rigid support arm supporting rotation of said second bucket drum in at least said second direction.

6. An excavator as in claim 2, further comprising:
   - a first mechanism coupled to said first bucket drum for moving said first bucket drum in at least said first direction; and
   - a second mechanism coupled to said second bucket drum for moving said second bucket drum in at least said second direction.

7. An excavator as in claim 2, wherein said first axis of rotation is parallel to said second axis of rotation.

8. An excavator as in claim 2, wherein said first bucket drum has a plurality of first scoops formed thereon and said second bucket drum has a plurality of second scoops formed thereon, and wherein at least one of said first scoops is in engagement with the surface throughout rotation of said first bucket drum in said first direction and at least one of said second scoops is in engagement with the surface throughout rotation of said second bucket drum in said second direction.

9. An excavator as in claim 2, wherein each said first scoop and each said second scoop terminates in a serrated edge.

10. An excavator as in claim 2, wherein an angular relationship of greater than zero degrees is defined between said flat baffle wall and said open end.

11. An excavator as in claim 2, wherein said baffle further includes a curved baffle wall coupled to said flat baffle wall.

12. An excavator, comprising:
   - a vehicle adapted for movement over a surface;
   - a first cantilevered assembly pivotally coupled on one end to said vehicle and having an outboard end rotatable to a position offset from a first end of said vehicle;
   - a first bucket drum having a first axis of rotation, said first bucket drum coupled to said outboard end of said first cantilevered assembly in support of said first axis of rotation, said first bucket drum having at least one open-ended first scoop formed thereon and providing access to an interior region of said first bucket drum, each said first scoop adapted to dig into a surface when said first bucket drum is placed on the surface by said first cantilevered assembly and is rotated about said first axis of rotation in a first direction wherein said first cantilevered assembly is placed in compression;
   - a second bucket drum having a second axis of rotation, said second bucket drum coupled to said outboard end of said second cantilevered assembly in support of said second axis of rotation, said second bucket drum having at least one open-ended second scoop formed thereon and providing access to an interior region of said second bucket drum, each said second scoop adapted to dig into the surface when said second bucket drum is placed on the surface by said second cantilevered assembly and is rotated about said second axis of rotation in a second direction that is opposite to said first direction wherein said second cantilevered assembly is placed in compression; and
   - each said first scoop on said first bucket drum being a mirror image of one said second scoop on said second bucket drum when (i) said first bucket drum and said second bucket drum couple to said chassis, said second bucket drum having at least one open-ended second scoop formed thereon that provides access to an interior region of said second bucket drum and that is adapted to dig into the surface when said second bucket drum is placed on the surface and is rotated about said second axis of rotation in a second direction that is opposite to said first direction;

13. An excavator, comprising:
   - a vehicle adapted for movement over a surface;
a first bucket drum having a first axis of rotation, said first bucket drum coupled to said outboard end of said first bucket drum when (i) said first bucket drum and said second bucket drum are on the surface and offset from said first end of said vehicle and said second end of said vehicle, respectively, and (ii) said first bucket drum is rotated in said first direction and said second bucket drum is simultaneously rotated in said second direction, wherein each said first scoop and each said second scoop has an open end, and wherein said first bucket drum and said second bucket drum include a baffle adjacent each said open end, each said baffle including a flat baffle wall substantially aligned with said open end, said flat baffle wall having an area greater than that of said open end.

14. An excavator as in claim 13, further comprising a blade attachable to an outboard edge of each said first scoop and each said second scoop.

15. An excavator as in claim 13, further comprising:
a first mechanism coupled to said first bucket drum for moving said first bucket drum in one of said first direction and said second direction; and
a second mechanism coupled to said second bucket drum for moving said second bucket drum in one of said first direction and said second direction.

16. An excavator as in claim 13, wherein said first axis of rotation is parallel to said second axis of rotation.

17. An excavator as in claim 13, wherein said first bucket drum has a plurality of first scoops formed thereon and said second bucket drum has an identical plurality of second scoops formed thereon, and wherein at least one of said first scoops is in engagement with the surface throughout rotation of said first bucket drum in said first direction and at least one of said second scoops is in engagement with the surface throughout rotation of said second bucket drum in said second direction.

18. An excavator as in claim 13, wherein each said first scoop and each said second scoop terminates in a serrated edge.

19. An excavator as in claim 13, wherein an angular relationship of greater than zero degrees is defined between said flat baffle wall and said open end.

20. An excavator as in claim 13, wherein said baffle further includes a curved baffle wall coupled to said flat baffle wall.

21. An excavator, comprising:
a vehicle adapted for movement over a surface;
a first bucket drum having a first axis of rotation, said first bucket drum coupled to said outboard end of said first bucket drum in support of said first axis of rotation, said first bucket drum having at least one open-ended first scoop formed thereon and providing access to an interior region of said first bucket drum, each said first scoop adapted to dig into a surface when said first bucket drum is placed on the surface by said first cantilevered assembly and is rotated about said first axis of rotation in a first direction wherein said first cantilevered assembly is placed in compression;
a first bucket drum having a first axis of rotation, said first bucket drum coupled to said outboard end of said first bucket drum in support of said first axis of rotation, said first bucket drum having at least one open-ended first scoop formed thereon and providing access to an interior region of said first bucket drum, each said first scoop adapted to dig into a surface when said first bucket drum is placed on the surface by said first cantilevered assembly and is rotated about said first axis of rotation in a first direction wherein said first cantilevered assembly is placed in compression;
a second bucket drum having a second axis of rotation, said second bucket drum coupled to said outboard end of said second bucket drum in support of said second axis of rotation, said second bucket drum having at least one open-ended second scoop formed thereon and providing access to an interior region of said second bucket drum, each said second scoop adapted to dig into a surface when said second bucket drum is placed on the surface by said second cantilevered assembly and is rotated about said second axis of rotation in a second direction that is opposite to said first direction wherein said second cantilevered assembly is placed in compression;
a second bucket drum having a second axis of rotation, said second bucket drum coupled to said outboard end of said second bucket drum in support of said second axis of rotation, said second bucket drum having at least one open-ended second scoop formed thereon and providing access to an interior region of said second bucket drum, each said second scoop adapted to dig into a surface when said second bucket drum is placed on the surface by said second cantilevered assembly and is rotated about said second axis of rotation in a second direction that is opposite to said first direction wherein said second cantilevered assembly is placed in compression;
and each said first scoop on said first bucket drum being a mirror image of one said second scoop on said second bucket drum when (i) said first bucket drum and said second bucket drum are on the surface and offset from said first end of said vehicle and said second end of said vehicle, respectively, and (ii) said first bucket drum is rotated in said first direction and said second bucket drum is simultaneously rotated in said second direction, wherein each said first scoop and each said second scoop has an open end, and wherein said first bucket drum and said second bucket drum include a baffle adjacent each said open end, each said baffle including a flat baffle wall substantially aligned with said open end, said flat baffle wall having an area greater than that of said open end.

22. An excavator, comprising:
a vehicle adapted for movement over a surface;
a first bucket drum having a first axis of rotation, said first bucket drum coupled to said outboard end of said first bucket drum in support of said first axis of rotation, said first bucket drum having at least one open-ended first scoop formed thereon and providing access to an interior region of said first bucket drum, each said first scoop adapted to dig into a surface when said first bucket drum is placed on the surface by said first cantilevered assembly and is rotated about said first axis of rotation in a first direction wherein said first cantilevered assembly is placed in compression;
to a position offset from a second end of said vehicle that is opposite said first end of said vehicle;
a second bucket drum having a second axis of rotation, said second bucket drum coupled to said outboard end of said second cantilevered assembly in support of said second axis of rotation, said second bucket drum having at least one second scoop formed thereon and adapted to dig into the surface when said second bucket drum is placed on the surface by said second cantilevered assembly and is rotated about said second axis of rotation in a second direction that is opposite to said first direction wherein said second cantilevered assembly is placed in compression;
said first cantilevered assembly and said second cantilevered assembly coupled to said vehicle at mirror image locations thereon relative to a center of said vehicle between said first end and said second end thereof; and
each said first scoop on said first bucket drum being a mirror image of one said second scoop on said second bucket drum when (i) said first bucket drum and said second bucket drum are on the surface and offset from said first end of said vehicle and said second end of said vehicle, respectively, and (ii) said first bucket drum is rotated in said first direction and said second bucket drum is simultaneously rotated in said second direction, wherein each said first scoop and each said second scoop has an open end, and wherein said first bucket drum and said second bucket drum include a baffle adjacent each said open end, each said baffle including a flat baffle wall substantially aligned with said open end, said flat baffle wall having an area greater than that of said open end.

23. An excavator as in claim 22, further comprising a blade attachable to an outboard edge of each said first scoop and each said second scoop.

24. An excavator as in claim 22, further comprising:
a first mechanism coupled to said first bucket drum for moving said first bucket drum in one of said first direction and said second direction; and
a second mechanism coupled to said second bucket drum for moving said second bucket drum in one of said first direction and said second direction.

25. An excavator as in claim 22, wherein said first axis of rotation is parallel to said second axis of rotation.

26. An excavator as in claim 22, wherein said first bucket drum has a plurality of first scoops formed thereon and distributed evenly thereabout, said second bucket drum having an identical plurality of second scoops formed thereon and distributed evenly thereabout, and wherein at least one of said first scoops is in engagement with the surface throughout rotation of said first bucket drum in said first direction and at least one of said second scoops is in engagement with the surface throughout rotation of said second bucket drum in said second direction.

27. An excavator as in claim 22, wherein each said first scoop and each said second scoop terminates in a serrated edge.

28. An excavator as in claim 22, wherein an angular relationship of greater than zero degrees is defined between said flat baffle wall and said open end.

29. An excavator as in claim 22, wherein said baffle further includes a curved baffle wall coupled to said flat baffe wall.