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MOBILE WORK PLATFORM FOR INITIAL LUNAR BASE CONSTRUCTION

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Described is a system of equipment intended for site preparation and construction of a lunar base. The proximate era of lunar exploration and the initial phase of outpost habitation are addressed. Drilling, leveling, trenching, and cargo handling are within the scope of the system's capabilities. The centerpiece is a three-legged mobile work platform, named SKITTER. Using standard interfaces, the system is modular in nature and analogous to the farmer's tractor and implement set. Conceptually somewhat different from their Earthbound counterparts, the implements are designed to take advantage of the lunar environment as well as the capabilities of the work platform. The proposed system is mechanically simple and weight efficient.

INTRODUCTION

Conceptual design is in progress for a system of equipment to conduct site preparation and construction on the lunar surface. This effort is centered in the Engineering Design Laboratory at the Georgia Institute of Technology in conjunction with the NASA/USRA University Advanced Design Program.

Minimal attention has been previously directed to the phase of lunar surface activity that spans the period between the landing of construction equipment on the Moon and the habitation of a lunar base. Many of the artistic renderings have envisioned familiar types of equipment such as the bulldozer and the backhoe constructing lunar habitats. Engineering analysis shows the impracticality of such terrestrial equipment that has not been uniquely designed for the lunar environment. In particular, such traditional equipment typically depends on its earthly weight for counterbalance as well as reaction to applied forces.

Deliverability to the Moon and the absence of human operators during the unmanned phase of surface preparation places additional constraints on the design and implementation of any construction equipment. The approach for this proposed system uses mechanically reliable, multipurpose vehicles and implements to overcome operational and transportation constraints.

A three-legged walker is proposed as a mobile work platform for most of the activities involved in lunar base site preparation and construction. Using the principle of dynamic stability and taking advantage of the Moon's gravity, it is capable of walking in six preferred directions and rotating about a point. The platform is envisioned to be a lunar version of the farmer's tractor where a variety of implements, such as crane or drill assemblies, are attached. By using the inherent stability of a three-legged structure, along with SKITTER's unique capability for complex motion, the implements can accomplish a variety of complicated operations efficiently.

MOBILE WORK PLATFORM: SKITTER

SKITTER is a comparatively simple device from a mechanical point of view. The central body serves as a housing for supporting hardware and control instrumentation as well as a host for a variety of implements attached via upper and lower body inter faces (Fig. 1). The legs are essentially identical to one another each connecting to the central body by a hinged joint referre to as a hip. A femur link connects the hip and knee joints. Anothe hinged joint, referred to as the knee, connects the femur link an tibia link. Active or passive end effectors can be attached to th free end of each tibia link depending upon the terrain and typ of alternative mobility desired. Each leg operates in its respectiv plane, each of which contains the centerline of the central bod Each hip and knee joint is powered by an actuator that is capabl of causing or resisting rotation of the joint. The angular position velocity, acceleration, and torque of the joints are logic controlled The platform requires only three sets of two actuators and thre sets of two moving links to generate complex motions with a hig degree of mechanical reliability.

Although SKITTER is mechanically simple in nature, th platform's control schemes can become quite complex. However the complexity lies in the governing control algorithms an

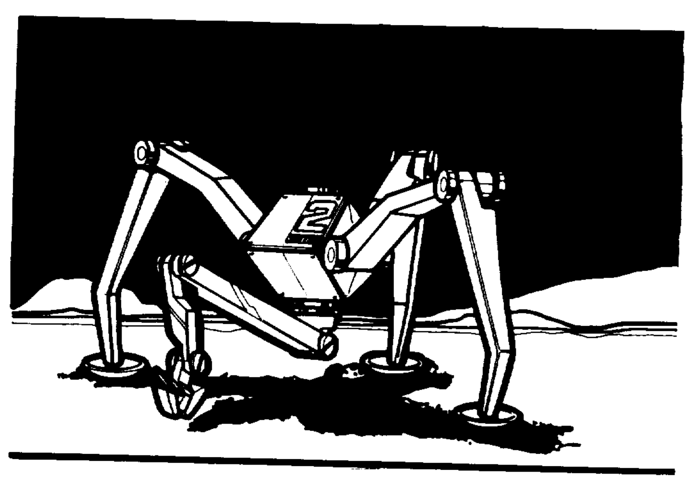

Fig. 1. SKITTER. Illustration courtesy of Pacer Works, Ltd., Atlanta Georgia.

support software, which can be easily revised or upgraded to incorporate new technologies. Some of the platform's motions are described below. For a more detailed explanation of the platform motions, refer to *MacLaren and McMurray,* 1988).

Lean

The basic mode of operation for the platform is to reorient its central body or to lean by reconfiguring the legs while always maintaining static stability. One inherent capability of a three-legged platform is that it will be statically stable while all three feet are in contact with the surface and its center of gravity is positioned over the triangle formed by the feet.

Single Step

A simplified step for walking includes pushing off the surface with one foot, reorienting the foot radially and/or laterally while it remains off the surface and using gravity to restore the foot to the surface at a new location. The central body is thus repositioned from its initial configuration. Radial motion of the foot is achieved by an angular change in the raised leg, while tangential motion is achieved by an angular change in the hip and/or knee joints of the legs that remain on the surface.

Jump

SKITTER has the capability of traversing large distances or negotiating small obstacles by using the jump mode sequence. The platform simply leans in the direction of intended travel then reacts its legs in such a way as to cause the platform to jump. One advantage of the jump mode is that the magnitude of directions in which SKITTER can translate is limited only by the possible orientations of the central body; therefore, with proper design, motion in any radial direction can be obtained.

Crutch Walk

SKITTER capitalizes on its inertial characteristics and dynamic stability for translational motion. By sequencing the single step mode of operation, SKITTER can be made to translate in a manner similar to a person walking on crutches. The crutch mode sequence allows the platform to negotiate small obstacles by stepping over them as well as a method for traversing large distances in unknown terrain.

Turning

With the simplest of control strategies, the platform has six preferred radial directions for translation. However, there will be situations that will require the platform to rotate. SKITTER is capable of pivoting about any one of the three feet or, through a sequence of movements, pivot about the centerline of the platform.

The complex motions of the platform enable the mechanical simplification of the implement assemblies. For instance, the central body has the ability to translate along its vertical centerline at any obtainable platform configuration. Therefore, as a drill rig platform, SKITTER eliminates the need for angular positioning and vertical feed mechanisms by leaning to the correct orientation and then raising and lowering itself along the drill string path by a series of coordinated actuator movements. Additonally, SKITTER has the ability to repeat the single step mode for each leg until the central body comes to rest on the surface with the legs extended outward. This particular position, referred to as the squat mode, is advantageous if the platform is being used in conjunction with a lifting device such as a crane boom. In squat mode, the legs form outriggers to counter the moment due to the cargo being lifted, thus eliminating the need for counter weights or other stability mechanisms.

One distinct advantage of the platform is its ability to right itself from an overturned position. The key to this feature is the range of motion of the legs, which can extend above and below the midplane of the central body. For example, if SKITTER landed completely upside down on the surface, the platform could tuck two legs in toward the central body while the third leg pushed against the surface to flip the platform to the correct orientation. The resulting motion is analogous to a person somersaulting and landing on his feet (*Brazell et al.,* 1988a).

Attachments to the mobile platform include many of the devices needed for the construction of a lunar base. The envisioned implements include crane device, drilling apparatus, digging device, and cargo transportation. Each of these devices derives some benefit from the worksite motions of SKITTER (*Brazell et al.,* 1988b).

CURRENT AND FUTURE PROJECTS

The following projects are currently being developed or are envisioned for the future:

1. *Soil engaging implement.* The soil engaging implement, which attaches to the lower platform interface, is a multi-degree-of-freedom robotic arm with a suitable end effector for leveling, trenching, and digging. The attachment causes the platform to be more stable during operation.

2. *Drilling implement.* The drilling implement, which is housed in the central body of the platform, has the capability of core sampling and boring by using dry drilling techniques currently being developed. Platform motions are intrinsic to the operation of the implement for angular positioning of the bit and vertical feed of the drill string.

3. *Lifting implement.* The crane implement, which attaches to the upper platform interface, would accomplish various material handling tasks via a standard interface. Through the use of the platform's squat mode of operation, mass counterbalancing techniques are not required. To facilitate efficient material handling, standardized cargo interfaces are also being developed and tested.

4. *Dual mobility concepts.* Research is currently being conducted to incorporate alternative mobility systems into the SKITTER design. The platform would be more adaptable to varied terrain due to the respective attributes of each type of mobility. Also, assorted mobility systems attached by standard interfaces to the platform increases the reliability of the system for use in remote operations.

5. *Cargo transportation.* Through the use of standardized attachments to the underside of the platform, cargo could be transported on the lunar surface. Interface mechanisms that allow for emergency release of cargo are also being developed.

Following kinematic and dynamic analysis (*MacLaren and McMurray,* 1986), a proof-of-principle model was constructed (*MacLaren and McMurray,* 1987a,b). The purpose of the scale model was to demonstrate different lean positions, obtain and recover from the squat mode, and take a few steps simulating the crutch walk sequence. SKITTER I, which was completely self-contained and weighed approximately 80 lb, was successfully demonstrated at the NASA/USRA Summer Conference as well as at Kennedy and Johnson Space Centers in 1987. The mobile platform concept was a Grand Prize Winner in the 1987 *Design News Magazine* "Excellence in Design" competition (*Bak,* 1988) and is currently patent pending.

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