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DESIGN OF A PORTABLE POWERED SEAT LIFT

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Bruce Weddendorf
NASA Marshall Space Flight Center
MSFC, Alabama 35812

ABSTRACT

People suffering from degenerative hip or knee joints find sitting and rising from a seated position very difficult. These people can rely on large stationary chairs at home, but must ask others for assistance when rising from any other chair. An orthopedic surgeon identified to the MSFC Technology Utilization Office the need for development of a portable device that could perform a similar function to the stationary lift chairs. The MSFC Structural Development Branch answered the Technology Utilization Office's request for design of a portable powered seat lift. The device is a seat cushion that opens under power, lifting the user to near-standing positions. The largest challenge was developing a mechanism to provide a stable lift over the large range of motion needed, and fold flat enough to be comfortable to sit on. CAD 3-D modeling was used to generate complete drawings for the prototype, and a full-scale working model of the Seat lift was made based on the drawings. The working model is of low strength, but proves the function of the mechanism and the concept.

INTRODUCTION

This paper describes how the portable powered seat lift prototype was designed. It includes how requirements were derived and how they were met through the design of the prototype. Also included are the lessons learned from building and testing the working model and possible improvements to the design to make it lighter and less costly to manufacture.

BACKGROUND

People suffering from degenerative hip or knee joints find sitting and rising from a seated position very difficult. These people can rely on large stationary chairs at home, but must ask others for assistance when rising from any other chair. An orthopedic surgeon identified to the MSFC Technology Utilization Office the need for development of a portable device that could perform a similar function to the stationary lift chairs. The MSFC Structural Development Branch answered the Technology Utilization Office's request for design of a portable powered seat lift.

DESIGN REQUIREMENTS

Engineers in the MSFC Structural Development Branch began the design process by developing functional requirements for a portable seat lift. These requirements were generated with the help of the orthopedic surgeon requesting the technology. The first requirement established was strength: The portable powered seat lift must support a load of 300 pounds with a factor of safety of 2 on yield. This requirement was established to prevent collapse of the seat lift during use and applies throughout the lifting range. The seat lift mechanism also must lift a 300-pound weight from the fully closed position. Maximum lift time was decided to be 10 seconds. A maximum weight of ten pounds for the seat lift was established. This weight was not met with the prototype design, as meeting the requirement of low cost and ease of fabrication were considered more important. In addition to guidelines laid out by the orthopedic surgeon, this effort included research by MSFC engineers. The research included videotaping several people standing and sitting in front of a grid and entering the hip positions into the CAD system. This information was used for generating the range of motion requirement for the seat lift.

CONFIGURATION SELECTION

Several types of overall lifting schemes were considered, including crutch type lifts, a walker with a built in lift, and others. When the criteria of ease of use by most patients and portability were applied, the powered opening seat cushion configuration was selected. The seat lift configuration chosen has an unobtrusive, briefcase-like appearance when being transported, and operation should be familiar to anyone who has used a powered lift arm chair. This configuration requires a slim overall height, but this height is still significant and may pose problems in some cases when the user sits at a low table. This choice of configuration also requires the user always to sit on the lift when they need its assistance, making comfort of the seat over long periods a concern. Use of the device in a chair on casters may pose problems, as there may be a tendency for the chair to roll back away form the user when lifting.

PROTOTYPE DESIGN PHILOSOPHY

Design of this prototype was based upon meeting the requirements for lift angle and height, strength, and overall size as described above. In addition to these requirements, the design was based upon production of one or two units using commonly available machine tools. No molds, dies, or special tools were required to build the prototype design. Cost was considered to be a major design driver, and simplicity of fabrication took precedence over weight. Further influencing the design was the intended use of the prototype as a test article to prove if the portable powered seat lift concept is technically and medically feasible. Because the powered seat lift prototype is intended for use with patients in a controlled and supervised testing environment, no effort was made to generate or meet safety requirements beyond simple structural strength.

MECHANISM DESIGN

Design of the mechanism proved challenging because of the large range of motion, high forces, and thin packaging envelope. Many different overall mechanism types and layouts were considered before the final type was developed (see figure 3). This mechanism features front and rear facing arms, attached to shafts mounted in bearings on the stationary base, with the front arm crossing over the shaft for the rear arm. The front arm is pivoted behind the rear arm pivot, which allows both arms to be as long as possible. The two shafts on which the arms are pivoted are geared together with a ratio chosen to give the right amount of lift at the front and the rear of the seat. The front of the seat is pinned to the front arm, while the rear of the seat is supported by rollers pinned to the rear arm. The system of two arms and the seat has one degree of freedom and can therefore be controlled at any one location. The control location chosen for the mechanism is the rear arm shaft. Crank arms fixed to the rear arm shaft are pinned to connecting links that are pinned to a slider on a track fixed to the base frame. The links and crank arms convert the linear motion of the slider into rotation of the shaft. The position of the slider on the track is determined by an acme screw which runs through it. The screw is supported on thrust bearings and features a worm gear made onto its forward end. The worm gear is driven by a worm directly connected to the motor shaft. This system has a large gear reduction which allows the use of a small motor. The large gear reduction cannot be back driven, so it will remain stationary unless the motor turns.

VERIFICATION OF THE GEOMETRY

The geometry of the mechanism was tailored to match the lift curve generated by a 5 foot 10 inch subject from the data. To check the validity of the design, two stationary wood models of the lift at different heights were made and tested subjectively by people of varying size. The results were as expected, so no changes to the geometry were made. The tests demonstrated that the increasing tilt of the seat as the lift progresses allows shorter users to be supported closer to the front of the lift, and taller users closer to the rear. The wood models also allowed us to learn that handles were necessary on the rear corners of the seat lift, and that under one of these would be a good location for the control switch. The width of the seat lift was also determined by use of the wood models. Originally, the planned seat lift width was as close to the width of a chair as possible, with minimum clearance for the chair arms. This was found to be a poor assumption, as the user's hands must fit between the seat lift and the chair arms as they hold the handles at the rear of the seat. The width of the design was reduced to allow this clearance. See figure 1 for the overall dimensions and figure 2 to see the motion of the lift.

DESIGN METHODS AND DETAILS

In order to package the mechanism within the confines of the seat lift envelope without any interferences, a 3-D model of the entire assembly was made using Intergraph EMS computer aided design (CAD) software. Strength critical parts were first sketched and hand analyzed for strength, then sized and input into the CAD. Other parts which were not as highly loaded were sized in the CAD by clearance constraints. The solid modeling allowed clearances between all parts to be verified throughout the range of motion of the mechanism. As the design progressed, several design changes were incorporated as new problems surfaced. For example, a potential pinch hazard between the seat top and the base was eliminated by making the sides of the seat from soft closed cell foam (see figure 3). Pinching from the internal mechanism is also a consideration. The prototype design does not include protection for this type of pinching, as it is intended to be used as a development and test article only, and pinching could only occur with a deliberate and deep insertion of the hand into the opened seat lift. A production model may require a guard for certain parts of the mechanism.

DESIGN DRAWINGS AND DOCUMENTATION

Engineering drawings of all parts and assemblies of the prototype design were made. The drawings were made from projected views of the parts and assemblies of the CAD solid model. There are over 90 sheets of drawings documenting the prototype design, which meet the MSFC drawing standards.

WORKING MODEL

A working model of the prototype design has been built which is very close in appearance and operation to the prototype, except it is of low strength. It was built at the MSFC model shop using the prototype drawings as a guide. The overall dimensions of the model are made to the drawings, but the materials and tolerances are changed. The gears of the model are standard low-strength aluminum and brass, instead of the high-strength steel parts of the prototype. The model does use the same bearings, a similar aluminum frame, and identical electric parts as the prototype would. Similarity of the model to the prototype allows testing of the mechanism and electric system function for less cost than construction of the prototype itself. The model is a valuable demonstration tool for the portable powered seat lift as well as helping in the development of the prototype.

Construction and testing of the model taught several important lessons. Building the model verified the assembly of the mechanism and electric hardware was possible without interference. Testing the model uncovered a problem with the original location of the limit switches which interrupt the circuits of the control switch when the lift reaches fully closed or fully open. The closed position switch was damaged by the rear arm whose position it was suppose to sense. This was because the mechanism had enough momentum to move slightly even after the motor power was cut. This problem was solved by using a different type of limit switch and relocating both limit switches to operate by the position of the slider block, which has a much more controlled motion. The most important lesson of the model, however is that the motor originally selected is inadequate. This motor was selected based upon its advertised power output, light weight, small size and low cost alone. No curves of torque vs speed were available, as the motor came from a hobby shop. The motor makes very little torque at zero speed, where the powered seat lift requires maximum torque, and therefore cannot lift the necessary load. A different motor must be selected for the prototype which meets the torque requirement.

POWER REQUIREMENTS

The requirement of lifting a 300-pound load to the full extent of the lift in 10 seconds was used to calculate the required power of the portable powered seat lift. Power required to perform this task is 61 watts or about 1/12 horse power. Friction in the linkage can add significantly to the actual motor power required. No testing was available to quantify this friction, so an attempt was made to calculate it. Minimum motor power was determined to be about 150 watts, but the accuracy of the calculations is still untested at this writing. The gear ratio can be varied between the motor and the acme screw, depending upon the speed at which the motor will run and its torque output. The prototype design has a reduction of 20:1 from the motor shaft to the acme screw. The 20:1 reduction allows the motor to lift the seat in 720 shaft revolutions, with a speed of 4320 revolutions per minute achieving the desired 10-second lift. The torque requirement on the motor is 0.135 Nm (1.20 inch-pounds) minimum at startup to move the seat using the 20:1 ratio, and neglecting friction. With the calculated friction, the motor should produce no less than 0.33 Nm (2.93 inch- pounds). These numbers can be adjusted for different speed motors and their required gear ratios, given that they produce the sufficient power.

Large torsion springs were added to the prototype design to assist the motor, to balance the upward lift torque requirement and the lowering requirement. These springs are not required for the system to function if a motor is selected using the above criteria for motor power. Springs may prove beneficial in reducing wear in the mechanism by off loading about 70 pounds of the user's weight. The springs are then energized by the motor in the closing cycle of the seat lift making a more even split of work for the motor during opening and closing of the lift.

RECOMMENDED PROTOTYPE DESIGN CHANGES

The portable powered seat lift prototype design presented here is a good starting point for any effort to produce a production portable seat lift. The prototype design drawings are complete, but changes to the design should be made before even a prototype unit is built from them. These changes are mostly the result of learning from the model. The most important change is the selection of a different motor with proven torque capability and the modification of the motor mount and gear ratio to install it. The limit switches should be installed as they are now in the working model. It may be better to eliminate the springs provided the motor chosen has enough torque to start the lift when loaded. An area of concern is the friction in the plain thrust bearings retaining the acme screw. This friction has not been measured at this time, but a ball thrust bearing of sufficient strength should be considered as a replacement in this area.

DESIGN IMPROVEMENTS FOR PRODUCTION

Many changes in the design should be made to make it more suitable for mass production. These changes should be made in conjunction with other changes made based on knowledge gained from construction and testing of the prototype. Changes made for production only should focus on the areas of weight and cost reduction first. To help meet these goals for the production design, molded reinforced plastic top and bottom halves for the seat lift should be considered. These parts are complex assemblies on the prototype and can be made easily in one piece after investing in the molds required to make them. The top may require the tracks on which the rear arm rollers rest and the bracket to which the front arm pins to be die cast aluminum parts co-molded into the plastic shell. A similar solution could work on the base plastic shell and the metal frame which supports the mechanism. The aluminum frame supporting the shaft bearings and motor could be cast in one piece instead of machined from billet and welded into an assembly as in the prototype. Each arm, with its attached shaft and gear could be made in one net shape piece using powdered metallurgy. The large shafts could be made hollow, and the shaft gears do not have to go all the way around, as only a partial rotation of each is made. Smaller shaft bearings and bearing supports may also be possible. A study should be made to determine if springs in conjunction with a smaller motor would have a weight and cost advantage to a larger motor without assist springs. Taking into account all the areas for possible weight savings, the target weight of 10 pounds can be met, and perhaps significantly undercut.

DESIGN LICENSING

The portable powered seat lift prototype design is the property of NASA and a patent application will be filed to protect the key design features. Prospective manufacturers are encouraged to contact the MSFC Chief Patent Council, CC01, MSFC Alabama 35812 for licensing information.

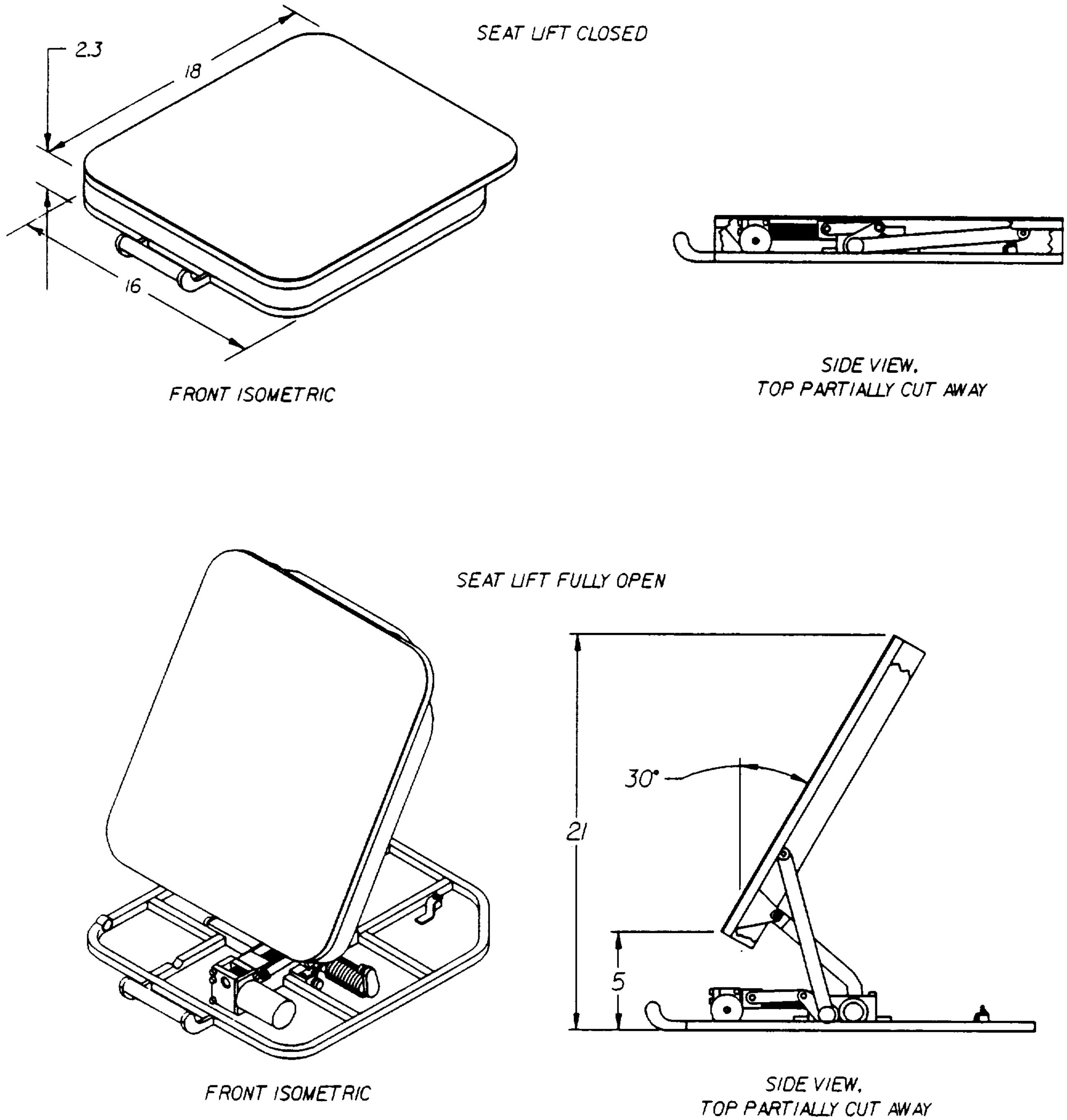
SEAT LIFT CLOSED
2.3
18
16
FRONT ISOMETRIC
SIDE VIEW,
TOP PARTIALLY CUT AWAY
SEAT LIFT FULLY OPEN
30°
21
5
FRONT ISOMETRIC
SIDE VIEW,
TOP PARTIALLY CUT AWAY

FIGURE I

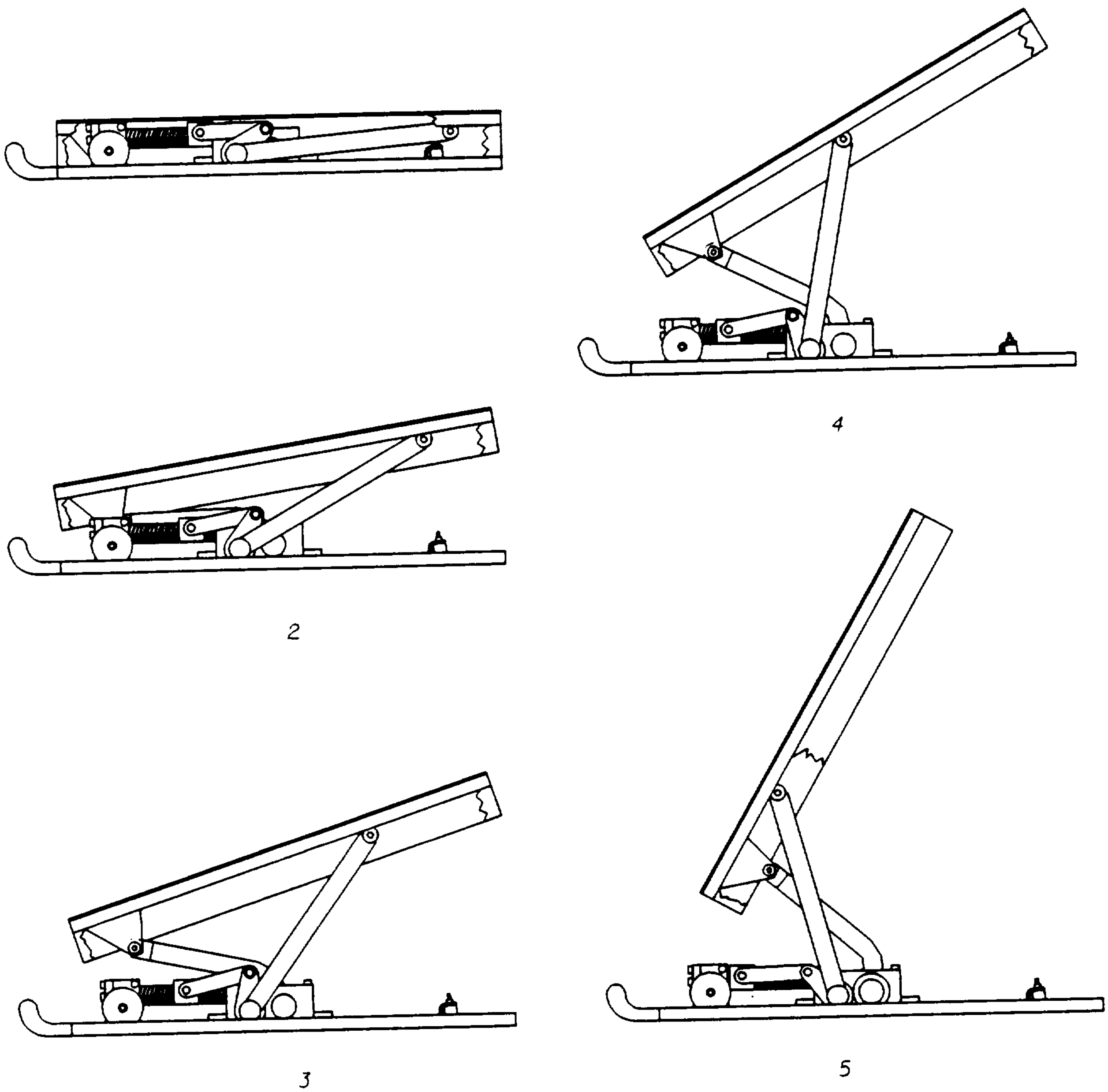

FIGURE 2

PORTABLE POWERED SEAT LIFT SHOWN IN FIVE POSITIONS INCLUDING CLOSED (1) AND FULLY OPEN (5). ALL VIEWS FROM SIDE. WITH TOP PARTIALLY CUT AWAY.

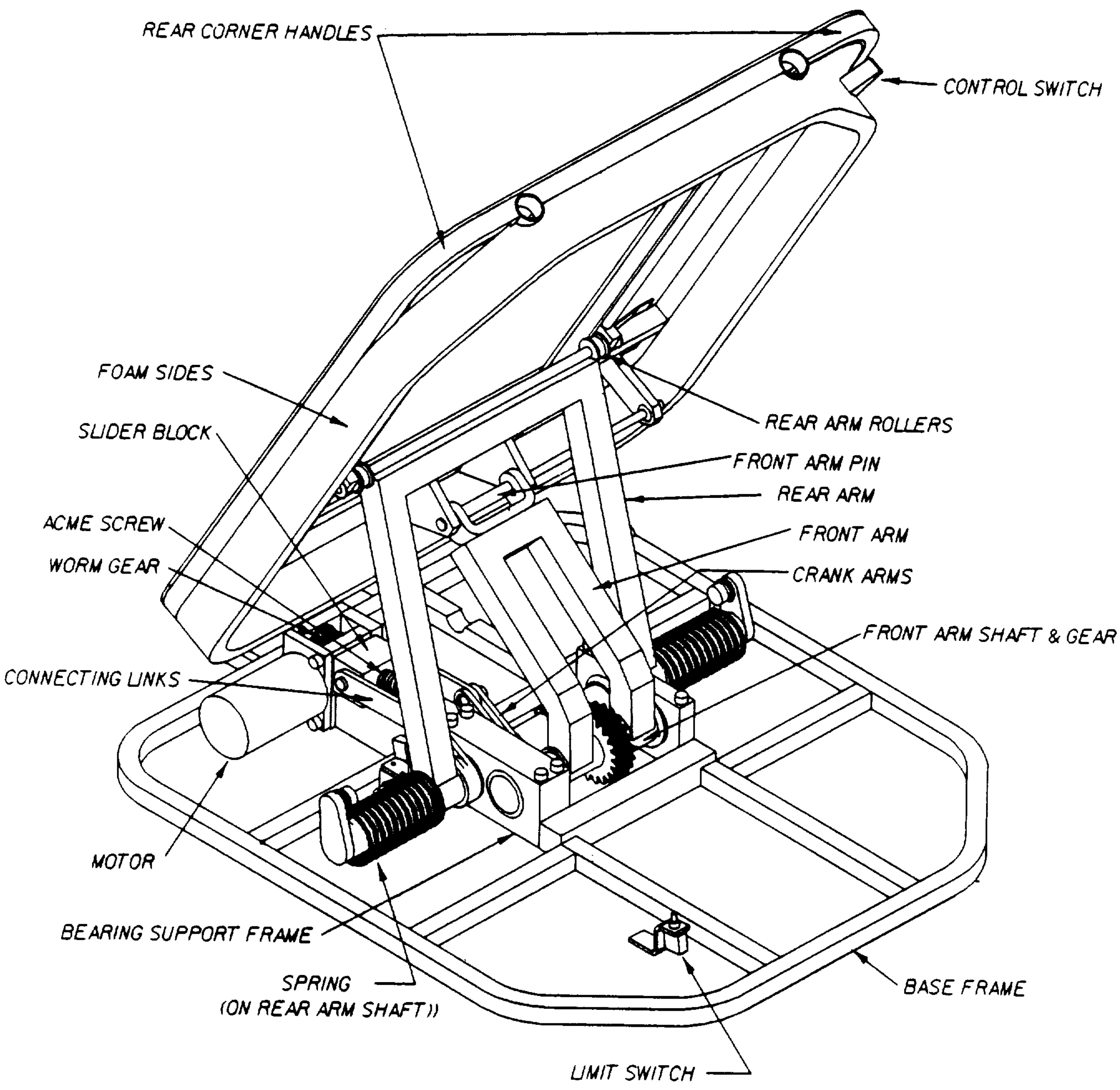

FIGURE 3

ISOMETRIC VIEW, SEAT LIFT FULLY OPEN