DESIGN AND CONTRUCTION OF A SEATED ICE SKATING DEVICE FOR THE PHYSICALLY DISABLED

by

David Norman Atherton, Jr.

Submitted to the Department of
Mechanical Engineering
in Partial Fulfillment of the
Requirements for the Degree of

BACHELOR OF SCIENCE
in
Mechanical Engineering

at the

Massachusetts Institute of Technology

May, 1991

Signature of
Author______________________________
Department of Mechanical Engineering
May, 1991

Certified
by______________________________
Carl Peterson
Professor, Mechanical Engineering
Thesis Supervisor

Accepted
by______________________________
Peter Griffith, Chairman
Department Committee
Department of Mechanical Engineering

DESIGN AND CONTRUCTION OF A
SEATED ICE SKATING DEVICE
FOR THE PHYSICALLY DISABLED

by

David Norman Atherton, Jr.

Submitted to the Department of Mechanical Engineering on May 10, 1991 in Partial Fulfillment of the Requirements for the Degree of

BACHELOR OF SCIENCE
in
Mechanical Engineering

ABSTRACT

The ice recreational needs of the physically disabled have been largely ignored. This project addresses this issue, in the design and construction of a three-skate vehicle for use on the ice. It is propelled by the circular arm motion already familiar to anyone accustomed to the use of a wheelchair, and is steered by a tilting of the body in the direction of the turn desired.

Simplicity of function and design, ease of construction and adjustment, and ultimate user compatibility were considered to be the most important factors in the design of the chairskate.

Thesis Supervisor: Prof. Carl Peterson
Professor of Mechanical Engineering

ACKNOWLEDGEMENTS

I WOULD LIKE TO THANK MY PARENTS FOR EVERYTHING.

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

The winter recreational needs of the handicapped are, for the most part, ignored. David Law, of the Woodrow Wilson Rehabilitation Center, as well as John Ward from the Institute for Technology Development were both helpful in efforts to obtain information on the technology currently available. Various skiing alternatives have been designed and made available for the general public, such as the Sit-Ski, developed by Peter Axelson of Beneficial Designs, Inc., and other sitting versions of Alpine and Nordic skiing events. Discussion with Peter Axelson, as well as the viewing of two tapes, one from the National Handicapped Sports and Recreation Association, the other of the Wintersports Workshop for Wheelchair Athletes held in Engelberg, Switzerland in 1987, revealed no such technology development for the disabled user for ice recreation. The design, development, and construction of such a device was the purpose of this project.

A device capable of safe, fun speed on the ice was desired. Propulsion for the device had several necessary requirements. **The motion used to actuate the propulsion needed to be both simple and comfortable, for the muscles used needed to be inherently strong and developed** for the target population: the active, wheelchair-constrained paraplegic. **The propulsion mechanism had to be safe for the user when on-board**, thus a spiked version of the regular wheelchair was not considered a viable option. **The propulsion also needed to be relatively non-destructive to the ice** on which it was used, allowing its use alongside regular skates, in an ordinary skating rink. **The propulsion needed also to be actuated by either one or both hands**, allowing one-hand-free operation, such that the other hand could be used for something else, such as carrying a hockey stick.

Steering was the other major problem that needed to be addressed in the device's design. From the onset of the project, **a hands-free method of steering was desired**, for much the same reason the similar restriction was placed upon the propulsion. The user would not be required to shift from propulsion, to steering, to playing the game in which he is involved in the requisite short period of time; these functions were to be, for the most part, decoupled and independent. Considering the anatomical function of the majority of the target population, it was decided that the most effective, indeed, perhaps the only method of hands-free steering feasible utilised the user's leaning ability for actuation.

As with any carefully thought out prototype design process, there were factors external to the actual design noted above. The prototype was originally designed to be adjustable, in any and all ways that could either accommodate the user or enhance or improve functionality. Experimental determination of important design parameters was chosen as an alternative to lengthy and time-intensive calculations, the accuracy of which indeterminate without experimental data. Taken into account had to be the wide range of potential users, from the sixty pound child to the two-hundred pound adult, and their corresponding strength and geometric differences, as well as their driving needs while on the machine, such as steering sensitivity, and power stroke of the propulsion device.

The availability of the building materials was also a constraint. All of the material used in the construction of the chairskate, excepting only the stainless steel tubing for the frame, was found in various machine shops on campus. Several of the parts, including the propulsion ball joint ball and the tapered roller bearing assemblies, were prefabricated, and merely reused for the chairskate.

DESIGN AND CONSTRUCTION

Figure 1 shows the basic frame and configuration of the chairskate. All parts seen in the figure are either type 316 or type 304 stainless steel, with welded joints.

Figure 2 shows the propulsion mechanism. As the slider cable is pulled away from the back of the chairskate, its attachment to (through the drive pulley) and subsequent force upon the blade lever arm serves to first bring the retracted blade into contact with the ice, and then pull the entire slider assembly towards the back of the chairskate, propelling it forward. As tension is released on the slider cable, the slider retraction spring serves to both lift the blade from the surface of the ice, and pull the entire slider assembly towards the front of the chairskate. This process is repeated at will. The slider cable for both hands is one piece. The slider cable from one hand is first passed around the corresponding slider cable pulley (one for each hand), around the drive pulley, then back to the other hand. The drive pulley is attached to the blade lever arm. This allows either one- or both-handed operation. The construction of this mechanism required extensive machine work with aluminum (slider body), steel (blade assembly), and lexan (slider bearing).

Figure 3 shows the steering mechanism. As the user twists the input by leaning, the ball joint holder is twisted along the same axis. This forces the female elbow shaft to comply in several ways. It moves translationally through the ball of the ball joint, to accommodate the required increase in distance between the elbow and the ball. It also twists within the ball. Lastly, the ball itself rotates in the ball-joint holder, accommodating the increased angle at the elbow caused by the twisting of the input. The transmission's variable transmission ratio and range are determined by the initial value of the elbow angle, as well as various geometrical ratios of the linkages. The construction of this mechanism required also extensive machine work with aluminum (ball joint assembly) and steel (elbow and output coupling). An actual ball from a commercially available, standard ball valve was used, as well as its premade, correctly radiused bearing washers.

Figure 4 shows the chairskate in its entirety.

Figure 1: The Chairskate Frame Without Steering or Propulsion Mechanisms

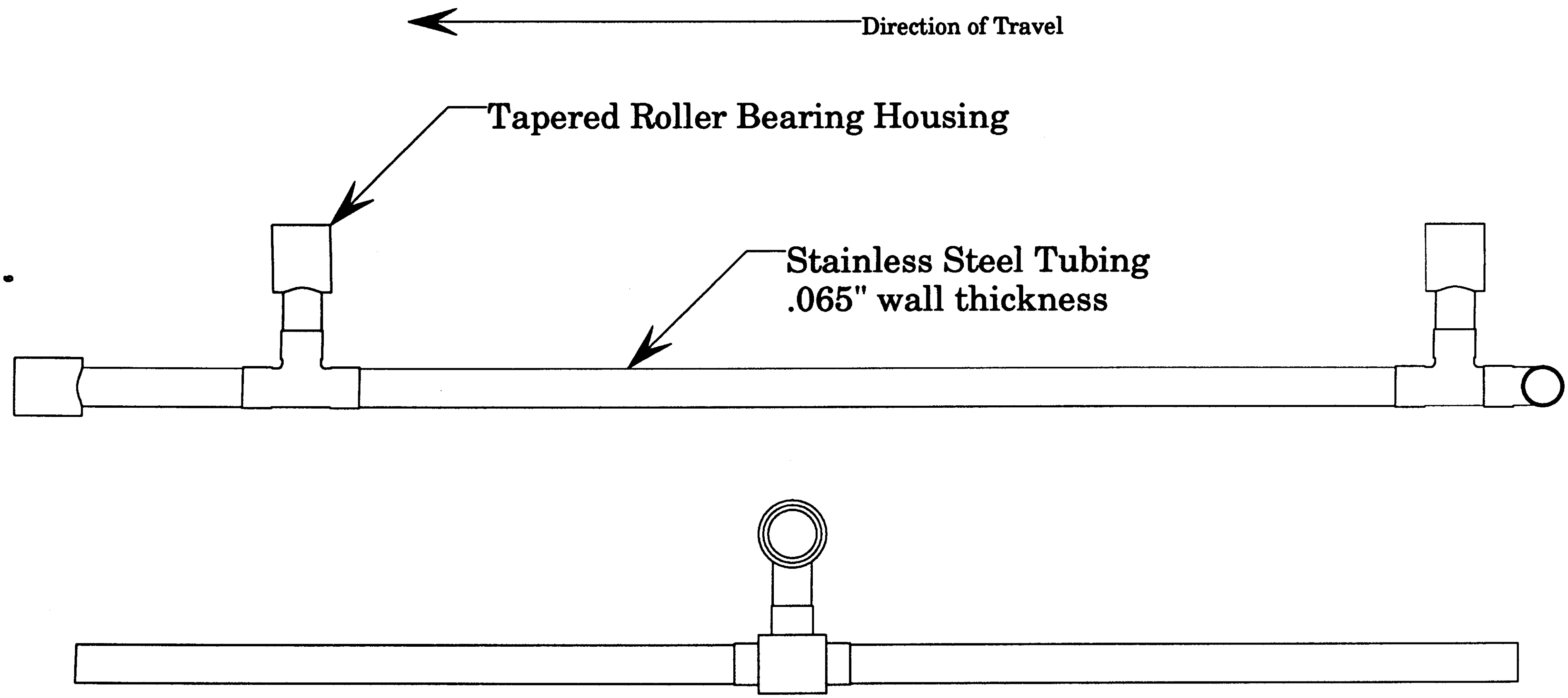


Figure 2: The Chairskate Propulsion Mechanism

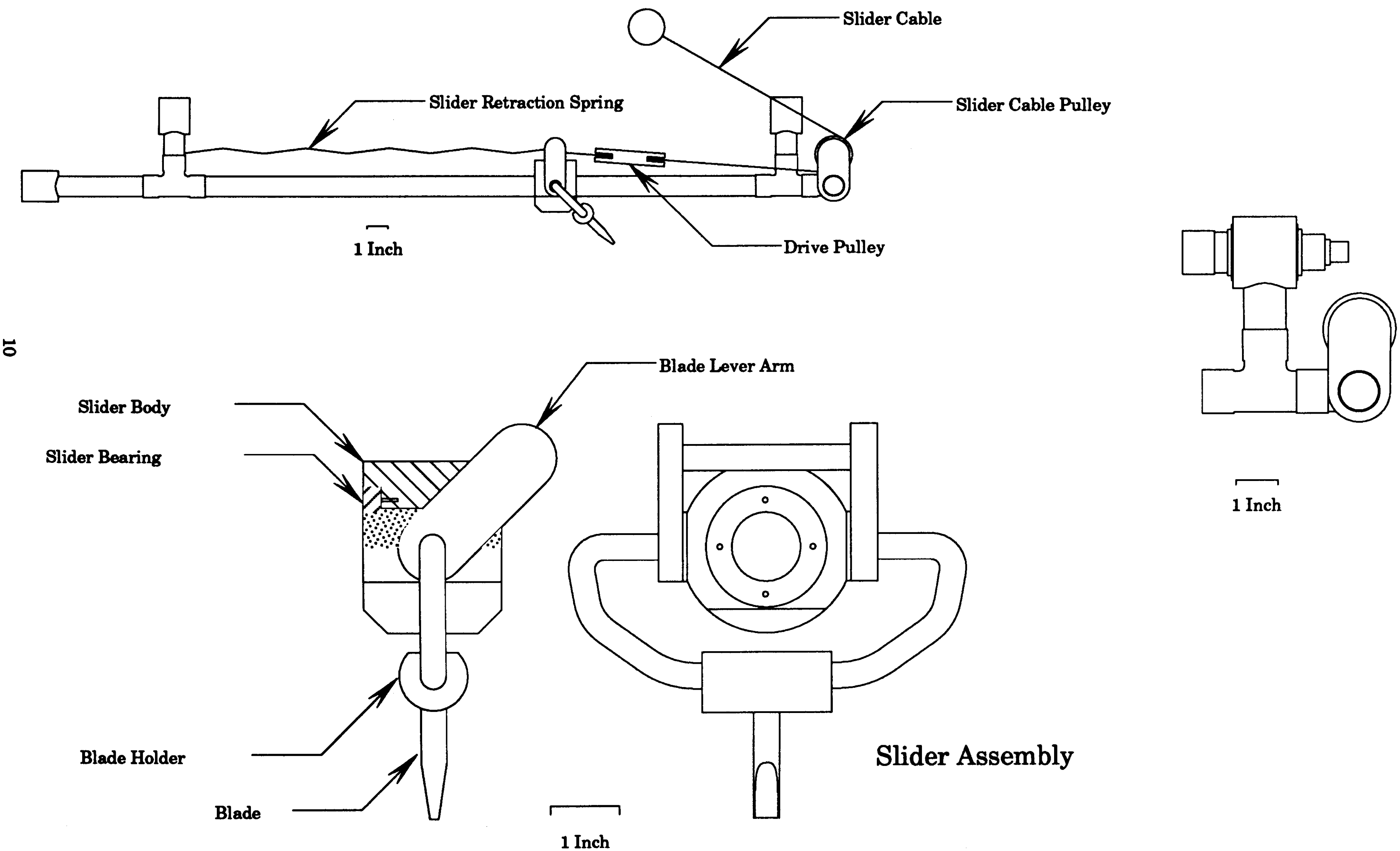


Figure 3: The Chairskate Steering Mechanism

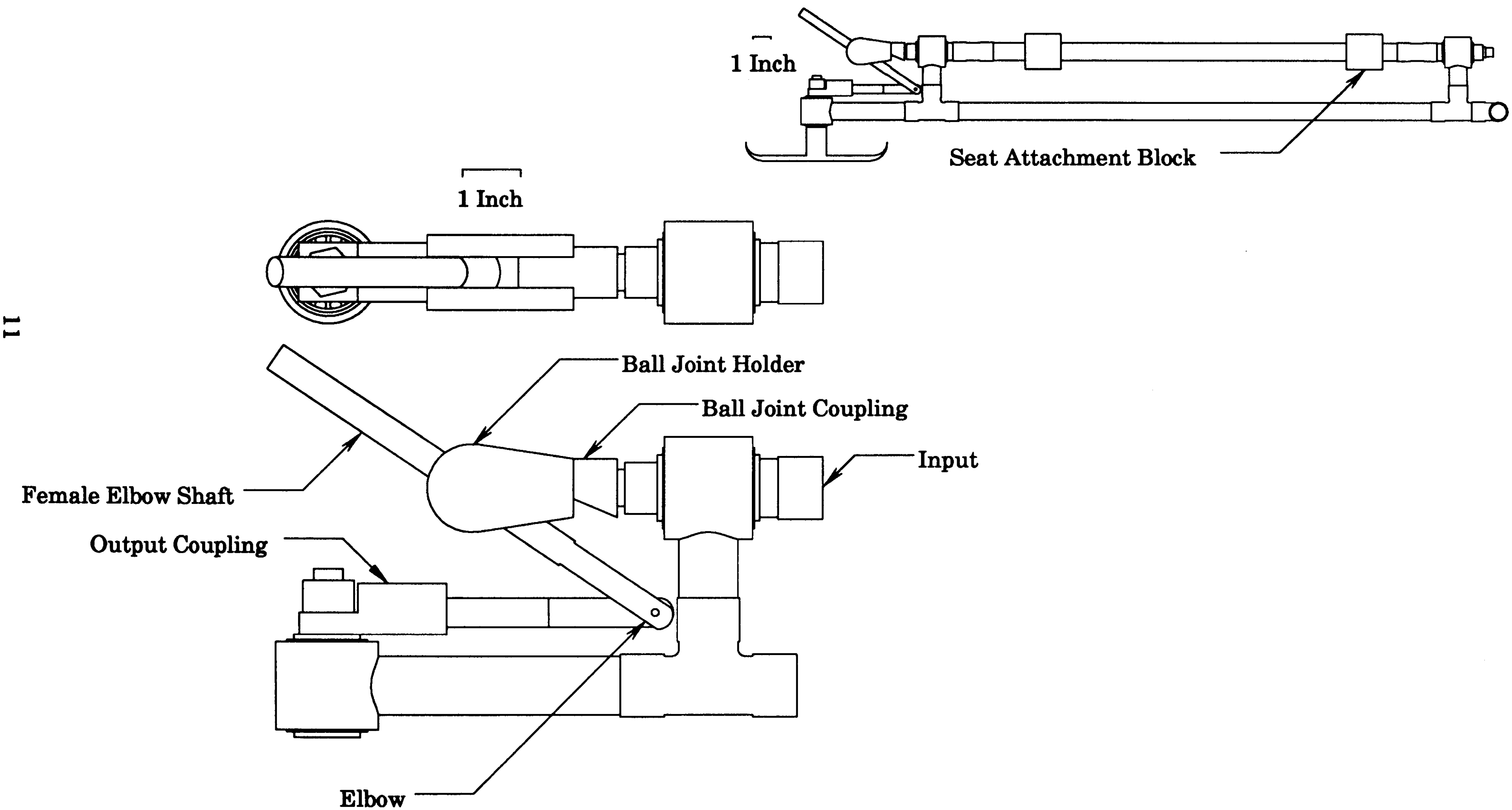
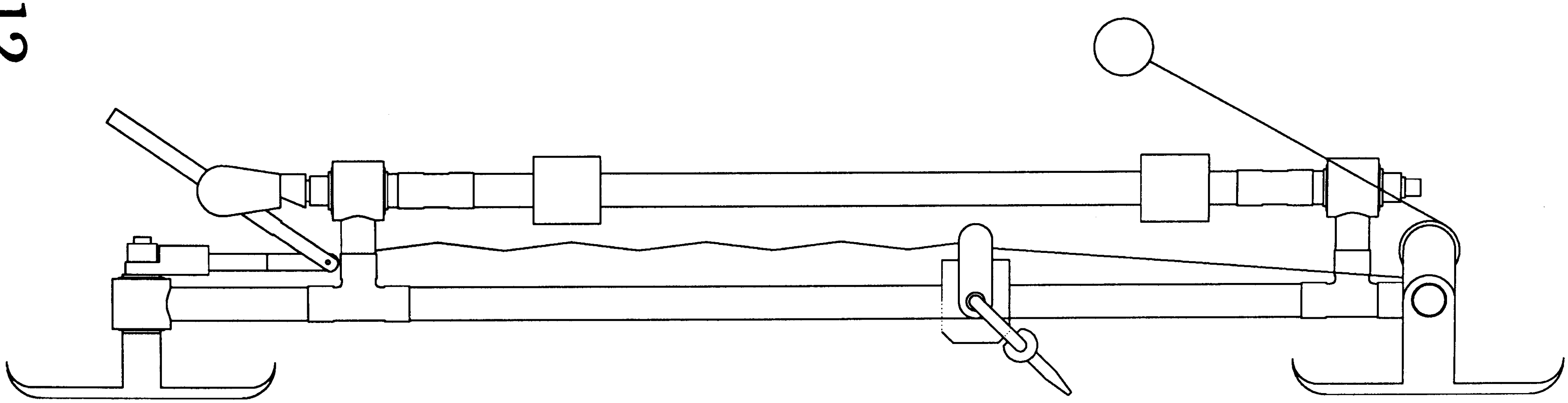


Figure 4: The Complete Apparatus



DISCUSSION

The design worked as expected, that is to say the linkage and propulsion systems were kinematically feasible and did produce the desired effect. On the ice testing, however was not completed. The precluded the determination of several important parameters of the design. Firstly, the proper angle of contact between the ice and the blade was not determined, nor was the proper, or optimal blade contact surface configuration. With a reasonable amount of time, these parameters could be experimentally determined, most likely with more expediency and ease than with paper and pencil alone. The best performing steering mechanism configuration was also thus not determined.

There are several design enhancements that could occur, even though the design process for the chairskate was dynamic, and continuously changing to account for unforeseen difficulties.
The female elbow shaft apparently, for the configuration used in this prototype, needs to be spring loaded against the ball joint holder.
Pulley guards for the slider cable pulleys, as well as the drive pulley are necessary, for there is at times considerable slack in the cable; the slider retraction spring cannot be too strong, or propulsion is difficult.
The chairskate is also in need of some sort brake, for the propulsion blade is incapable of exerting sufficient braking forces, due to the nature of its connection to the slider.

CONCLUSION AND RECOMMENDATIONS

The technology of the chairskate is new and has definite possibilities for the future. The ice, an area for fun for most people, has now been made an option for the physically disabled, where in the past no such option has existed. Further and important research to develop the parameters discussed earlier, such as the steering mechanism geometry, and ice-to-blade contact surface optimization are both necessary for the complete development of the concept herein presented, as well as well within the grasp of practical research limits.