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EXERCISE/RECREATION FACILITY FOR A LUNAR OR MARS ANALOG

UNIVERSITY OF IDAHO

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The University of Idaho, NASA/USRA project for the 1990-91 school year is an exercise/recreation station for an Earth-based simulator of a lunar or martian habitat. Specifically, we designed a stationary bicycle that will help people keep fit and prevent muscular atrophy while stationed in space. To help with motivation and provide an element of recreation during the workout, the bicycle is to be enhanced by a virtual reality system. The system simulates various riding situations, including the choice of a mountain bike or a road bike. The bike employs a magnetic brake that provides continuously changing tension to simulate actual riding conditions. This braking system is interfaced directly with the virtual reality system. Also, integrated into the virtual reality display will be a monitoring system that regulates heart rate, work rate, and other functions during the course of the session.

INTRODUCTION

With the proposed plans to have permanent manned stations on the Moon or Mars, it is vital to have facilities that help keep the crew members in shape both physically and psychologically. Serious muscle atrophy results from living in microgravity for long durations, and ill psychological effects due to isolation and confinement can occur. The scope of this project is to develop a facility to overcome these problems that will be tested in an Earth-based simulator of a lunar or martian habitat. Several types of entertainment and exercises could be incorporated into the exercise/recreation facility to maintain the crew members' wellbeing. This paper gives a summary of research, and describes an exercise bike with a virtual reality system, which combines recreation with exercise.

RESEARCH

Psychological and Physical Effects of Isolation and Confinement in Long-Duration Space Flight

This exercise/recreation station is for use in an Earth-based habitat, but it needs to be adaptable to a lunar or martian habitat. Since the lunar or martian habitat will be in a harsh environment without outdoor access, it is possible for the crew members to feel confined and isolated. This feeling affects people in several ways. In an isolated and confined environment, crew members can often feel that the area they occupy is smaller than it actually is. It is also common for the crew to become short-tempered with one another, especially in high stress situations. This is due, in part, to the fact that these crew members have been separated from their original social groups and placed together for a long period of time in a dangerous environment with limited living space. Provisions for the crew member who wants to "get away from it all" also need to be considered during the station's design phase. Chris McKay, senior scientist at Ames Research Center, who has "wintered over" in Antarctica and is familiar with isolation and confinement, emphasized this point. During his expeditions, there were many instances when he would go to his tent in an effort to be alone. Even though he could not see anyone, he still heard the voices and radios of the rest of the crew. In order for the crew to maintain a healthy attitude in this harsh environment, some form of entertainment must be provided. Exercise, as active entertainment, can supply a physical and mental release not present in other forms of recreation. Studies of Navy crewmen show that exercise can help maintain a better attitude in isolated and confined environments.

In addition to the psychological reasons for exercise, two physical purposes are accomplished: (1) minimizing the deconditioning effects of reduced gravity and (2) ensuring that the crew members will be fit enough to perform their required duties, both at the station and when they return to Earth. The deconditioning effects from reduced gravity are the most important. At reduced gravity, a person's body is not "strained" as much as in Earth's gravity, so the body tends to deteriorate and lose what it does not need or use. This loss affects the physiological and cardiovascular characteristics of the body. The primary physiological effects that are seen include decreased muscle mass (atrophy), strength loss in both the skeleton and muscles, a decrease in bone density, and a decrease in overall mobility. The primary cardiovascular effects are a decrease in oxygen intake during normal breathing, an elevated resting heart rate, and an overall decrease in the flow of blood to all parts of the body.

Entertainment

The equipment in the facility must be durable, safe, and compact. It should also be entertaining enough for the crew members to enjoy exercising. If crew members enjoy using the equipment, they will be more likely to stick to a stringent exercise plan. The equipment should also be realistic enough to allow the crew members to temporarily "escape" from their confined quarters and reduce the effects of isolation and confinement. Entertainment can be supplied in a number of ways such as windows, photographs, books, communication with Earth, and television.

One way to accomplish all of these is with a virtual reality (VR) system. Virtual reality consists of computer-generated "worlds" displayed to the viewer through binocular goggles. The viewer is actually an active participant of the generated world, and since the images are generated continuously, the viewer is given the opportunity to change the scene by physical actions. This is accomplished by placing motion sensors on the equipment or body. One advantage of VR is that it is not limited to reality, as the participant can enter the realm of fantasy by causing things to occur in the computer world that cannot actually happen in the real world, such as walking through walls or flying.

Auditory signals accompanying a visual display will increase the entertainment value. Possibilities range from loudspeaker systems to personal sound systems transmitted monaurally, in stereo, or through 3-D sound imaging. Three-dimensional sound imaging is a way that sound can be more realistically transmitted. As the listener's location changes with respect to the source, sensors mounted to the head allow the sound that is heard to vary in location. So if a plane is up and to the right, that is where the sound would appear to come from. In other words, this allows the listener to hear the position of the sound source.

Equipment

The equipment in the exercise facility is primarily designed to prevent, or slow down, the deconditioning effects of reduced gravity. As stated earlier, reduced-gravity conditions affect both the physiological and cardiovascular aspects of the body. The equipment is designed to improve both muscle and skeletal strength and to maintain certain endurance requirements. Muscle strength must be improved so that the muscles do not experience atrophy when exposed to reduced gravity, and usually isometric, isokinetic, or isotonic exercises are sufficient for this. The body needs to improve its skeletal strength, which is accomplished through impact due to exercises such as normal walking . However, walking in reduced-gravity does not impose as much stress on the body as walking in Earth's gravity, so the exercise machine is designed to simulate the impact one would feel on Earth during exercise.

Physical endurance obtained through constant exercise must also be maintained to ensure that crew members can perform their required duties. The equipment should be designed to provide an adequate cardiovascular workout. One of the indicators of aerobic workload is the amount of oxygen intake during breathing. A high oxygen intake, which is an indication of a good workout, must be accomplished during exercise to make sure that the crew members are experiencing a complete workout. Also, the heart must be exercised extensively so that it can maintain proper blood flow to all parts of the body.

Various types of exercises were investigated in order to determine which were best for physiological and cardiovascular workouts. Resistance and impact exercises were found to be the best for the physiological workout, and aerobic exercises were found to be the best for the cardiovascular workout. Studies have shown that the tension developed and the stretch maintained by muscle fibers during resistance exercises are key factors in maintaining muscle mass. Also, aerobic exercises maintain a strong heart and keep up the oxygen intake to the lungs. A combination of a treadmill, exercise bike, rowing machine, and Nautilus-style resistance machine would be the most effective for minimizing deconditioning effects and maintaining the body at its proper physical condition. The selection of the exercise machines in the facility is based upon a correct balance between the cardiovascular and physiological conditioning.

FINAL EQUIPMENT SELECTION

Exercise Bike

The objective of this project is to incorporate exercise with recreation so an exercise bike with a VR system was chosen. The exercise bike was chosen for several reasons. It provides an excellent physiological and cardiovascular workout, while keeping the entertainment aspects diversified. The rider is in a stationary, upright position most of the time, and is therefore able to do many things, such as watch a television screen, read a magazine, or look out of a window. Biking is a form of exercise that will give the rider more enjoyment and a more realistic feeling. It will also be easier to incorporate VR in the design to give the rider a larger variety of exercise experiences.

Virtual Reality System

A VR system with 3-D audio imaging was selected to satisfy the entertainment criteria of the exercise bike. As described in the background portion of this report, VR allows us to simulate a realistic biking experience on a stationary bike in a confined area. Virtual reality is a relatively new technology that restricts a detailed design for our bike. The main components that are needed are a set of viewing goggles, ear phones, motion sensors, and an appropriate software and hardware package. With the VR system, the user will be able to create whatever course is desired for the ride. It can be a mountainous terrain, a street course, or one of many other choices. The 3-D sound adds to the realistic effect in that if a plane flies overhead from right to left, the rider would hear that plane passing overhead in that direction.

The user's input to the VR system will be accomplished through turning the cranks, steering the bike and using the brake levers and shifters in accordance with what is seen through the goggles. The system will be preprogrammed for each rider according to an exercise physiologist's prescribed work rate. If the rider falls below the necessary intensity, the VR may show an approaching hill in his riding world that must be climbed. A stronger current would then be signaled into the eddy brake, thus increasing the workload. If the rider is above the desired work rate, a gradual downhill stretch may appear on the VR screens. A weaker current could be signaled to the eddy brake and the rider's workload would decrease. The same thing can be accomplished by having the rider simply shift up or down. Shifting up would signal the computer to decrease the current in the eddy brake and increase the current when shifting down.

RIDING SYSTEM

The riding system consists of four major components: a bike, a tilting mechanism, a braking system, and a harness. A riding system was developed that could simulate all possible riding situations, such as going up hills and banking around corners.

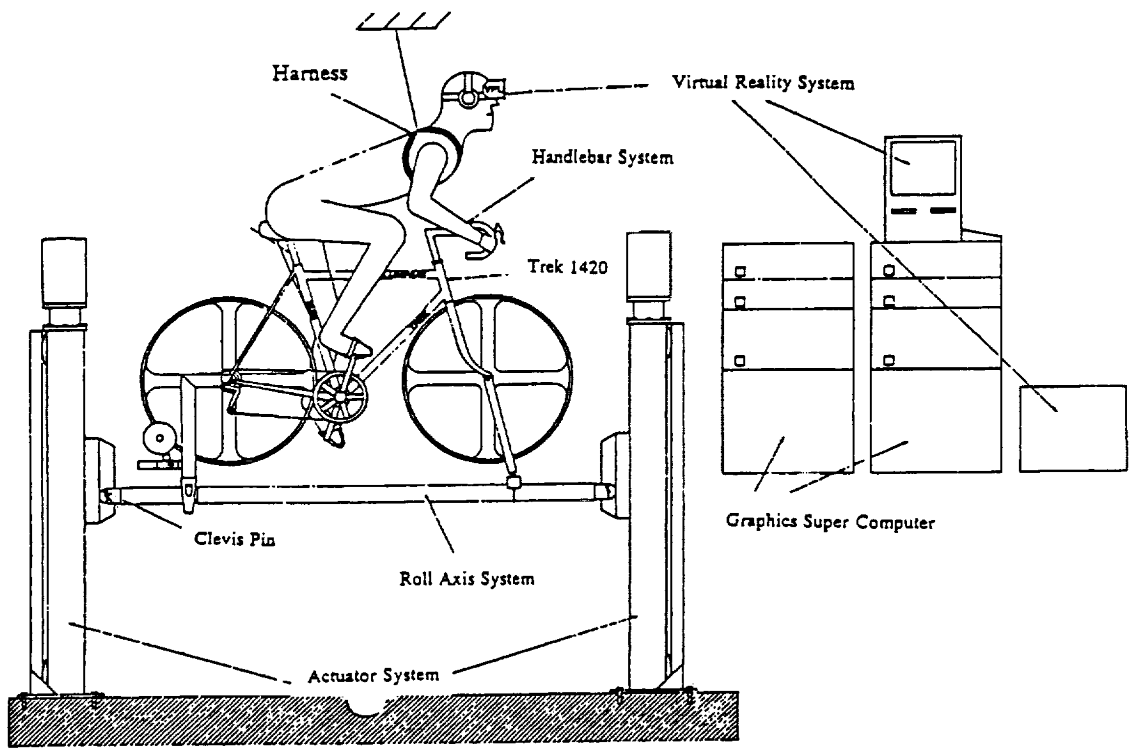

Fig. 1. Riding system.

The system was designed to have both pitch and roll, as well as a variable rolling resistance. The riding system is shown in Fig. 1.

The Bike

A nonferrous bike, constructed of aluminium, was selected because the magnetic properties of ferrous materials interfere with the tracking mechanism used by the VR system. In order to simulate varied riding conditions, the bike needs to be versatile. The bike that was selected combined the performance qualities of a racing bicycle with the comfort of a touring cycle. The geometry of the bike was selected according to Military Standard 1472 to fit the height range requirement for the 95th percentile man to the 5th percentile woman. A Trek 1420, Aluminium size 50 combination bicycle was selected because it fulfills the above requirements. In order to fit the 5th to 95th percentile, adjustable handlebars and an adjustable seat are incorporated into the design.

Handlebar Assembly

A handlebar assembly that simulates both a mountain bike and a road bike will replace the handlebar assembly that comes with the Trek 1420, as shown in Fig. 2. This handlebar assembly will have brake levers and gear shifters that will be tied into the VR system. The handlebar stem will be inserted into the bicycle headset of the Trek 1420. This will provide the typical steering rotation of the handlebars giving the user a very realistic feeling from a stationary bike. An adjustment feature will be added to the handlebars, since the bars must slide forward 20 cm to meet the anthropometric data requirements of the different crew member sizes.

Tilting Mechanism

The bicycle is mounted on a tilting mechanism that provides both pitch and roll for the bicycle. The tilt mechanism consists of two actuators, a connecting bar, and supports. The actuators provide pitch by adjusting the height of the roll bar. The actuator system consists of two electric linear actuators mounted vertically. The actuators are driven by a 1-hp DC motor that will be mounted on the top of each actuator column. These actuators have a maximum throw of 3 ft, which allows the bicycle to reach a maximum pitch of 25°. A maximum speed of 10 in/s can be obtained by the actuators, which will facilitate the simulation of hills and dips commonly encountered while riding.

The roll bar acts as the rolling mechanism for the bicycle and is connected between the two actuators. The roll bar is constructed of two pieces of aluminium tubing coupled to a telescoping section. This telescoping section allows the roll bar to elongate so that binding does not occur during pitch changes. Aluminium tubing is used because it is easy to machine, nonferrous, and lightweight. The telescoping section is made of a heavy-load spline nut, press fit into the aluminium tubing so that the bearing is fixed in one part of the tubing and the

1	CAMPAGNOLA C-RECORD HEADSET
2	MOTION SENSOR
3	QUICK RELEASE
4	GRIP SHIFT PROLINE 1990
5	RITCHEY TRUE GRIP
6	DIACOMPE XCE SHORT STOP
7	MODOLO 8/X-TENDS
8	DURA-ACE BRAKE/SHIFT LEVERS

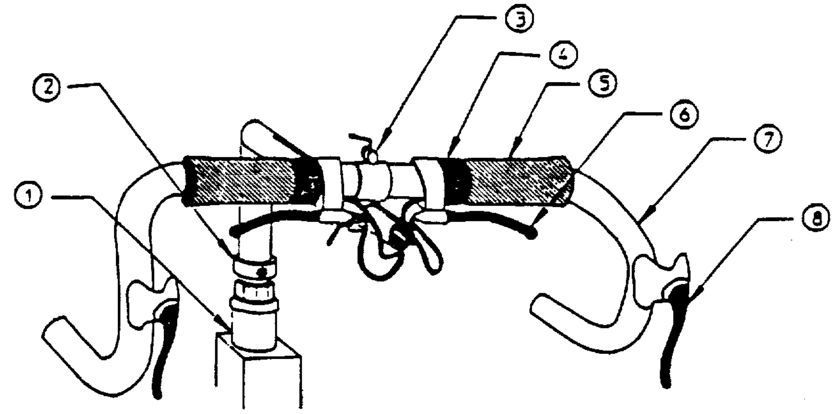

Fig. 2. Handlebar assembly.

shaft is free to slide within it. The bike is attached to the roll bar using a pillow block on the rear assembly. A ball-joint assembly attaches to the front hub allowing a full range of motion for the crankset. This is desirable for both gyroscopic stability and riding simulation. The pillow block assembly attached to the rear hub allows the bike to roll about the roll bar axis, enabling the rider to lean the bike to simulate cornering in a more realistic manner. The bike is stabilized by supports on the ground when the wheels are not rotating and by the gyroscopic effects of the wheel when they are spinning, as on a real bike. A small motor will be attached to the front wheel to rotate it at the same speed as the rear wheel.

The support system holds the actuators in place. These are attached to the floor to provide the bike with a solid foundation, preventing any flex from occurring between the bicycle and the actuator system.

Resistance Mechanism

The resistance mechanism is designed to replicate the rolling resistance of the bicycle as it travels over varied terrain, such as hills, dips, corners, etc. This is accomplished by attaching a permanent magnet braking system, which provides a smooth, quiet, and efficient resistance. This is attached to the roll bar mechanism and a spring-loaded link holds the braking system against the rear tire of the bicycle. The resistance of the bike can be adjusted depending on the riding condition that is simulated during the VR session. This particular resistance mechanism was selected because of its low magnetic flux output and because it is easily controlled using an analog signal.

Harness

The function of the harness (Fig. 3) for the riding system is to protect the rider from any accidents. If the crew member becomes overexerted and loses consciousness, no injury will occur. The main function of the harness is to prevent accidental falls from the bike. The harness was designed to be easily adjustable, comfortable, nonrestrictive, easy to put on and take off, and strong enough to protect the rider. Therefore, a harness similar to a rock climbing safety strap was selected because of its unique quality of high strength without being restrictive and heavy. The harness is very easy to adjust to various body sizes and is not gender specific. The harness is attached to a point above the rider by a cable fixed to the back of the harness. This will protect the rider from falls in the forward and lateral directions.

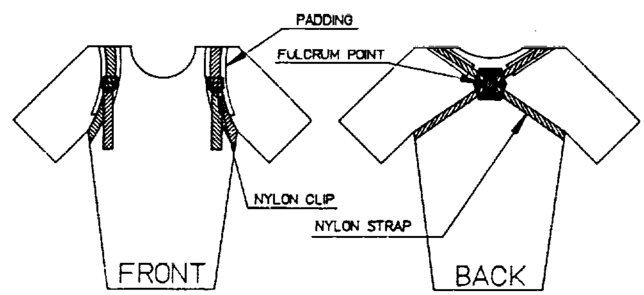

Fig. 3. Upper restraint harness.

CONCLUSION

This design accomplishes the purposes of having both an exercise and a recreation facility. It will reduce the effects of deconditioning and also the ill effects of isolation and confinement. With the VR system and the tilt and roll feature of the riding system, the bike will be entertaining and realistic enough that the crew members should want to stick to their exercise plan.

Since gyroscopic effects are not completely understood, tests will have to be performed to determine the stability of the bike. Once this is determined, the design may need some adjustments to maintain a realistic feel and to ensure the safety of the rider. Also, virtual reality is only in its beginning stages. As the technology in this field increases, the entertainment value and the capabilities of the system will also increase.