

Final Report: Phase I
Small Business Innovation Research Program
National Institute of Occupational Safety and Health

Feasibility of Adjustable Laboratory and Work Bench

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Contents

I.	Significant Findings	2
II.	Usefulness of Findings	3
III.	Abstract	5
IV.	Body of Report	6
	A. Background for Project	6
	B. Specific Aims	7
	C. Procedures and Methodologies	9
	D. Results and Discussions	11
	E. Conclusions	30
V.	Planned Publications	31

Appendix

- A. CAD Drawings of Prototype Test Beds
- B. Annotation of Relevant Building Codes
- C. Annotation of CABO/ANSI A117.1 Requirements
- D. Focus Group Questionnaires
- E. Contract with Ohio University for IRB Review

I. Significant Findings

Accessible Designs-Adjustable Systems, Inc. (ADAS) has researched the technical and social feasibility of developing an adjustable laboratory and work bench. The primary objective of the research has been to determine feasibility of producing a prototype height-adjustable laboratory bench system which is handicapped accessible and provides an ergonomic solution to musculoskeletal disorders caused from laboratory work. Other terms for musculoskeletal disorders used in this report are: cumulative trauma disorders (CTDs), repetitive trauma disorders, repetitive strain injuries (RSIs) and overuse syndromes.

Accessibility Required By Law

AD-AS researched the legal requirements for accessible laboratory and work benches that employers and schools must meet. Project staff learned that Public Law 101-336, **The Americans with Disabilities Act** and other accessibility laws explicitly require science laboratory benches, storage, and fixtures to be accessible to persons with disabilities within newly constructed schools which they attend or within the workplace where they are employed. Section 504 of the Rehabilitation Act and Title II of the ADA address *program accessibility* for schools and universities requiring them to ensure that their programs such as science laboratory classes are accessible (including architecturally accessible) to persons with disabilities.

Code Requirements Can Be Met

AD-AS researched the specifications for laboratory fixtures in order to determine if the water, gas, and electric fixtures could be integrated into a moveable configuration allowing vertical travel of the lab bench and still comply with relevant building codes. Project staff determined that the water and electric fixture lines can be housed in flexible conduit and comply with Ohio Building Codes and National Electric Codes. Project staff identified materials that can be used in applications for flexible supply and waste water lines and conduit which allows electric lines to move vertically and remain in compliance with the National Electric Codes. Project staff identified technical options which allow gas lines to move vertically. However, more research is needed on the national code requirements for utilities used in this application.

End Users and Purchasers Desire Integration

AD-AS queried end users and intermediary purchasers on their physical, aesthetic, and functional requirements of laboratory benches. Project staff identified the most important factors with each group and learned that "able-bodied" end users and intermediary purchasers desired a laboratory setting which allowed workers or students with physical disabilities to be completely integrated into all aspects of the laboratory environment rather than segregated to separate lab stations. Project staff queried a group of university students with physical disabilities and learned that they were wildly enthusiastic about the concept of height-adjustable laboratory benches. Additionally, the participants in this group indicated that accessible science laboratories would enable them to enroll in science lab courses and they expressed a desire to use the same laboratory bench configuration as their able-bodied peers as a means to avoiding stigma.

Feasibility of Adjustable Laboratory and Work Bench

Purchaser Requirements

Project staff queried architects and facilities planning personnel with experience specifying laboratory furniture and equipment to learn purchasing criteria for laboratory benches. This group expressed support for the concept of an all inclusive height-adjustable laboratory bench, but cautioned the Principal Investigator of strict budget restraints at most educational institutions and reported the implementation of less expensive alternatives.

Overall, facilities personnel were in favor of height-adjustable laboratory benches provided they were: ADA compliant, met the functional requirements of standard labs, and cost effective. One project consultant indicated that federally funded and private research labs have larger budgets to make modifications in the lab design when they bring in new scientists.

Viable Prototypes Developed

Project staff defined the technical criteria for evaluating the primary components of prototyped adjustable laboratory bench systems and identified many technical options that enable AD-AS to meet these technical criteria. Multiple prototypes were considered and tested, and results showed that it is possible to meet the ergonomic and accessibility objectives of the Phase I project. Staff successfully designed the height adjustment range to meet the needs of people in both a standing and seated position. Staff designed the prototypes to meet or exceed the accessibility standards with respect to knee clearance space, counter height(s), and reach to controls.

II. Usefulness of Findings

The legal requirements for schools, universities and employers to provide accessible science laboratory facilities to its students or employees are extant, but not exceptionally straightforward, which may explain why widespread compliance has not occurred. The accessibility laws impacting an institution or workplace vary depending upon the type of institution and whether the institution or workplace receives federal funding. Project staff researched the accessibility laws and used a matrix for cross-referencing the different laws to the institution impacted.

The focus groups indicated that science instructors and facilities planners are interested in providing inclusive facility designs for people with physical disabilities as a way of meeting legal requirements of the Americans with Disabilities Act and other accessibility laws. These participants also indicated that they are seeing more students with disabilities enrolled in college as a result of laws and programs designed to provide educational opportunities for disabled persons. They also stated that more and more people with physical injuries have enrolled due in part to the retraining programs of Workers Compensation and vocational rehabilitation.

The participants in the focus group comprised of students with disabilities reported that the environmental barriers were so great in a science laboratory that it restricted them from full participation. Many individuals in this focus group session reported that science lab work is done in two person teams and that when a student with a disability was teamed with an able-bodied teammate, that person had to rely on the able-bodied student to perform the “hands

Feasibility of Adjustable Laboratory and Work Bench

on” work. These findings suggest a serious deficiency in the delivery of accessible educational programs to students with disabilities.

AD-AS has estimated the technical feasibility of three different height-adjustable laboratory benches which incorporate accessibility. Successful commercialization of the prototypes developed during the Phase I will improve the laboratory design and work environment for prospective end-users. It will better facilitate the inclusion of students with disabilities into their educational curriculum. Additionally, commercialization of an easily adjustable laboratory bench will provide a design option for employers who want to include people with disabilities and older workers into the workforce.

Employers are also interested in ergonomics and human factor designs which facilitate productivity and provide a safe and healthy work environment for the employee. The legal requirements for employers to protect employees from workplace hazards such as CTDs and RSIs have become increasingly stringent. OSHA has become increasingly concerned with repetitive stress injuries which now account for one in every three worker’s compensation claims. OSHA initiated an ergonomics rule making process that was recently interrupted by Congress until additional studies were completed.

During the focus group comprised of able-bodied students who work in science labs, the participants unanimously reported that the standard lab bench design and height was awkward and even painful to work at for periods of time longer than 30 minutes. The consensus of these focus group participants was that fixed heights did not allow for a comfortable work environment and that sitting was impossible if not awkward due to crowded or non-existent knee space. The participants reported that working at fume hoods or pipette stations had to be done at awkward and painful postures due to the extended reaches for the individual. Each of these factors negatively impact the quality of work performed.

Staff found that able-bodied users would not be opposed to working at accessible laboratory benches if it provided mutual benefit to both disabled and able-bodied users. The able-bodied focus group participants accepted and encouraged the idea of a height-adjustable laboratory bench as a means of reducing the discomfort from using standard height laboratory benches for long periods of time. They also expressed a desire to work jointly with their disabled peers.

Project staff studied a publication titled “Health Hazard Evaluation Report 95-0294-2594” written by James McGlothlin, Ph.D. and Thomas Hales, MD and supported by NIOSH. In this publication, the authors performed an ergonomic study of a federally supported science lab which had an enormously high incidence of cumulative trauma injuries and consequent workers compensation claims. In this publication, much of the anecdotal evidence project staff gained from focus group participants was validated by this well-documented research on lab technicians and causal factors of overuse injuries. Among the specific lab design recommendations made in the above publication to mitigate injury were: adjustable height pipette stations, adjustable height fume hoods, creation of leg room space, and reduction of reach ranges (which adjustability would solve).

Feasibility of Adjustable Laboratory and Work Bench

The project consultants indicated that virtually every ergonomic study supports the idea that adjustable task height is an ergonomic solution to CTDs. Project staff reviewed ergonomic documents and studies and identified the risk factors which cause CTDs and determined which ergonomic hazards, if any, a proposed prototype adjustable laboratory bench control or prevent. Staff determined that the standard laboratory environment causes users to incur awkward postures and static loading of muscles when performing repetitive tasks. An adjustable-height laboratory bench is a prevention measure that changes the work stations and environment to better fit the worker.

Staff identified technical options to attain the technical objectives of an adjustable-height laboratory bench. Each of these technical options were evaluated in the context of performance and building code requirements. Staff determined that three prototypes were technically feasible for potential commercialization.

The legal requirements combined with user needs and technical feasibility indicate a market for cost effective laboratory facilities which provide ergonomic and accessibility solutions. A well-designed height adjustable laboratory bench will provide an ADA compliant environment useful to both disabled and able-bodied users. A universally accessible laboratory bench will be more cost effective than providing separate laboratory benches for disabled users. It will encourage compliance to accessibility laws because it avoids excessive cost of compliance. Increased compliance will result in a better working environment for laboratory workers which will reduce worker's compensation claims and lost working time for employers.

III. Abstract

AD-AS has researched the technical and social feasibility of developing an adjustable laboratory and work bench. The primary objective of the research has been to determine the feasibility of producing a prototype height-adjustable laboratory bench system which is handicapped accessible and provides an ergonomic solution to musculoskeletal disorders caused from laboratory work. Subsequent commercialization of a height-adjustable laboratory bench system will have universal application to an increasingly diverse student population and work force.

An adjustable-height laboratory bench is of interest to schools and universities which have science or engineering laboratories; employers and employees in industrial research laboratories; and other laboratory work sites. Schools, universities, and employers are interested in providing inclusive facility designs for people with disabilities. The ergonomic objectives of the project focused on an employers' interest in an ergonomic laboratory bench which provides: accessibility, a productivity solution, a quality control solution, and an injury prevention solution. The technical opportunity was focused on creating an affordable system for schools and universities.

AD-AS's technical approach to determining the feasibility of producing an adjustable laboratory bench took place in five phases designed to 1) generate design requirements; 2) develop technical criteria; 3) identify technical options; 4) evaluate and assess technical options; and 5) integrate the preferred solutions into prototype designs.

AD-AS developed three versions of an adjustable laboratory bench. Each of the versions corresponds to the technical criteria established as a result of the research conducted. Additionally, the range of preferences articulated by focus groups and consultants were also integrated into the prototypes. Each of the prototypes relies to a large extent on readily available materials.

Successful product development and subsequent commercialization will improve the laboratory design and work environment for end users. It will facilitate the inclusion of students with physical disabilities into mainstream educational environments. An adjustable laboratory bench will be targeted to the private sector science, engineering, and research laboratories which may encourage students with disabilities to pursue careers in these fields resulting in improved job opportunities for people with disabilities. Educational institutions and employers will receive social and economic benefits from including members of society who historically have been excluded due to environmental and/or ergonomic barriers.

IV. Body of Report

A. Background for Project

AD-AS is an innovative manufacturer of ergonomic and accessible products. The company's mission is to profitably develop and market ergonomic products for all people and accessible to people with disabilities. Since our inception we have developed and commercialized motorized kitchen cabinet and counter systems that adjust at the touch of a button, and four lines of computer stations which feature quick height adjustment.

AD-AS customers consist of colleges, universities, rehabilitation hospitals, private homes, federally subsidized multi-family residences and independent living centers. The height-adjustable kitchen sink and wall cabinet systems are used in public housing as an accessibility solution which allows disabled individuals to live independently. The accessible desks and workstations AD-AS manufactures are often specified through state offices of vocational rehabilitation for disabled individuals who require an accessible work environment to gain employment or return to work after an injury.

Staff learned from our past work in the development, production, and marketing of accessible products that with respect to counter heights, wall cabinet heights, and desk heights- adjustability meets a broad range of user needs. Each user can adjust what is normally a fixed-height surface to an appropriate height to improve the comfort and efficiency of the working position. The Americans with Disabilities Act ushered in new design specifications for counter and desk heights in an effort to accommodate persons with disabilities. These specifications required lower fixture heights which often rendered them awkward and unusable for able-bodied people.

The Principal Investigator recognized the need and opportunity to incorporate the concept of adjustability into the science laboratory environment. All the science labs he had visited were inaccessible to persons in wheelchairs or scooters and not at all ergonomic for able-bodied users. An adjustable laboratory bench system which can be easily adjusted up and down and provide knee clearance space at certain work stations or envelopes would create

Feasibility of Adjustable Laboratory and Work Bench

an accessible laboratory environment for people with disabilities and improve the human factors design of a laboratory for all.

AD-AS staff believed that successful product development of an adjustable laboratory bench was needed for schools and universities which wanted to include students with disabilities in their enrollment. Employers would also benefit by having the technical design options of an accessible component in a working science or engineering laboratory and from providing an ergonomically sound work environment. Staff also recognized the tremendous social and economic benefits resulting from the removal of environmental and ergonomic barriers in school and at work. Additionally, both educational institutions and private employers are required by law to provide reasonable accommodations for people with disabilities.

Universal design is the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design.¹ Universal design is more inclusive than accessible design. Accessible design eliminates obstacles or makes special accommodations to the physical environment.² AD-AS envisioned an adjustable laboratory bench that is usable by most people regardless of their ability or disability and is useful and marketable to any group. Project staff believe that an adjustable laboratory bench which is easy and comfortable to use and incorporates accessibility in a transparent manner would be accepted by most people.

Despite the above observations, the development of an adjustable laboratory bench which could be easily adjusted in height had not been developed. Prior to the start of the project AD-AS staff conducted a literature search of six manufacturers of laboratory and work benches. Each of these companies is well established and has significant market share. Two of the six manufacturers offer single-user "handicapped" lab stations for ADA compliance. These stations feature fixed height counter surfaces and knee clearance for a single person in a wheelchair. These designs fulfill the requirements of the ADA accessibility guidelines, but only work for some disabled people since the ideal work surface height varies because wheelchair heights are not standardized. Additionally, these stand alone lab stations segregate the user from other laboratory users.

All of the above findings prompted project staff to explore the feasibility of the production of an affordable adjustable laboratory and workbench system with universal applicability to benefit an increasingly diverse labor and student population.

B. Specific Aims

- 1. Answer three research questions which will establish technical constraints and design parameters for an adjustable laboratory bench. These questions are:**
 - a. What are the current *legal requirements* and specifications for employers and schools to design laboratory and work benches accessible to people with physical and developmental disabilities? What are the applicable installation and safety codes?
 - b. What are the *specifications* for the fixtures (water supply, water waste, gas, and electric) and materials that might affect the installation and acceptance by

¹ The Principles of Universal Design, Version 1.1 Raleigh: Center for Universal Design, 1995

² Universal Design as Innovation, IDEA Center, Steinfeld, 1996

tradespeople of “non-standard” laboratory and work bench components such as an adjustable height system? [What type of flexible water supply and waste lines could be integrated? What type of flexible conduit would be needed to house and protect the gas and electric lines?]What installation issues must be addressed?

- c. What are the *physical, aesthetic, and functional* requirements of purchasers and potential end users? What factors are most important? What trade-offs would most users find acceptable? What are the attitudes and considerations of the “able-bodied” workforce and student population toward accessible laboratory benches and work station components?

2. Define the technical criteria for evaluating alternative technical solutions for the following five subsystems:

- a. mechanisms for vertical movement of laboratory and work benches;
- b. control mechanisms;
- c. safety systems;
- d. methods for rigid counter construction and design; and
- e. integration of laboratory fixtures (water supply, water waste, gas, and electric).

3. Identify the technical options for the five subsystems: vertical movement, control, safety, counter construction and design, and integration of laboratory fixtures.

4. Assess the technical options for the five subsystems: vertical movement, control, safety, counter construction/design, and integration of laboratory fixtures.

5. Select a preferred set of technical options and integrate them into a proposed adjustable laboratory and work bench prototype which addresses the technical options and integrates the ergonomic objectives.

Each of these technical objectives will be accomplished while considering the following **ergonomic design objectives:**

- a. the counter design and height adjustments will accommodate people who use wheelchairs, people of differing heights, and others with special needs;
- b. the leg space underneath the laboratory and work bench will be unrestricted to allow free movement about the laboratory and work area;
- c. the bench surface will be shaped to bring work closer, to optimize space and function; and
- d. the equipment supports will be adaptable to allow for adjustments during work sessions, thereby reducing stress and fatigue.

C. Procedures and Methodologies

1. Research Questions

The answers to these questions were determined using four methodologies. First, project staff reviewed documents which describe current regulations and building codes concerning accessibility. Second, project staff consulted with two experts during this phase: Dr. Edward

Feasibility of Adjustable Laboratory and Work Benches

Steinfeld and Abir Mullick of The School of Architecture at The University of Buffalo. Third project staff reviewed “Residential Access: Criteria for Designing Residential Environments” written by Dr. Margaret Wylde as a result of a three year study funded by the National Institute on Disability Rehabilitation Research. Fourth, project staff convened three focus groups which responded to questions intended to elicit design requirements and purchasing criteria.

a. To research the legal requirements, project staff met with project consultants and determined the relevant legal documents to research. Project staff conducted a review of the Americans with Disabilities Accessibility Guidelines (ADAAG), the American National Standard Document CABO/ANSI A117.1-1992, and Section 504 of the Rehab Act. An annotation was written for the CABO/ANSI A117.1-1992 technical requirements for accessibility. Additionally, staff determined which sections of the accessibility laws impacted the different institutions and workplaces.

b. To determine the code specifications for fixtures (water supply, water waste, gas, and electric) project staff reviewed the pertinent codes and laws. The Ohio Plumbing Code Chapter 4101;2-56-69 section of the Ohio Basic Building Code was used to conduct research on the water supply and water waste fixtures. Staff searched the code book and annotated the relevant portions as they relate to a moveable, vertically adjusted plumbing system. To determine the code specifications for electric lines staff reviewed the 1996 edition of the National Electrical Code. Staff annotated the relevant documents which pertain to flexible electric fixtures and wiring.

c. To determine the physical, aesthetic, and functional requirements of purchasers and end users project staff met with project consultants which have extensive experience in architecture, industrial design, and accessibility. These consultants directed us to additional documents which address anthropometrics to enable us to determine the task height ranges which would provide: **accessibility, a productivity solution, a quality control solution, and an injury prevention solution.** Staff reviewed Measure of Men and Measure of Women both by Dreyfus to provide a scientific basis at determining the task height of a prototype adjustable laboratory bench. Project staff also reviewed Human Scale by Diffrient and Human Dimensions by Penarro for more background on human interface. Project consultants also made recommendations as to task height ranges.

Project staff referred to the ergonomic recommendations made in the NIOSH Health Hazard Evaluation Report published by James McGlothlin and Thomas Hales to gain a greater perspective on ergonomic issues in science laboratories.

Staff also reviewed Residential Access: Criteria for Designing Accessible Residential Environments published by Margaret Wylde. Although this document primarily addresses residential access, Ms. Wylde dedicates a large portion to multifamily rental housing and assisted living centers which is subject to multiple users due to tenant turnover. The Principal Investigator referred to this document because of the important psychosocial factors associated with the disabled and the able-bodied perceptions of accessibility.

Three focus groups were convened consisting of end users and intermediary end users to elicit design requirements for laboratory benches. Each focus group consisted of an

introduction to AD-AS, a statement as to the purpose of the focus group, a short questionnaire and a 90 minute qualitative discussion. The questionnaire was intended to orient the participants to the issues of laboratory accessibility and ergonomics and to elicit quantitative data. Each focus group had 4-8 participants which was determined to be too small of a sampling size to provide statistically meaningful quantitative data. Staff used the quantitative data to provide a comparison to what the participants said during the qualitative portion. The qualitative portion was intended to probe for greater detail and depth on these issues and to discover additional issues relating to laboratory accessibility and ergonomics. Each of the participants was paid to participate.

Project staff convened one focus group comprised of students with disabilities. These students were recruited for the focus group through the Disability Support Services at Ohio University. During this focus group the facilitator elicited design needs in the science laboratory from this group and their attitudes regarding accessibility and inclusion. Project consultants also pointed out the need for a study of sub-adult anthropometrics which would impact height ranges for an adjustable laboratory bench in a primary school environment. Project staff reviewed the Accessibility Standards for Children published by The Center for Accessible Housing.

To elicit design requirements and ascertain the attitudes and considerations of able-bodied populations regarding accessible laboratory stations, project staff convened one focus group comprised of junior and senior college students who were also enrolled in science lab classes.

Staff convened a final focus group of college and university science instructors and laboratory furniture specifiers to gain an understanding of the importance of “accessibility” in a school laboratory from the perspective of the individuals that actually make purchasing decisions.

AD-AS obtained IRB approval of focus group activities which involved human subjects. All focus groups were conducted in a manner that protected the participants anonymity. To ensure that participants were protected from research risks, the Principal Investigator followed the protocol of outlined by the Ohio University Institutional Review Board (IRB) for the Protection of Human Research Subjects. A concerted effort was made to include women and minority participants in each focus group.

2. Define the technical criteria for evaluating alternative technical solutions for five systems

- a. mechanisms for vertical movement of laboratory and work benches;
- b. control mechanisms;
- c. safety systems;
- d. methods for rigid counter construction and design; and
- e. integration of laboratory fixtures (water supply, water waste, gas, and electric).

Based upon information derived from initial research, information provided by consultants, research documents, and the three focus groups, staff generated initial statements of proposed criteria for technical solutions for each problem. Staff then reviewed the information describing technical problems, conducted literature reviews, and met with

Feasibility of Adjustable Laboratory and Work Bench

manufacturers' reps to determine the technical solutions for each system. Project staff used the specifications in the literature to narrow our field of possibilities based upon cost, performance, ease of implementation. Staff searched for components that were available off the shelf to avoid any high costs associated with specialized tooling or fabrication.

3. Identify the technical options for the five subsystems: vertical movement, control, safety, counter construction and design, and integration of laboratory fixtures.

Based on AD-AS's prior experience in developing adjustable motorized kitchen cabinets and counters, and hydraulically adjustable computer tables, project staff generated a range of technical solutions to the problem. Project staff then developed a comprehensive list of technical options which will solve the technical problem. Staff then consensed upon non-feasible solutions in order to generate the list of possible technical solutions for systematic evaluation.

4. Assess the technical options for the five subsystems: vertical movement, control, safety, counter construction/design, and integration of laboratory fixtures.

Project staff outlined a methodology for systematic evaluation of possible technical solutions. The methodology included multiple measures or indicators of the various criteria developed in Step 2. above. Separate test beds for each of the major subsystems were constructed. Alternative solutions for each subsystem were fabricated and tested.

Mock-ups and prototypes were produced in order to test the integration of subsystems. Project staff then carried out the evaluation. Technical factors including weight bearing capacity, structural integrity, and performance under stress were assessed under the supervision of engineering staff. Technical factors affecting the control and safety subsystems were assessed by the electrical engineering staff. Technical factors affecting the counter support and integration of the fixtures was assessed by project staff.

5. Select a preferred set of technical options and integrate them into a proposed adjustable laboratory and work bench prototype which addresses the technical options and integrates the ergonomic objectives.

In this final phase, staff brought together the design criteria (as determined in 1. Above) with the technical criteria (as determined in 2-4) to propose adjustable laboratory system prototypes. On the basis of the results of the systematic evaluation, the project staff selected a preferred set of technical options that met the design criteria and technical constraints.

D. Results and Discussion

1. Research Questions

- a. Legal requirements and specifications for employers and schools to design laboratory benches to be accessible.

The legal requirements for schools, colleges, universities, and employers to provide accessible laboratory facilities for its students and employees are extant, but not exceptionally straightforward which may explain why widespread compliance has not occurred. With

Feasibility of Adjustable Laboratory and Work Bench

respect to accessibility, the legal requirements for laboratory design address both *Accessible Buildings* and *Program Accessibility*.

For purposes of this project, project consultants recommended CABO/ANSI A117.1 as the technical criteria for establishing accessibility. In this report we will refer to CABO/ANSI A117.1 as "ANSI". The ANSI technical requirements are what the Americans with Disabilities Act Accessibility Guidelines are based upon with some exceptions. The ANSI standards apply to Accessible Elements and Spaces for facilities and buildings, including public-use, employee-use, and common-use. An annotation of the ANSI requirements for laboratory design and specifications for space allowance, clear floor space, reach, laboratory sinks, counter height(s), controls and operating mechanisms, thresholds, and storage space are in the appendix of this report.

The ANSI specifications are based upon adult dimensions and anthropometrics. That is, the specified heights, reach limits, and knee clearance minimums are based upon the abilities of an average sized adult in a wheelchair. This project is intended to provide an accessibility solution for people who use wheelchairs or have mobility impairments. Accessibility issues and assistive devices that pertain to vision and hearing impairments are of equal significance, but are beyond the scope of this project and therefore not addressed in this paper. One of the possible outcomes of this research project is to develop height adjustable laboratory benches for applications in primary schools (grades K-12). In this event, the accessibility standards would have to be modified to reflect the sub-adult dimensions and anthropometrics.

The following is a brief description of the accessibility laws and a matrix of which law is applicable to different institutions that may have science laboratory facilities:

ADA Title I-prohibits employment discrimination on the basis of disability. Employers must provide reasonable accommodations that include modifications or adjustments that enable employees with disabilities to perform their jobs.

ADA Title II-prohibits discrimination on the basis of disability in state and local government services. Most programs and activities of State and local governments are recipients of federal financial assistance from one or more federal funding agencies.

Architectural Barriers Act-is the portion of Section 504 that addresses building and facility accessibility and impacts buildings constructed or operated with federal funds.

Section 504 of the Rehabilitation Act- under section 504, private industries which receive federal funds must ensure that their programs are accessible to qualified individuals with disabilities. The focus of section 504, for existing facilities, is on programs, *not* buildings. Only when it is absolutely necessary to achieve program accessibility are recipients required to retrofit existing facilities. New construction and alterations must be fully accessible.

Applicable Law

Institution	ADA Title I	ADA Title II	Architectural Barriers Act	Sec. 504 of Rehab Act
Public Primary School	Yes	Yes		Yes
Private Primary School	Yes			Yes**
Public College/University	Yes	Yes		Yes
Private College/University*	Yes	Yes *		Yes
State/Federal Labs	Yes		Yes	Yes
Lab Employees of College/University	Yes			
Private Employer	Yes			

* Only if they receive federal monies which most private colleges and universities do in the form of student loan programs.

** Only if they receive federal monies

The following examples were provided by project consultants as a means of elucidating the information in the matrix. For example, primary and secondary public schools would have to provide accessible buildings and accessible programs to students with disabilities under Title II of the ADA and Section 504 of the Rehab Act. The ADA requires full accessibility only in new construction, including accessible laboratory benches. Reasonable accommodation is the approach required in existing buildings, which would not require accessible laboratory benches unless they had a student with a disability enrolled in a laboratory class.

Primary and secondary private schools would not come under Title II of the ADA. However, they may have to comply with the state laws concerning accessibility, and if they receive Federal funds they would come under Section 504 of the Rehab Act.

For example, in New York where two of the project consultants live, a private school would not be required by Federal laws to provide accessible science laboratories, however, they would have to comply with New York State building codes which require buildings to meet ANSI requirements for accessibility. State Universities typically do not have to comply with local building codes, but must comply with state codes.

If a public or private university hired a disabled science laboratory instructor or employee, they must provide reasonable accommodation for this person under Title I of the ADA. State and federal laboratories which are federal funds recipients must comply with the Architectural Barriers Act. This would mean that "scoping" applies whereby 5% of the laboratory facilities must be accessible to persons with disabilities. State building codes may have more stringent standards regarding accessibility and can supercede federal laws. For

Feasibility of Adjustable Laboratory and Work Bench

example, Massachusetts and California state building codes each have more stringent accessibility requirements than federal codes.

A private employer would not have to provide an accessible science laboratory unless the employer hired a person with a disability and an accessible laboratory bench was determined to be a "reasonable accommodation" needed for this employee.

- b. Specifications for the fixtures (water supply, water waste, gas, and electric) to be integrated into a flexible system.

In terms of plumbing and building codes, research indicated that these codes may vary widely from state to state, and from county to county. The National Conference of States on Building Codes and Standards, Inc. indicated that some 44,000 jurisdictions adopt an amended version of one of several model codes, resulting in a complex system. However, the model code groups are moving toward one national model code and eventually an international code.

For this research project we focused on Ohio Plumbing Codes, the National Electric Codes, and Ohio Basic Building Codes. Annotations of code requirements as they relate to this project are located in the appendix of this report.

The water supply lines in commercial applications consist of: non-flexible copper lines, non-flexible PVC lines, and flexible PVC lines housed in a protective and flexible metal conduit. The latter is becoming the most common type of supply line and is presently used exclusively in residential building.

The water waste lines in commercial applications consist of non-flexible PVC 1.5 inch pipe which fits into a 1.5 inch P-Trap to transmit waste water.

- c. Determine the physical, aesthetic, and functional requirements of purchasers and end users
 - (i) project staff met with project consultants to perform a systematic determination of laboratory bench end user's physical and functional requirements.

Project consultants and project staff determined that the height ranges for disabled users should be the same counter height ranges for sinks and work stations specified in the ADA Accessibility Guidelines. Project consultants directed staff to a study done by Dr. Edward Steinfeld which involved evaluating the reaching ranges of people with disabilities to further elucidate the functional reach range of the 90th percentile of people with disabilities.

The counter surface height range(s) outlined in the ADA Accessibility Guidelines specify 28-34 inches (711-864 mm) high measured from the floor. Project consultants recommended work surface heights of 28-42 inches (711-1067 mm) for able-bodied and disabled persons. The lower ranges would be appropriate for adults in a seated position in a standard size chair or stool and the higher ranges would be appropriate for most adult individuals in a standing position and some wheelchair users who are most comfortable

when working surfaces are as close to knee height as possible. Project consultants stated that task height can vary greatly depending upon the specific task. For example, work which requires the use of a microscope may require a raised counter height to avoid stooping. Work which requires the use of flasks and vessels may require a lowered height to allow users to work at the top of the vessel height.

Staff reviewed several documents on ergonomics to determine whether an adjustable-height laboratory bench would control or prevent ergonomic hazards. Risk factors to musculoskeletal injury that were cited in the documents included: awkward posture, repetitiveness, and static loading. Awkward posture is caused from working at non-optimal work positions while sitting or standing. Static loading refers to body postures that are held and require muscle contraction for more than a short time. This may occur from working at the same work station height for long periods of time.

Staff learned that engineering controls which change the work stations, tools or equipment used on the job are often the preferred ergonomic solution because they are permanent changes that eliminate hazards at the source. Engineering controls are often more expensive to implement, compared to other controls, but their effect is often more significant. An engineering control which relates to the ergonomic objectives of this project is *workstation design*. Recommendations for improving the workstation design includes the shape of the work surface and height-adjustability of the work surface, storage, and fixtures. Recommendations cited for improving the workspace layout include: adjustability to fit each worker's size, ability for workers to maintain neutral posture and avoid awkward and extended reaches, a variety of working positions to avoid static postures, and full range of motion and adequate leg room. Work surfaces should be at the proper height and angle for the individual worker's size and equipment used. They should permit neutral postures and be adjustable, especially where different kinds of tasks are performed or the workstation is shared.

One document included a checklist for hazard prevention and control for workstations³. Some of the questions in the checklist were:

- Does the working space allow for a full range of movement?
- Is the height of the work surface adjustable?
- Is the workstation designed to reduce or eliminate reaching and static muscle loading?
- Is the employee able to vary posture?
- Are all task requirements visible from comfortable positions?
- Are employees trained in when and how to adjust their workstations?

The above findings are very important in the context of determining if an adjustable-height laboratory bench is an ergonomic solution. Project consultants also indicated that all of the studies they were familiar with indicated that variable task height prevented CTDs.

To determine the knee clearance space for the adjustable-height laboratory bench, project staff used the ANSI requirements. These requirements specified that the depth needed for wheelchair access is 19 inches (483 mm) from the counter edge. The below counter

³ Alexander, David and Pulat, Babur Mustafa. *Industrial Ergonomics: A Practitioner's Guide*. Industrial Engineering and Management Press, 1985.

Feasibility of Adjustable Laboratory and Work Bench

clearance height needed is a minimum of 27 inches (686 mm) measured from the floor. The knee clearance width needed is 30 inches (762 mm) in order to accommodate a wheelchair. Since the aim of the project is to produce a system with universal applicability, staff also researched ergonomic data which outlined the knee clearance space for individuals seated in standard work chairs. Staff found that the knee clearance requirements for accessibility meet or exceed the knee clearance and reach ranges for a person seated in a standard work chair.

To determine the reach ranges for laboratory controls and fixtures we referred to “Hands-On Architecture” prepared by Edward Steinfeld et al. This document was created to develop information that can be used as a basis for designing products that are intended to be used by people with disabilities. The paper includes findings from laboratory and field research on human performance issues of people with disabilities involving free reach anthropometrics.

The above referenced report cited the following recommendations for design specific to the laboratory bench project. These are:

- maximum height of an operable part should be 48 inches (1220 mm) with the exception of side reach which requires little force to operate
- clearance for push buttons from the edge of a control to the edge of the next control should be 0.7 inches (18 mm)
- hand control objects within a work sphere should be located within 34 inches (864 mm) and 46 inches (1168 mm) for comfortable reach without an obstacle
- for seated people using a side reach approach these ranges should be 36 inches (914 mm) and 41 inches (1041 mm)

Other accessibility issues addressed in this document are for usable hardware for drawers and cabinets. For example, U-shaped drawer pulls are much more universally usable than small knob drawer pulls since a person with below average hand strength can operate a U-shaped device. In summary, this report recorded the human performance of wheelchair users, however it is a fallacy to assume that satisfying the needs of some wheelchair users will satisfy the needs of the most severely disabled group.

- (ii) Project staff reviewed “Residential Access: Criteria for Designing Accessible Residential Environments” by Margaret Wylde.

This document studied the interactions of 71 individuals with varying levels of ability in “test kitchen environments” in order to determine the effects of accessible environments on able-bodied and disabled populations. In the section on work station heights, users worked at work station heights of 36, 32, and 28 inches (914, 813, and 711 mm). This document noted that 100% of the “No Disability” group, 80% of the “No Prostheses” group, and 72% of the “Other Prostheses” group preferred the work station height of 36 inches (915 mm). The majority (74%) of the wheelchair user group preferred the work station height of 32 inches (813 mm) as did 28% of the “Other Prostheses” group and 20% of the “No Prostheses” group. Thirteen percent of the wheelchair user group preferred the work station height of 28 inches (711 mm). Many in the wheelchair user group complained that this height was too low because they could not get their wheelchair under the counter.

Feasibility of Adjustable Laboratory and Work Bench

The implications of accessible environments to the disabled and able-bodied populations are significant in the context of this project. First, it reflects the need for variable work station heights by the disabled population. This is often due to the non-standardization of wheelchair sizes and the widely differing reaching abilities of people with disabilities. Second, it may be imputed based upon preferences for 36 inches (915 mm) work station heights, that the able-bodied populations may resent working at laboratory benches which are fixed at height(s) of 28 inches (711 mm), 32 inches (813 mm), or 34 inches (864 mm) designed to accommodate persons in wheelchairs.

Regarding the need for knee clearance space at primary work areas, this document reports that most users in the test environment appreciated the opportunity to sit, particularly when performing tasks that take a long time. The conclusion drawn in this document is that an adaptable work station that permits both sitting and standing may best serve wheelchair users and non-wheelchair users.

- (iii) Project staff conducted three focus groups of end users and intermediary end users to elicit design requirements for laboratory benches.

The first focus group was comprised of upper level university students who had declared science as their major. The Principal Investigator recruited these participants through an Ohio University science professor on the basis of the extensive time these students have spent in a science laboratory. All of the participants were able-bodied.

All of the participants in Focus Group One reported “some experience” or “extensive experience” in working in a laboratory. Participants responded that their level of ease in using a science laboratory was very easy or somewhat easy. When queried for the level of ease of specific parts of the laboratory bench, it became apparent that standard height counters and laboratory sinks at the 36 inches (915 mm) height were less easy or more difficult to use. Most of the participants reported that base cabinets below the counter area increased the difficulty of using the laboratory. Most participants reported some difficulty in accessing the fixtures.

Two thirds of the participants reported that their level of activity in the science or engineering laboratory was affected by the ease of use or accessibility of the design. All of the participants reported that they cannot work at a laboratory bench in a seated position due to base cabinets. Two of the participants reported that in biology labs they can sit due to the different laboratory bench configuration.

None of the participants were aware of laboratory bench designs which would accommodate students with disabilities. All but one of the participants responded that there was a need for accessible laboratory bench designs. All but one of the participants responded that there was a need for laboratory bench designs which could be easily adjusted in height by each user to an accessible height and that they were not aware of such a product.

When asked what word(s) they most closely associate with “accessibility”, the primary responses were **reachable** and **useable**. Only one participant was aware of a situation where a student with a disability was discouraged from pursuing a career in science due to the inaccessibility of lab benches.

Feasibility of Adjustable Laboratory and Work Bench

The majority of the participants reported that they were unfamiliar or somewhat unfamiliar with the concept of ergonomics. The majority of the participants reported that they believe the current lab designs can cause lab users to work in awkward or uncomfortable positions leading to fatigue, stress, or injury. When asked to identify the lab component(s) which become uncomfortable after long periods of time, **fume hoods** and **fixed height counters** were the predominant responses. Three-fourths of the participants reported that laboratory work requiring close visual inspection becomes uncomfortable at fixed height counters.

When asked what laboratory counter configurations may improve the ergonomics of work which requires close visual inspection, **height-adjustable counters** and **more leg room below the counter** were the responses.

One-half of the participants were aware of cumulative trauma injuries which result from repetitive stress and one participant reported that he/she had actually experienced a cumulative trauma disorder resulting from lab work. All but one participant believed an adjustable height work surface would mitigate fatigue, muscle discomfort or cumulative trauma injuries. When the participants were asked if they saw a need for an adjustable height laboratory bench, all participants responded "yes". The rationale(s) checked were: **a raised height would allow a neutral posture when performing work in a standing position, a lowered height would allow a better posture when working in a seated position.**

The participants in Focus Group One were generally very supportive of the idea of height-adjustable laboratory benches. They responded that chemistry lab classes which lasted 3 hours were very fatiguing and inspecting containers or microscopes became difficult after long periods of time. The participants said that they like to stand when working with flasks, but would prefer sitting when working at a microscope. One participant stated that he had students with disabilities in other classes, but he had never seen a student with a disability taking a science lab class. Another participant felt that lab class work would be impossible for students with disabilities in the present laboratory environment because of the reaching and moving around required. Many in the group felt that the inaccessibility of a science laboratory would discourage students with disabilities from pursuing a science career.

When asked to prioritize the areas in a laboratory which may need to be adjustable- the laboratory bench was the biggest priority, followed by the fume hood. The laboratory sink was not as high of a priority because it was used for cleanup at the end of the session. One participant responded that she desired the water, gas, and electric fixtures to be able to be lowered.

The facilitator queried the students on their attitudes toward accessible laboratory stations which were used exclusively by persons with disabilities. None of the participants were familiar with these stations, so the facilitator described them. One student responded that this would be problematic because in labs you work in pairs and the able-bodied partner would not be able to work at the lab station. This group supported the idea of a laboratory bench which could be used by people of all physical ability levels.

Focus Group Two was comprised of students who were recruited through Ohio University's Disability Support Services. All of the participants had had some experience in a science

Feasibility of Adjustable Laboratory and Work Bench

laboratory. When asked to describe their general level of ease in using a laboratory, the majority of this group reported that science labs were somewhat difficult for them to use. When asked to rate their level of ease for the specific components, the participants responded that standard height lab counters (36 inches (915 mm)) were somewhat difficult to somewhat easy. Laboratory sinks and the faucet, gas fixtures, and electric fixtures were described as somewhat difficult. The laboratory counter configuration with base cabinets below was described as somewhat difficult.

Each participant in this group responded that their level of activity was affected by the ease of use and that they were not aware of any laboratory bench designs that accommodated persons with disabilities. The consensus in this group was that there was a need for accessible laboratory benches and that height-adjustable benches.

When the participants were asked which word(s) they most closely associate with “accessibility”, they responded **reachable, useable, handicapped, and getting from one place to another.**

Only one participant was aware of a situation where a student with a disability was discouraged from pursuing a career in science. Each of the participants in this focus group responded that they had some familiarity with the concept of ergonomics and that they believed current laboratory bench designs could cause all users to work in awkward positions.

When asked which laboratory components become awkward after longer work periods, the participants responded: **“fixed-height laboratory counters,” “fixed-height laboratory sinks,” “pipette stations,” and “fume hoods.”**

When asked what changes to the standard laboratory counter could be made to allow users to work more comfortably when performing laboratory work which requires close visual inspection, the participants responded: **“height-adjustable counters,” and “more leg room below the counter.”**

Focus Group Two participants were aware of cumulative trauma injuries and one participant responded that he/she had experienced cumulative trauma due to static posture while working at a desk. The majority of the participants responded that a work surface that could be easily adjusted in height would mitigate fatigue, muscle discomfort, and cumulative trauma. Additionally, they each responded that there was a need for such a product and selected the following rationales: **“a lowered height would allow a better posture when working in a seated position,” “a raised height would allow a neutral posture when performing work in a standing position,” “frequent shifts in work surface height would allow variations in lab users shoulder,” “arm, and hand positions, and the need to move from one position to another to eliminate back pain.”**

The participants in this focus group were strongly supportive of the concept of height-adjustable laboratory benches which would be more accessible to students with disabilities. When asked to provide a general reaction to the concept of height-adjustable laboratory benches, the participants related individual incidents of architectural and social barriers they have encountered in a school setting. One participant reported that he experienced

Feasibility of Adjustable Laboratory and Work Bench

significant pain from standing the entire lab period and that he felt “insulted” to have to stand in pain for a class. Other participants reported that the quality of their work deteriorated as they became fatigued, and that if they were comfortable they could concentrate on the work better.

One participant reported that with adjustable laboratory benches, a student with a disability would not be isolated, but would work alongside other students. In general, the participants in this focus group voiced a strong desire to use the same facilities as the rest of the student population. One participant stated that he is less likely to use some “handicapped” products because they look different and it points out that he is “different”. The participants agreed that they are more inclined to use something that is universal and equally used by able-bodied persons. They indicated that Ad-AS should make a height-adjustable laboratory bench that looks “normal” because if it points out that it is intended to be used by only people with disabilities, they may avoid using it.

When asked to provide other suggestions in the lab design which would improve accessibility, the participants stated that leg room was needed and that base storage cabinets needed to be moved to the ends of the bench. They stated that you should be able to adjust a laboratory bench to a seated person’s height requirements and that this height varies because of the different dimensions of wheelchairs.

When probed for their attitudes regarding the ADA lab stations made by some manufacturers, this focus group responded extremely negatively to this concept. One participant stated that the purpose of the accessibility laws was to include everyone, and that if you put someone in a corner they are not include. Another participant stated that labs are designed for groups, not for a disabled individual to be put aside. One participant stated that a dedicated ADA lab station would not provide the flexibility and that adjustability would be better. The participants agreed that a height-adjustable laboratory bench could be used by everyone and not be deemed “for handicapped people”.

When asked to prioritize the laboratory fixtures which need to be adjustable, the participants responded that fume hoods are a high priority because they are impossible to use for wheelchair or scooter users. The second priority is laboratory benches because students in wheelchairs have to work sideways. The third priority was storage shelves which are out of reach for students who use wheelchairs.

Focus Group Three was comprised of facility planning personnel and science instructors from Ohio University and Hocking College. These participants were chosen on the basis of their experience in science laboratories and their experience in the purchasing decisions of laboratory benches and casework.

The majority of the participants in this focus group had had extensive involvement in specifying laboratory benches in an educational facility. When asked to estimate the frequency that a university or college replaces the laboratory benches, the responses ranged from every 10 –20 years.

The participants responded that functionality, aesthetics, and competitive costs were the most important purchasing points. When asked what they see as the most significant

Feasibility of Adjustable Laboratory and Work Bench

concern for the end user, the participants responded: reliability and operations/means of using as most important.

The majority of the participants were aware of laboratory bench designs which accommodated students with disabilities and the relevant ADA laws impacting accessibility in laboratories. When asked if they see a need for a height-adjustable laboratory bench that could be easily adjusted the responses ranged from “Yes” to “Not Sure”. When asked what percentage over and above the standard cost would be acceptable for a laboratory bench which adjusted in height to accommodate students with disabilities, the responses ranged from 5-20%.

When asked what word(s) they most closely associate or relate with the word “accessibility”, the participants responded “**handicapped**” and “**reachable**”. All of the participants responded that they believed the future demand for accessible products will grow mostly because: school and work populations are becoming more diverse (including people with disabilities). None of the participants were aware of a situation where a student with a disability was discouraged from pursuing a career in science due to the inaccessibility of school science laboratories.

The majority of the participants were very familiar with ergonomics. When asked if they believe current laboratory designs can cause users to work in awkward or static positions which may lead to fatigue or injury, the participants who were instructors responded “Yes” and the participants who were facilities planners responded “No” or “Not Sure”.

When asked what laboratory bench configurations may improve the ergonomics of a laboratory- **height-adjustable counters** and **more leg room below the counter** were the predominant responses. The participants were aware of cumulative trauma injuries, but did not know of any students or instructors who had suffered any cumulative trauma injuries. When asked if they believed a lab work surface which could be easily adjusted in height would mitigate these injuries, the participants all responded “Yes”. When asked for their rationale for this, the participants cited frequent shifts in work surface height as the chief reason.

During the discussion portion of this focus group, the participants were generally supportive of the concept and its intended benefits. However, they cautioned the Principal Investigator that the cost of the system may be difficult to justify for colleges and universities. Some of the participants cited less expensive alternatives than they thought a height-adjustable system might cost.

The participants stated that they have witnessed an increasing number of students with disabilities enrolling in college. Numbers of older students and injured students receiving college retraining as a result of worker’s compensation claims have also increased. However, despite the rise in enrollment, the participants estimated that the percentage of students with disabilities relative to the entire student population is very low. They indicated that an adjustable-height laboratory bench should be sold as something that benefits the entire student population in order to make the cost feasible.

Feasibility of Adjustable Laboratory and Work Bench

The participants stated that storage space is critical in a science laboratory and that an adjustable laboratory bench with knee clearance space would eliminate some storage space. The participants stated that the system would have to be durable and “student proof.” Most of the participants stated that they felt height-adjustability would benefit the student and instructor populations.

The participants were prompted to describe what reasonable accommodations for students with disabilities in laboratories they were aware of. One science instructor described an experience with a disabled student for whom working at a traditional bench was impossible. This participant stated that they rigged up a desk raised on books for this student to use as a lab bench. Another participant explained that lab work is done in two person teams. When they have a student with a disability in a lab class, the disabled student takes notes and the able-bodied student performs the lab work. This participant related to project staff that he would prefer for the disabled student to gain the hands on experience of laboratory work. Another participant was aware of a laboratory bench that had an entire section lowered to 34 inches (864 mm) high for accessibility. This lowered section included one accessible lab sink out of four.

When prompted for the importance of ergonomic issues in a school or university laboratory, the participants involved in facility planning stated that it was not a big priority. They stated that student’s comfort and task performance were not the crucial issues in the laboratory equipment purchasing process. One participant cited an example of ergonomic chairs which are seldom adjusted.

The participants in this focus group were prompted to provide purchasing issues that would be important for AD-AS to know for future commercialization efforts. The participants mentioned aesthetics and cost as the most important issues. They look for consistency in design and appearance and competitive cost. Quality was the third most important attribute. The participants mentioned 5-10 year warranty included with some laboratory furniture. They mentioned the need for laboratory furniture to last up to 20 years.

The facility planning participants mentioned trade magazines as an important source of new laboratory products. Sales reps were listed as an additional source of new product information. Trade shows were not a primary source of new information due to the difficulty and expense of sending facility personnel.

The Principal Investigator had hoped to convene a focus group of builders and contractors in order to elicit information from people who actually install laboratory furniture. Unfortunately, we were unable to assemble this group, and we learned that many laboratory bench and casework manufacturers send their own installation crews rather than use local tradespeople.

2. Define the technical criteria for evaluating alternative technical solutions for five systems.

The technical criteria derived from initial research consultants input, research documents, and the three focus group sessions are: accessibility, adjustable-height counters, knee clearance space for seating, cost, performance, user safety, and ease of installation.

3. Identify the technical options for the five subsystems: vertical movement, control, safety, counter construction, and integration of laboratory fixtures.

- a. The technical options identified for vertical movement are: (i) a 110 volt AC motor actuator with a linear worm drive controlled by an electronic circuit board, (ii) a motor driven hydraulic system with four pistons for adjustment, and (iii) a gas piston system.
- b. The technical options for control and guidance are: (i) extruded telescoping legs, (ii) steel rods moving in bronze bushings held by 1.5 inch tubes, (iii) telescoping channels known as Telespar
- c. The technical options identified for safety are: (i) micro-switches attached to a safety shroud and wired through the electronic circuit board or electronic controls and (ii) touch sensitive ribbon tape. These system(s) require a means for touch sensitive shut-off abilities to prevent users from pinning themselves.
- d. The technical options identified for rigid counter construction are: (i) aluminum mounting plates with wood support gussets, (ii) Telespar channel with metal angle support brackets, and (iii) extruded channels which span the unsupported counter sections. To provide clear knee space there would be more unsupported counter space than in standard laboratory installations. To enhance the ergonomics a counter could have curved recesses or concavities at dispersed work envelopes to allow users to be closer to their work and maintain arm or elbow support.
- e. The technical options identified for integration of laboratory fixtures to accommodate up to 14 inches (356 mm) of vertical travel are:
 - (i) Water supply lines for hot and cold are commonly available in 24 inch braided PVC which is flexible.
 - (ii) Water drain lines require a smooth bore interior to eliminate material build-up and a corrugated exterior for tight radius bends. Additionally, the waste line would need to be chemical and heat resistant to avoid corrosion and breakdown resulting from elimination of chemicals in a laboratory. This is available in the form of a food and materials transfer hose designed for food processing operations. A PVC plastic trap with a two inch seal is required since the seal cannot depend upon moveable parts. Staff identified a telescoping drain line where one piece retracts into a larger diameter line, but determined that this option would not trap properly.
 - (iii) Gas lines are commonly available in flexible lines wrapped in braided metal conduit which is flexible to allow easy positioning during installation.
 - (iv) Electric wires housed in protective plastic and rubber casement are available off the shelf. These wires could be housed in a central conduit to further protect from frequent vertical movement of an adjustable-height laboratory bench.

4. Assess the technical options for the five subsystems

Given the technical criteria determined from legal documents, information provided by the consultants, the focus groups, and project staff, three test beds were developed representing the technical options identified in # 3 above.

a. Assess the mechanisms for vertical movement.

The **110 volt AC motor actuator** is a reliable, cost-effective solution for vertical travel. The weight bearing load is sufficient to move 500 pounds (227 Kg) of dynamic weight. The load cycles are sufficient to be adjusted over 50 times per day and last over ten years. This motor actuator requires an electronic control board to process the current and deliver low voltage to control buttons.

The **motorized hydraulic piston system** is a reliable, cost effective solution to vertical travel. This system is comprised of a hydraulic crankcase, a motor actuator with built-in electronic controls and four hydraulic pistons with an adjustment range of 14 inches. This system provides stable, safe vertical movement.

The **gas spring mechanism** consists of spring-loaded pistons which are engaged by levers. The gas springs exert force in the up direction. The physical principle on which this system was based was to use the weight of the laboratory counter and guidance lift system to lower the counter and the lever to raise the counter. For example, if the laboratory counter weighed 160 pounds (73 Kg) then four 50 pound (23 Kg) gas springs would exert the upward force of 200 pounds (90 Kg) to lift the counter and then a user could engage another lever to lower the counter to the desired height. However, during the first iteration, project staff determined that the friction in the springs themselves and the guidance system did not allow the system to exert the required force. The useful life of the gas pistons, according to the manufacturers rep, is less than seven years. Staff determined that seven years is not sufficient based upon information gained from laboratory facility planners. This prototype was therefore not integrated into the test bed.

b. Assess the control mechanisms

The extruded aluminum legs provide the necessary adjustment stroke for the work surface heights. Additionally, this option provided a cost effective, stable means of vertical adjustment. The aluminum legs can be machined to modify the adjustment range(s). To attach the extruded legs to the floor and counter for stability is a simple process.

The steel rods held by bushings in metal tubes was cost effective and stable. The bronze bushings are oil impregnated to reduce friction and provide more longevity.

The Telespar channel is configurable to several adjustment ranges and is cost effective. This option provided stable vertical movement and is minimally difficult to integrate into the counter and floor.

c. Assess the safety systems

The 110 volt AC motor actuator and the motorized hydraulic system both maintain their position during power outages. This was determined necessary to protect users who may be seated underneath the counter. Due to the weight of the counter and the use of motor driven systems in prototype versions, a safety system was devised to protect the user from being crushed by the counter in its downward travel. The devised system shuts off via safety panels underneath the lab counter/sink/fixtures to prevent the counter from lowering any further.

One version of this safety system uses multiple limit switches wired to the electronic control board and mounted to the counter fascia. The under panel is installed to have .125 inch (3 mm) of play in order to engage the limit switch. When the under panel is touched, it engages the switch and kills the system. Staff used multiple limit switches dispersed at intervals to insure adequate contact points and minimize the risk of failure resulting from single switches.

The second version of the safety system uses a ribbon switch which is commonly found in floor mat switches for automatic doors. For this version, staff wired the ribbon switch into the electronic control board and mounted into the under side of the fascia. This system had a continuous contact point along the under panel and fascia. The risk of failure for ribbon switches is extremely low according to product specifications.

d. Assess the methods of rigid counter construction and design

Staff used aluminum plates with pre-drilled holes to attach the underside of the counter to the extruded aluminum legs and the Telespar. This dispersed the counter load over four contact points. To ameliorate the strength and stability, support gussets were attached creating an angled support spanning from the underside of the counter to the adjustable legs.

e. Assess the options for integration of laboratory fixtures

- (i) The water supply lines available off the shelf are flexible PVC hose able to withstand high pressure wrapped in a flexible metal conduit. Staff determined that this configuration was feasible in a moveable laboratory bench with up to 14 inches of vertical travel. Integrating the water distribution lines into a moveable laboratory counter complies with the accepted engineering practice and workmanship for plumbing.
- (ii) The water waste lines evaluated are: (1) a Hi-Flex 1.5 inch Water Suction/Discharge PVC hose with 72 psi that can withstand temperatures from -10 degrees F to 158 degrees F. This hose is smooth bore and handles, air, liquids, liquid borne wastes and resists most acids and alkalies. Staff bonded this PVC hose to a PVC P-trap with plumbing adhesive to ensure a strong bond; (2) a 1.5 inch Sure-Flo Rubber Hose with 150 psi working pressure. This hose is smooth bore and handles oils and chemicals. Staff attached this hose to a PVC P-trap with a coupling; (3) an ultra high molecular weight (UHMW) chemical transfer hose with a working pressure of 200 psi and a temperature range tolerance of -40 degrees F to 160 degrees

- F. All hoses were capable of making the necessary radius bends to accommodate vertical travel and maintain the vertical pitch needed to meet code requirements. Vertical movement did not appear to affect the tightness of the joint with the P-trap. However, staff were not able to have these configurations tested by a plumbing inspector for water pressure thresholds.
- (iii) The off the shelf gas lines that convey natural gas used in science laboratories for Bunsen burners are comprised of a small diameter hose wrapped in flexible metal conduit. Staff determined that it is technically feasible for a gas fixture to be mounted on a moveable laboratory counter. However, it was determined to be beyond the scope of the Phase I project to actually hook these lines up to gas and test for potential leaks and failures arising from movement. Additionally, more code research is needed to determine if this proposed configuration would comply with codes.
 - (iv) The electric lines needed to power electrical outlets on a laboratory bench are housed in rigid metal conduit. Staff experimented with liquid tight flexible PVC conduit which is non-metallic, nonconductive and is designed to protect wiring in damp or high vibration environments. This conduit was not affected by vertical movement when integrated into a prototype.

5. Select a preferred set of technical options and integrate them into prototype adjustable laboratory benches.

- a. **Prototype 1: Motorized Hydraulic Piston System**
 - (i) Physical Construction

Vertical movement was provided by a motorized hydraulic crankcase that powers four hydraulic piston rods. This system provides 14 inches (355 mm) of vertical travel. Prototype 1 was fabricated with a modular counter section that could move independent of the standard height base cabinets on either side.

The guidance control system consisted of aluminum extruder legs which house the pistons. The extruder legs were attached to the floor with a metal mounting plate that bolts to the floor. The legs were attached to the counter with the same type of metal mounting plate which screwed into the underside of the counter. The legs were placed in an opposing configuration to provide counter support and recessed 4 inches (101 mm) from the counter edge to avoid encroaching on knee clearance space.

The motorized hydraulic crankcase was mounted to the underside of the counter with the control switches at the counter edge. We mounted a three inch (76 mm) fascia to the front and sides of the moveable counter. The control switches for the motor were housed in the three inch (76 mm) fascia or counter valance.

Staff constructed a 4 inch (101 mm) deep column to house the plumbing, electrical, and gas fixtures. This column was built on the floor 22 inches (560 mm) from the counter edge on either side of the counter.

A safety system consisted of limit switches attached to the underside of the fascia and wired into the electronic controls of the motor. The mechanism used to engage the safety switches

Feasibility of Adjustable Laboratory and Work Bench

was .375 inch (9.5 mm) plywood that also served as a concealment shroud. The plywood concealment shroud attached to the inside of the fascia with cabinet hardware that provided enough play to engage the switch. The concealment shroud sloped down to contour the angle of the sink basin and the Bunsen burner fixture attached at the center to the column that housed the fixtures. When the plywood concealment panel was touched during the down travel, it engaged the switches and shut the system off.

Counter stability was achieved by four mounting plates and support gussets attached to the extruder legs.

(ii) Capacities

This prototype tested with a dynamic weight of 1200 lbs. The adjustment range was from a nominal counter height of 27.5 inches (700mm) to 40 inches (1016 mm). This configuration provided 22 inches (560 mm) of knee depth and 30 inches (762 mm) of width for wheelchair access. The clear knee space (underneath the counter) ranged from 23 inches (584 mm) at the counter edge when in the lowest position to 35.5 inches (902 mm) when in the raised position.

(iii) Cost

A non-production rate for the direct component costs of Prototype 1 follows:

(4) Extruder Legs	\$272.00
(8) Mounting Plates & hardware	22.80
Motorized Hydraulic System	1100.00
Plywood for concealment shroud	25.00
Counter Fascia	18.00
Flexible Waste Line	14.75
Flexible Wire Conduit	13.20
Limit Switches/Wiring	<u>13.75</u>
Total	\$1479.50

(iv) Need for Additional Improvement

This system addresses the primary concern of the focus groups for a moving counter with knee clearance space. The safety system was somewhat difficult to install but fail proof once installed. The extruder legs and motorized hydraulic system achieved stable linear movement lending itself to a relatively simple prototype. Some additional work is needed to eliminate all torsional movement in the counter under extremely heavy loads. Additional wiring would be necessary to provide control switches on both sides of the laboratory bench.

b. Prototype 2: Motorized Hydraulic Piston System

(i) Physical Construction

This prototype used a similar version of the motorized hydraulic piston system as Prototype 1. The counter and cabinet dimensions were identical to the laboratory bench configuration in Prototype 1.

Feasibility of Adjustable Laboratory and Work Bench

The pistons were mounted with specialized hardware into industrial channel known commercially as Telespar. Mounting plates identical to those in Prototype 1 were used to attach each of the four Telespar columns to the underside of the counter. The hydraulic pistons used in this version are supported by round plates with factory drilled holes enabling each piston to be bolted to the floor. Each Telespar column was recessed three inches (76 mm) from the counter edge to avoid encroaching on knee clearance space.

The three inch (76 mm) fascia was used for the counter valance on this prototype. The safety system used in this version was identical to the version used in Prototype 1. The concealment panel was also identical to that used in Prototype 1.

(ii) Capacities

Prototype 2 was tested at a static weight of 1000 pounds (454 Kg). The hydraulic pistons used in this prototype have an adjustment range of 14 inches (355 mm). Prototype 2 was configured to achieve a nominal counter range of 28 inches (711 mm) to 42 inches (1067 mm). The knee clearance depth was 22 inches (560 mm) from both approaches to the counter and the knee clearance width was 36 inches (914 mm). The clear knee space from the underside ranged from 23 inches (584 mm) in the lowest position to 37.5 inches (953 mm) in the raised position

(iii) Cost

A non-production rate for the direct component costs of Prototype 2 follows:

Guidance System (Telespar)	\$ 48.00
(4) Mounting Plates	11.40
Motorized Hydraulic System	1100.00
Plywood for concealment shroud	25.00
Counter Fascia	18.00
Flexible Waste Line	14.75
Flexible Wire Conduit	13.20
Limit Switches/Wiring	<u>13.75</u>
Total	\$1244.10

(iv) Need for Additional Development

Prototype 2 lends itself to a relatively simple and conventional cycle of product development and commercialization. Some of the guidance system components could be produced more cheaply through specialized tooling. This prototype met the requirements of the focus group by providing a height-adjustable laboratory counter with knee clearance space below for seated use. The nominal counter height ranges satisfy the ANSI technical requirements for counter height ranges and reach ranges to the sink and gas fixture outlet. Additionally, the higher height ranges would enable people to work in a standing position without stooping.

This version was more difficult to assemble. Some improvement in this would occur during multiple iterations of the prototyping process. Additionally, this version may require UL certification prior to being purchased by public institutions.

c. Prototype 3: Motor Driven

(i) Physical construction

Vertical movement is provided by a 2.7 amp 110 volt ac motor actuator driving a ball screw bearing. The guidance system consisted of 2 inch (51 mm) angle irons attached by two 1 inch (25 mm) steel rods threaded through oil impregnated bronze bushings held by 1.5 inch (38 mm) stainless steel tubes. These tubes are held parallel and plumb by steel compression clamps and attached to a steel channel frame.

The safety system used in this prototype works on a similar principle as the other two prototypes. However, Prototype 3 was tested using touch sensitive electrically wired ribbon tape as a means for disengaging the motorized system. Staff routed the ribbon tape along the bottom of the counter fascia. The plywood concealment panel attached to the underside of the fascia with cabinet mounting hardware. The concealment panel sloped back to the fixture column with the contour of the sink and drain plumbing fixtures. When the plywood concealment panel touched something in the downward travel it had enough play to engage the ribbon switch and disengage the motor.

The AC motor electronic control board was designed by electronic engineering staff and provides 5 volt DC operator interface buttons. The 5 volt low voltage wires supplied power to the control buttons to reduce the potential for electric shock. The electronic control board controls power from a standard ground fault circuit interrupt 3-prong outlet and delivers current to the motor actuator. Staff wired push buttons to control the up/down direction of this motor. Additional wiring integrated multiple input and sensory shut off wired to the ribbon switches. The multiple input was determined to be necessary to eliminate unwanted movements when both up and down switches are engaged simultaneously which may occur accidentally. The sensory shut-off was necessary to keep the motor-driven counter from crushing users who lacked sensation in their lower extremities or accidentally lowered the counter onto themselves. The control board also includes overcurrent fuses and a circuit breaker to protect from electrical surges.

(ii) Capacities

The motor actuator has a static weight bearing capacity of 500 pounds (227 Kg). The counter support arms used to lift the counter have a 300 pound (136 Kg) capacity at a 24 inch (610 mm) cantilever. The control buttons are large format 12 volt push button on/off design. These control buttons are commonplace in computer game applications and are designed to withstand constant use.

Staff produced 5 versions of Prototype 3 with differing motor actuator stroke ranges. The stroke ranges were: 8, 10, 12, 14 inches. The use of motor actuators with different stroke ranges required slight modifications to the guidance system. Additionally, the high/low range of the counter adjustment was affected by the stroke range.

(iii) Cost

Feasibility of Adjustable Laboratory and Work Bench

A non-production rate for the direct component costs of Prototype 3 follows:

Guidance System	\$240.00
Motor Actuator (average)	215.00
Circuit Board (estimate)	135.00
Plywood for concealment shroud	25.00
Counter Fascia	18.00
Flexible Waste Line	14.75
Flexible Wire Conduit	13.20
Push Buttons	4.50
Ribbon Switch/Wiring	<u>27.50</u>
Total	\$ 692.95

(iii) Need for Additional Development

Prototype 3 is relatively simple and appears to lend itself to commercialization. The improvements needed are in the attachment of the guidance system to improve counter stability. Additionally, the counter support system was stable and sturdy, but created a perceptible cantilever. This cantilever was removed when staff shimmed the area between the counter support arms and the counter. However, future iterations of this prototype should attempt to remove the cantilever effect out of the guidance system rather than relying on shims. Additional work is needed to refine the electronic circuit board. Additional development work would be necessary to make the circuit board for large scale production.

The following paragraphs describe additional development which applies to all versions of the prototypes. A disabling switch would also be needed as a means of cutting the system off to avoid unwanted use. These switches are sometimes referred to as “parent switches” because they keep children or other unwanted users from operating the system. This idea is in response to the facility planner focus group participants that indicated the proposed system would need to be “student proof” and resistant to vandalism.

Each prototype included knee clearance space which supplants base cabinet storage. This may require additional floor space in a laboratory or innovative methods of creating storage space in other parts of the laboratory to maintain needed storage. Another issue which indirectly impacts cost is that having sit down space would require chairs, which are not usually provided in laboratory settings based on the information gained from the focus group participants.

For the moveable laboratory counter sections which do not include a sink, Staff should have reduced the “drop” of the fascia to improve usability.

E. Conclusions

The goal of this project was to determine the technical and social feasibility of an adjustable laboratory bench. Social feasibility is demonstrated by the set of constraints and design parameters imposed by legislative mandates, construction practices, and the physical, aesthetic, and functional requirements of the range of potential users. Technical

Feasibility of Adjustable Laboratory and Work Bench

feasibility is based on evaluation of the relative merits of various technical options. The goal is to bring together the socially feasible (what is desired), with the technically feasible (what is possible), and thereby provide a sound basis for the subsequent design of an adjustable laboratory bench.

AD-AS established technical and social feasibility of an adjustable laboratory bench in three versions. Each of the versions corresponds to a range of preferences articulated by focus groups and consultants. Each of the prototypes relies to a large extent on readily available materials. Additional testing of prototypes (to be developed in Phase II) is needed to refine user requirements and product specifications.

An estimate of the production cost and installation cost for the prototype adjustable laboratory bench systems is planned for Phase II. A cost comparison with conventional laboratory benches will then be made to determine how AD-AS can manufacture a system falling within the cost constraints established by the market.

Three laboratory bench and casework manufacturers have expressed interest in some type of joint venture to commercialize the adjustable laboratory bench. One manufacturer has expressed an interest in exhibiting a prototype to laboratory furniture buyers at a national trade show as early as Fall 1997.

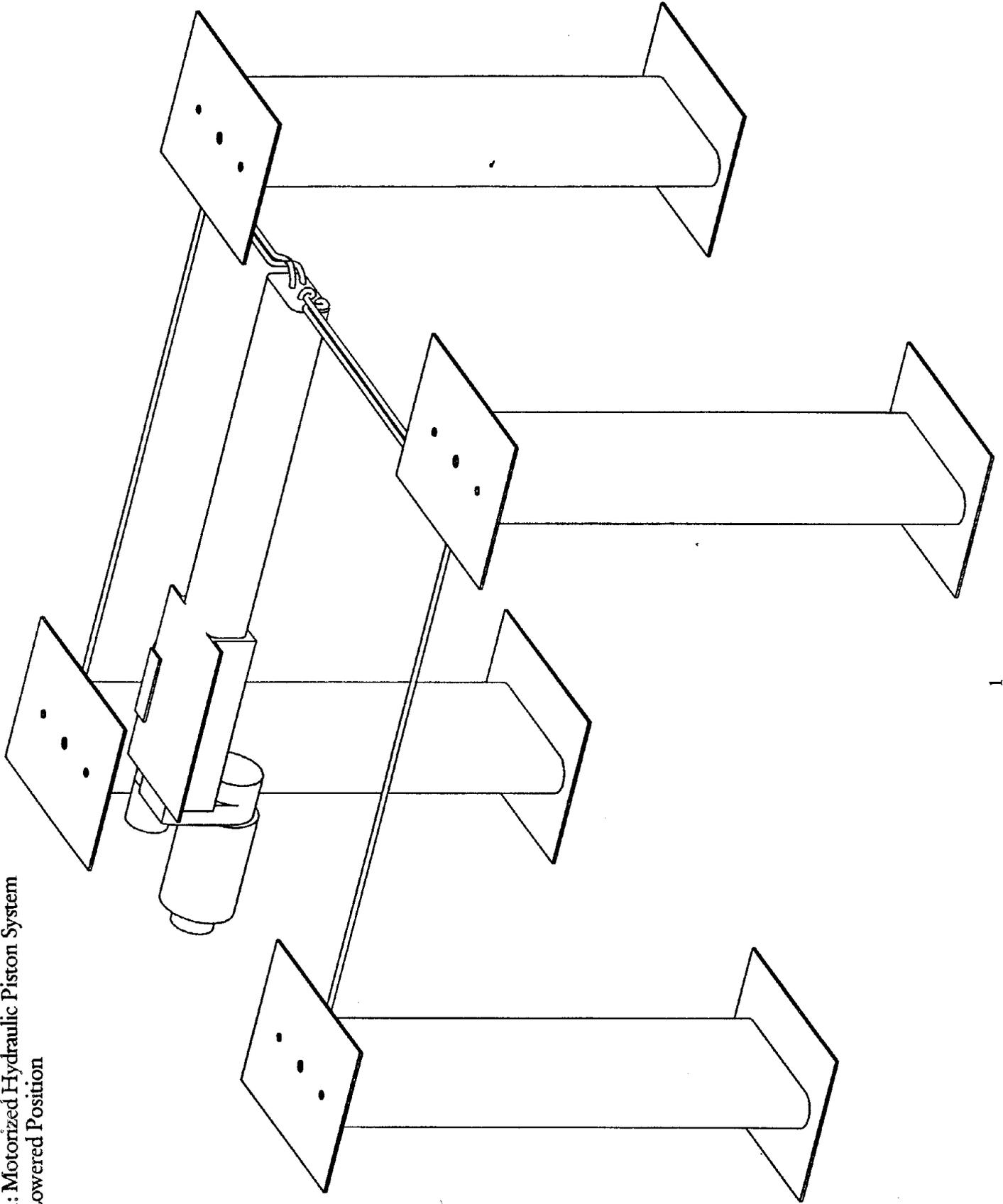
The costs of occupational injuries are high, in sharp contrast to the limited resources devoted to their prevention. AD-AS has identified an engineering control that based upon ergonomic principles will prevent or mitigate workplace injuries. In summary, the development and commercialization of a height-adjustable laboratory bench which is handicapped accessible and ergonomic will result in significant social and financial benefits for schools, universities, and employers and the individuals who make up these institutions.

V. Planned Publications

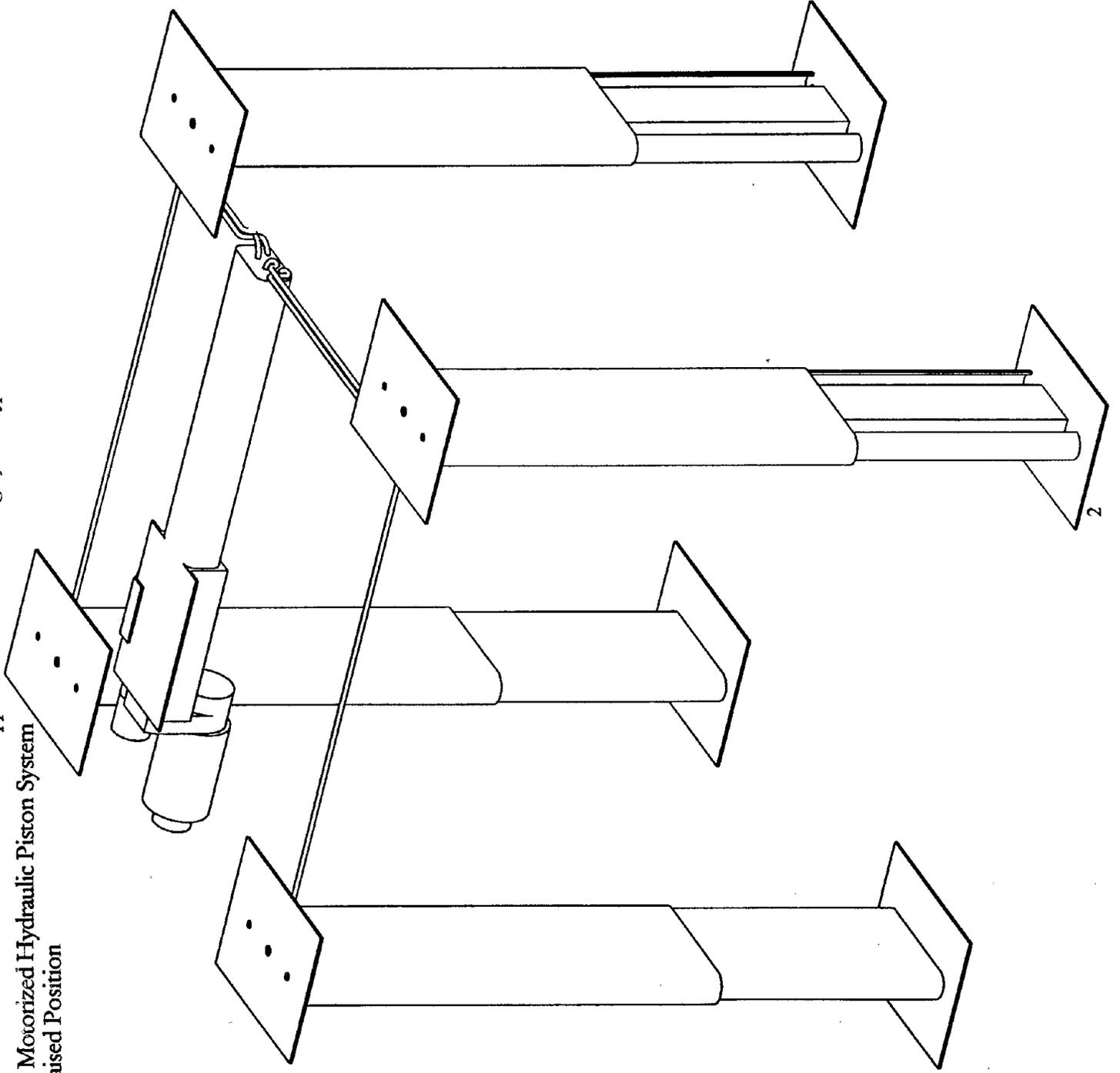
Subsequent to the any commercial outcomes of the prototypes designed and built, staff will publish this paper as a case study for product development.

Appendix A. CAD Drawings of Prototype Test Beds

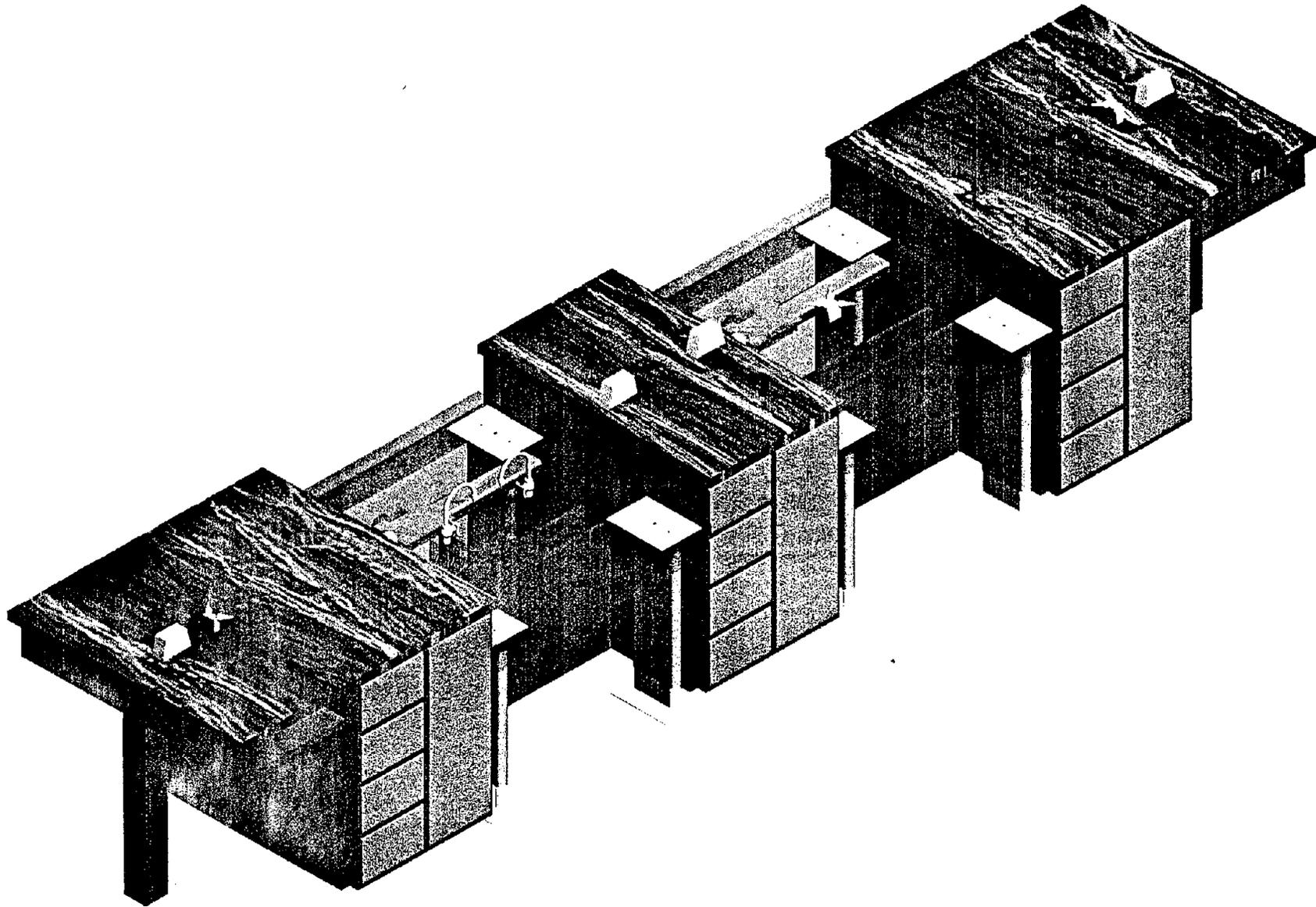
**Prototype 1: Motorized Hydraulic Piston System
System in Lowered Position**



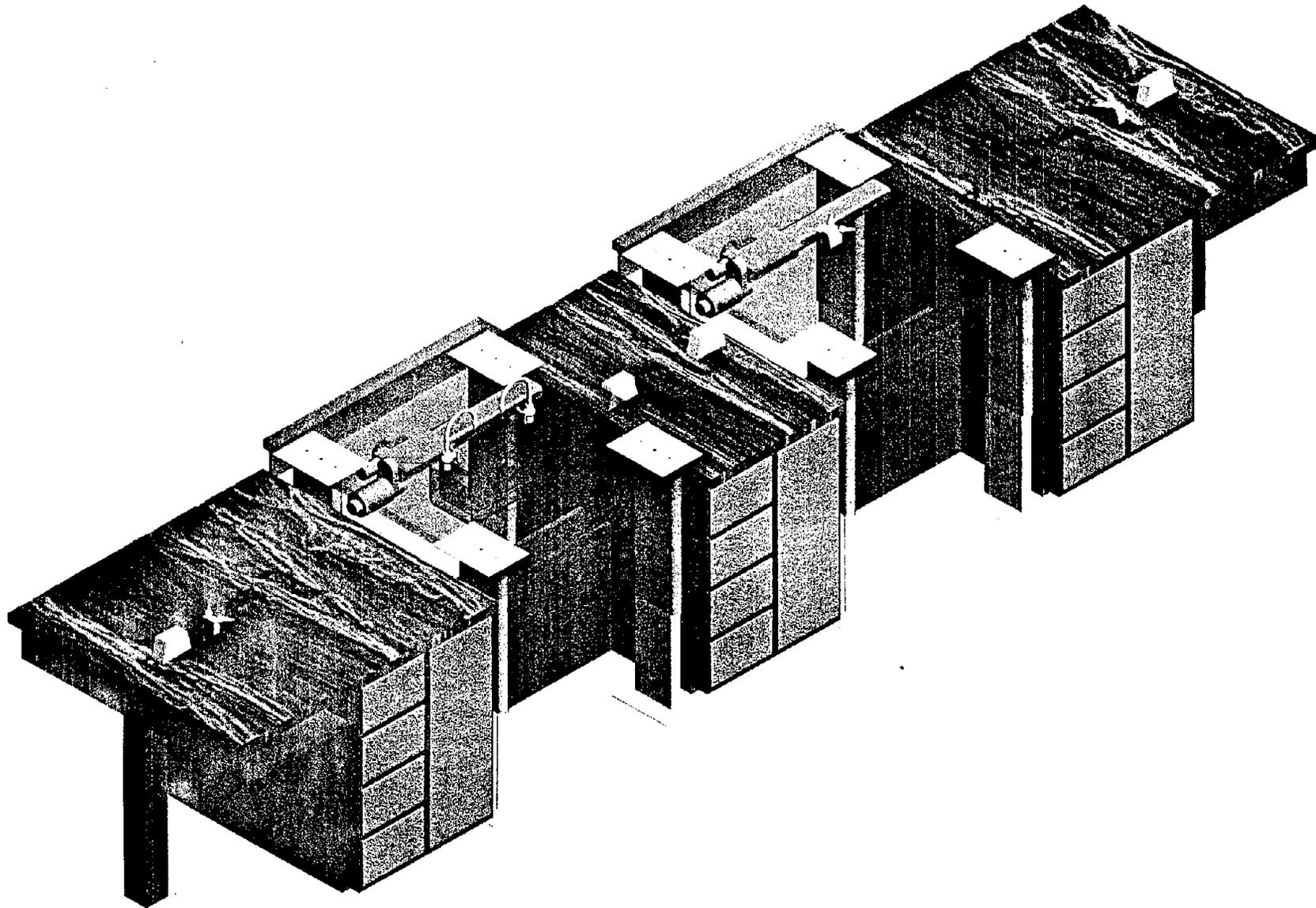
Prototype 1: Motorized Hydraulic Piston System
System in Raised Position



**Prototype 1: Motorized Hydraulic Piston System
System in Lowered Position in Laboratory Bench Test Bed**

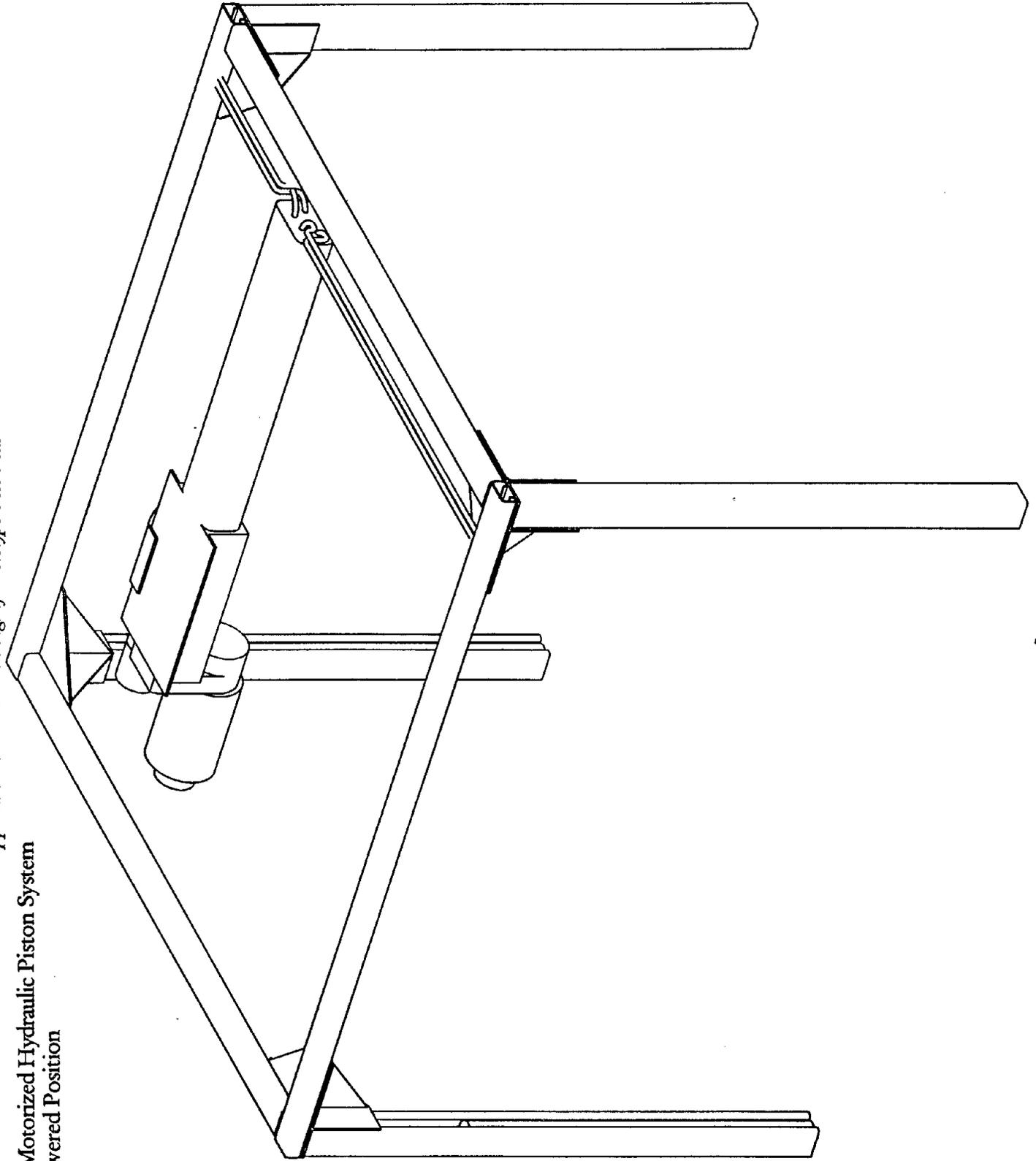


**Prototype 1: Motorized Hydraulic Piston System
System in Raised Position in Laboratory Bench Test Bed**

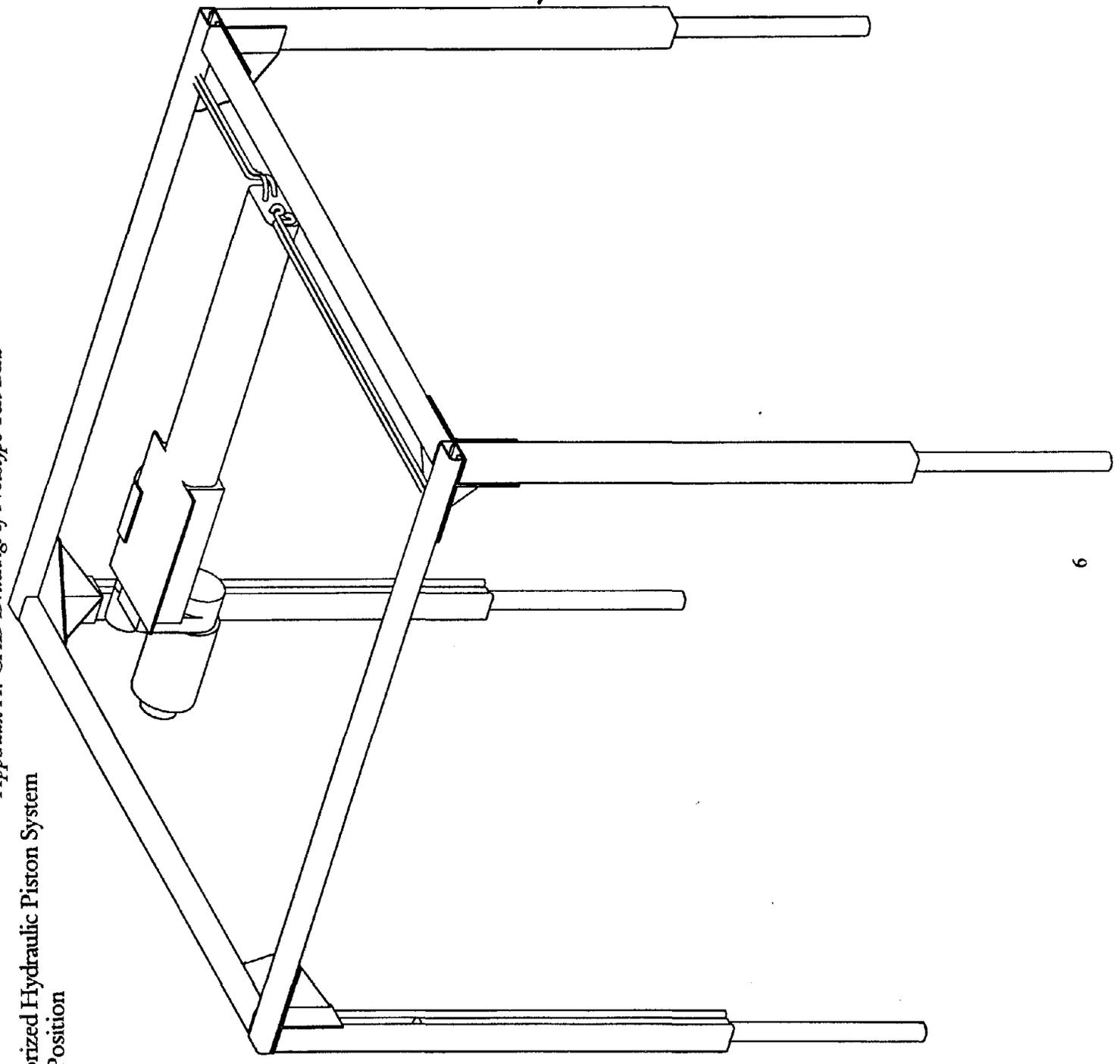


Appendix A. CAD Drawings of Prototype Test Beds

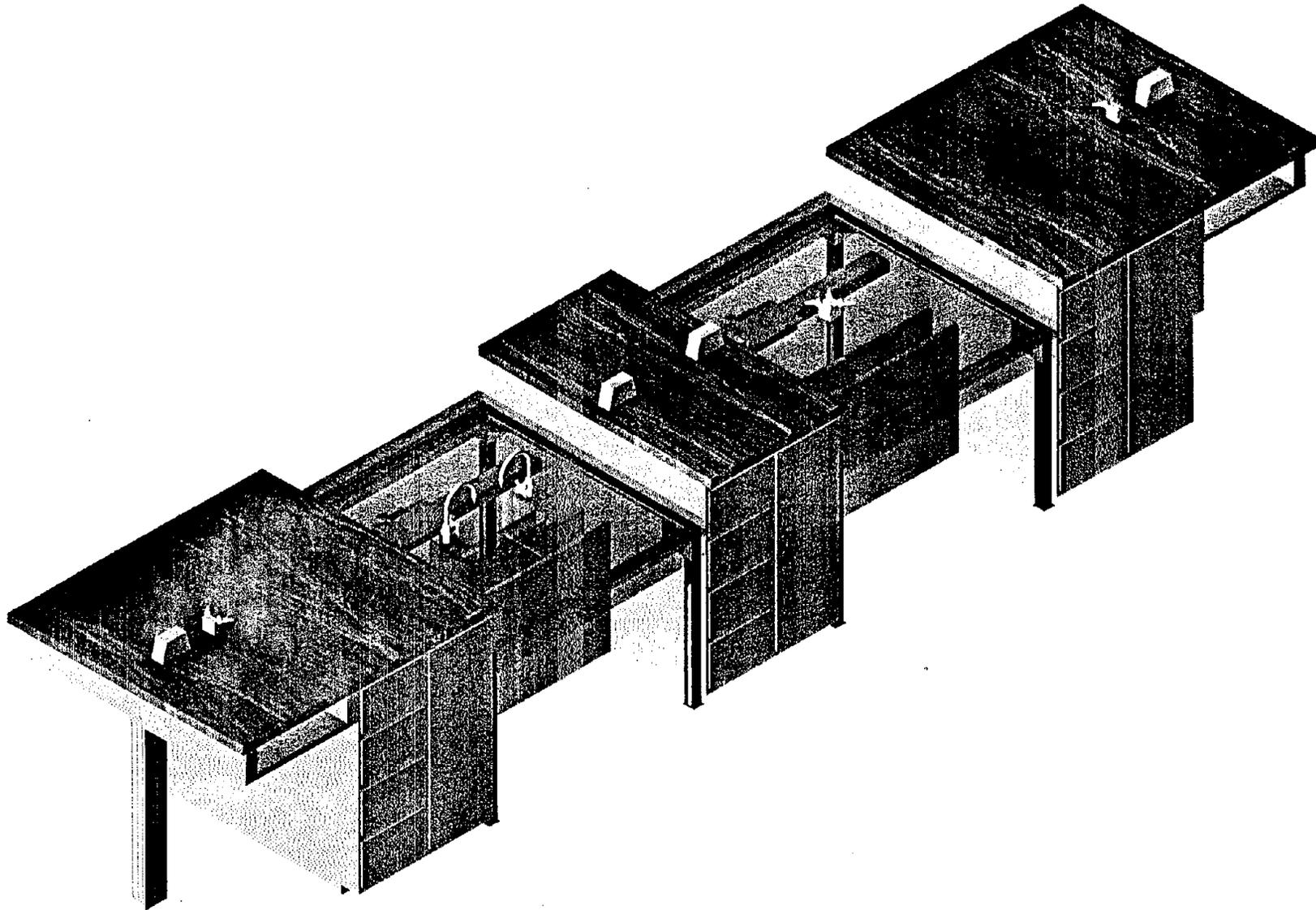
**Prototype 2: Motorized Hydraulic Piston System
System in Lowered Position**



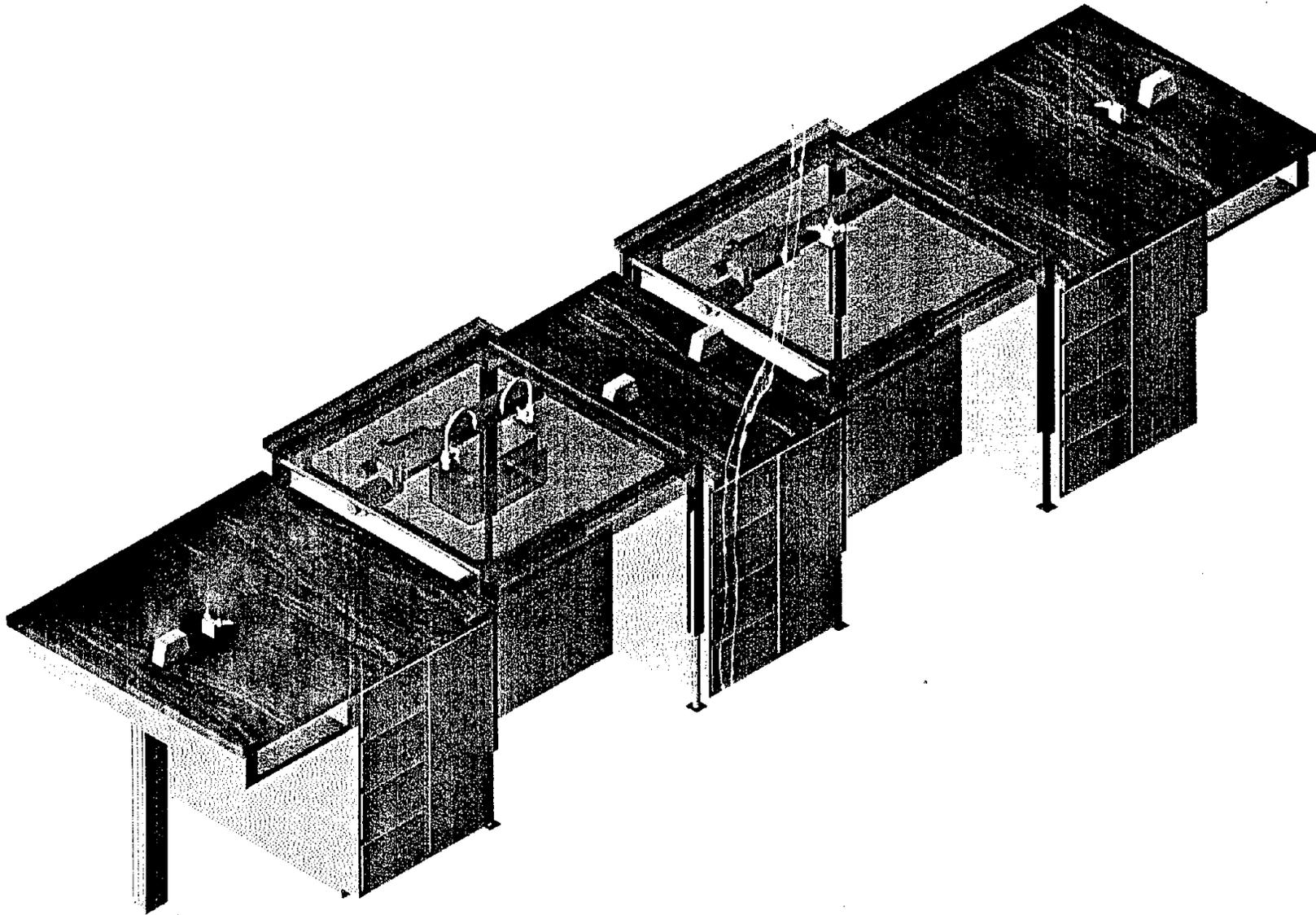
Prototype 2: Motorized Hydraulic Piston System
System in Raised Position



**Prototype 2. Motorized Hydraulic Piston System
System in Lowered Position in Laboratory Bench Test Bed**

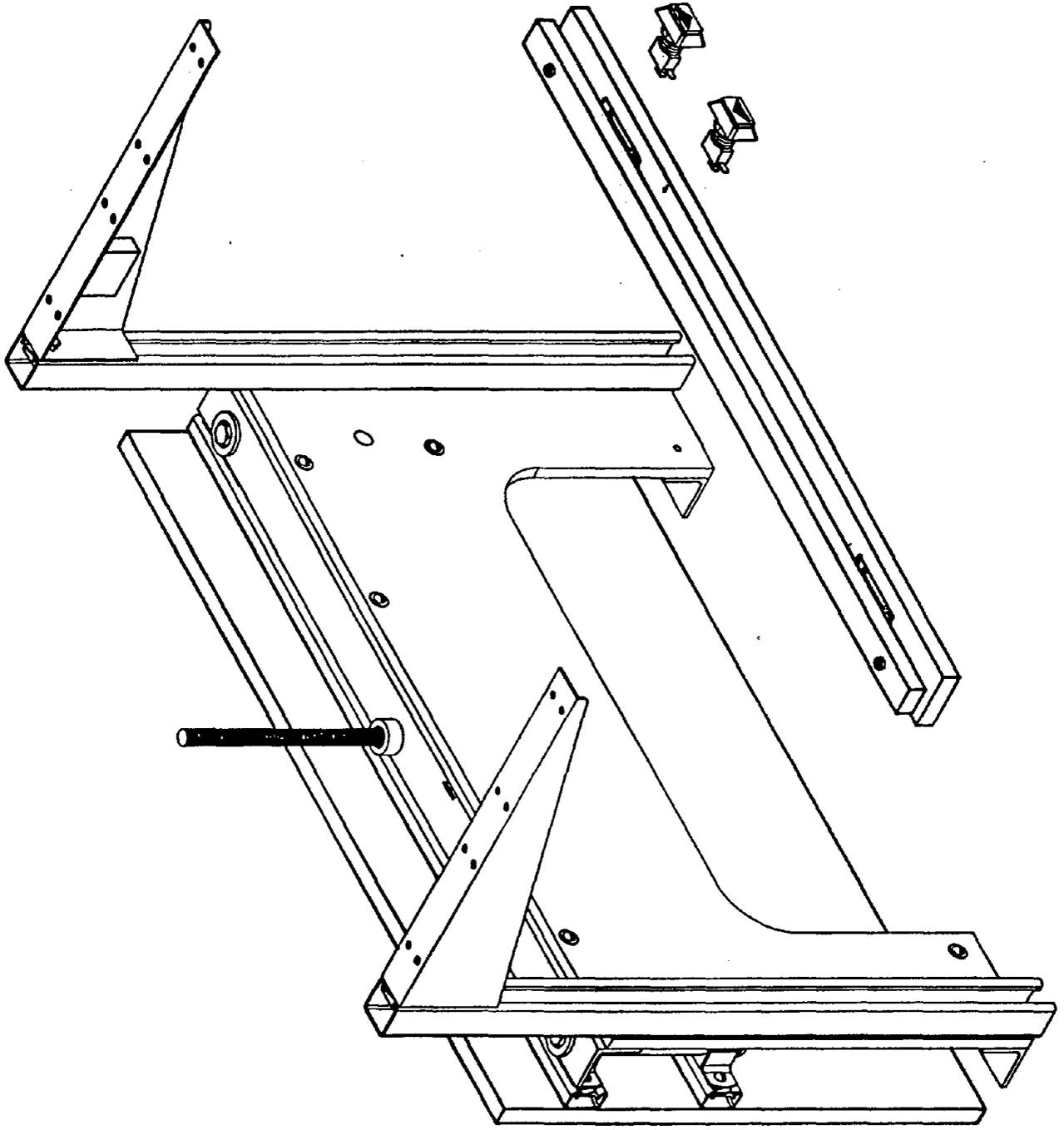


Prototype 2. Motorized Hydraulic Piston System
System in Raised Position in Laboratory Bench Test Bed



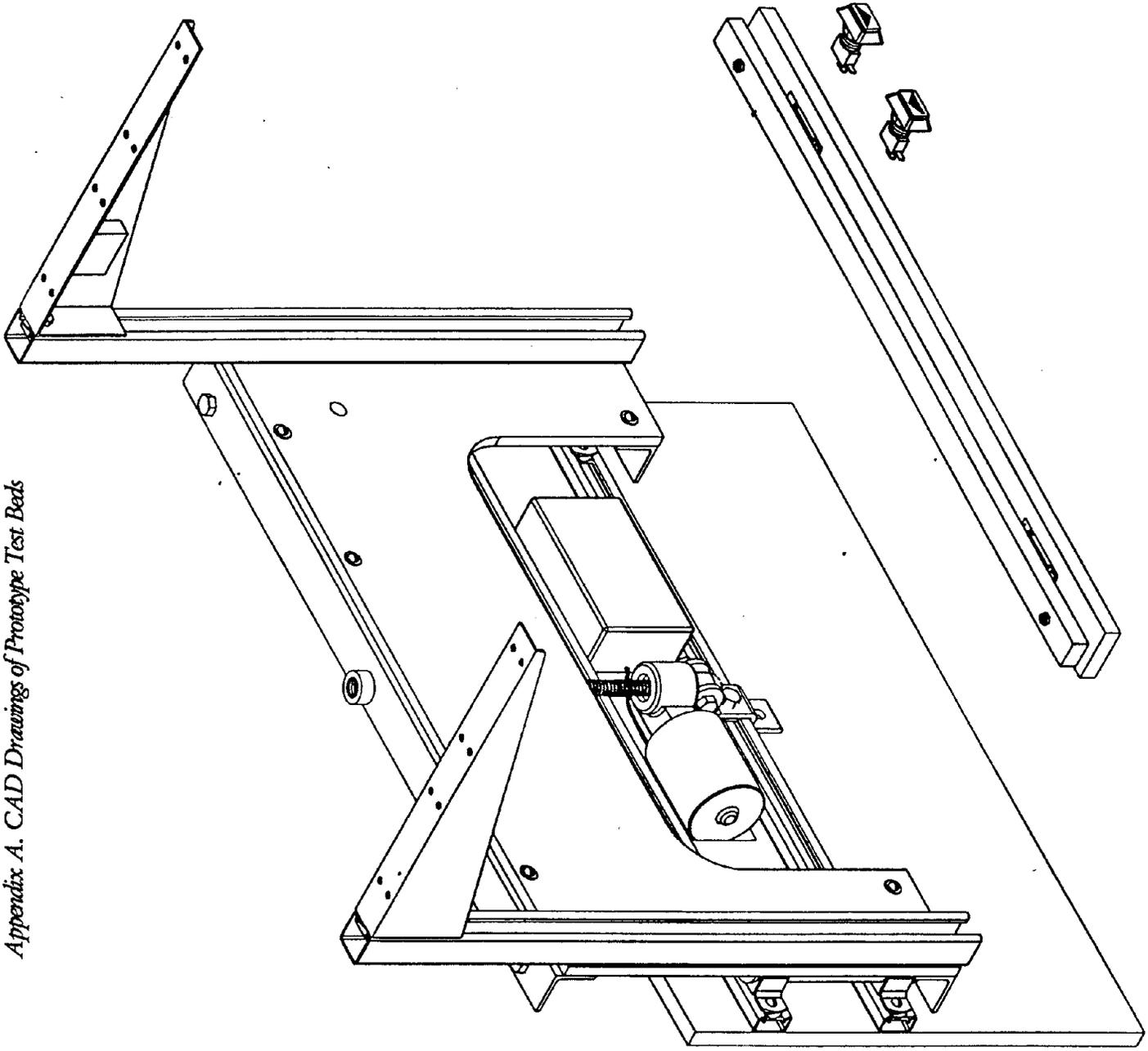
Appendix A. CAD Drawings of Prototype Test Beds

**Prototype 3: Motor Driven
System in Lowered Position**



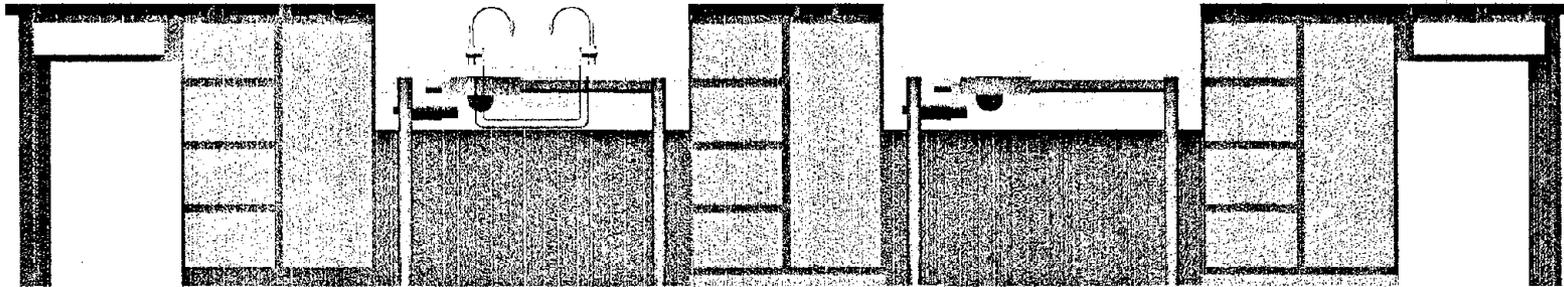
Prototype 3: Motor Driven
System in Raised Position

Appendix A. CAD Drawings of Prototype Test Beds



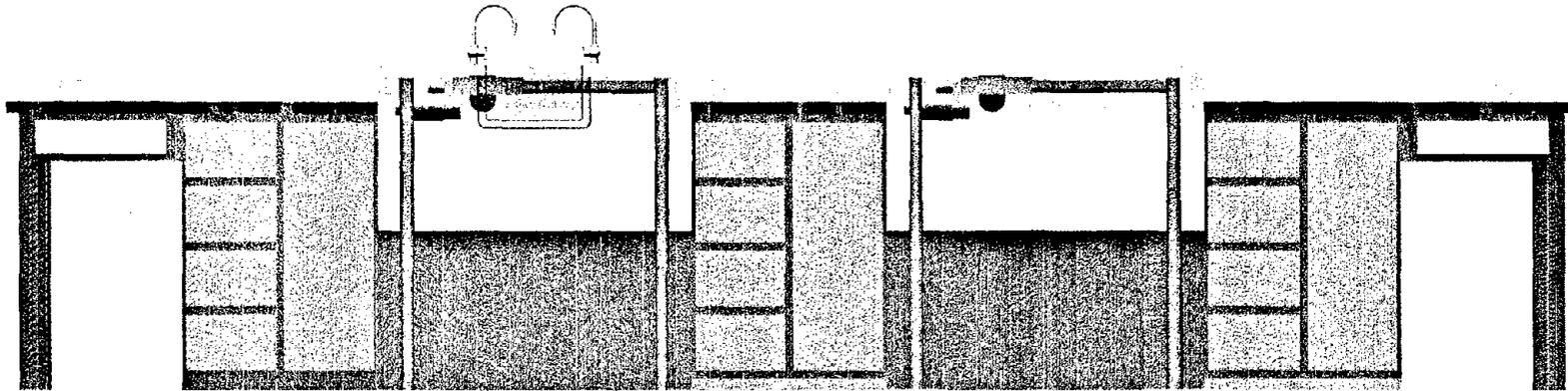
Appendix A. CAD Drawings of Prototype Test Beds

Prototype 1: Motorized Hydraulic Piston System
Front View
Lowered Position in Laboratory Bench Test Bed



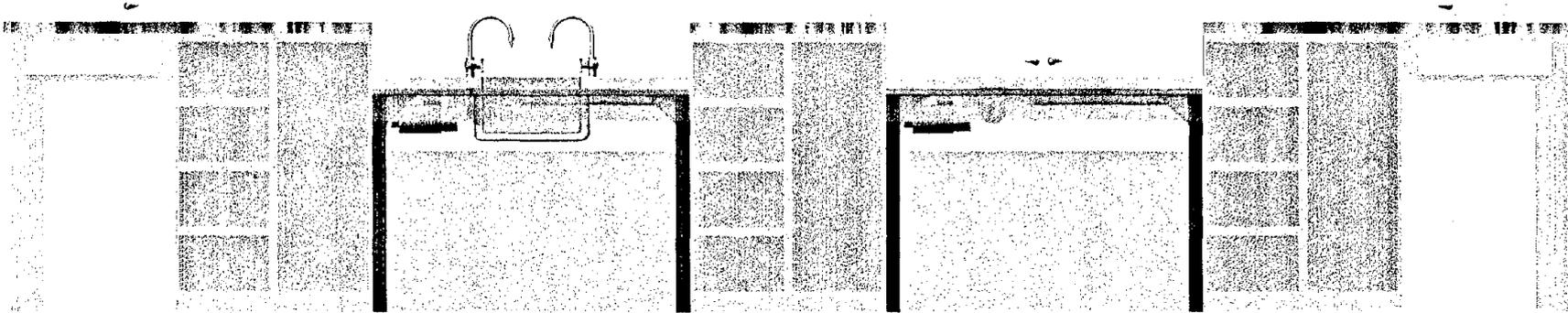
Appendix A. CAD Drawings of Prototype Test Beds

Prototype 1: Motorized Hydraulic Piston System
Front View
Raised Position in Laboratory Bench Test Bed



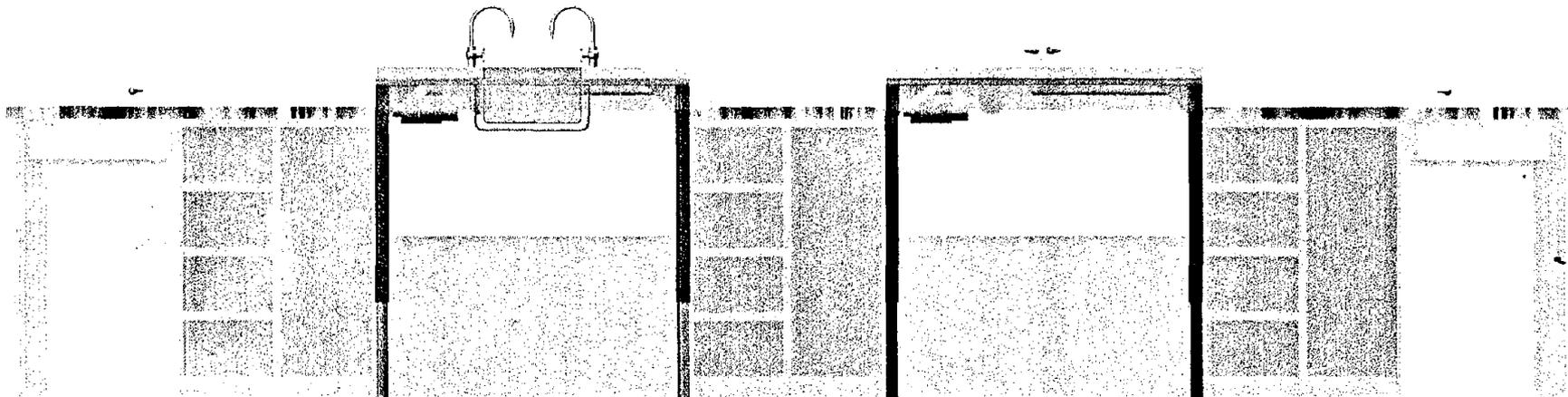
Appendix A. CAD Drawings of Prototype Test Beds

**Prototype 2: Motorized Hydraulic Piston System
Front View
Lowered Position in Laboratory Bench Test Bed**



Appendix A. CAD Drawings of Prototype Test Beds

Prototype 2: Motorized Hydraulic Piston System
Front View
Raised Position in Laboratory Bench Test Bed



Appendix B. Annotation of Relevant Building Codes

Annotation of OHIO PLUMBING CODE
Chapter 4101:2-56-69
Ohio Administrative Code

An adjustable height laboratory workbench with a plumbing system must comply with the applicable provisions of the rules of the Ohio board of building standards, which requires compliance to the Administrative Code. Chapters 4101:2-56 to 4101:2-69 of the Administrative Code are collectively known as "The Plumbing Code" of the "Ohio Basic Building Code" in accordance with rule 4101:2-1-03 of the Administrative Code. The plumbing code states that the design, erection, installation, alteration, repairs, relocation, replacement, addition to, use or maintenance of plumbing systems and equipment shall comply with the requirements of this code.

A laboratory workbench with a plumbing system is a plumbing fixture, defined as a device which is supplied with water or which receives or discharges liquids or liquid-borne wastes, with or without discharge into the drainage system with which it may be directly or indirectly connected. Plumbing systems in laboratory workbenches must comply with the specific provisions of plumbing fixtures, Chapter 4101:2-59-03 of the plumbing code.

4101:2-59-03 Fixtures. Plumbing fixtures shall be manufactured in accordance with fixture standards under the conditions of Chapter 4101:2-69 of the Administrative Code. All fixtures shall be installed in accordance with Chapters 4101:2-56 to 4101:2-69 of the Administrative Code and accepted engineering practice.

Chapters 4101:2-56 through 4101:2-57 describe the general coverage of the rules, and lists definitions of plumbing terminology used in the Plumbing Code. Chapter 4101:2-58 specifies acceptable workmanship, supports, joints, connections, safety devices, drainage, supply, prohibitions, inspections and tests which apply to all fixtures and buildings with plumbing systems. The following are specific rules that apply to laboratory workbenches, and a brief description of these rules.

4101:2-58-01 Accepted engineering practice and workmanship. Drainage piping shall be installed and properly supported to maintain the required alignment, horizontal drainage piping shall have a uniform pitch, and vertical drainage piping shall be plumb. Water distribution piping shall be installed to maintain alignment and distinct separation of not less than four inches and be supported by materials compatible with the piping material. The water distribution system shall be installed to allow total evacuation of the system.

4101:2-58-03 Hangers and supports. For both rigid and flexible systems - piping and fittings shall be provided for wall connections and penetrations and shall be firmly supported to maintain proper fixture connection.

4101:2-58-04 Tightness of joints. Joints and connections in the plumbing system shall be gas tight and water tight for the pressure required by test.

4101:2-58-05 Types of joints. Joints of any material shall be made in accordance with accepted engineering practice. Conformity to applicable standards, under the conditions of rule

Appendix B. Annotation of Relevant Building Codes

4101:2-69-01 (A) of the Administrative Code is prima-facie evidence of conforming to accepted engineering practice.

4101:2-58-06 Special joints. In drainage and water piping, slip joints may be used only on the inlet side of the trap or in the trap seal.

4101:2-58-13 Protection for pipes. Pipes coming in contact with corrosive materials shall be protected against external corrosion.

4101:2-58-15 Drainage velocities. Building drainage systems shall provide velocities of flow in accordance with "Table 4101:2-62-02" of the Administrative Code.

4101:2-58-16 Building drainage systems. Piping for the building drainage system shall be installed using materials meeting the applicable standards as set forth in "Table 4101:2-69-01 (A)" of the Administrative Code.

4101:2-58-24 Inspections. All plumbing shall be inspected to assure compliance with Chapters 4101:2-56 to 4101:2-69 of the Administration Code.

4101:2-58-25 Tests of plumbing. Water or air rough-in tests shall be applied, final air tests shall be applied to the entire system after fixtures are connected, and all tests shall be made in the presence of the plumbing inspector.

Chapter 4101:2-61 contains rules applicable to water supply and distribution. The plumbing system of an adjusting laboratory bench must comply with all codes, including the following.

4101:2-61-02 Water distribution. A shutoff valve shall be provided on each fixture supply. Water piping shall be of galvanized steel, brass, copper, cast-iron, PVC, CPVC, or polybutylene (PB) plastics with brass, cast-iron galvanized malleable-iron, copper or appropriate plastic fittings.

4101:2-61-04 Water distribution, sizing. The sizing of the water distribution system shall conform to accepted engineering practice. The minimum fixture-supply pipe size shall be as given in "Table 4101:2-61-04" of the Administrative Code. The maximum flow and water consumption for a sink faucet is 2.2 gallons per minute at 60 pounds per square inch.

4101:2-61-06 Test of water-supply system. The water supply system shall be tested and proved tight under a water pressure of one hundred twenty five PSI.

The number of fixture units and the minimum size of their respective traps are listed in chapter 4101:2-62. We are assuming a laboratory workbench is listed as a wash sink with multiple faucets. General rules applying to all traps are listed in chapter 4101:2-65.

4101:2-62-01 Fixture units, number. A wash sink with multiple faucets has a nominal minimum trap size of 1 1/2 inches, and each set of faucets has a fixture-unit value load factor of 2. This load factor is used in calculating building drain requirements.

4101:2-65-01 Traps. Each fixture trap shall have a water seal of not less than two inches. Traps shall be self-cleaning and made of lead, brass, bronze, copper, cast-iron, galvanized or malleable iron, ABS or PVC plastic. Traps shall have a full-bore smooth interior waterway. No trap shall be used which depends for its seal upon the action of movable parts. Waste outlets from fixtures shall be separately trapped as near to the fixture as possible, but in no case shall the vertical distance from the fixture outlet to the trap weir exceed twenty-four inches. A two- or three-compartment fixture may connect with a single trap. No fixture shall be double trapped.

Appendix B. Annotation of Relevant Building Codes

The approved standards for plumbing materials are listed in chapter 4101:2-69. Applicable standards are referenced in Table 4101:2-69-01(A) for building drains, water distribution, plumbing fixtures, and miscellaneous materials.

Table 4101:2-69-01(A) Approved Standards for Plumbing Materials. Fixtures and sinks are regulated under ANSI A112.19. Materials must follow ASTM guidelines.

When researching the feasibility of producing a height-adjustable laboratory bench, the applicable standards listed above were used as a minimum guide when identifying and assessing the technical options and products available.

Appendix B. Annotation of Relevant Building Codes

Annotation of NATIONAL ELECTRIC CODE
National Fire Protection Association, Inc., 70
1996 Edition

An adjustable height lab workbench electrically powered and providing electrical outlets for general use must comply with the applicable provisions of the *National Electrical Code* (NFPA 70-1996). The *National Electrical Code* states that the design, erection, installation, alteration, repair, relocation, replacement, addition to, use or maintenance of electrical systems and equipment shall comply with the requirements of this code.

The *National Electrical Code* applies to all standard laboratory workbenches containing electrical power. Additionally all electrical equipment used in the operation of a laboratory bench must meet state and/or federal approval. A nonstandard height-adjustable laboratory bench must comply with all general and specific requirements for code applicable to standard laboratory benches, including general installation, wiring and protection, use and identification, branch circuits, overcurrent protection, grounding, wiring methods and materials, and equipment for general use. In addition to meeting code applicable to standard laboratory benches, a height-adjustable laboratory bench must meet other provisions applicable as a result of designing the height adjustment feature.

A laboratory workbench that is powered electrically and provides electrical outlets for general use is an appliance, defined as utilization equipment, generally other than industrial, normally built in standardized sizes or types, that is installed or connected as a unit to perform one or more functions. Electric appliances must comply with the specific provisions of the National Electrical Code, Chapter 4, Equipment for General Use, Article 422, Appliances. The articles listed have been summarized to inform specifically of regulations applicable to a height-adjustable laboratory bench as designed in this research project.

Article 422 Appliances. This article stipulates all appliances must comply with applicable code and covers electric appliances used in any occupancy. Appliances shall have no live parts normally exposed to contact, and the installation of motor-operated appliances shall meet the requirements of Article 430.

A height-adjustable laboratory bench typically has receptacle outlets located on or near the work surface. A motor-operated appliance with receptacle outlets must meet the branch-circuit requirements of Article 422(B)-4.

Article 422(B)-4 Branch-Circuit Rating. This article stipulates a circuit supplying two or more loads, as in a motor-operated appliance and receptacle outlet suitable to variable load conditions, shall be rated in accordance with Article 210-23 Permissible Loads. This is a general article prohibiting the load on a branch circuit to exceed the branch circuit ampere rating applicable to general construction.

Installation of appliances is covered under general Article 422(C). Specific articles that apply to the design of a height-adjustable laboratory bench are listed below.

Article 422(C)-6 General. All appliances shall be installed in an approved manner.

Appendix B. Annotation of Relevant Building Codes

Article 422(C)-8 Flexible Cords (c) Other Appliances. Flexible cord shall be permitted (1) for connection of appliances to facilitate their frequent interchange or to prevent the transmission of noise or vibration or (2) to facilitate the removal or disconnection of appliances that are fastened in place, where the fastening means and mechanical connections are specifically designed to permit ready removal for maintenance or repair, and the appliance is intended or identified for flexible cord connections.

Article 422(C)-16 Grounding. Appliances required to be grounded shall have exposed noncurrent-carrying metal parts grounded in the manner specified.

The control and protection of height-adjustable laboratory benches must as a **minimum** meet the regulations of Article 422(D). The articles listed below apply to the height-adjustable laboratory benches as designed in this research project.

Article 422(D)-20 Disconnecting Means. A means shall be provided to disconnect each appliance from all ungrounded conductors in accordance with the following sections of Part D.

Article 422-22 Disconnection of Cord- and Plug-Connected Appliances. For cord- and plug-connected appliances, an accessible separable connector or an accessible plug and receptacle shall be permitted to serve as the disconnecting means. The rating of a receptacle or of a separable connector shall not be less than the rating of any appliance connected thereto.

Article 422-23 Polarity in Cord- and Plug-Connected Appliances. An appliance provided with a manually operated, line-connected, single-pole switch for appliance on-off operation shall have an attachment plug of the polarized or grounding type.

Article 422-25 Unit Switch(es) as Disconnecting Means. A unit switch(es) with a marked "off" position that is a part of an appliance and disconnects all ungrounded conductors shall be permitted as the disconnecting means required by this article where other means for disconnection are provided in the following types of occupancies:

- (d) Other Occupancies. The branch-circuit switch or circuit breaker, where readily accessible for servicing of the appliance, shall be permitted as the other disconnecting means.

Researching the feasibility of developing a height-adjustable laboratory bench included possible design options integrating flexible, movable electrical wiring and connections. Design attempts using these options must meet *National Electrical Code* regulations on flexible wiring methods and materials. Laboratory benches are used in various ways and for various purposes, and they may come in contact with a wide array of liquids, corrosives, and electrically conductive elements. Safe operation of a height-adjustable laboratory workbench warrants protection from these hazards, above and beyond the regulated methods deemed acceptable by the *National Electrical Code*. In a laboratory environment, electric conductors used in the operation of a height-adjustable laboratory bench should be installed in liquidtight flexible metal or nonmetallic conduit for maximum safety. Summarized below is Article 351 of the *National Electrical Code*, which specifies regulations for the use of liquidtight flexible metal and nonmetallic conduit.

Article 351 Liquidtight Flexible Metal Conduit and Liquidtight Flexible Nonmetallic Conduit

Appendix B. Annotation of Relevant Building Codes

Article 351-4 Use. (a) Permitted. Listed liquidtight flexible metal conduit shall be permitted to be used in exposed or concealed locations:

- (1) Where conditions of installation, operation, or maintenance require flexibility or protection from liquids, vapors, or solids.

Article 351-5 Size. Liquidtight flexible metal conduit smaller than ½-in. electrical grade size shall not be used. The maximum size of liquidtight flexible metal conduit shall be the 4-in. trade size.

Article 351-8 Supports. Liquidtight flexible metal conduit shall be securely fastened in place by an approved means within 12 in. (305 mm) of each box, cabinet, conduit body, or other conduit termination and shall be supported and secured at intervals not to exceed 4 ½ ft (1.37 m).

Article 351-10 Bends – Number in One Run. There shall not be more than the equivalent of four quarter bends (360 degrees total) between pull points, e.g., conduit bodies and boxes.

Article 351-23 Use. (a) Permitted. Listed liquidtight flexible nonmetallic conduit shall be permitted to be used in exposed or concealed locations:

- (1) Where flexibility is required for installation, operation, or maintenance;
- (2) Where protection of the contained conductors is required from vapors, liquids, or solids.

Article 351-23 Use. (b) Not Permitted. Liquidtight flexible nonmetallic conduit shall not be used:

- (3) In lengths longer than 6 ft (1.83 m).

Article 351-24 Size. The sized of liquidtight flexible nonmetallic conduit shall be electrical trade sizes ½ in. to 4 in. inclusive.

Article 351-27 Supports. Liquidtight flexible nonmetallic conduit shall be securely fastened at intervals not greater than 3 ft (914 mm) and within 12 in. (305 mm) on each side of every outlet box, junction box, cabinet, or fitting.

Article 351-30 Bends – Number in One Run. There shall not be more than the equivalent of four quarter bends (360 degrees total) between pull points, e.g., conduit bodies and boxes.

Appendix C. Annotation of CABO/ANSI A117.1 Requirements

Annotation of America National Standard CABO/ANSI A117.1 Accessible and Usable Buildings and Facilities

A. Space Allowance

The following are the ANSI requirements for space allowance which would be applicable for laboratory design. These design requirements apply to the space(s) within a science laboratory, but not means of ingress and egress.

4.2 Space Allowance.

4.2.1* Wheelchair Passage Width. The minimum clear width for single wheelchair passage shall be 32 in (815 mm) at a point and 36 in (915 mm) continuously

4.2.2 Width for Wheelchair Passing. The minimum width for two wheelchairs to pass is 60 in (1525 mm)

4.2.3* Wheelchair Turning Space. The space required for a wheelchair to make a 180-degree turn is a clear space of 60 in (1525 mm) or a T-shaped space.

B. Clear Floor Space

The requirements for clear floor space are intended to allow an unobstructed approach to a laboratory bench or laboratory equipment for persons with disabilities. These standards are based on the width(s) and maneuverability of wheelchairs and adult anthropometrics.

4.2.4* Clear Floor or Ground Space for Wheelchairs.

4.2.4.1 Size. The minimum clear floor or ground space required to accommodate a single, stationary wheelchair and occupant is 30 in by 48 in (760 mm by 1220 mm).

4.2.4.2 Approach. The minimum clear floor or ground space for wheelchairs may be positioned for forward or parallel approach to an object. Clear floor or ground space for wheelchairs may be part of the knee space required under some objects.

4.2.4.4 Relationship of Maneuvering Clearance to Wheelchair Spaces. One full unobstructed side of the clear floor or ground space for a wheelchair shall adjoin or overlap an accessible route or adjoin another wheelchair clear floor space.

C. Reach

The standards for reach consider the height and depth of the reach limits for persons with disabilities. These standards consider both forward and side reach limits for obstructed and unobstructed approaches.

4.2.5.1 Unobstructed Forward Reach. If the clear floor space only allows forward approach to an object, the maximum high forward reach allowed shall be 48 in (1220 mm). The minimum low forward reach is 15 in (380 mm).

4.2.5.2 Obstructed Forward Reach. If the high forward reach is over an obstruction, reach depth and heights shall comply with Table 4.2.5.2

Appendix C. Annotation of CABO/ANSI A117.1 Requirements

4.2.6* Unobstructed Side Reach. If the clear floor space allows parallel approach by a person in a wheelchair, the maximum high side reach allowed shall be 54 in (1370 mm) and the low side reach shall be no less than 15 in (380 mm) above the floor.

4.2.6.1 Obstructed Side Reach. If the side reach is over an obstruction, the high reach shall be 46 in (1170) maximum providing the height of the obstruction from the floor or ground is 34 in (865mm) maximum, and the depth of the obstruction is 24 in (610mm) maximum.

Table 4.2.5.2 Reach limits for Obstructed Forward Reach

	<u>in</u>	<u>mm</u>	<u>in</u>	<u>mm</u>
Reach Depth	0-<20	0-<510	20-25	510-635
Reach Height	48	1220	44	1200

D. Sinks

The sinks that are integrated into a laboratory bench or casework must comply with the ANSI standards for accessible lavatory fixtures, sinks, vanities, and built-in lavatories.

4.20.2.2 Sink Height and Depth. Sinks shall be mounted with the counter or rim no higher than 34 in (865 mm) above the finish floor. Sinks shall be 6 ½ in (165mm) deep maximum.

4.20.3.1 Knee and Toe Clearances. Fixtures shall extend 17 in (430mm) minimum from the wall. Knee clearance that is at least 27 in (685 mm) high, 30 in (760 mm) wide, and 19 in (485 mm) deep shall be provided underneath sinks.

4.20.3.2 Clear Floor Space. A clear floor space at least 30 in by 48 in (760 mm by 1220 mm) complying with 4.2.4 shall be provided in front of a sink to allow forward approach. The clear floor space shall be on an accessible route and shall extend a maximum of 19 in (485 mm) underneath the sink (see Fig. 32).

4.20.4 Exposed Pipes and Surfaces. Hot water and drain pipes exposed under sinks shall be insulated or otherwise configured so as to protect against contact. There shall be no sharp or abrasive surfaces under sinks.

4.24.7 Faucets. Faucets shall comply with 4.25.4. Lever-operated, push-type, touch-type, or electronically controlled mechanisms are acceptable designs. Self-closing faucets, when used, shall remain open for 10 seconds minimum. 4.25.4 operable parts of faucet shall be operable with one hand and shall not require tight grasping, pinching, or twisting of the wrist. The force required to activate operable parts shall be 5lb. (22.2N) maximum.

D. Counter Heights(s)

The issue of laboratory bench height or counter height is addressed by section 4.31 Seating, Tables, Work Surface, and Service Counters of the ANSI standards. These standards would apply to two common styles of commercial laboratory furniture. The most prevalent style is a straight bench and counter that is mounted over base cabinets. The standard counter height for this style is 36 inches. Another style features a laboratory table with open knee clearance space and laboratory fixtures on the table top. The standard height for this table style laboratory bench is 36 inches.

4.31.2.1 Seating. If seating spaces for people in wheelchairs are provided at fixed tables or counters, clear floor space complying with 4.2.4 shall be provided. Such clear floor space shall not overlap knee space by more than 19 in.

Appendix C. Annotation of CABO/ANSI A117.1 Requirements

4.31.3 Knee Clearances. Accessible seating for people in wheelchairs at tables, service counters, and work surfaces shall have knee spaces at least 27 in high, 30 in wide, and 19 in deep minimum.

4.31.4* Height of Tables or Counters. The tops of accessible tables and counters shall be from 28 in to 34 in above the finish floor or ground.

E. Storage and Cabinets

The ANSI specifications for cabinets would apply to the base cabinets located below the laboratory table height and upper cabinets that are integrated into the laboratory bench design or attached to the wall.

4.25 Storage.

4.25.1 General. Fixed storage facilities such as cabinets, shelves, closets, and drawers required to be accessible by 4.1 shall comply with 4.25.

4.25.2 Clear Floor Space. A clear floor space at least 30 in by 48 in complying with 4.2.4 that allows either a forward or parallel approach by a person using a wheelchair shall be provided at accessible storage facilities.

4.25.3 Height. Accessible storage spaces shall be within at least one of the reach ranges specified in 4.2.5 and 4.2.6 (see Fig. 5 and Fig 6).

4.25.4 Hardware. Hardware for accessible storage facilities shall comply with 4.27.4. Touch latches and U-shaped pulls are acceptable.

F. Controls and Operating Mechanisms

The ANSI specifications for controls and operating mechanism would apply to laboratory fixtures and other mechanisms integrated into the laboratory such as eye wash, fire extinguisher.....

4.27 Controls and Operating Mechanisms.

4.27.1 General. Controls and operating mechanisms required to be accessible by 4.1 shall comply with 4.27.

4.27.2 Clear Floor Space. Clear floor space complying with 4.2.4 that allows a forward or a parallel approach by a person using a wheelchair shall be provided at controls, dispensers, receptacles, and other operable equipment.

4.27.3* Height. The highest operable part of controls, dispensers, receptacles, and other operable equipment shall be placed within at least one of the reach ranges specified in 4.2.5 and 4.2.6. Electrical and communications system receptacles on walls shall be mounted no less than 15 in (380 mm) above the floor.

EXCEPTION: These requirements do not apply where the use of special equipment dictates otherwise or where electrical and communications systems receptacles are not normally intended for use by building occupants.

4.27.4 Operation. Controls and operating mechanisms shall be operable with one hand and shall not require tight grasping, pinching, or twisting of the wrist. The force required to activate controls shall be no greater than 5 lb. (22.2 N).

Appendix D. Focus Group Questionnaires

AD•AS Focus Group Questions

Questions 1-4 are intended to gain an understanding of your experience in university, college, and school science laboratories.

1. Describe your past experience in **using science or engineering laboratory benches and tables** in either an educational facility or other laboratory setting.
 No Experience
 Some Experience
 Extensive Experience

2. Describe your **level of ease** in using a science or engineering laboratory.
Very Easy Impossible
1 2 3 4

3. How easy is it to work at the **laboratory counters** at the standard counter height of 36 inches?

4. How easy is it to use **laboratory sinks** at the standard lab bench height of 36 inches?

5. How easy is it to use a **laboratory bench** which has base cabinets or drawers below the work surface?

6. How easy is it to reach **the faucet, gas fixtures, and controls** of a laboratory bench at the standard height of 36 inches?
Very Easy Impossible
1 2 3 4

7. Is your level of activity in science or engineering laboratories affected by the accessibility or ease of use of the laboratory design?
Yes No

8. Do you work at a laboratory bench in a seated position?
Yes No

Appendix D. Focus Group Questionnaires

Questions 9-15 are intended to gauge the need for handicapped accessible laboratory bench designs in schools and universities.

9. Are you aware of any laboratory bench designs which **accommodate students with disabilities and mobility impairments**? Yes No
10. Do you see a need for laboratory bench designs in schools, colleges, and universities which have counter heights, sink heights and cabinet storage which are all **handicapped accessible**? Yes No
11. Do you see a need for laboratory bench designs in schools, colleges, and universities which can be **easily adjustable in height** by each user (including students or instructors with disabilities) to a height which is usable and accessible for that person? Yes No
12. Are you aware of any such product described in Question # 11? Yes No
13. Which word(s) do you most closely associate or relate with the word "accessibility"? handicapped reachable
 getting from place to place useable
 other _____
14. Are you aware of situations, where a student with a disability or mobility impairment may have been discouraged from pursuing a career in science due to the inaccessibility of school science laboratories? Yes No
15. Do you think the future demand will grow for **accessible products** mostly because:
(please check each one you agree with)
- School and work populations are becoming more diverse (including people with disabilities)
 - Laws, such as the Americans with Disabilities Act, are going to demand it
 - People will simply want to have the most modern & convenient environmental control features

Appendix D. Focus Group Questionnaires

Questions 16-26 are intended to find out students and laboratory users interest in ergonomics in the design of science laboratories. Ergonomics defines the relationship among users and their work environment.

16. Describe your familiarity with the concept of **ergonomics**. 1 2 3 4
Very Familiar Unfamiliar
17. Focusing on lab users of all ability levels and sizes, do you believe that current lab designs can cause lab users to **work in awkward or static positions** which may lead to fatigue, stress or injury. Yes No
18. Please check any or all of **the laboratory components** which are awkward for you to work at for long periods of time (i.e. 1 hour or more of continuous work.) Laboratory fixed height work surface
 Laboratory fixed height sink
 Pipette station
 Fume hood station
 Other lab fixtures _____
19. When performing laboratory work which requires close visual inspection, does the standard laboratory work counter allow you to work comfortably for long periods of time (i.e. 1 hour or more of continuous work.) Yes No
20. If you checked "No" to question #19, what laboratory counter configurations may **improve the ergonomics** of work which requires close visual inspection? Concave Counter
 Convex Counter
 Height Adjustable Counter
 Arm Rests on Counters
 More leg room below the counter
21. Are you aware cumulative trauma injuries which may result from repetitive motions at awkward or static positions? The most common cumulative trauma injury is carpal tunnel syndrome. Yes No

Appendix D. Focus Group Questionnaires

22. Have you experienced cumulative trauma disorders, carpal tunnel syndrome, or musculoskeletal disorders as a result of awkward or static positions assumed while working at lab benches? Yes No
23. Are you aware of students or other lab users who have experienced cumulative trauma disorders, carpal tunnel syndrome or musculoskeletal disorders as a result of awkward or static positions assumed while working at lab benches? Yes No
24. If the **work surface** of a laboratory bench could be **frequently adjusted in height**, do you believe it would mitigate fatigue, muscle discomfort, stress or cumulative trauma injuries? Yes No
25. Do you see a need for **height adjustable laboratory benches and cabinets** which may reduce cumulative trauma disorders, carpal tunnel syndrome or musculoskeletal disorders by providing an ergonomically sound lab environment? Yes No
26. If you answered yes to question #25, please check the boxes corresponding to your rationale.
- A raised height would allow a neutral posture when performing work in a standing position
 - A lowered height would allow a better posture when working in a seated position
 - Frequent shifts in work surface height would allow variations in lab users shoulder, arm and hand positions
 - Other
-

This research and development is conducted by Accessible Designs• Adjustable Systems, Inc. and is funded by The National Institutes of Health.

Appendix D. Focus Group Questionnaires

AD•AS Focus Group Questionnaire

Questions 1-6 are intended to gain an understanding of the facility planning process for university, college, and school science laboratories.

1. Describe your past involvement in specifying laboratory benches, casework, and lab components into an educational facility or science laboratory.

- No Involvement
- Some Involvement
- Extensive Involvement

2. Estimate your experience in either facility planning related to school science laboratories or instruction in a laboratory setting.

- Less than 1 year
- 1-5 years
- 5-10 years
- more than 10 years

3. In your estimation, how often do schools replace the laboratory benches, storage cabinets, and laboratory casework?

- every 3 years
- every 5 years
- every 10 years

4. Rank the following purchase points in ascending order of importance- using 1 as the most important and 6 as the least important.

- _ Manufacturer's reputation
- _ Competitive cost
- _ Delivery/installation time
- _ Functionality
- _ Aesthetics
- _ Other _____

5. How do you learn about new laboratory bench and casework products?

- Trade Shows
- Professional/trade magazines
- Sales Representatives
- Architects
- Contacts at other schools
- Other _____

6. Which do you see as the most significant concern for the end user?

- cost
- maintenance/reliability
- aesthetics/choice
- operation/means of using

Appendix D. Focus Group Questionnaires

Questions 7-15 are intended to determine the importance of handicapped accessibility in the facilities planning process with respect to science laboratories.

7. Are you aware of any laboratory bench designs which **accommodate students with disabilities and/or mobility impairments?**

- Yes
- No
- Somewhat

8. Are you familiar with the relevant **Americans with Disabilities Act Accessibility Guidelines (ADAAG)** for school science laboratory bench heights, lab sinks and storage cabinet heights?

- Yes
- No
- Somewhat

9. Do you see a need for laboratory bench designs in schools, colleges, and universities which can be **easily adjustable in height** by each user (including students or instructors with disabilities) to a height which is usable and accessible for that person?

- Yes
- No
- Not Sure

10. Are you aware of any such product described in Question # 9?

- Yes
- No
- Not Sure

11. With respect to Question #9, rank the following **purchase issues** that would influence your decision to specify a height adjustable laboratory bench in your school or facility. In ascending order of importance rank the most important issue with 1 and 5 as the least important.

- _ Manufacturer's reputation/reliability
- _ Competitive cost
- _ Usability for students with disabilities and non-disabled students
- _ Attitudes and considerations of the non-disabled population toward accessible lab benches
- _ code compliance of fixtures (gas, water, electric) for moveable lab benches

12. If laboratory benches were available which **easily adjusted up and down in height** to create handicapped accessible counter space, sink space, and storage space, and all other attributes were equal to standard lab benches, what percentage over and above the standard cost would you consider acceptable?

- 0% no additional cost
- 5-10% over standard cost
- 10-20% over standard cost
- 20-30 over standard cost

Appendix D. Focus Group Questionnaires

13. Which word(s) do you most closely **associate or relate** with the word "accessibility"?

- Handicapped
- Reachable
- Options
- Other _____

14. Do you believe future demand will grow for accessible products mostly because:

- School and work populations are becoming more diverse (including people with disabilities)
- Laws, such as the Americans with Disabilities Act, are going to demand it
- People will simply want to have the most modern & convenient environmental control features

15. Are you aware of situations, where a student with a disability or mobility impairment may have been discouraged from pursuing a career in science due to the inaccessibility of school science laboratories?

- Yes
- No
- Not Sure

Questions 16-24 are intended to gauge facility planners' interest in ergonomics in the design of science laboratories. Ergonomics defines the relationship among users and their work environment.

16. Describe your familiarity with the principles of **ergonomics** as they may apply to lab designs.

- Unfamiliar
- Somewhat Familiar
- Familiar
- Very Familiar

17. Focusing on **non-disabled laboratory users**, do you believe that current lab designs can cause lab users to work in awkward or static positions which may lead to fatigue, stress or injury?

- | | |
|--------------------------|--------------------------|
| Yes | No |
| <input type="checkbox"/> | <input type="checkbox"/> |

18. Please check any or all of the laboratory components which you believe **may be awkward for lab users after long periods of time** (i.e. 1 hour or more of continuous work).

- Laboratory fixed height work surface
- Laboratory fixed height sink
- Pipette station
- Fume hood station
- Other lab fixtures _____

Appendix D. Focus Group Questionnaires

19. When lab users are performing work which requires **close visual inspection over a long period of time**, do you believe the standard lab counter design allows the user to work comfortably?

Yes No

20. If you checked "No" to question #19, what laboratory counter configurations **may improve the ergonomics** of work requiring close visual inspection?

- Concave Counter
- Convex Counter
- Height Adjustable Counter
- Arm Rests on Counters
- More leg room below the counter

21. Are you aware of cumulative trauma injuries which may result from repetitive motions at awkward or static positions? The most common cumulative trauma injury is carpal tunnel syndrome.

Yes No

22. Are you aware of students or other lab users who have experienced cumulative trauma disorders, carpal tunnel syndrome or musculoskeletal disorders as a result of awkward or static positions assumed while working at lab benches?

Yes No

23. If the **work surface** of a laboratory bench could be **frequently adjusted in height**, do you believe it would mitigate muscle strain, stress or cumulative trauma injuries?

Yes No

24. If you answered yes to question #23, please check the boxes corresponding to your rationale.

- A raised height would allow a neutral posture when performing work in a standing position
- A lowered height would allow a better posture when working in a seated position
- Frequent shifts in work surface height would allow variations in lab users shoulder, arm and hand positions
- Other _____

This research and development is conducted by Accessible Designs• Adjustable Systems, Inc. and is funded by The National Institutes of Health.

Focus Group Description

Title of Research Project: Feasibility of Adjustable Laboratory and Work Bench

Company: Accessible Designs • Adjustable Systems, Inc.

Principal Investigators: Gary P. Davis

I. Introduction

The primary objective of the project is to determine the technical feasibility of producing a prototype adjustable laboratory and work bench system which will have universal application to an increasingly diverse work force and student population. The technical opportunity is focused on creating an affordable system which is appropriate for private sector businesses as well as schools and organizations with fewer financial resources.

To generate design requirements AD • AS will utilize focus groups and attempt to integrate the design requirements into prototype designs.

II. Recruitment of Focus Group Participants

We will convene four focus groups during the project period. One focus group will be comprised of installation contractors and code enforcement officials. The second will be comprised of purchasers and product specifiers. The third will be comprised of people with physical disabilities or mobility impairments. The fourth will be comprised of a cross section representative of people who work in laboratories. We will pay focus group participants a nominal amount for their participation. This payment will be made at the start of the focus group.

We wish to seek the perspectives of women and members of minority groups. Our recruitment of focus group participants will specifically attempt to include these groups. We will provide details of the proposed involvement of humans in the research, including the characteristics of the subject population, age ranges, and health statuses.

II. Focus Group Questions and Discussions

There are three general areas of objectives for the focus groups:

Feedback from a variety of potential laboratory bench users on physical, aesthetic, and functional requirements.

Feedback from tradespeople and code enforcement people on the acceptance on non-standard laboratory designs.

Feedback from a cross section representative of laboratory users on their attitudes pertaining to laboratory designs intended solely by people with disabilities.

All written focus group responses will be anonymous and there will be no way for any participant to be personally identified by their written responses. The verbal responses will be audiotaped for further analysis by the principal investigator. The principal investigator will be the only person with access to these tapes.

OHIO UNIVERSITY
PROJECT DIRECTOR'S PROJECT OUTLINE FORM
FOR PROPOSALS SUBMITTED TO THE INSTITUTIONAL REVIEW BOARD

IRB No. _____ (To be completed by ORSP)

Name of Project Director Gary Davis

Department or School AD/AS, Inc. Phone 614-593-5240

Title of Research Proposal Feasibility of Adjustable Laboratory and Work Bench

Starting Date _____ Duration 6.5 months

Source of Funding National Institute of Health

All requests must include the following elements: Completed and Signed IRB-1 (this form); a description of the research including the methodological and analytical techniques; copies of consent forms (or a request for exemption from informed consent with full justification); copies of all surveys to be utilized in the study or, if incomplete at the time of submission, a description of the topics to be covered and sample questions; and any additional materials that will assist the Board in completing its review.

Estimated Number of Human Subjects Involved in Project 40

I. Characteristics of subjects (check as many boxes as appropriate).

<input type="checkbox"/> Minors	<input checked="" type="checkbox"/> Disabled	<input checked="" type="checkbox"/> University Students
<input checked="" type="checkbox"/> Adults	<input type="checkbox"/> Pregnant	<input type="checkbox"/> Secondary School Students
<input type="checkbox"/> Prisoners	<input type="checkbox"/> Legal Incompetency	<input type="checkbox"/> Elementary School Students
<input type="checkbox"/> Others (Specify) _____		

IA. Exemption Requested _____

Has this or a similar research protocol been approved by OU IRB or any other.

Date _____ Project _____

II. Consent

A. Consent obtained from: Individual .
Legally Authorized Representative _____.

B. Method of presenting information on which to base informed consent:
Written , Oral _____.
(For an oral presentation, attach a summary, signed by the project director, or the information which will be presented orally to the prospective subjects)

C. Briefly describe the methods used for selection of subjects. The response to this item and items III, and IV, should be typewritten on a separate page(s) and attached to this form.

III. Attach a description of the Project (See Section I. Review of the guidelines)

IV. Agreements: By signing this form, the project director (and his/her faculty advisor) agrees to the following:

- A. To comply with Ohio University policies on research and investigation involving human subjects (O.U. Policy # 19.052)
- B. To provide documentation of selection and informed consent procedures upon request by the IRB.
- C. To inform the IRB of any planned changes in procedures which involve human subjects, giving the IRB sufficient time to review and approve such changes before they are implemented, and to supply IRB with such progress reports or annual assessments as it may require.
- D. It is understood that any approval granted by the IRB applies to this project only and only under the conditions and procedures described in the application. Any change in the protocol or conditions set forth will require separate approval.
- E. It is understood that the identification of human subjects in any publication is an invasion of privacy and requires the execution of a consent form. Informed consent must be obtained from each subject or the subject's legally authorized representative. Documentation of informed consent must be retained, in a secure environment, for a minimum of four years after termination of the project.

Date 10-21-96 Signature Mary Davis

If the project director is an undergraduate or graduate student, the student's advisor for this research proposal must sign the form.

Date _____ Signature _____

Signature of IRB Chair

Date

Approved through full ___ or expedited ___ review.
Approved Exemption _____

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Ohio University

Office of the Vice President
Research and Technology Center 101
Athens, Ohio 45701-2979

Research and Graduate Studies

614-593-0371
FAX: 614-593-0380

CERTIFICATION OF REVIEW AND APPROVAL

The Ohio University Institutional Review Board for the Protection of Human Research Subjects has reviewed the proposal indicated below and approved the use of human subjects. Review was in accordance with Health and Human Services Policy as set forth in the Code of Federal Regulations 45CFR46.

Title of Proposal: Feasibility of Adjustable Laboratory and Work Bench

Principal Investigator: Gary Davis

Department: AD/AS, Inc.

College:

Grantor Agency: National Institute of Health

Date of Approval: October 21, 1996

Type of Review: Expedited/Exempt

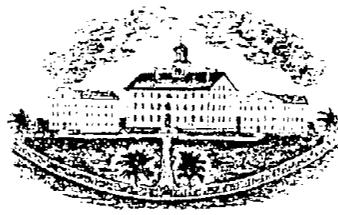
A handwritten signature in black ink, appearing to read "C. L. Hale".

Claudia L. Hale, Ph.D., Chair
Institutional Review Board

10/27/96

Date

Research &
Technology Center 101
Athens OH 45701-2979
614-593-0370 phone
614-593-0380 fax



OHIO UNIVERSITY

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Assurance of Compliance with DHHS Regulations for
Protection of Human Research Subjects

Ohio University, hereinafter known as the "institution", hereby gives assurance that it will comply with the Department of Health and Human Services (DHHS) regulations for the protections of human research subjects (45 CFR 46) as specified below.

PART 1
Ethical Principles and Institutional Policies Governing
Research Involving Human Subjects

I. Applicability

Except for research exempted or waived under the DHHS regulations 45 CFR 46.101, Part 1 of this Assurance applies to all research involving human subjects, and all other activities which even in part involve such research, regardless of whether the research is otherwise subject to federal regulation, if:

- a. the research is sponsored by this institution, or
- b. the research is conducted by or under the direction of any employee or agent of this institution in connection with institutional responsibilities, or
- c. the research is conducted by or under the direction of any employee or agent of this institution using any property or facility of this institution, or
- d. the research involves the use of this institution's nonpublic information to identify or contact human research subjects or prospective subjects.

II. Ethical Principles Governing Human Subjects Research

This institution is guided by the ethical principles regarding all research involving humans as subjects as set forth in the report of the National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research entitled, Ethical Principles and Guidelines for the Protection of Human Subjects of Research (the "Belmont Report") and as specified below.

- A. This institution recognizes the principles of respect for persons, beneficence (including minimization of harms and maximization of benefits), and justice as stated in the Belmont Report and will apply these principles in all research covered by this Assurance.
- B. This institution acknowledges and accepts its responsibilities for protecting the rights and welfare of human research subjects.

III. Policies

- A. This institution acknowledges that it and its investigators bear full responsibility for the performance of all research covered by this Assurance, including full responsibility for complying with Federal, state, and local laws as they may relate to such research.
- B. This institution assures that before human subjects are involved in research, proper consideration will be given to:
 - (1) the risks to the subjects,
 - (2) the anticipated benefits to the subjects and others,
 - (3) the importance of the knowledge that may reasonably be expected to result,
 - (4) the informed consent process to be employed,
 - (5) the provisions to protect the privacy of subjects, and
 - (6) the additional safeguards for vulnerable populations.
- C. This institution recognizes the need for appropriate additional safeguards in research involving subjects who are likely to be vulnerable to coercion or undue influence, such as children, prisoners, pregnant women, mentally disabled persons, or economically or educationally disadvantaged persons.
- D. This institution encourages and promotes constructive communication among the institutional officials, research administrators, department heads, research investigators, clinical care staff, human subjects, and all other relevant parties as a means of maintaining a high level of awareness regarding the safeguarding of the rights and welfare of the subjects.
- E. This institution will exercise appropriate administrative overview carried out at least annually to assure that its practices and procedures designed for the protection of the rights and welfare of human subjects are being effectively applied.

PART 2

IRB, Institution, and Investigator Compliance with 45 CFR 46

I. Applicability

Part 2 of this Assurance applies to the following research project which is conducted or sponsored by this institution and supported by the Department of Health and Human Services (DHHS).

Project title Feasibility of Adjustable Laboratory and Work Bench

DHHS Project number 1 R43 OH03379-01A1

Project Investigator or Director Gary P. Davis

II. Institutional Responsibilities

- A. This institution has complied and will continue to comply with the requirements of 45 CFR 46 as specified below.
- B. In accordance with the compositional and quorum requirements of 45 CFR 46.107 and 46.108, the Institutional Review Board (IRB) designated in Part 3 and in the attached roster is responsible for the initial and continuing review of this project.
- C. This institution has provided and will continue to provide both meeting space for the IRB and sufficient staff to support the IRB's review and record keeping duties.
- D. In addition to the review and approval of the IRB, this institution has reviewed and sponsors the project referenced above.

III. IRB Review

- A. The IRB shall review, and have the authority to approve, require modification in, or disapprove this research activity or proposed changes in it before human subjects may be involved.
- B. The convened IRB reviewed and approved the above project.
- C. The IRB determined, in accordance with the criteria found at 45 CFR 46.111, and where applicable, 45 CFR 46 Subparts B, C, and D, that protections for human research subjects are adequate.
- D. The IRB has the authority to suspend or terminate approval of the above referenced research in accordance with 45 CFR 46.113 for (1) non-compliance with 45 CFR 46, and this Assurance document or the IRB's requirements, and (2) for elimination of unexpected serious harm to subjects.
- E. The IRB has determined that legally effective informed consent [copy of document must be attached unless specified otherwise by OPRR] will be obtained in a manner and method which meets the

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requirements of 45 CFR 46.116 and 46.117.

- F. Certification of IRB approval, at least annually shall be submitted to the DHHS awards unit that issued the award, as a condition for receipt of funds for a non-competing continuation and/or additional involvement of human subjects.
- G. Continuing reviews by the IRB shall be conducted at intervals appropriate to the degree of risk, but not less than once per year (45 CFR 46.109[e]). The IRB may be called into an interim review session by the Chairperson at the request of any IRB member or Institutional Official to consider any matter concerned with the rights and welfare of any subject.
- H. The IRB shall prepare and maintain adequate documentation of its activities in accordance with 45 CFR 46.115.
- I. The IRB shall report promptly to institutional officials and the Office for Protection from Research Risks (OPRR):
 - (1) any serious or continuing noncompliance by investigators with the requirements of the IRB,
 - (2) any suspension or termination of IRB approval,
 - (3) any unanticipated problems or injuries involving risks to subjects or others, and
 - (4) any changes in this research activity which are reviewed and approved by the IRB.
- J. Where appropriate, the IRB will determine that adequate additional protections are ensured for fetuses, pregnant women, prisoners, and children as required under Subparts B, C, and D of 45 CFR 46. The IRB will notify OPRR promptly when IRB membership is modified to satisfy the requirements at 45 CFR 46.304 and when the IRB fulfills its duties under 45 CFR 46.305(c).
- K. The IRB will comply fully with the requirements of all applicable Federal policies and guidelines, including those concerning notification of sero-positivity, counseling, and confidentiality of subjects.

IV. Research Investigator Reporting Responsibilities

- A. Investigators acknowledge and accept their responsibility for protecting the rights and welfare of human research subjects and for complying with all applicable provisions of this Assurance and 45 CFR 46.
- B. Research investigators shall report promptly to the IRB proposed changes in this research activity and the changes shall not be initiated without IRB review and approval except where necessary to eliminate apparent immediate hazards to the subjects.
- C. Research investigators shall report promptly to the IRB any unanticipated problems involving risks to subjects and others.

PART 3

Certification of IRB Approval and Institutional Endorsement

Project title Feasibility of Adjustable Laboratory and Work Bench

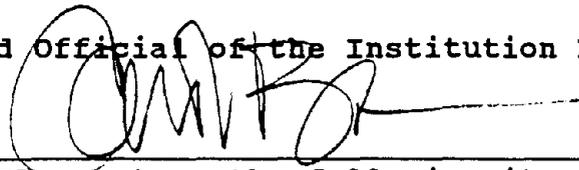
DHHS Project number 1 R43 OH03379-01A1

Project Investigator or Director Gary P. Davis

Date of IRB Approval 11/13/96 Date of Next Scheduled IRB Review _____

The officials signing below assure that the project referenced above was approved by the IRB on the date indicated and that the project will be conducted in accordance with the requirements of Part 46, Title 45 of the Code of Federal Regulations and this Assurance document. A dated roster listing the current membership of the designated IRB is attached.

I. Authorized Official of the Institution Providing This Assurance

Signature  Date: 11/13/96

Please type the following items.

Name and Title: Carol J. Blum, Associate Vice President, Research & Graduate Studies

Address: Ohio University

Research & Technology Center 101

Athens, OH 45701-2979

Telephone: (614) 593-0372

FAX: (614) 593-0380

**II. Authorized Official of the Institution with the IRB
(Include only if different from the institution above)**

This institution authorizes the designation of its IRB for review of the project referenced in this Assurance.

Signature _____ Date: _____

Please type the following items.

Name and Title:

Address:

Telephone:

FAX:

**III. IRB Chairperson
(Must be completed in all cases [see IRB membership list])**

Signature  Date: 11/1/96

Please type the following items.

Name and Title: Claudia L. Hale

Address: Lasher Hall 202A, Ohio University

Athens, OH 45701

Telephone: (614) 593-9168

FAX: (614) 593-4810

MPA number if applicable _____

Single Project Assurance

IV. Responsible Project Investigator or Director at Institution Providing this Assurance

I have attached copies of all OPRR requested and IRB approved Informed Consent Documents to be used in this project unless the designated IRB operates under an OPRR-approved Multiple Project Assurance (MPA) or unless OPRR has indicated otherwise.

Signature Gary P Davis Date: 11-13-96

Please type the following items.

Name: Gary P. Davis
Title: Business Developer
Address: Accessible Designs Adjustable Systems
94 Columbus Rd.
Athens, OH 45701
Telephone: (614) 593-5240 FAX: (614) 593-5451

- SPACE BELOW FOR DHHS -

All parts of this Assurance are in compliance with the requirements of Part 46, Title 45 of the Code of Federal Regulations.

DHHS Approving Official

Signature _____ Date: _____

Name:
Address: Assurance Coordinator, Assurance Branch
Division of Human Subject Protections
Office for Protection from Research Risks (OPRR), OD
National Institutes of Health
6100 Executive Boulevard, Suite 3B01 (MSC 7507)
Rockville, Maryland 20892-7507
Rockville, Maryland 20852 (for courier delivery only)

Telephone #: 301-496-7041
FAX #: 301-402-0527

ASSURANCE NUMBER S- _____

An application for new or competing support for continuation in which human subjects will be involved will require a new and separate Assurance, unless the activity is exempt under section 45 CFR 46.101(b).

