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Facility Design Program Requirements for the National Science Center

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This research was conducted to develop specific facility design program requirements for a hands-on science museum called the Discovery Center. This information generated creative ways to use current materials, technologies, and approaches to integrate the complex systems and interactive devices within the building, and to create a facility that is appealing to the visitor, provides exciting educational opportunities, and sets the standard for an Army maintained science museum. This information will be used to provide the government's input to the architects contracted by the National Science Center Foundation to plan, design, and prepare construction documents.

This report contains detailed program requirements and design criteria for the major building facilities, including square footage requirements. Recommendations for interior and exterior aesthetics are also included.

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FOREWORD

This study was conducted for The Discovery Center, National Science Center, Fort Gordon, Georgia under Intra-Army Order (IAO) DPCA 11-89, dated 20 June 1989, "NSCF Discovery Center Building." The Fort Gordon point of contact was Dr. George J. Fry, ATZH-NSC-D under Commander COL C.F. Rimby.

This research was performed by Professors William C. Bullock and W.R. Peter Pittman, employed by the Georgia Institute of Technology, for the Facility Systems Division (FS) of the U.S. Army Construction Engineering Research Laboratory (USACERL) under Purchase Order CECER-FS-89-429. Dr. Michael J. O'Connor is Chief of USACERL-FS. The work was initiated by the Habitability Team and completed by the Architectural Design and Management Team where L. Michael Golish is the Team Leader. The USACERL technical editor was Gloria J. Wienke, Information Management Office.

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COL Everett R. Thomas is Commander and Director of USACERL and Dr. L.R. Shaffer is Technical Director.

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FACILITY DESIGN PROGRAM REQUIREMENTS FOR THE NATIONAL SCIENCE CENTER

1 INTRODUCTION

Background

The National Science Center for Communications and Electronics is a partnership between a civilian foundation, The National Science Center Foundation (NSCF), and the U.S. Army, represented by the National Science Center Task Force at Fort Gordon, GA. The partnership is committed to supporting improved education in science and technology. Lack of educational support in science and technology is a national problem that affects both industry and the Army. This national resource center will stimulate an interest in science and technology in the youth of our nation, will provide facilities for educational research, and will sponsor activities and products to enhance education in communications, electronics, physical sciences, and related mathematics. One activity of the partnership is to construct the Discovery Center, a dynamic facility that will feature over 350 hands-on exhibits representing principles and applications of science and technology, supported by demonstrations and informal educational programs. The Task Force will develop the facility information, including programmatic requirements and functional specifications for the Discovery Center building; the National Science Center Foundation will build and equip the facility in Augusta, GA. Upon completion, the building will be donated to the Army for operation and maintenance.

The project has high priority with the U.S. Army. It was initiated with a Memorandum of Understanding signed by the Secretary of the Army and endorsed by Public Law 99-145 passed by Congress in November 1985. The program is directed by two distinguished executive committees: the Army's Executive Steering Committee composed of Department of the Army general officers and led by the Commander of the United States Training and Doctrine Command (TRADOC), and the NSCF Board of Directors composed of leaders in business and industry chaired by Harry Gray, former Chief Executive Officer of United Technologies. The Discovery Center, representing a national concern for math and science illiteracy, will be a focal point for educational research in those arenas and will be a dynamic public relations outreach for the Department of Defense. The building must reflect this national focus on high technology.

Construction of the Discovery Center is expected to begin in 1991 with a grand opening scheduled for 1993. Currently, the Task Force is developing design and space requirements. This research report is an integral part of the foundation for implementing the site-specific program. This research supports and identifies the design functions necessary for the Discovery Center's mission of presenting technology through the use of interactive hands-on devices. Consideration must be given to the technical needs peculiar to the exhibits; the electromechanical, electronic, telecommunication, and automation requirements. Because the ultimate operation and maintenance of the building will be the Army's responsibility, it is in the government's best interest to develop comprehensive facility information and present these requirements in clear and technically accurate terms.

Objective

The objective of this work was to develop specific facility design program requirements for a hands-on science museum called the Discovery Center. This information generates creative ways to use current

materials, technologies, and approaches to integrate the complex systems and interactive devices within the building; to create a facility that is appealing to the visitor, provides exciting educational opportunities, and sets the standard for an Army maintained science museum. This information will be used to provide the government's input to the architects contracted by the National Science Center Foundation to plan, design, and prepare construction documents for the Discovery Center.

Approach

During the course of this research, the researchers visited different national science centers: Sci Trek in Atlanta, GA; Ontario Science Center in Toronto, Ontario, Canada; St. Louis Science Center, St. Louis, MO; Children's Museum in Indianapolis, IN; and the Science Museum of Minnesota in Minneapolis, MN. Researchers also had the opportunity to visit La Villette/Centre de Science and Industry in Paris, France. In addition to tours of these facilities and discussions with knowledgeable administrators and employees, researchers photographed each facility, reviewed extensive literature on design and operation of museums nationwide, and examined photographic documentation collected both by the researchers and by the Task Force (which had extensive slide files on facilities that had been visited previously). Information the Task Force provided to the researchers (originally prepared by Oak Ridge Associated Universities) was also very beneficial. The Oak Ridge study compiled statistical data on 38 centers* from 16 states.

A special report published by the U.S. Army Construction Engineering Research Laboratory (USACERL)¹ presented information to determine state-of-the-art technologies, techniques, or products that could be brought to bear on the project. General information was gathered by interviewing National Science Center (NSC) staff members and other experts, by reviewing existing studies, documentation, technical literature, and by visiting similar institutions and structures for "lessons learned." Researchers also prepared some artistic renderings.

Specific information for the current research (facility design requirements) was gained from extensive, detailed information and interviews with the NSC staff members. It is both a quantitative and qualitative analysis of the physical spaces that are necessary to carry out the programs of the National Science Center. It is intended to provide architectural programming information and space guidance to the National Science Center Task Force and their contracted Architect/Engineer (A/E).

Chapter 2 includes recommendations regarding interior and exterior aesthetics, including "way finding" (location and directional signs) and standards for energy efficient design set forth by the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE). The Facility Design Program Summary of Chapter 3 provides a summary of the major building facilities with required square footage. The Facility Design Program Outline of Chapter 4 breaks out the spaces in more detail showing the major building facilities with required areas and square footage. The Facility Design Program Requirements of Chapter 5 expands the information to include detailed program requirements and design criteria for the National Science Center.

* For brevity, all science centers/museums visited will be referred to as "centers," realizing that the distinction between the two may be somewhat a matter of personal opinion.

¹ W.C. Bullock, W.R. Peter Pittman, and Douglas C. Heinen, *Program Analysis and Design Requirements for the National Science Center*, USACERL Special Report P-91/11 ADA235409 (U.S. Army Construction Engineering Research Laboratory [USACERL] February 1991).

2 GUIDELINES FOR AESTHETICS AND ENERGY EFFICIENCY

The new National Science Center shall be built with the utmost concern for an appropriate architectural aesthetic. Image studies developed during the course of this research to explore appropriate directions for interior and exterior aesthetics are provided in Appendix A. These studies are provided as examples of possible aesthetic character and building direction for the new National Science Center. The center must also promote, through design, enjoyment and ease of use for employees and patrons. It should exemplify the highest standards of energy efficient design and construction. Every effort should be made to realize a state-of-the-art facility of which the nation can be proud.

Exterior aesthetics of existing centers are varied and range from existing structures that were converted from other uses to new facilities representing some of the most innovative construction and design methods in contemporary architecture. Some are located in natural settings while others are in more urban settings with less open area around them. The majority of the centers visited use older, converted structures and many have been expanded over the years through building additions, thus creating a variety of architectural styles. This is true for the five-story Indianapolis Center, for instance, which has undergone three building additions since 1976.

The extremes in building architecture are represented at one end of the spectrum by the Exploratorium Science Center in San Francisco, which uses a turn of the century structure and secondhand furniture to display exhibit items, to the Ontario Science Center in Canada which is a 10-year-old building complex with more contemporary architecture and furnishings. An even more contrasting extreme is the newly opened La Villette Center for Science and Industry in Paris; the entire facility is designed as an operating machine using state-of-the-art exhibits, design, construction, and systems for learning and pleasure. Although all three are very different in their mission, each is a highly successful facility.

"Way finding" can affect building aesthetics and is important for easy use and understanding by patrons both inside and outside the facility, and should be considered an integral part of the facility design. In addition to designing the facility to promote ease of "way finding," signs and graphics can be used on both the exterior and interior of the building.

Exterior building signs are those attached or adjacent to the facility. This group of signs includes building identity signs and directional signs for pedestrians and motor vehicles. Signs should be appropriate in size, scale, and number. Building identity signs should be compatible with building architecture. Their size, style of lettering, and location should be in keeping with building architecture. Directional signs should be well coordinated with building architecture and site landscaping and should be positioned so they are easily read from vehicles.

Interior signs are grouped into three types: informational and directional, kiosks, and decorative. Informational and directional signs should be well designed, positioned, and lighted for easy reading by visitors. Signs should be consistent in shape, color, and the use of graphic elements.

Signs should be used where needed, but sparingly. Observations regarding the use of signs by the public indicate that visitors first use the building architecture whenever possible to find their way by relying on prominent features and landmarks. If architecture doesn't help them find their way, they will ask other visitors or staff where to go. As a last resort, people look for signs. A building map that is easy to read and understand is also suggested.

Kiosks may be used to provide directional maps, ticket and pricing information, and photographic images of center attractions, videos, and coming events. One advantage of this form of information presentation is that a lot of information about the center can be centralized in a relatively small area.

Decorative signs can also be used. These consist of either posters or banners to advertise coming attractions or purely for aesthetic purposes. They are typically displayed on walls or hung from ceilings. A variety of decorative banners or flags should be designed and used on special occasions to create a festive and decorative atmosphere. The designer should give consideration to both visual and audio sign displays. These signs could be passive or interactive as required in the overall design presentation.

The interior of the new Augusta NSC should reflect the use of modern construction techniques and materials. A coordinated system using a restricted color palette and spot lights with a preselected palette of colors should be considered. Gray or other neutral colors should be considered for background areas such as carpeting, ceilings, and nonessential parts of displays while using colors as accents on important parts of displays.

Lighting should be used to focus attention on the exhibits and items displayed. The premise is one of lighting the exhibits with direct, focused light while reducing ambient light levels in the surrounding areas. This creates a dramatic effect similar to a theatrical setting by drawing attention to the lighted displays and away from surrounding less important areas. This approach is also effective in reducing visual clutter by hiding unattractive ceiling and other background elements. These may be painted dark grey or black to reduce the visual impact in the space.

The down side of this approach, however, is that it can be overdone and carried to extremes, by creating too much contrast between exhibits and surrounding background areas. This contrast can lead to eye fatigue. This lighting method can also result in light levels that are too low in areas such as stairways and ramps, leading to safety problems.

Wall to wall carpeting is recommended for use throughout most of the center with vinyl, ceramic tile, or similar floor coverings recommended for areas that receive heavy traffic. Carpet material should be of such quality as to allow maximum life for a heavy traffic area. Dark shades of carpeting are recommended. The heavy wear areas should be of lighter shades than that of the carpet.

Ceilings should be of lay-in acoustical tile to reduce noise and visual pollution.

Permanent and modular (movable) walls should be of a durable material to allow maximum flexibility for display support, longevity, and visual aesthetics.

Interior atriums and other public areas should allow the use of graphic banners and other temporary and permanent information signs. These areas should also have adequate shading devices to minimize excessive heat/cooling gain and/or loss.

Exhibits and displays can be extremely varied in their design and use of materials, color, and texture. The trend, however, is away from the more traditional museum aesthetic of "hands-off, behind-the-glass" exhibits to more hands-on interactive displays and devices. The success of the Exploratorium in San Francisco is attributed, in part, to the ability of visitors to handle and use items on display. Essentially this same philosophy is practiced by the Ontario Science Center and the La Villette Centre. Several of the Ontario center exhibits use a unistrut metal system, wooden beams, and other architectural interior elements to create the feeling of a more comfortable space. The La Villette facility is one large operating interior organism where the structure of the building is both functional and incorporated as an

aesthetic device and display presentation. These techniques should be considered for the new science center building.

Displays should be as user friendly as possible and should be compatible with interior building architecture, allowing for maximum flexibility in patron usage and servicing.

Exhibits that attract attention first are those that use sound, light, and scale and that stand out from surrounding exhibits. At Indianapolis, this was perceived as a problem because visitors would "leap-frog" ahead, bypassing important exhibits along the way. However, at La Villette, these devices are used to enhance the architectural life, variety, and character of the spaces.

The new National Science Center Complex shall be designed to incorporate and adhere as close as possible, but not be limited to, the energy efficient design standards, set forth by ASHRAE and detailed in Appendix B. The architectural and engineering designers will be encouraged and requested to present concepts that are energy conscious and creative while addressing general principles of effective building design through the use of building and site orientation, architectural shape, scale, massing, skin, and innovative construction methods and building systems.

3 FACILITY DESIGN PROGRAM SUMMARY

The Facility Design Program for the National Science Center is both a quantitative and qualitative analysis of the physical spaces necessary to carry out the programs of the Center. The program itemizes every space that is included in the complex and provides a functional description for each space and its critical design criteria, such as the need for special power, plumbing, mechanical exhaust, security, acoustical separation, etc.

Net square footage is shown for individual spaces. Net area is defined as usable space, including mechanical and electrical rooms. It does not include wall thicknesses, circulation areas, stairs, elevators, etc. The gross area, which is used to determine the estimated construction cost, is defined as the total enclosed building area contained within the outer surfaces of the exterior walls. The gross area is estimated at 1.3 times the net area.

The Facility Design Program Summary, below, provides a listing of the major building facilities with required square footage. The Facility Design Program Outline (Chapter 4), breaks out the spaces in more detail showing the major building facilities with required areas and square footage. The Facility Design Program Requirements (Chapter 5), expands the information to include detailed program requirements and design criteria for the National Science Center.

	<u>Net Sq Ft*</u>
1. Visitor Services Facilities	10,950
2. Exhibition Areas	50,000
3. Education Areas	8270
4. Programs	400
5. Exhibit Support Facilities	7930
6. Education and Technology Department	3170
7. Administrative Facilities	6765
8. Building Services Facilities	8695
Total Net Area	96,180
Total Circulation Area (@ 85% efficiency)	16,973
Total Gross Area	113,153

* A metric conversion table is on page 38.

4 FACILITY DESIGN PROGRAM OUTLINE

1. Visitor Service Facilities	Net Sq Ft
1.1 Vehicles	
1.1.1 Covered Automobile Dropoff	
1.1.2 Parking	250 cars 10 buses
1.2 Lobby/Ticketing/Information	3450
1.3 Visitors Coat Storage Areas	550
1.3.1 Locker Storage Area	(150)*
1.3.2 School Group Coat Storage	(250)
1.3.3 Public Coat Storage Room	(150)
1.4 National Science Center Store	2125
1.4.1 Sales Area	(1100)
1.4.2 Inventory Storage	(600)
1.4.3 Office for Manager	(150)
1.4.4 Work Area	(200)
1.4.5 Office for Assistant Museum Shop Manager	(75)
1.5 Food Service Areas	2825**
1.5.1 Dining Area to Serve 120 @ 14 sq ft each	(1680)
1.5.2 Private Dining Area to Serve 12 @ 14 sq ft each	(170)
1.5.3 Kitchen	(625)
1.5.4 Office for Food Service Manager	(100)
1.5.5 Catering Kitchen	(250)
1.6 First Aid Area	80
1.7 Public Toilets	1500
1.8 Office for Supervisor of Visitor Services	120
1.9 Office for Volunteer Coordinator	150
1.10 Office for Box Office Coordinator	75
1.11 Work Station for Telephone Operator	75
Subtotal of Visitor Service Facilities:	10,950

* Numbers in parentheses are the square footages for individual items in a category.

** Area to be expandable into exterior secured courtyard dining for brown bag lunch and picnicking.

2. Exhibition Areas

2.1 Long Term Exhibition Areas	42,000
2.1.1 Fundamental Principles	(16,000)
2.1.2 Core Technologies	(14,000)
2.1.3 Real World Applications	(12,000)
2.2 Young Scientist Area	3000
2.3 Temporary Exhibition Areas	5000
2.4 Mobile Exhibits*	
Subtotal of Exhibition Areas:	50,000

3. Education Areas

3.1 Multi-purpose/Classrooms (@ 500 sq ft each)	1500
3.2 Theater	6770
3.2.1 Queuing Area	(1000)
3.2.2 Projection Equipment Room	(850)
3.2.3 Seating Area, + 300 seats	(4570)
3.2.4 General Storage	(350)
Subtotal of Education Areas:	8270

4. Programs

4.1 Office for the Director of Research and Special Projects	150
4.2 Office for Secretary to Director	120
4.3 Conference Room	130
Subtotal of Programs:	400

5. Exhibit Support Facilities

5.1 Office for Exhibit	150
5.2 Exhibit/Graphic Design Studio	800
5.3 Office for Exhibit Production Supervisor	120
5.4 Reception/Clerical Work Area	120
5.5 Exhibit Design Supplies Storage	100

* The Mobile Exhibits are to be integrated in the proposed facility. USACERL is currently engaged in research that will develop and model prototype facilities intended to be used as Mobile Exhibits. For the purposes of this program, the designer should be aware of the need to have a facility that will support the function of Mobile Exhibits in the form of transportable facility types.

5.6 Exhibit Darkroom Projection Area	100
5.7 Graphic Production Facilities	800
5.7.1 General Work Area	(300)
5.7.2 Silkscreening Area	(300)
5.7.3 Darkroom	(200)
5.8 Carpentry Shop	1320
5.8.1 Carpentry Work Area	(1000)
5.8.2 Building Materials Storage	(200)
5.8.3 Office and Reference Area	(120)
5.9 Painting Facilities	350
5.9.1 Painting Area	(150)
5.9.2 Drying Area	(150)
5.9.3 Paint Storage Area	(50)
5.10 Technical Maintenance	1320
5.10.1 Repair and Maintenance Shop	(500)
5.10.2 Audiovisual and Electronics Parts Storage	(100)
5.10.3 Audiovisual and Electronics Equipment Storage	(200)
5.10.4 Exhibit Audiovisual/Computer Control Room	(400)
5.10.5 Office for Electronics/Audiovisual/Computer Coordinator	(120)
5.11 Exhibit Staging and Clean Assembly Area	1500
5.12 Exhibit Prop Storage Area	650
5.13 Short Term Crating Area	600
Subtotal of Exhibit Support Facilities:	7930

6. Education and Technology Department

6.1 Office for Chief, Education and Technology	150
6.2 Office for Education Outreach Manager	75
6.3 Office for Education Technology Manager	75
6.4 Office for Professional Development/Workshop Manager	75
6.5 Office for Education Specialist/Resource Center	75
6.6 Office for Electronics Program Manager	75
6.7 Office for Specialists (3 offices)	225
6.8 Office for Education Technician/Typing	75
6.9 Secretary/Steno	75
6.10 Work Area for Exhibition Areas Lecturer, Demonstrators, Science Teaching Instructors, and Outreach Program Presenters (8 @ 75 sq ft each)	600
6.11 Conference Room for Education Staff	200
6.12 Education Prop/Artifact Storage	300

6.13 Education Outreach Equipment Storage	100
6.14 Resource Center	800
6.15 Visiting Fellows Office	150
6.16 Reception/Clerical Work Areas	120

Subtotal of Education and Technology Department: 3170

7. Administrative Facilities

7.1 Office of the Discovery Center	450
7.1.1 Chief, Discovery Center (Deputy Director, National Science Center)	(200)
7.1.2 Research and Special Projects Officer	(150)
7.1.3 Secretary/Steno	(100)

7.2 Administrative Department	175
7.2.1 Resource Management Clerk - in area for accounting clerk and cash control	(100)
7.2.2 Supply Clerk	(75)

7.3 Exhibits and Special Programs Department	1275
7.3.1 Chief, Exhibits and Special Programs	(200)
7.3.2 Exhibits Manager	(200)
7.3.3 Exhibit Maintenance Officer - in Exhibit Maintenance area	(150)
7.3.4 Lead Education Specialist	(200)
7.3.5 Science Education Specialist/Special Programs	(100)
7.3.6 Science Education Specialist/Traveling Programs	(100)
7.3.7 Science Education Specialist/Volunteer Coordinator - near Volunteer Office/Lounge area	(100)
7.3.8 Secretary/Typing	(75)
7.3.9 Clerk/Typist/Receptionist - located near entrance	(75)
7.3.10 Visual Information Specialist - in Graphics area	(75)

7.4 Engineering and Automation Department	1075
7.4.1 Chief, Engineering and Automation	(200)
7.4.2 Computer Specialist - in Computer Maintenance area	(100)
7.4.3 Computer Technician - in Computer Maintenance area	(100)
7.4.4 Computer Program Analyst	(100)
7.4.5 Computer Specialist (data base)	(100)
7.4.6 Computer Specialist - in Exhibits area	(100)
7.4.7 Building Manager - near Maintenance and Building Services area	(200)
7.4.8 Electronic Technician - in Exhibits area	(100)
7.4.9 Secretary/Typing	(75)

7.5 Challenger Center	1480
7.5.1 Manager, Challenger Center Program (office/workroom)	(200)
7.5.2 Space Station and Mission Control	(1280)

7.6 Work Area for Accounts Payable Clerk, Payroll Clerk, General Ledger Clerk, and Accounting Clerk	225
7.7 Administration Reception Area	150
7.8 Board Room	700
7.9 Copy Machine/Mail Room	125
7.10 Staff/Docent/Volunteer Lounge	600
7.11 Staff Toilets	400
7.12 Executive Kitchenette Area	110
Subtotal of Administrative Facilities:	6765
 8. Building Services Facilities	
8.1 Office for Building Services Supervisor and Assistant	175
8.2 Building Services Workshop/Storage	600
8.3 Security Control Room	120
8.4 Custodial Storage	200
8.5 Outdoor Maintenance Storage	200
8.6 Lockers/Shower/Toilets	300
8.7 Receiving Area/Loading Docks	600
8.8 Mechanical/Electrical Rooms	6500
Subtotal of Building Services Facilities:	8695
 TOTAL NET AREA	 96,180

5 FACILITY DESIGN PROGRAM REQUIREMENTS

1. Visitor Service Facilities

The extent to which visitor service areas are well run and efficient is probably indicative of how well the Center itself functions for the public. The number of visitors at science centers can be extremely high (as many as 20,000 visitors a day). The facility must be completely barrier free to provide unrestricted handicapped accessibility.

1.1 Vehicles

1.1.1 Covered Automobile Dropoff. Private automobile and school bus drop-off areas must be provided at the Center. These should be readily accessible and clearly visible for vehicle operators. School bus unloading areas should be located in low traffic areas to the side or rear of the building and away from the main entrances. Covered pedestrian entry ways are also suggested.

1.1.2 Parking. Parking should be conveniently located a short distance from the building. It is recommended that a minimum of 250 parking spaces be provided. Parking spaces for 10 buses should also be provided away from the main entrance but readily accessible.

Function: Covered area where visitors can be dropped off from buses and other vehicles.

Critical Criteria: Adjacent to main public entry.

1.2 Lobby/Ticketing/Information

3450 sq ft

Front door ticket counters must be readily accessible. The ticket counter should not be too close to the main entrance and should provide sufficient queuing area for people waiting to get tickets. These areas should also provide adequate information about the exhibits, admission prices, and related data.

Ticketing and information areas can be separated or combined and there is no apparent advantage of one over the other. Information areas providing box office and center scheduling information should be provided. The lobby offers the opportunity to introduce the visitor to the facility by becoming somewhat of an exhibit itself.

Since people will naturally gather here (by choice or necessity) the lobby should take advantage of this audience.

Function: Main entry/orientation area, with directional and information signage, for public visitors. Area to sell admission tickets to special exhibits and other activities such as the Theater, and provide information regarding the National Science Center programs, memberships, daily events, etc. From this space visitors may proceed to various program areas or be escorted to support areas. A portable information kiosk can be set up within this area for peak visitation days.

Critical Criteria:

- Accessible directly from main public entrance.
- The following areas should be accessible from this space: Exhibition Areas, Discovery Room, Classrooms, Theater, and National Science Center Store Sales Area.

- Accessible public seating and rest areas should be provided throughout the Science Center facility.
- Public seating should be provided at strategic locations. A quiet, private seating and rest area for nursing mothers should be considered.

1.3 Visitors Coat Storage Areas

550 sq ft

Pigeon hole or other storage cabinets for children's school books, coats, and boots should also be provided at the center. Public coat storage rooms should be considered as well as rental strollers for small children.

1.3.1 Locker Storage Area	(150 sq ft)
1.3.2 School Group Coat Storage	(250 sq ft)
1.3.3 Public Coat Storage Room	(150 sq ft)

Function:

- Area for lockers where visitors can store packages, umbrellas, etc.
- Lockable storage cubicles for coat storage for individual classes visiting the Center.
- Area for general public coat storage.

Critical Criteria:

- Accessible from Lobby/Ticketing/Information area.
- Accessible from Young Scientist Area (see item 2.2) and Classroom.
- Accessible from Lobby.

1.4 National Science Center Store

2125 sq ft

A Center store, accessible to lobby and entry way areas, is recommended and visitors should have access without entering the Center proper. The store should be well lit and create an inviting atmosphere through design and display of merchandise. Public access should be controlled by a single entry into the store.

An open store layout should be considered to provide maximum flexibility. Merchandise and display designs should be coordinated with exhibits to bring about an interesting synergistic relationship between the store and exhibit areas. The store should become an extension of the exhibit areas and provide entertainment for visitors who may wish to try out many of the science oriented gifts displayed.

1.4.1 Sales Area	(1100 sq ft)
1.4.2 Inventory Storage	(600 sq ft)
1.4.3 Office for Manager	(150 sq ft)
1.4.4 Work Area	(200 sq ft)
1.4.5 Office for Assistant Museum Shop Manager	(75 sq ft)

Function: Area for sale of books, posters, cards, slides, games, science experiments, etc., related to the National Science Center programs; inventory storage; and staff work areas.

Critical Criteria:

- Sales Area should be directly accessible from the Lobby.
- Office for either Manager or Assistant Manager and the Work Area should be contiguous to the Sales Area.
- Vault storage for daily cash receipts in Office for Manager.
- Plumbing and water service in Work Area.

1.5 Food Service Areas

2825 sq ft*

Two separate dining facilities should be available in the center for visitors: a full-service cafeteria with public and private dining rooms as well as an indoor/outdoor secured picnic/dining area. The full-service cafeteria should be run by a contractor, not by the Science Center, and should include a small kitchen for catering receptions for exhibition openings and other special events. The indoor and outdoor sack lunch areas should be maintained by the Science Center. Orientation for the full-service cafeteria should be northeast and should provide a view of the natural environment.

Function: Area to prepare and serve food and refreshments to National Science Center visitors and staff. This function would be a franchised service rather than a museum operated facility.

1.5.1 Dining Area to serve 120	(1680 sq ft)
1.5.2 Private Dining Area to serve 12	(170 sq ft)
1.5.3 Kitchen	(625 sq ft)
1.5.4 Office for Food Service Manager	(100 sq ft)
1.5.5 Small kitchen for catering receptions for exhibition openings and other special events	(250 sq ft)

Critical Criteria:

- The Dining Areas should be accessible from the Exhibition Areas.
- The semipublic dining area should be able to be used as a private dining room or become a part of the main Dining Area.
- The Kitchen should be accessible to the Receiving Area.
- Plumbing and water service in Kitchen.
- Floor sloped to drain in Kitchen.
- Adequate ventilation to exhaust food odors out of building.
- Directly accessible to the Receiving Area with access to other areas of the building by means of a freight elevator.
- Plumbing and water service.
- 110/220 electrical service with outlets around perimeter of room.
- Equipment to include large stove and warming oven, large microwave oven, food preparation work area, double sink and water service with garbage disposal, large refrigerator.
- Nonskid floor surface sloped to drains.

* Area to be expandable into exterior secured courtyard dining for brown bag lunch and picnicking.

1.6 First Aid Area (combined with Office for Assistant Supervisor of Visitor Services) 80 sq ft

A first aid area should be provided for museum visitors and staff.

Function: Area to provide assistance to Museum visitors.

1.7 Public Toilets 1500 sq ft

These facilities should be located near the security area. Changing tables should be provided in both male and female toilets for persons with small children.

Function: Toilet facilities for Museum visitors.

Critical Criteria:

- Some toilet facilities should be directly accessible from the Lobby; others should be accessible from the Exhibition Areas.
- Men's toilet facilities: 4 urinals, 9 water closets, and 5 lavatories with mirrors.
- Women's toilet facilities: 14 water closets and 6 lavatories with mirrors.
- Plumbing and water services.
- One water closet and one lavatory in each restroom must be accessible to the handicapped.
- Nonskid floor surface sloped to drains.

1.8 Office for Supervisor of Visitor Services 120 sq ft

Offices for staff related to Visitor Services must be located close to lobby to provide easy access without having to enter exhibition spaces.

Function: Work area for Supervisor of Visitor Services.

Critical Criteria: Accessible to Administration, Exhibit, and Education staff.

1.9 Office for Volunteer Coordinator 150 sq ft

Volunteer staff will likely be needed to help support the center, especially on weekends. Volunteers can serve as "visitor aids" (explainers) and guides, work at information desks, stores, collections areas, etc. The friendliness and outgoing nature of these volunteers are essential to a well run facility.

Function: Work and meeting area for Volunteer Coordinator.

Critical Criteria: Accessible to Administration, Exhibit, and Education staff.

1.10 Office for Box Office Coordinator 75 sq ft

Function: Work area for Box Office Scheduling Coordinator.

Critical Criteria: Accessible to Administration, Exhibit, and Education staff.

1.11 Work Station for Telephone Operator 75 sq ft

Function: Work area for Telephone Operator.

Critical Criteria: Accessible to Administration, Exhibit, and Education staff.

Subtotal Visitor Service Facilities: 10,950 sq ft

2. Exhibition Areas

Exhibition areas should be essentially generic spaces with the exhibits creating defined interior spaces and atmosphere. These areas can include low, fixed partitions as well as movable partitions.

The exhibit theme recommended is the open plan that uses strategically located displays and products within a larger open space using color, texture, and lights to focus attention on the exhibits and away from surrounding ambient and more neutral areas (i.e., walls, floors, and ceilings).

Installing new exhibits and moving existing ones for repair or maintenance will be accomplished by using a variety of dollies, hand trucks, and carts as well as hand carrying methods. Fork lifts will be used to move larger exhibit areas. This will require the use of loading docks, freight elevators, and 12-foot wide corridors for moving large equipment and displays. Knockout or movable walls will be necessary in certain areas for extremely large items and large exhibits. Cabling or plumbing should not be located in areas where they would have to be disconnected and removed to move large exhibits.

The safety of visitors is an important concern. Staff should look for hazards associated with the exhibits, which must be designed with maximum safety in mind. Misuse of a display or device must always be considered. Most serious accidents in centers have been associated with stairways, ramps, and escalators. Older patrons and children appear to be the most likely to be injured in these areas.

2.1 Long Term Exhibition Area 42,000 sq ft

2.1.1 Fundamental Principles (16,000 sq ft)

2.1.2 Core Technologies (14,000 sq ft)

2.1.3 Real World Applications (12,000 sq ft)

2.2 Young Scientist Area 3000 sq ft

Function: Exhibition areas for the National Science Center's long term exhibits.

Critical Criteria:

- Accessible from Lobby.
- Accessible to Exhibit Support Facilities.
- A 12 ft by 12 ft roll-up door for each above-ground level; all openings connecting the exhibition areas to be a minimum of 12 ft by 12 ft.
- Ceiling heights should vary from a minimum of approximately 12 ft to as high as 40 ft.
- Flexible incandescent track lighting.
- Permanent lighting system for cleaning operations separately switched from the exhibit lighting circuits.

- Flexible electrical power distribution system from the floor level using an under-carpet flat wiring system, and from above by an electrical bus duct power distribution system. Cost analysis should be performed using raised flooring vs. flat wiring to ensure the most beneficial solution.
- Plumbing and water service to selected areas.
- Provision should be made for a computer distribution system that would encompass all of these exhibition areas and tie into the Exhibit Audiovisual/Computer Control Room.
- Floor loading should be 150 lb per sq ft.
- Natural light should be excluded within most exhibition areas. Where natural light is introduced, it should be done in a limited and controllable manner and related to a specific exhibit area.
- The ability to close off the Exhibition Areas in the evening when visitors are using other public program facilities should be provided.

2.3 Temporary Exhibition Areas

5000 sq ft

Exhibition areas may include both permanent and temporary traveling exhibitions and the center should be designed to accommodate temporary (traveling) exhibits. Generally, these are elaborate and are well designed and constructed. The new center will showcase these newer displays in order to attract visitors.

It is recommended that the new center always have a certain percentage of new exhibits on display. This is a way to try new ideas and improvements. These eclectic areas can become very popular attractions.

Function: Exhibition areas for major traveling shows.

Critical Criteria:

- Accessible from Lobby.
- Accessible to Exhibit Support Facilities.
- Flexible incandescent track lighting.
- A permanent lighting system for cleaning operations, separately switched from the exhibit lighting circuits.
- Ceiling height of approximately 16 ft.
- Ability to subdivide this space with a movable wall system.
- Floor loading should be 150 pounds per sq ft.
- Flexible electrical power distribution system from the floor level using an under-carpet flat wiring system, and from above by an electrical bus duct power distribution system. Cost analysis should be performed to compare raised flooring vs. flat wiring to ensure the most beneficial solution.
- Flexible high security system.
- Ability to control access by both the general public and staff.
- Provision should be made for a computer distribution system that will tie into the Exhibit Audiovisual/Computer Control Room.
- It should be possible to close off all or part of these exhibition areas during transitional periods and when the public is using other program facilities.

2.4 Mobile Exhibits

Mobile exhibits will be housed in transportable facilities consisting of "containerized" exhibits that are either motorized, like vans, or stand alone on wheels, such as trailers or box containers on trailers. These types of exhibits will have a direct connection to the main Science Center facilities, which allow their use while at the Center, as well as to aid in the expedient deployment to remote locations. Further research on transportable facilities for the National Science Center is proposed.

Function: This component of the National Science Center complex will help the Center in a national outreach program which is part of the Center's mission. The transportable facility will provide a system that allows several of the mobile exhibits to assemble and establish remote, self-supporting integrated facilities for public display.

Critical Criteria:

- **Parking and Roadway Network:** It is imperative that both pedestrian and vehicle circulation allow for both the use of these facilities while at the Center and easy dispatch and rotation of these transportable facilities.
- **Interface Area/Corridor:** A space connecting the main display areas must be provided to allow access to transportable facilities while they are located at the Science Center.
- **Exterior Closure:** Standardized containers shall have the advantage of being compatible with a variety of transportation vehicles and systems (e.g., road, rail, ship, and airplane). These containers will be equipped with standard fittings and towing eyes, and provide enclosures that are durable, lightweight, and waterproof. Note: standard fixed-axle semitrailer type containers are not acceptable.
- **Interior Construction:** Mobile exhibits consist of modular building blocks (MBB) and a standard packing approach, which allows for different classes of exhibits and electronic systems to be used interchangeably.
- **Furnishings:** Minimal use of lightweight chairs and tables; modular containers for tool and support equipment storage.
- **Electrical:** Use of home port system when at the Center; self-contained systems requiring plug-in external electrical power interfaces when in the field.
- **Mechanical/HVAC:** See electrical above for criteria.
- **Fire Protection:** Fire extinguishers.

Subtotal Exhibition Areas: 50,000 sq ft

3. Education Areas

3.1 Multipurpose/Classrooms (3 @ 500 sq ft each) 1500 sq ft

Multipurpose classrooms should be provided for smaller presentations, lectures, and discussions as well as audiovisual presentations.

Function: Area for daytime and evening classes and demonstrations related to the National Science Center programs, for training sessions, and for use by outside groups with interests related to the National Science Center programs.

Critical Criteria:

- Ability to combine all three rooms by moving the walls to achieve one room of 1500 sq ft.
- Ability to use in the evening without opening Exhibition Areas.
- Plumbing and water service in each room.
- Gas outlet and vent in each room.
- Flexible fume hood at teaching station at one end of each room.
- Electrical convenience outlets located approximately 3 ft on-center around perimeter of room.
- Ability to achieve total darkness for audiovisual presentations.

- Ceiling height of approximately 12 ft.
- Dimmable incandescent lighting supplemented by incandescent track lighting for display surfaces.

3.2 Theater

6770 sq ft

A theater facility shall be provided to allow for unique educational opportunities. A 300-seat theater for multimedia slide and audiovisual programs is recommended.

3.2.1 Queuing Area	(1000 sq ft)
3.2.2 Projection Equipment Room	(850 sq ft)
3.2.3 Seating Area for 300 seats	(4570 sq ft)
3.2.4 General Storage	(350 sq ft)

Function: Area for daytime and evening presentation of films.

Critical Criteria:

- Projection Equipment Room requires the following temperature and humidity ranges to be maintained 24 hours per day, 365 days per year: 65 to 80 °F temperature range; 40 to 60 percent relative humidity range.
- Equipment Room requires the following temperature and humidity ranges: 65 to 80 °F temperature range; 75 percent maximum relative humidity.
- Projector: Power supplied from electrical control cabinet. Air exhaust 800 cubic feet per minute (cfm) minimum from 8-in. outlet, at a minimum of 0.6-in. water static pressure (suction) at the projector. (Note high suction pressure required.)
- Projector Exhaust Fan: Induced draft (suction) fan to be provided. Fan must be rated to remove 800 cfm through lamphouse restriction (0.6-in. water static pressure) in addition to duct and all other losses.
- Electrical Control Cabinet: Mounted on coolant conditioning unit. Requires 120/208-volt, 3-phase, 4-wire, 60-Hz, 100-ampere supply circuit.
- Control Console: Separate unit, floor-mounted adjacent to the projector. Power supplied from the electrical control cabinet.
- Rectifier: Requires 208-volt, 3-phase, 3-wire, 60-Hz, 175-ampere supply circuit. Heat rejection to room approximately 6 kilowatts (kW). Cooling air flow induced by integral fan; recirculates 1200 cfm room air.
- Coolant Conditioning Unit: Power supplied from electrical control cabinet. Heat exchanger requires 10 gal/min minimum cooling water, at maximum inlet temperature of 70 °F and minimum pressure of 20 psi. Suitable drain or return provision required for this water.
- Air Compressor: Requires 208-volt AC, 3-phase, 3-wire, 60-Hz, 40-ampere supply circuit. Air intake requires 30 cfm at 65 percent maximum relative humidity. The cylinder head and after-cooler require 2 gpm maximum water at 70 °F maximum and 20 psi minimum. Drain provision required for this water.
- Air Receiver: Requires 120 gal capacity. Vertical tank approximately 24-in. diameter by 78-in. high, working pressure 150 psi.
- Electrical Supply: Voltage regulation must not be poorer than plus or minus 5 percent of normal supply voltage.
- Projector:
 - Movement Type - Horizontal rolling loop film transport with fixed pin registration at the aperture.
 - Format - 1.96- by 2.74-in. projection aperture, 15 perforations per frame, 24 frames per sec.

- Film - 70-mm motion picture film. Kodak standard 0.1870-in. perforation pitch, Estar base.
- Illumination System - Horizontal lamphouse, accepts 15,000-watt Xenon short-arc lamp. Includes air-cooled ellipse-based collector mirror, complete starting circuitry, cooling flow controls, dowsers, and safety interlocks. Water-cooling to lamp electrodes and two beam-folding dielectric-coated cold mirrors.
- Lens - Leitz C430 180-degree fisheye, 13-element lens, f/2.8, 25-mm focal length, especially designed for the Omnimax format.
- Reel Unit: Film Feed and Takeup - Reel unit equipped with two pairs of 48-in. diameter horizontal feed and takeup reels.
- Sound Equipment: Projector is equipped with an integral six-track magnetic sound head.
- Auxiliary Equipment: Rectifier - 450 ampere, 40 volt DC, 15 kW power output (100 volt DC minimum open circuit voltage); integral fan cooling; heat rejection to room approximately 6 kW maximum. Unit should be 57-in. wide by 22-in. deep by 34-in. high.
 - Coolant Conditioning Unit - Closed circuit distilled water system; turbine pump; filter, deionizer; heat exchanger; flow, pressure, temperature, and level meters; and control interlocks. Requires cooling water and suitable drain. Approximately 54 in. wide by 24 in. deep by 42 in. high.
 - Air Compressor - 10 hp (7 kW) oil-free compressor, 30 cfm free-air capacity, 100 psi delivery pressure. Requires cooling water for cylinder head and after-cooler, and suitable drain. Approximately 26 in. wide by 56 in. long by 44 in. high.
 - Elevator and Projection Port - to fit the Omnimax projector into the theater, the projection room is located under the seating area. The projector is equipped with a power-driven elevator; an automatic power-driven projection lens port cover; and flexible power, control, air, and exhaust connections. This allows the projector to rise from the projection room into operating position in a compact housing in the theater.
- Sound System: Each channel of the sound system shall be capable of producing a sustained program level of 95 dBA at the center of the seating area when measured with pink noise 300 Hz to 8 kHz, and shall provide 20 dB of headroom before clipping above this level.

Subtotal Education Areas:

8270 sq ft

4. Programs

4.1 Office for the Director of Research and Special Projects

150 sq ft

Function: Work area for the Director.

Critical Criteria: Accessible to Administration, Exhibit, and Education staff.

4.2 Office for the Secretary to the Director of Research and Programs

120 sq ft

Function: Work area for the Secretary to the Director of Research and Programs.

Critical Criteria: Accessible to the Director of Research and Programs.

130 sq ft

4.3 Conference Room

Critical Criteria: Adjacent to Director's office.

Subtotal Programs Area:

400 sq ft

5. Exhibit Support Facilities

5.1 Office for Exhibit 150 sq ft

Exhibit design is considered a team effort. Design is usually accomplished by having a larger team contribute initial ideas and suggestions and as ideas become more fixed, streamlining the team for final design and execution. The facility design should facilitate this kind of interaction.

Function: Work area for the Exhibit Design Director.

Critical Criteria: Accessible to Administration, Exhibit, and Education staff.

5.2 Exhibit/Graphic Design Studio 800 sq ft

The graphic design studios should have silk screening, photographic, light carpentry, painting facilities (including a spray booth and drying area), staging and prop area, and access to crating and shipping facilities.

The ratio of maintenance time to time spent on development of new designs varies greatly depending on the complexity of the exhibit design. The following percentages of time are estimated. For electronic exhibits, 80 percent of exhibit staff time is spent maintaining the exhibit and 20 percent is devoted to developing new ideas. With metal exhibits, the percent of maintenance time to new design development is estimated at 50/50. For wood exhibits, the percentages are 10 percent for maintenance and 90 percent for new design effort.

Function: Work areas for the exhibit and graphic design staff.

Critical Criteria:

- Accessible to Exhibit Design Director.
- Natural light.
- Small sink and water service.

5.3 Office for Exhibit Production Supervisor 120 sq ft

Function: Work area for the Exhibit Production Supervisor.

Critical Criteria: Accessible to exhibit production facilities.

5.4 Reception/Clerical Work Area 120 sq ft

Function: Work area for Exhibition Department clerical staff and control point for access to the exhibit design and planning staff.

Critical Criteria: Accessible to Administration, Exhibit, and Education staff.

5.5 Exhibit Design Supplies Storage 100 sq ft

Function: Area for secure storage of exhibit support staff supplies.

Critical Criteria:

- Accessible to exhibit design staff.
- Controlled access to a secure storage area.

5.6 Exhibit Darkroom Projection Area 100 sq ft

Function: Area that can be darkened for projection of images that will be used in developing/creating exhibit backdrops, graphics, etc.

Critical Criteria:

- Accessible to exhibit design staff.
- Ability to darken room for projection purposes.

5.7 Graphic Production Facilities 800 sq ft

5.7.1 General Work Area	(300 sq ft)
5.7.2 Silkscreening Area	(300 sq ft)
5.7.3 Darkroom	(200 sq ft)

Function: Area for production of graphics for Science Center exhibits, publications, and signage.

Critical Criteria:

- Accessible to Exhibition Areas and other exhibition production facilities.
- Double-door access, clear opening of 10 ft by 10 ft to General Work Area and Silkscreening Area.
- 120 volt single-phase and 240 volt single-phase electrical service.
- Adequate ventilation to exhaust chemical fumes from building.
- Dust-free environment.
- Plumbing and water service to darkroom sink and a utility sink.
- Floors sloped to drains.

5.8 Carpentry Shop 1320 sq ft

Workshop facilities will be necessary in the new center. These should include woodworking and metal machine shop capabilities. Shop facilities will be used extensively. New exhibit construction may also be contracted out. Much of the exhibit research and design will be done in-house. Effective management and shop safety are critical for these facilities.

5.8.1 Carpentry Work Area	(1000 sq ft)
5.8.2 Building Materials Storage	(200 sq ft)
5.8.3 Office and Reference Area	(120 sq ft)

Function: Area for the fabrication of exhibit components and for storage of building materials.

Critical Criteria:

- Accessible to Exhibition Areas (particularly Temporary Exhibition Area) and other exhibit production facilities.
- Double-door access with a clear opening of 10 ft by 10 ft to Carpentry Work Area and building Materials Storage.
- Minimum ceiling height of 12 ft.
- Plumbing and water service to a utility sink.
- Dust collection system.
- 120/240 volt three-phase and 240 volt single-phase electrical service.

5.9 Painting Facilities

350 sq ft

Painting areas should include spray booth, drying area, and paint storage areas. These areas should be designed to provide quick color application for repair and new construction.

5.9.3 Painting Area and Spray Booth

(150 sq ft)

5.9.2 Drying Area

(150 sq ft)

5.9.3 Paint Storage Area

(50 sq ft)

Function: Area for painting and drying exhibit components, panels, etc., and for storage of paint and related supplies and materials.

Critical Criteria:

- Accessible to Exhibition Areas (particularly Temporary Exhibition Area) and other exhibit production facilities.
- Double-door access with a clear opening of 10 ft by 10 ft connecting Painting Area and Spray Booth, Drying Area, and an opening to a major service corridor.
- Two-hour fire-resistive rated construction in all paint areas.
- Explosion-proof electrical apparatus in Paint Spray Room and Paint Drying Area.
- Heavy duty exhaust system in Painting Area and Spray Booth.
- Plumbing and water service to a utility sink.
- Dust-free Drying Area.

5.10 Technical Maintenance

1320 sq ft

Depending on use, computers can have a life expectancy of about 3 years and then must then be replaced. Repair is a constant necessity and can be intense. Electronics technicians must be provided to maintain these exhibits. Flat wiring under carpeting is recommended. It is sometimes less expensive and more easily changed than a more permanent floor grid wiring system. Cost analysis should be performed to compare raised flooring versus flat wiring to ensure the most beneficial solution.

Audiovisual exhibits should be used sparingly. Exhibits that visitors can see and touch whenever possible are much more effective. Sound and pictures are abstractions and should only be used when it is not possible to demonstrate a particular principle. It should be noted that downtime on exhibits occurs most frequently with electronic exhibits, and the expense of maintaining some exhibits can be more than the cost to redesign them for more efficiency and less maintenance. The message is "do it right the first time."

Areas must be provided for audiovisual and electronics repair and maintenance, parts storage, and audiovisual and electronics equipment storage. These areas will receive heavy use in proportion to the amount of electronics work done in-house or contracted out.

5.10.1 Repair and Maintenance Shop	(500 sq ft)
5.10.2 Audiovisual and Electronics and Parts Storage	(100 sq ft)
5.10.3 Audiovisual and Electronics Equipment Storage	(200 sq ft)
5.10.4 Exhibit Audiovisual/Computer Control Room	(400 sq ft)
5.10.5 Office for Electronics/Audiovisual/Computer Coordinator	(120 sq ft)

Function: Work and storage area related to audiovisual equipment and components used in the exhibits and other National Science Center programs.

Critical Criteria:

- All Audiovisual and Electronics areas should be located together and be accessible to the Exhibition Areas.
- Compressed air service in the Repair and Maintenance Shop.
- Incandescent lighting in the Repair and Maintenance Shop.
- Dust-free environment in the Repair and Maintenance Shop and the Exhibit Audiovisual/Computer Control Room (mechanical exhaust to be outside so as to create a positive air pressure).
- Separate temperature and humidity controls in the Exhibit Audiovisual/Computer Control Room.
- Acoustical separation from other building areas for the Exhibit Audiovisual/Computer Control Room.
- The Exhibit Audiovisual/Computer Control Room should be connected to an emergency generator.
- Anti-static floor covering and grounded rubber mat at entrance to room in the Exhibit Audiovisual/Computer Control Room.

5.11 Exhibit Staging and Clean Assembly Area 1500 sq ft

An exhibit staging and clean assembly area is needed for final assembly and testing of exhibits before they are displayed for public use. This is important to work out exhibit design and safety problems in advance.

This is important space and should not be overlooked. It is not recommended that this activity be piggy-backed on other areas such as hallways and storage areas adjacent to workshops.

Function: Area for evaluation and selection of objects, colors, and graphics to be used in temporary exhibitions and for clean assembly work prior to moving finished exhibition components into the Exhibition Areas.

Critical Criteria:

- Good connection to Temporary Exhibition Areas.
- Double-door access with clear opening of 10 ft by 10 ft.
- Accessible to Long Term Exhibition Areas, Carpentry Shop, Painting Facilities, Graphic Production Facilities, Audiovisual and Electronics Areas, Exhibit Prop Storage Area, and Crating and Crate Storage Area.
- Plumbing and water service.
- Incandescent track lighting to duplicate lighting conditions of Exhibition Areas.

5.12 Exhibit Prop Storage Area 650 sq ft

The center should provide storage to meet a variety of needs including the following: temporary exhibits; displays to be repaired, crated, uncrated, and shipped; permanent center collections; workshop supplies such as wood and metal; expendable office supplies; surplus exhibit and display parts; spare

building parts; and equipment to support evening activities (tables, chairs, portable bar, etc.). The amount of space needed is directly related to the size of the center and the number of repair and construction activities provided in-house versus those contracted out. General, multipurpose storage space shall be provided for the facility.

Function: Area for storage of exhibit components such as cases, lighting fixtures, panels, etc.

Critical Criteria:

- Accessible to Exhibit Staging Area.
- Double-door access with a clear opening of 10 ft by 10 ft.

5.13 Short Term Crating and Crate Storage Area 600 sq ft

Function: Area for crating and uncrating exhibit objects and components and for the storage of crates for major traveling shows.

Critical Criteria:

- Adjacent to Receiving Area.
- Good connection to Exhibit Staging Area.
- Ability to secure this area.

Subtotal Exhibit Support Facilities: 7930 sq ft

6. Education and Technology Department

6.1 Office for Chief, Education and Technology 150 sq ft

Function: Work area for the Education Programs Director.

Critical Criteria: Accessible to Administration, Exhibit, and Education staff.

6.2 Office for Education Outreach Manager 75 sq ft

Outreach activities will be an essential part of the mission of the facility. A primary purpose will be to engage the elementary and high school students of the community, region, and nation through the use of a mobile exhibit program.

Function: Work area for the Education Outreach Manager.

Critical Criteria: Accessible to Chief, Education and Technology.

6.3 Office for Education Technology Manager 75 sq ft

Function: Work area for the Education Technology Manager.

Critical Criteria: Accessible to Chief, Education and Technology.

- 6.4 Office for Professional Development/Workshop Manager 75 sq ft
Function: Work area for the Professional Development/Workshop Manager.
Critical Criteria: Accessible to Chief, Education and Technology.
- 6.5 Office for Education Specialist/Resource Center 75 sq ft
Function: Work area for the Education Specialist/Resource Center.
Critical Criteria: Accessible to Chief, Education and Technology.
- 6.6 Office for Electronics Program Manager 75 sq ft
Function: Work area for the Electronics Program Manager.
Critical Criteria: Accessible to Chief, Education and Technology.
- 6.7 Office for Specialists (3 offices) 225 sq ft
Function: Work area for specialists.
Critical Criteria: Accessible to Chief, Education and Technology.
- 6.8 Office for Education Technician/Typing 75 sq ft
Function: Work area for specialists.
Critical Criteria: Accessible to Chief, Education and Technology.
- 6.9 Secretary/Steno 75 sq ft
Function: Work area for secretary.
Critical Criteria: Accessible to Chief, Education and Technology.
- 6.10 Work Area for Exhibition Areas Lecturer/Demonstrators, Science Teaching Instructors and Outreach Program Presenters (8 @ 75 sq ft each) 600 sq ft
Function: Work stations where the National Science Center's teaching staff can prepare for presentations, store their belongings, do research, etc.
Critical Criteria: Accessible to Chief, Education and Technology.
- 6.11 Conference Room for Education Staff 200 sq ft
Function: Conference and meeting space for the Education Program staff.
Critical Criteria: Accessible to the Education Program staff located in the National Science Center building.

6.12 Education Prop/Artifact Storage 300 sq ft

Function: Secure area for storage of demonstration objects, supplies, equipment, and collection objects used in the National Science Center's education programs.

Critical Criteria: Accessible to Classrooms, Discovery Room, and Exhibition Areas.

6.13 Education Outreach Equipment Storage 100 sq ft

Function: Secured storage area for outreach equipment, exhibits, and supplies.

Critical Criteria: Accessible to Receiving Area.

6.14 Resource Center 800 sq ft

Function: Staff research area.

Critical Criteria: Accessible to Administration, Exhibit, and Education staff.

6.15 Visiting Fellows Science Office 150 sq ft

Function: Work area for use by Visiting Science Fellows.

Critical Criteria: Accessible to Administration, Exhibit, and Education staff.

6.16 Reception/Clerical Work Area 120 sq ft

Function: Clerical work area and control point for visitors to the Curator of Collections and Collection facilities.

Subtotal Education and Technology Department: 3170 sq ft

7. Administrative Facilities

7.1 Office of the Discovery Center 450 sq ft

7.1.1 Chief, Discovery Center (Deputy Director, National Science Center). (200 sq ft)

7.1.2 Research and Special Projects Officer. (150 sq ft)

Function: Office of Research and Special Projects Officer.

Critical Criteria: Accessible to Chief, Discovery Center.

7.1.3 Secretary/Steno. (100 sq ft)

Function: Office of Secretary.

Critical Criteria: Accessible to Chief, Discovery Center.

7.2 Administrative Department 175 sq ft

7.2.1 Resource Management Clerk - in area for accounting clerk and cash control.(100 sq ft)

Function: Office of Resource Management Clerk.

Critical Criteria: Accessible to Chief, Discovery Center.

7.2.2 Supply Clerk. (75 sq ft)

Function: Office of Supply Clerk.

Critical Criteria: Accessible to Resource Management Clerk.

7.3 Exhibits and Special Programs Department 1275 sq ft

7.3.1 Chief, Exhibits and Special Programs. (200 sq ft)

Function: Office of Chief, Exhibits and Special Programs.

7.3.2 Exhibits Manager. (200 sq ft)

Function: Office of Exhibits Manager.

Critical Criteria: Accessible to Chief, Exhibits and Special Programs.

7.3.3 Exhibit Maintenance Officer - in Exhibit Maintenance Office. (150 sq ft)

Function: Office of Exhibit Maintenance Officer.

Critical Criteria: Accessible to Chief, Exhibits and Special Programs.

7.3.4 Lead Education Specialist. (200 sq ft)

Function: Office of Lead Education Specialist.

Critical Criteria: Accessible to Chief, Exhibits and Special Programs.

7.3.5 Science Education Specialist/Special Programs. (100 sq ft)

Function: Office of Science Education Specialist/Special Programs.

Critical Criteria: Accessible to Chief, Exhibits and Special Programs.

7.3.6 Science Education Specialist/Traveling Programs. (100 sq ft)

Function: Office of Science Education Specialist/Traveling Programs.

Critical Criteria: Accessible to Chief, Exhibits and Special Programs.

7.3.7 Science Education Specialist/Volunteer Coordinator - near Volunteer Office/Lounge Area. (100 sq ft)

Function: Office of Science Educator Specialist/Volunteer Coordinator.

Critical Criteria: Accessible to Chief, Exhibits and Special Programs.

7.3.8 Secretary/Typing (75 sq ft)

Function: Office of Secretary.

Critical Criteria: Accessible to Chief, Exhibits and Special Programs.

7.3.9 Clerk/Typist/Receptionist - located near entrance. (75 sq ft)

Function: Office of Clerk/Typist/Receptionist.

Critical Criteria: Accessible to Chief, Exhibits and Special Programs.

7.3.10 Visual Information Specialist - in Graphics Area. (75 sq ft)

Function: Office of Visual Information Specialist.

Critical Criteria: Accessible to Chief, Exhibits and Special Programs.

7.4 Engineering and Automation Department 1075 sq ft

7.4.1 Chief, Engineering and Automation. (200 sq ft)

Function: Office of Chief, Engineering and Automation.

Critical Criteria: Accessible to Computer Specialist - in Computer Maintenance Area.

7.4.2 Computer Specialist - in Computer Maintenance Area. (100 sq ft)

Function: Office of Computer Specialist.

Critical Criteria: Accessible to Chief, Engineering and Automation.

7.4.3 Computer Technician - in Computer Maintenance Area. (100 sq ft)

Function: Office of Computer Technician.

Critical Criteria: Accessible to Chief, Engineering and Automation.

7.4.4 Computer Program Analyst. (100 sq ft)

Function: Office of Computer Program Analyst.

Critical Criteria: Accessible to Chief, Engineering and Automation.

- 7.4.5 Computer Specialist (data base). (100 sq ft)
Function: Office of Computer Specialist.
Critical Criteria: Accessible to Chief, Engineering and Automation.
- 7.4.6 Computer Specialist - in Exhibits Area. (100 sq ft)
Function: Office of Computer Specialist.
Critical Criteria: Accessible to Chief, Engineering and Automation.
- 7.4.7 Building Manager - near Maintenance and Building Service Area. (200 sq ft)
Function: Office of Building Manager.
Critical Criteria: Accessible to Chief, Engineering and Automation.
- 7.4.8 Electronic Technician - in Exhibits Area. (100 sq ft)
Function: Office of Electronic Technician.
Critical Criteria: Accessible to Chief, Engineering and Automation.
- 7.4.9 Secretary/Typing. (75 sq ft)
Function: Office of Secretary.
Critical Criteria: Accessible to Chief, Engineering and Automation.
- 7.5 Challenger Center 1480 sq ft
- 7.5.1 Manager, Challenger Center Program (office/workroom). (200 sq ft)
Function: Office of Manager, Challenger Center Program.
- 7.5.2 Space Station and Mission Control. (1280 sq ft)
Function: Office of Space Station and Mission Control.
Critical Criteria: Accessible to Manager, Challenger Center Program.
- 7.6 Work Area for Accounts Payable Clerk, Payroll Clerk, General Ledger Clerk, and Accounting Clerk 225 sq ft
Function: Work areas for accounting staff.
Critical Criteria: Located within the Finance and Personnel area.

7.7 Administration Reception Area 150 sq ft

Function: Control point for visitors to the administration area. Work station for receptionist.

Critical Criteria: Accessible to Administration, Exhibit, and Education staff.

7.8 Board Room 700 sq ft

Function: Meeting space for the Board of Directors of the National Science Center and other special functions.

Critical Criteria:

- Accessible from President's office and to Administration, Exhibit, and Education staff.
- Accessible to small kitchen.
- Ability to achieve total darkness.
- Built-in audiovisual projection equipment and screen.
- Plumbing and water service.

7.9 Copy Machine/Mail Room 125 sq ft

Function: Work area for photocopying and mail processing.

Critical Criteria: Accessible to Administration, Exhibit, and Education staff.

7.10 Staff/Docent/Volunteer Lounge 600 sq ft

Function: Lounge/eating area for the National Science Center staff, docents, and volunteers.

Critical Criteria:

- Accessible to Administration, Exhibit, and Education staff.
- Plumbing and water service.
- Kitchenette to include sink, refrigerator, and microwave.
- Adequate power and outlets to service coin-operated soft drink and snack machines.

7.11 Staff Toilets 400 sq ft

Function: Restrooms for the National Science Center staff.

Critical Criteria:

- Accessible to Administration, Exhibit, and Education staff.
- Plumbing and water service.
- Accessible to handicapped.
- Floors sloped to drains.

7.12 Executive Kitchenette Area

110 sq ft

Function: Kitchenette to service executive meetings.

Critical Criteria:

- Easily accessible to executive offices.
- Plumbing and water service.
- Adequate ventilation to exhaust food odors out of building.
- Floors sloped to drains.

Subtotal Administrative Facilities:

6765 sq ft

8. Building Services Facilities

A well organized building and grounds cleaning program is essential. Cleaning is a major undertaking and is continuous and expensive. It is very important to visitors (especially ones with small children) to have the building and the surrounding grounds clean. Bathrooms and outside eating areas are particularly problematic and can quickly become unsightly and unsanitary.

The center should have in-house housekeepers plus a supervisor on staff. An outside cleaning contractor may be required to do heavier power cleaning such as floors and carpeting. A weekly walk-through inspection is suggested to provide feedback and to assure that the job is done right. This "white glove" inspection is essential to keep the center clean and maintain the facility.

Cleaning the outside eating area can require one cleaning person all day to pick up trash, wash down spills, and clean tables. Insects can be a particular problem, and children seem to attract stinging bees. (A pine-based cleaning solution mixed with water can be sprayed on trash receptacles to control insects.)

Cleaning bathrooms can keep the in-house cleaning staff busy all day keeping paper stocked and emptying the trash. In larger centers, on average, one child a day gets sick in the bathroom.

8.1 Office for Building Services Supervisor and Assistant

175 sq ft

Function: Work area for the Building Services Supervisor and Assistant Building Services Supervisor.

Critical Criteria: Accessible to Receiving Area.

8.2 Building Services Workshop/Storage

600 sq ft

Function: Building maintenance workshop and building materials and supplies storage.

Critical Criteria:

- Accessible or adjacent to Carpentry Shop.
- Double-door access with a clear opening of 12 ft by 12 ft to both the workshop and storage areas.
- Accessible to Receiving Area.

- Minimum ceiling height of 12 ft.
- 110/220-volt electrical service.
- Plumbing and water service to a utility sink.
- Dust collection system.

8.3 Security Control Room

120 sq ft

Security is obviously serious business for science centers. There can be many nooks and crannies to monitor, and this should be kept in mind during facility design. Problems can range from simple vandalism to removal and theft of parts of exhibits to more serious malicious activity and the possibility of physical injury. Unfortunately, most public places, centers included, have to deal with a small percentage of the public that is dishonest, even malicious and dangerous. This has led to a variety of methods to deter theft and other undesirable activity. These vary from employment of security staff and volunteer "watchers," to video-based security systems, to locked rooms, cases and physical barriers, and signs. In many instances, it appears that lessons learned from displays is less than it could be because close examination and hands-on experience is limited for reasons of security. The center must balance the need to know with the ability to provide security. This usually equates to the ability of centers to have people available to help monitor displays. The more staff available to serve as monitors, the more hands-on experience is possible.

A camera security system should be considered as well as assigning personnel to watch certain exhibits. To deter "throw away" theft, trash collected in bags by night cleaning crews can be discarded at later and irregular times to deter retrieval from the trash. Anything fastened only by screws can be taken. To prevent theft or damage, objects should be fastened securely.

Function: Secured area to house central security, fire detection/suppression, and HVAC systems and controls.

Critical Criteria:

- Near Receiving Area and staff entrance.
- Glass walls to permit visual supervision of Receiving Area and staff entrance.

8.4 Custodial Storage

200 sq ft

Function: Areas for storage of custodial supplies and for custodial slop sinks.

Critical Criteria:

- Accessible to Receiving Area.
- Plumbing and water service.
- Floors sloped to drains.

8.5 Outdoor Maintenance Storage

200 sq ft

Function: Area for the storage of outdoor maintenance equipment and supplies, including lawn mowers, a forklift truck, etc.

Critical Criteria: Accessible to Receiving Area.

8.6 Lockers/Showers/Toilets (Men's and Women's) 300 sq ft

Function: Staff lockers, toilets, and showers.

Critical Criteria:

- Accessible to staff entry.
- Plumbing and water service.
- Floors sloped to drains.

8.7 Receiving Area 600 sq ft

Function: Receiving area for all deliveries to the National Science Center building.

Critical Criteria:

- Adjacent to loading dock.
- Roll-up door, 12 ft by 12 ft, with a separate 3-1/2 ft wide pass door.
- Accessible to all Exhibition Support and Building Service areas and to all Exhibition Areas.

8.8 Mechanical/Electrical Rooms 6500 sq ft

Function: Areas to house building mechanical equipment, electrical rooms, elevator machine rooms, and telephone equipment.

Critical Criteria:

- Located away from high security areas.
- Floor drains and curbs in mechanical rooms.

Subtotal Building Services Facilities: 8695 sq ft

TOTAL NET AREA 98,180 sq ft

METRIC CONVERSION TABLE

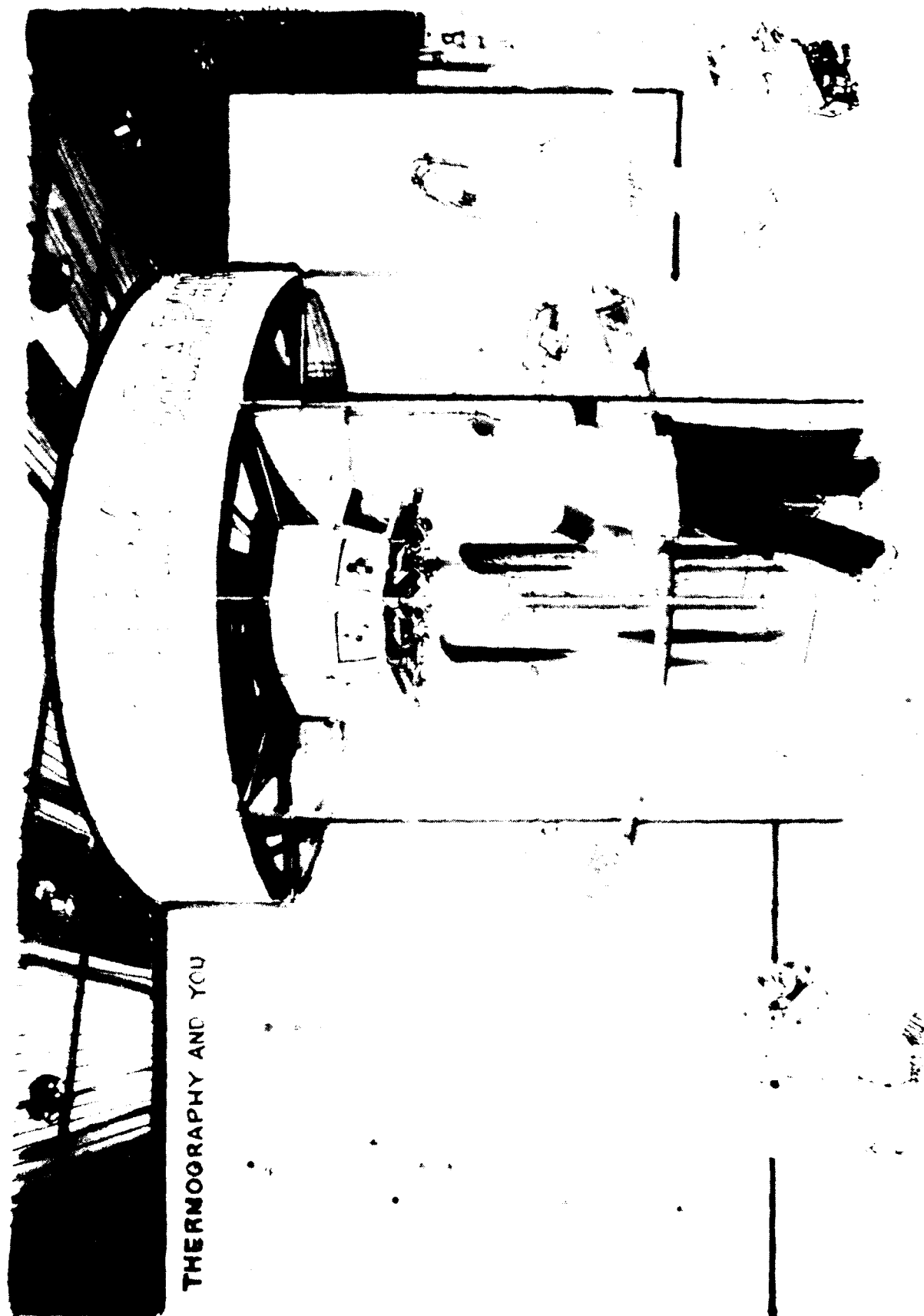
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1 ft =	0.305 m
1 gal =	3.78 L
1 in. =	2.54 cm
1 lb =	0.453 kg
1 psi =	68.9476 kPa
1 sq ft =	0.093 m ²
°C =	0.55(°F-32)

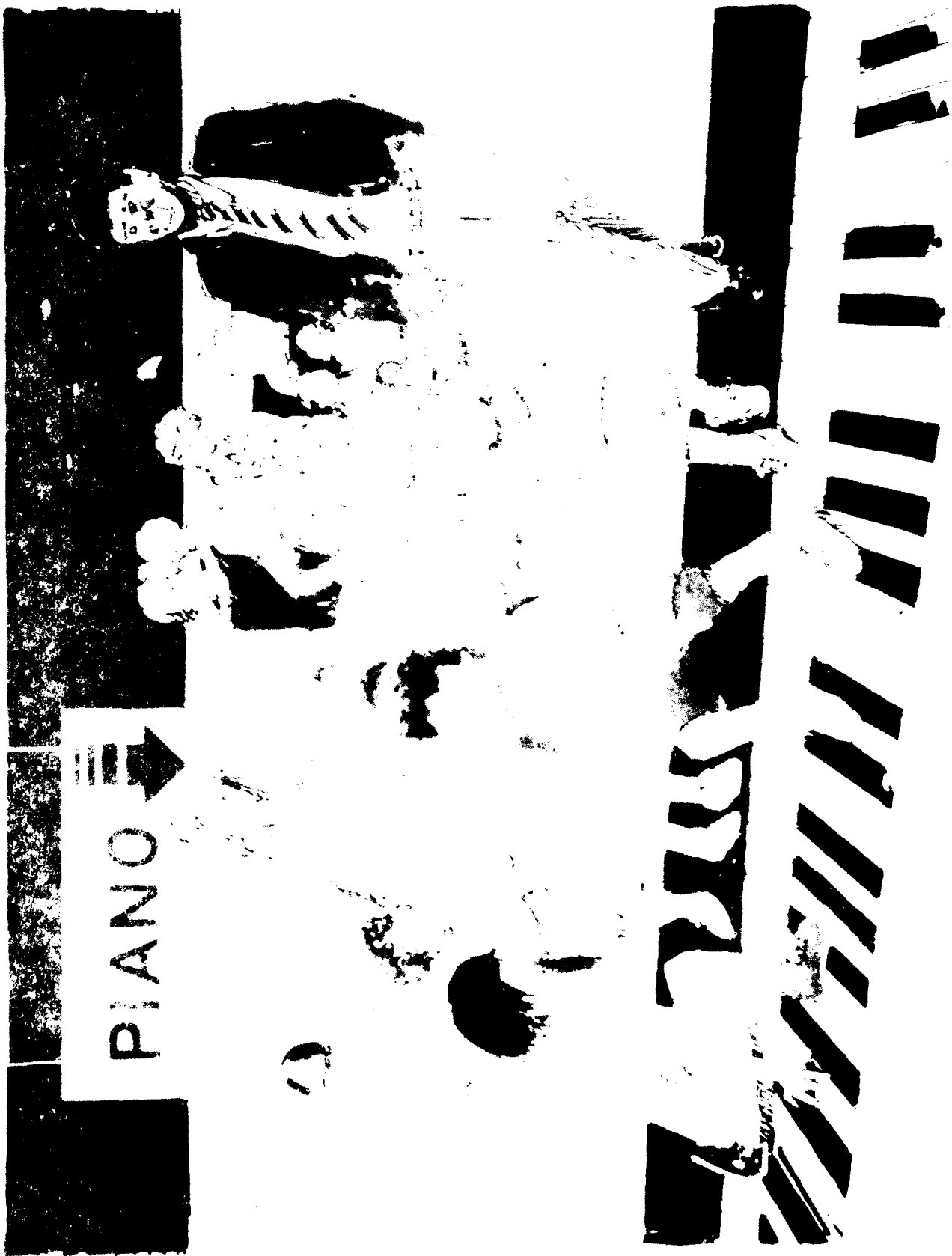
APPENDIX A:

CONCEPTUAL IMAGE STUDIES

The following conceptual images represent an exploration and investigation in exterior and interior spirit and language of a possible Science Center facility. The investigators present these studies only as examples of character and possibilities for design direction.

It is the responsibility of the specific design professional to explore and present a creative agenda in response to the program criteria and specifications.



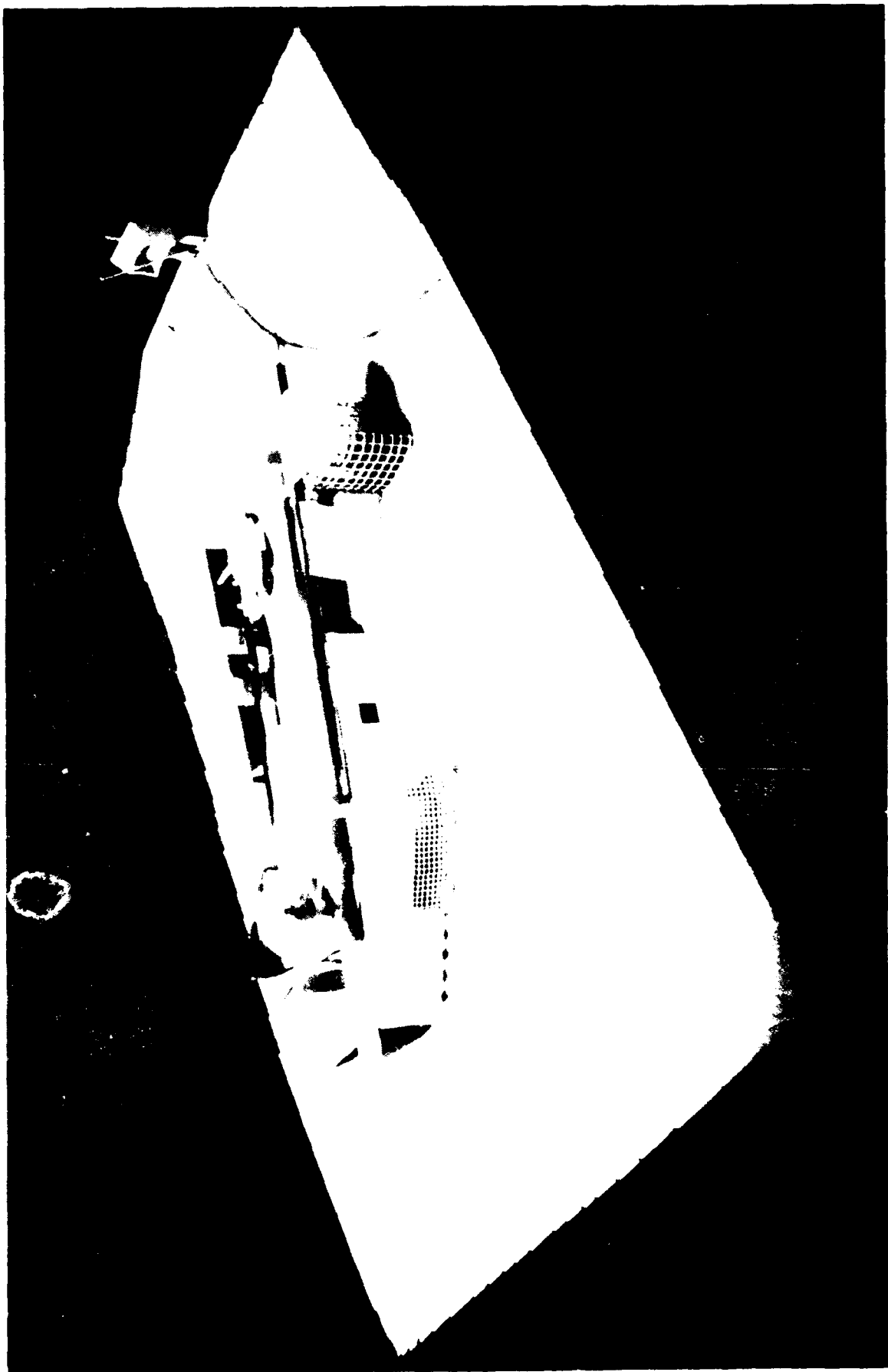


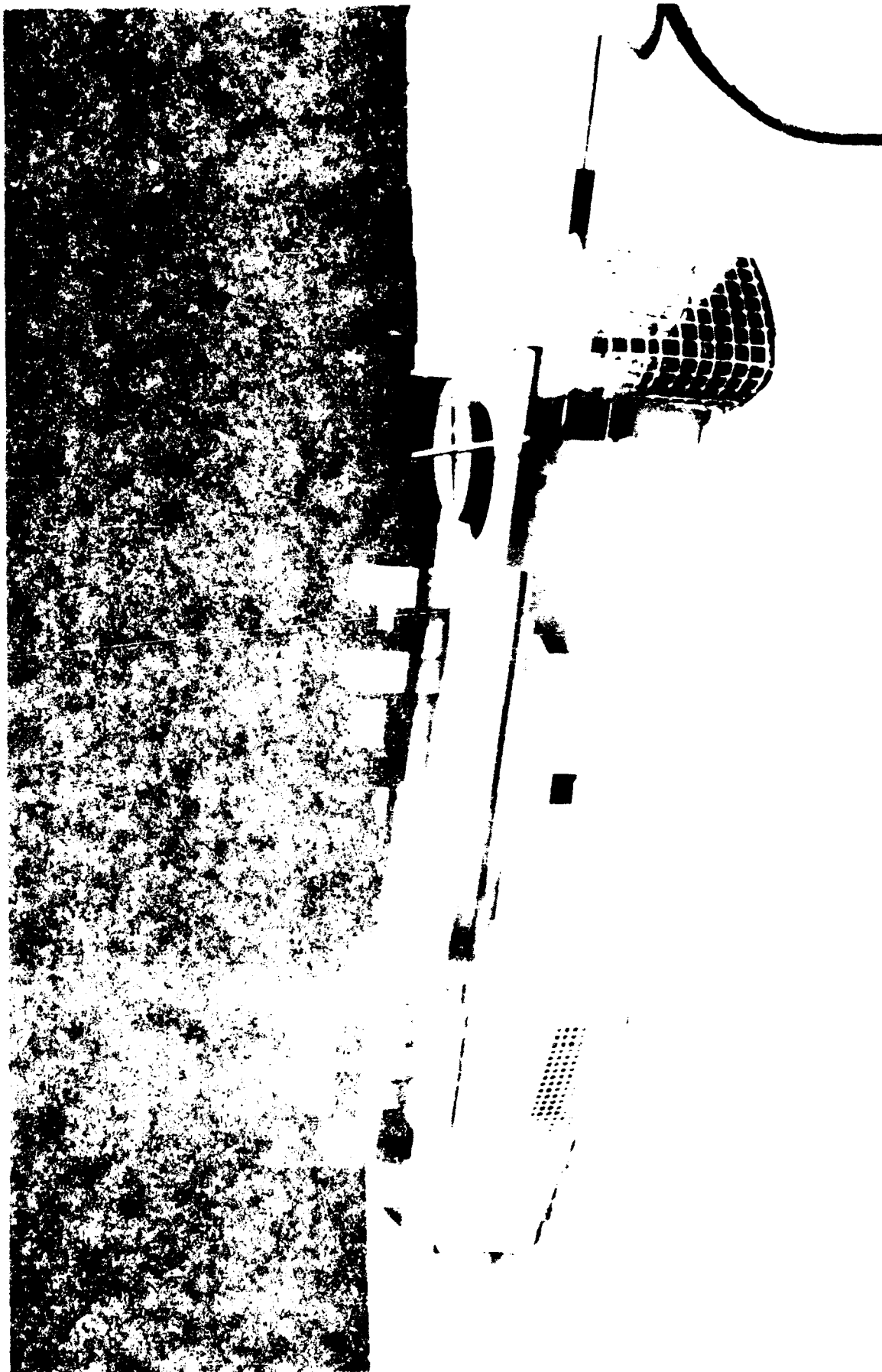


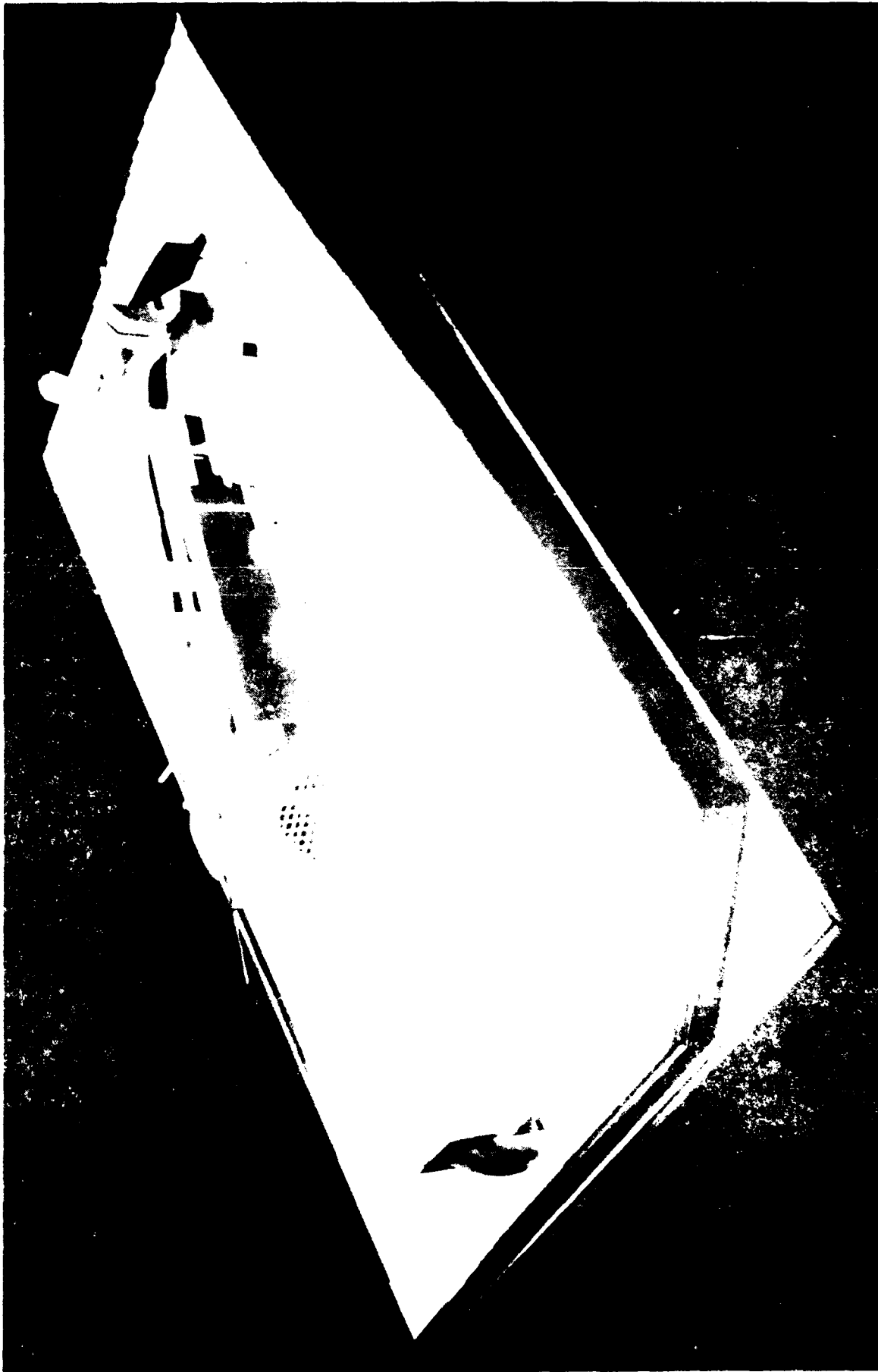


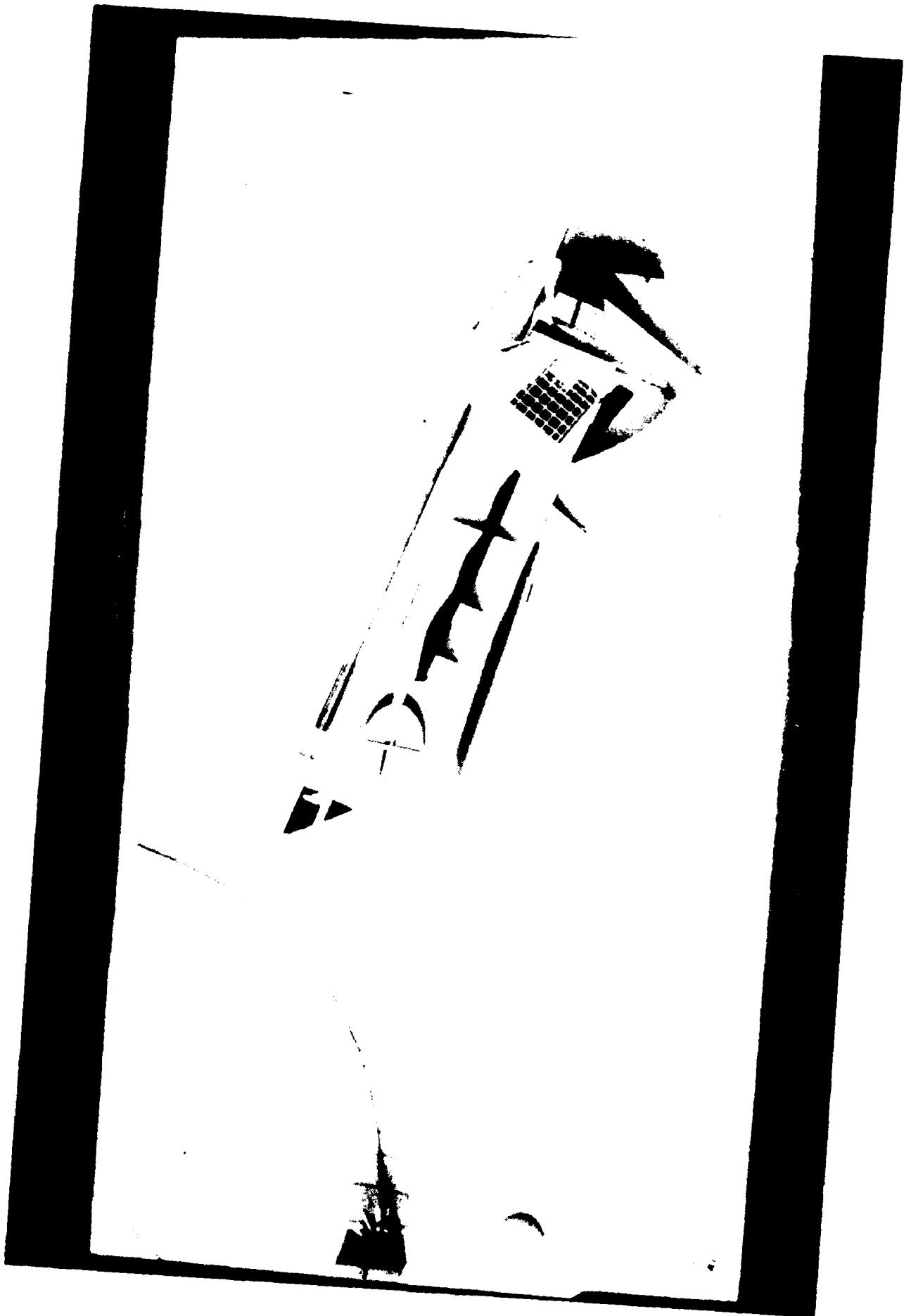












APPENDIX B:

DESIGN PRINCIPLES INCLUDING FACILITY ENERGY EFFICIENCY

The following are strategies and principles for effective energy design as specified by ASHRAE standards.

1. Consider energy efficiency from the initiation of the building design process, since design improvements are most easily and effectively made at that time. Seek the active participation of members of the design team early in the design process, including the owner, architect, engineer, and builder. Consider building attributes such as building function, form, orientation, window/wall ratio, and HVAC system types early in the design process. Each has major energy implications. These considerations most likely will result in solutions that minimize both construction and operation costs, including energy demand charges.
2. Address the building's energy requirements in the following sequence: minimize impact of the building functional requirements, minimize loads, improve the efficiency of distribution and conversion systems, and integrate building subsystems into an efficient whole.
3. Minimize impact of functional requirements by identifying major areas that offer energy efficiency opportunities based on the building's functional use, human occupancy requirements, and site characteristics. These areas will vary considerably from building to building depending on function and service requirements.
4. Minimize loads by analyzing the external and internal loads to be imposed on building energy-using subsystems, both for peak-load and part-load conditions. Include a determination of how the building relates to its external environment in the analysis, either adaptively or defensively. Consider changes in building form, aspect ratio, and other attributes that reduce, redistribute, or delay (shift) loads.
5. Improve subsystems by analyzing the diversified energy and demand (power) requirements of each energy-using subsystem serving the functional requirements of the building. Consider static and dynamic efficiency of energy conversion and energy transport subsystems and include consideration of opportunities to reclaim, redistribute, and store energy for later use.
6. Alternative ways to integrate systems into the building will be accomplished by considering both power and time components of energy use. Identify, evaluate, and design each of these components to control the overall design energy consumption. The following should be considered when integrating major building subsystems:
 - 6.1 Address more than one problem when developing design solutions, and make maximum use of building components already present for nonenergy reasons (e.g., windows, structural mass).
 - 6.2 Examine design solutions that consider time, since sufficient energy may already be present from the environment (e.g., solar heat, night cooling) or from internal equipment (e.g., lights, computers) but available at different times than needed. Thus, active (heat pumps with water tanks) and passive (building mass) storage techniques may be considered.
 - 6.3 Examine design solutions that consider anticipated space use. For example, in large but relatively unoccupied spaces, task or zone heating may be considered. Transporting energy (light and

heat) from locations of production and availability to locations of need should be considered instead of the purchase of additional energy.

6.4 Never reject the reuse of waste energy for space conditioning or other practical purposes without calculating the economic benefit of energy recovery or treatment.

6.5 Consider design solutions that provide more comfortable surface temperatures or increase the availability of controlled daylight in buildings in which human occupancy is a primary function.

6.6 Use design solutions that are easily understood; they have a greater probability of use by building occupants.

6.7 Where the functional requirements of the building may change, the installed environmental system should be designed to be adaptable to meet functional changes that can be anticipated and provide flexibility to meet indeterminate future changes in use, occupancy, or other functions.

7. The lighting system is designed to provide a productive, safe, and pleasing visual environment for the intended use of the space. However, lighting is both a major energy use in commercial buildings (especially in office buildings) and a major contributor to internal loads by increasing cooling loads and decreasing heating loads. Therefore, it is important to produce a design that also minimizes energy use.

8. Energy use is determined by the lighting load (demand power) and its duration of use (time). Minimize the actual demand load rather than just the apparent connected load, and control the load rather than just switching, if switching may adversely affect the quality of the luminous environment.

9. Consider daylighting along with the proper use of controls so that a savings from electric lighting can be realized. Design should be sensitive to window glare, sudden changes in luminance, and general user acceptance of daylighting controls. Window treatment (blinds, drapes, and shades) and glazing should be carefully selected to control direct solar penetration and luminance extremes while still maintaining view and daylight penetration.

10. Design the lighting system so that illumination required for tasks is primarily limited to the location of the task and from a direction that will minimize direct glare and reflections on the task. When the design concept is based on nonuniform illuminance, the walls should be lighted to medium color or otherwise be illuminated in order to provide visual comfort. In densely-occupied work spaces, uniform distribution of general lighting may be most appropriate. Where necessary, supplementary task illumination should be provided. General ambient illumination should not be lower than one third of the luminance required for the task. This will help maintain luminance ratios that are visually comfortable.

11. Use local task lighting whenever possible to accommodate the need for higher lighting levels due to task visual difficulty, glare, intermittently changing requirements, or individual visual differences (poor and aging eyesight) and on exhibitions.

12. Group similar activities so that high illuminance or special lighting for particular tasks can be localized in certain rooms or areas, and so that less efficient fixtures required for critical glare control do not have to be installed uniformly when they are required only sparsely.

13. When indirect lighting is appropriate, use schemes that create reasonably uniform ceiling luminance. If this is achieved, work spaces may be located anywhere and occupants may face in any direction without

being subject to excessive ceiling reflection on the tasks. The indirect system may allow more effective use of the space than other types of lighting systems.

14. Use lighting controls throughout so properly-designed lighting is available when and where it is needed but not wasted during those times when tasks are less critical, or spaces are not fully occupied. The designer must consider user acceptance of control strategies to maximize energy saving.

15. Use lower levels of ambient lighting in situations such as merchandising, where the contrast between accent lighting and ambient lighting is critical. Accent lighting should not exceed five times the ambient level. Consider fewer, more effectively-accented displays, rather than more, ineffectively-accented ones.

16. The following guidelines identify strategies to be considered in the selection of luminaires and lamps for inclusion in an energy efficient, visually-effective design:

16.1 Consider the use of more efficient equipment with appropriate distribution, glare control, and visual characteristics. Once the appropriate distribution is determined, fixtures with the highest classification should be used.

16.2 Review visual comfort probability (VCP) data, available from manufacturers, for specific luminaires when minimizing discomfort glare is a criterion.

16.3 Consider luminaire construction that minimizes light loss due to dirt collection.

16.4 Investigate the use of dimmers to reduce energy consumption when the system is new and capable of providing more light than the average depreciated value.

16.5 Use more efficient lamps with appropriate luminous efficacy, life expectancy, spectrum distribution, and color rendering characteristics.

16.6 Use more efficient ballasts for fluorescent and HID lamps with appropriate ballast factors, power factor, noise rating, starting, and restarting characteristics.

16.7 Consider the use of lighting fixtures with heat removal and heat recovery capabilities, thereby allowing the lighting equipment to operate more efficiently at lower ambient temperatures.

16.8 Limit the use of lower efficiency lamps, such as incandescent, to only those applications where their color, lumens, or distribution characteristics cannot be duplicated by other sources. Due to their lower efficiency, the use of "extended service" incandescent lamps should be limited to those applications where fixtures are difficult to reach and/or maintenance costs for relamping would be excessive.

16.9 It is important to carry through on the lighting design when completing the interior design. Reduce light absorption by encouraging the use of lighter finishes, particularly on ceilings, walls, and partitions. Select colors and surface materials so that their reflectance values are within the ranges recommended by the Illuminating Engineering Society (IES). This will aid the efficient use of light and help provide comfortable luminance ratios. In offices with visual display terminals (VDTs) that are susceptible to reflections, it may be necessary to use reflectance for some room surfaces at the low end of the recommended ranges to reduce unwanted reflections on the screens. Where practical, treat screens of VDTs with antiglare materials.

17. The building envelope is perhaps one of the most important energy considerations in the design of energy efficient buildings. Building loads result from both external and internal sources.

17.1 External loads from outdoor temperature, humidity, wind, and insolation fluctuate daily and seasonally.

17.2 Internal loads from the activities conducted within the building, including heating and moisture produced by the occupants, lights, and process equipment (e.g., appliances, computers), vary with internal activities.

Improving energy efficiency in a building depends on achieving a balance between and among the internal and external loads. The building design should attempt to offset gains and losses of heat, light, and moisture between the interior and exterior of the building, among interior spaces, and over time (daily, seasonally, and annually).

The desired goal of the energy design of the building envelope should be to produce a controlled membrane that allows or prevents heat, light, and moisture flow so as to achieve a balance between internal and external loads. Thus, the envelope becomes an integral part of the building's environmental conditioning system.

To achieve control of the building envelope as a membrane and to simultaneously achieve occupant comfort in the perimeter zones, many of the traditional building skin components must be used (insulation, mass, caulking, and weather stripping). However, other factors should also be considered (such as operable solar shading devices and the heat loss and gain of glazing systems) when designing the heating, ventilation, and air-conditioning (HVAC) system.

18. Thermal conductivity should be controlled through the use of insulation (including movable insulation), thermal mass and/or phase change thermal storage, at levels that minimize net heating and cooling loads on a time-integrated (annual) basis.

Unintentional or uncontrolled thermal bridges should be minimized and considered in energy related calculations since they can radically alter the conductivity of a building envelope. Examples include wall studs, balconies, ledges, and extensions of building slabs.

19. Heat loss or gain should be minimized and all efforts to achieve a zero-level atmospheric condition should be used. This will minimize fan energy consumption in pressurized buildings during occupied periods and minimize heat loss (or unwanted heat gain in warm climates) during unoccupied periods.

Infiltration reduction should be accomplished through design details that enhance the fit and integrity of building envelope joints in a way that may be readily achieved during building construction. This includes infiltration control by caulking, weather stripping, vestibule doors and/or revolving doors, with construction meeting accepted specifications.

The quantity of mechanical ventilation must vary with the need and with recommended values at any given time. Higher levels of ventilation (e.g., economizers) should be considered as substitutes for mechanical cooling. Operable windows may be considered to allow for occupant-controlled ventilation. When using operable windows, the design of the building's mechanical system must be carefully executed to minimize unnecessary HVAC energy consumption, and building operators must be cautioned about the improper use of the operable windows.

Nonmechanical ventilation can be enhanced in the shape of the building as well as the physical elements of the building envelope, such as cupolas.

20. Control of radiated heat losses and gains for occupant radiant comfort should be maintained regardless of whether the building envelope is designed to be a static or dynamic membrane. Opaque surfaces should be designed so that the average inside surface temperatures will remain within 5 °F of room temperature in the coldest anticipated weather (i.e., winter design conditions), and the coldest inside surface will remain within 25 °F of the room temperature.

In a building with time-varying internal heat generation, the thermal mass may be considered for controlling radiant comfort. In the perimeter zone, thermal mass is more effective when it is positioned internal to the envelope insulation.

The effective control of solar radiation is critical to the design of energy-efficient buildings due to the high level of internal heat production in most commercial buildings. In some climates, the lighting energy consumption savings due to daylighting techniques can be greater than the heating and cooling energy penalties from additional glazed surface area, provided that the building envelope is properly designed for daylighting and that lighting controls are installed and used. In other climates, this may not be true. Daylighting designs are most effective if direct solar beam radiation is not allowed to cause glare in building spaces.

The transparent portions of the building envelope should be designed to prevent solar radiant gain above that necessary for effective daylighting and solar heating. On south-facing facades, the use of low shading coefficients is generally not as effective as external physical shading devices in achieving this balance. Light shelves offer a very effective means of admitting daylight while shading the glazing and simultaneously allowing occupants to manipulate interior shading devices (draperies, blinds) without eliminating daylight.

The solar spectrum contains a range of wavelengths including visible and infrared (heat). Designers should consider which portion of the spectrum to admit into the building. For example, low emissivity, high-visible transmittance glazing may be considered for the effective control of radiant heat gains and losses. For shading control, designers may consider the careful use of vegetation that can block excess gain year-round or seasonally, depending on the plant species chosen.

21. Electric power and distribution transformers and generating units should be sized as close as possible to the actual anticipated load (i.e., oversizing is to be avoided so that fixed thermal losses are minimized). Distribution of electric power at the highest practical voltage and load selection at the maximum power factor consistent with safety should be considered. The use of distribution system transformers should be minimized.

22. The thermal impact of equipment and appliances on HVAC systems should be minimized by the use of hoods, radiation shields, or other confining techniques, and by use of controls to assure that such equipment is turned off when not needed. In addition, major heat-generating equipment should, where practical, be located where it can balance other heat losses. For example, computer centers or kitchen areas could have separate, dedicated HVAC equipment. In addition, heat recovery should be specifically considered for this equipment. Storage techniques should be used to level or distribute loads that vary on a time or spatial basis, to allow operation of a device at maximum (full-load) efficiency.

22.1 Separate HVAC systems should be considered to serve areas expected to operate on widely differing operating schedules or design conditions. For instance, systems serving office areas should

generally be separate from those serving retail areas. When a single system serves a multi-tenant building, provisions should be made to shut off or set back the heating and cooling to each area independently.

Spaces with relatively constant and weather-independent loads should be served with systems separate from those serving perimeter spaces. Areas with special temperature or humidity requirements, such as computer rooms, should be served by systems separate from those serving areas that require comfort heating and cooling only. Alternatively, these areas may be served by supplementary or auxiliary systems.

The supply of zone cooling and heating should be sequenced to prevent the simultaneous operation of heating and cooling systems for the same space. Where this is not possible due to ventilation or air circulation requirements, air quantities should be reduced as much as possible before reheating, recooling, or mixing hot and cold air streams. Finally, supply air temperature should be reset to extend economizer operations and to reduce reheat, recool, or mixing losses.

Systems serving areas with significant internal heat gains (from lighting, equipment, and people), especially interior zones with little or no exposure to weather, should be designed to take advantage of mild or cool weather conditions to reduce cooling energy if heat recovery systems are not used. These systems, called air or water economizers, should be designed to provide a partial reduction in cooling loads even when mechanical cooling must be used to provide the remainder of the load. Economizer controls should be integrated with the mechanical cooling (leaving air temperature) controls so that mechanical cooling is only operated when necessary and so that supply air is not overcooled to a temperature below that desired. The systems and controls should be designed so that economizer operation does not increase heating energy use. For instance, a single-fan, dual-duct system that uses the same mixed air plenum for both heating and cooling supplies should not be used.

Controls should be provided to allow systems to operate in either an occupied mode or an unoccupied mode. In the occupied mode, controls should provide for a gradually changing control point as system demands change from cooling to heating. In the unoccupied mode, ventilation and exhaust systems should be shut off if possible, and comfort heating and cooling systems should be shut off except to maintain setback conditions. The setback conditions should be the minimum and maximum levels required to prevent damage to the building or its contents and provide for a reasonable morning pick-up period. Note, however, that night setback may not conserve energy in buildings with a large thermal mass.

In areas where diurnal temperature swings and humidity levels permit, the judicious coupling of air distribution systems and building structural mass may be considered to allow the use of nighttime precooling to reduce the requirement for daytime mechanical cooling.

High ventilation rates, where required for special applications, can impose enormous heating and cooling loads on HVAC equipment. In these cases, consideration should be given to recirculating filtered and cleaned air rather than using 100 percent outside air and to preheating outside air with solar systems or reclaimed heat from other sources.

23. Energy should be transported by the most energy efficient means possible. The following options, are listed in order of efficiencies from the lowest (most efficient) energy transport burden to the highest:

23.1 Electric wire or fuel pipe.

23.2 Two-phase fluid transfer (steam or refrigerant).

23.3 Single-phase liquid fluid (water, glycol, etc.).

23.4 Air.

The distribution system should be selected to compliment other system parameters such as control strategies, storage capabilities, and conversion and utilization system efficiencies.

24. The use of steam systems may also be an option.

24.1 Provisions for seasonal or "nonuse time" shutdown should be incorporated.

24.2 The venting of steam and ingestion of air should be minimized with the design directed toward full vapor performance.

24.3 Subcooling should generally be prevented.

24.4 Condensate should be returned to boilers or source devices at the highest possible temperature.

25. The use of water systems may also be an option.

25.1 Flow quantity should be minimized by designing for the maximum practical temperature differential.

25.2 Flow quantity should be varied with load where possible.

25.3 The system should be designed for the lowest practical pressure rise (or drop).

25.4 Operating and idle control modes should be provided.

25.5 When locating equipment, the critical pressure path should be identified and the runs sized for minimum practical pressure drop.

26. An air system, on the other hand, shall be designed where the air flow quantity should be minimized by careful load analysis and an effective distribution system. If the psychometric nature of the application allows, the supply air quantity should vary with the sensible load (i.e., variable air volume [VAV] systems). The fan pressure requirement should be held to the lowest practical value. The use of fan pressure as a source for control power should be avoided.

Each fan system should be designed and controlled to reduce mechanical cooling requirements by taking advantage of favorable weather conditions.

Normal and idle control modes should be provided for both the fan systems and the psychometric systems.

Duct run distances should be as short as possible, and the runs on the critical pressure path should be sized for minimum practical pressure drop.

27. The designer should ascertain (from the suppliers of HVAC equipment, or otherwise) the rate of energy input(s) and the heating or cooling output(s) of all HVAC products. This information should be based on equipment in new condition and should cover full load, partial load, and standby conditions. The information should also include performance data for modes of equipment operation and at ambient conditions as specified in the equipment performance guidelines below.

28. To allow for HVAC equipment operation at the highest efficiencies, conversion devices should be matched to load increments, and operation of modules should be sequenced. Oversized or large scale systems should never be used to serve small seasonal loads (e.g., a large heating boiler to serve a summer service water heating load). Specific low-load units should be incorporated in the design where prolonged use at minimal capacities is expected.

All equipment should be the most efficient at both design and reduced capacity (part-load) operating conditions.

Fluid temperatures should be as low as practical for heating equipment devices and as high as practical for cooling equipment, while meeting loads and minimizing flow quantities.

29. Showerheads should be designed to provide and maintain user comfort and energy savings. They should not use removable flow-restricting inserts to meet flow limitation requirements.

Point-of-use water heaters should be considered where their use will reduce energy consumption and annual energy cost.

High temperature condensate, when returned to condensation pump tanks or other vented tanks, will have a certain portion flashed into steam, thus wasting energy. To conserve this energy, a heat exchanger should be considered for use in the condensate return line to heat or preheat the service water, cool the condensate, and prevent flashing.

Storage may be used to optimize heat recovery when the heat to be recovered is out of phase with the demand for heated water or when energy use for water heating can be shifted to take advantage of off-peak rates.

30. An energy management control system is critical to the effective management of building energy. An energy management system requires measurements at key points in the building system and must be capable of recognizing any special equipment capability for part-load operation. The system must be equipped with controls to match system capacity to load demands.

Controls cannot correct inadequate source equipment, poorly selected components, or mismatched systems. Energy efficiency requires a design that is optimized by realistic loads prediction, careful system selection, and full control provisions.

31. The construction drawings and specifications should show system types, sizes, performance criteria, controls, and materials. The system designer should provide or specify that documentation be provided for the education and guidance of the building operator showing the actual elements that have been installed, how they have been installed, how they performed during testing, and how they operate as a system in the completed facility. Operating procedures are one of the major factors in controlling energy

use in buildings. The activities of building occupants and operators can result in differences in the energy consumption of essentially similar buildings. While neither the designer nor this standard can control the way the building is actually operated, the designer should contribute to the education and guidance of the building operator by including this documentation in the contract specifications.

32. The building operator should be provided with the following:

32.1 As-built drawings and specifications,

32.2 Operating manuals with a schematic diagram, sequence of operation, and system operating criteria for each system installed,

32.3 A comprehensive balancing and testing program and report to demonstrate the energy performance capabilities of the system (where the building systems are complex).

32.4 Maintenance manuals with complete information for all major components in the facility.

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