DOT/FAA/AM-97/18

Office of Aviation Medicine
Washington, D.C. 20591

A Flexible Cabin Simulator

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August 1997

Final Report

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U.S. Department of Transportation
Federal Aviation Administration

NOTICE

Technical Report Documentation Page

1. Report No. DOT/FAA/AM-97/18	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle A Flexible Cabin Simulator		5. Report Date August 1997 6. Performing Organization Code
7. Author(s) Marcus, J.H.		8. Performing Organization Report No.
9. Performing Organization Name and Address FAA Civil Aeromedical Institute P.O. Box 25082 Oklahoma City, OK 73125		10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency name and Address Office of Aviation Medicine Federal Aviation Administration 800 Independence Ave., S.W. Washington, DC 20591		13. Type of Report and Period Covered 14. Sponsoring Agency Code
15. Supplemental Notes		

16. Abstract

Experimental research on issues related to emergency evacuation of a passenger aircraft cabin have tended to use existing aircraft cabins. While a great deal of useful information has been collected, these facilities have limited capabilities to be configured to investigate new or unusual cabin arrangements. A concept design for a flexible cabin simulator has been completed and is described. The proposed facility can simulate any aircraft cabin from a small, commuter category aircraft through a multi-aisle, multi-deck mega-jumbo transport. The simulator allows full flexibility in terms of exit type and placement, location and design of interior monuments, and the size and layout of the passenger cabin. Experimental control is possible of interior and exterior illumination levels, the presence of vision obscuring smoke, and the door sill height when using evacuation slides. Built from modular sections, it might be used in the future to investigate new and unusual cabin designs, such as the flying wing. The proposed simulator is described to illustrate its versatility. The associated building and project costs are also discussed.

17. Key Words Passenger aircraft evacuation, Evacuation, Experimental cabin simulator		18. Distribution Statement Document is available to the public through the National Technical Information Service Springfield, Virginia 22161	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 19	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

A Flexible Cabin Simulator

INTRODUCTION

Experimental research concerned with emergency evacuation of a passenger aircraft frequently uses aircraft cabin simulators. People serving as research subjects are placed in these simulators, which are configured to represent a typical airline passenger cabin, and then asked to evacuate as quickly as possible. Some aspect of cabin design or operational procedures, such as the width of aisles leading to exits, is then varied. Interactions between experimental subjects, their time and behavior while evacuating, and the cabin design are studied with the goal of evacuating the cabin in as short a time as possible.

Current cabin simulators are either retired aircraft, or a special purpose simulator that faithfully duplicates a single, or limited number of aircraft. The use of such simulators places many restrictions on the ability to conduct research. With these types of simulators, the location, size, and design of exits cannot be changed. New cabin designs, such as multi-deck, multi-aisle mega transports carrying 700-1,000 passengers cannot be simulated, nor can radically different aircraft designs, such as the flying wing, be studied. Consideration is currently being given to such aircraft designs that will present new unanswered questions related to emergency passenger evacuation. Finally, current simulators are not generally located adjacent to a water tank or swimming pool. This precludes the study of issues related to evacuation from an aircraft into water.

Regulatory issues related to emergency evacuation are a continuing concern. In many cases, decisions must be made for which there is little or no scientific research on which to base the decision. Frequently, the lack of research is due to lack of appropriate facilities for conducting the research. For example:

1) The requirement for a maximum of 60 feet between exits. The safety of a greater spacing could not be shown experimentally because no facility exists for varying the distance between exits.
2) The use of exits of a different size or design from those specified in airworthiness regulations is difficult. Determining appropriate ratings, and allowing their use is difficult.
3) The use of evacuation slides with multi-deck aircraft presents a number of new issues. Will there be slides from each deck, or will passengers need to make their way to a main deck before leaving in an emergency? If each deck has a set of slides, will people exiting from a slide from one deck interfere with people exiting from an adjacent slide connected to a different deck?
4) Limited ability of current evacuation research facilities to reconfigure their arrangements has hampered development of parameter data sets and validation exercises for computerized evacuation models. For the same reason, there has been only limited study of analytical techniques to address certification issues related to evacuation.

This document describes the requirements of an aircraft cabin simulator flexible enough to be reconfigured to study whatever evacuation issue needs to be examined. The requirements of the simulator, as well as required support facilities, are described. Projected construction costs of both the simulator and associated building are summarized. Finally, the current status of a Federal Aviation Administration (FAA) project to construct a flexible cabin simulator is discussed.

Requirements of a Flexible Simulator

The most fundamental requirement of a flexible simulator is the ability to simulate any type of a passenger aircraft cabin, from a small, "commuter" category aircraft through a large multi-deck, multi-aisle jumbo transport. The jumbo transport is limited to a maximum of three aisles and three decks, with 3-5-5-3 seating. Within these constraints, any width and/or length of a passenger cabin can be simulated.

A crew of two to four technicians and investigators working four to six weeks will be able to disassemble a configured cabin, and erect a different cabin.

The exterior appearance of the cabin is not important, but the interior appearance resembles a current commercial airliner. Within the cabin, it will be possible to locate any size and/or design of an aircraft exit anywhere along the length of the cabin. Exits can be located and used from either or both sides of the cabin. Interior monuments and bulkheads of varying size and shape can be installed anywhere within the cabin. Seat pitch is adjustable.

Evacuation slides are an important part of the emergency escape system. As such, the simulator must be able to use any current (or future) design of an aircraft slide. This requires that the door sill height be adjustable within the range of current aircraft. An open area at the end of each slide must be available so that research subjects using the slide can tumble at the end of the slide without hitting anything (e.g., a building wall).

Both cabin interior and cabin exterior illumination levels are variable to control for the influence of lighting levels on evacuation. A non-toxic theatrical smoke can be introduced into the cabin. This smoke completely obscures vision to simulate the visual impairment of smoke from an aircraft fire. After a smoke filled cabin evacuation is conducted, the air in the simulated cabin can be quickly exchanged with clean air so that subsequent experimental runs can be conducted.

Requirements for a Building

Early concepts for the flexible simulator envisioned a series of modules that would be built up to represent the cabin configuration of interest. It was determined that such a system could not be practically built if it would be outdoors and required to be weatherproof. In addition to the need to weatherproof the simulators, there are other requirements for the facility that dictate the need for the facility to be enclosed. Among these requirements is the ability to schedule and conduct experiments without regard to weather or time of day. Current research facilities that may be located outdoors cannot be practically used to investigate issues related to cabin exterior illumination levels. Evacuation experiments require months of preparation, and coordination with hundreds of people. Everything must be ready at the same time in order to run an experiment. When research facilities are located outdoors, weather conditions at the time of the test may make conduct of the test unsafe. If a cabin side pool is available for water survival studies, use of this pool also requires that it be in an enclosed building. Thus, the ability to design, schedule and conduct experiments with full control of illumination and environmental conditions requires that a flexible simulator be enclosed in a building.

In addition to a large area to house the simulator, with an appropriately sized open area around the simulator for research subjects to tumble without striking the building when exiting a slide, the building is required to house laboratory and workshop space to devise and maintain experimental equipment. Among this experimental equipment are the modules and fixtures required to configure the simulator. The largest size cabin for which the simulator may be configured is the triple aisle, triple deck transport. Experiments with this cabin configuration require as many as 500 research subjects. All of these subjects need to attend a safety briefing and provide informed consent to participation in the experiment. Basic subject information, such as height, weight, gender, and age must be collected and recorded. Subjects are interviewed about health problems that may make them unsuitable for an experiment. To ethically conduct such health reviews, a semi-private area is required where a subject may be interviewed by a research investigator. When many people gather in a single location, requirements for bathroom facilities and parking for their automobiles become important considerations.

The simulator requirement for a cabin side pool to investigate evacuation into water imposes a number of requirements on the building. The pool must be wide enough to properly deploy aircraft slide/rafts, and it must be long enough so that a plane load of people can be in the water without being so crowded that collisions are likely between subjects in the water and subjects jumping from the cabin. The pool must be deep enough and wide enough so that subjects will not hit the sides or bottom of the pool. The requirement for evacuation from either or both sides of the simulator implies that either the pool must be movable, the simulator must be movable, or that suitable covers for the pool are available. Research subjects participating in water survival studies need an area to change clothes and securely store their personal belongings. Thus, locker room facilities are needed for as many as 250 of each gender.

Concept Design Study

Allen Consulting, Inc. (ACI) was commissioned by the FAA to perform a concept design study of a flexible cabin simulator facility[1]. The resulting study provided guidance as to the feasibility and cost of a flexible simulator and building. The requirements described earlier guided the design. Because of the wide variation in cabin width, two simulators are proposed. One can be configured for any cabin, from a small commuter category plane, to as large as a single aisle airliner with 3-3 seating. This simulator is restricted to a single deck. The second simulator can be configured for a multi-deck cabin, with as many as three aisles. Both simulators are in a building with a water pool in between them. Covers can be placed over the pool when evacuations from both sides of a cabin onto dry land are being studied. Both simulators are on hydraulic positioning systems that can lift and tilt the simulators to any desired sill height and angle.

A series of artist concept drawings illustrating the flexibility of the simulator are shown in Figures 1-4. In these figures the dark area to the viewer's right of the cabin is the water pool. The simulator is shown in the rest position (i.e., door at floor level) with evacuation slides mounted on the rear floor level exit. Figures 1 and 2 show the commuter and narrow body simulator configurations, while Figures 3 and 4 illustrate the wide body, and the triple aisle, triple deck mega jumbo transport configuration. Figures 5-8 illustrate seating plans for the commuter category, narrow body single aisle, wide body main deck dual aisle, and mega jumbo transport triple aisle main deck cabin configurations.

The flexible simulator uses a modular design. Simulated cabins are created by matching a number of modules representing a short section of a cabin. This module, in turn, is built from a number of components representing such items as floors, ceiling, exits, and walls. Use of the modular design maximizes the flexibility of different cabin arrangements and designs possible. Use of a modular design allows, at some future date, the rapid fabrication of new cabin design features, and the easy incorporation of new cabin design features at some point 15-20 years after the simulator is completed. Because only the module needs to be fabricated, these new features can be studied for minimum expense. Future modules may be as simple as different exit size or orientation, through new and different door operations, as well as the study of radically different designs of cabins such as those being considered for a flying wing.

Figures 9-11 illustrate this modular design. Figure 9 shows an exploded view of the modules that might be used to configure a commuter/narrow body cabin. Figure 10 shows the same view for a triple deck mega-wide body cabin. Figure 11 shows an exploded view of a single module illustrating the components used to build a module.

The resulting building needed for such a facility is shown in Figures 12-14. Figure 12 shows a plan view of the building. Note the two simulators located adjacent to the evacuation pool. A bridge crane above this area allows the movement of pool covers from the storage area (shown on the left of Figure 12). The lobby of the building, shown on the lower right corner of Figure 12, can be transformed into a subject briefing area when large experiments are being conducted. Figure 12 shows the lobby as it might be set up with tables and chairs for processing subjects through their safety briefing, and in providing informed consent. Figures 13 and 14 show two cross sectional elevation views through the building, illustrating the simulators up on their positioning system. Note the location of the pool in Figure 13. In Figure 14, the orientation area/lobby is shown. Note in Figure 14 the administrative space above the lobby. Also note on Figure 14

[1] *Design Concept Prepared for the FAA Flexible Aircraft Cabin Simulator*, FAA Contract DTFA-02-94-D94303, August 1, 1995

the viewing gallery on the third level. From this viewing gallery, research scientists will be able to view experiments in the simulator area. The same area also permits monitoring during an experiment by the medical and safety staff required when using human research subjects.

The facility envisioned in the concept design features approximately 36,000 square feet of space for the simulator area, including a water survival tank 45 feet wide by 80 feet long by 15 feet deep. The associated administrative area, including the subject briefing/lobby area, offices, locker rooms, and equipment maintenance areas is 14,000 square feet.

Estimated Facility Cost

As part of ACI's concept design study, detailed cost estimates were performed. The wide body simulator cost was estimated as $4 million, and the narrow body simulator cost was estimated as $1.8 million. The building required to house the simulators is estimated to cost $9.3 million, exclusive of land cost. The pool required for water survival studies adds $900,000 to the cost of the building. Thus, the total facility, including wide and narrow body simulators, the required building, and a water survival tank, is estimated to cost $16 million.

SUMMARY

Aircraft cabin evacuation research relies on experiments conducted in retired transport aircraft, or in cabin simulators designed to represent one, or a limited number of aircraft. Current facilities significantly limit the ability of research scientists to design experiments. The locations, size, and shape of exits cannot be varied, nor can multi-deck or multi-aisle cabins be investigated. New, possibly radically different cabin designs, such as those associated with a flying wing, cannot be investigated. This paper describes the results of a concept design study to build a flexible simulator and its associated facilities.

The flexible simulator proposed features a number of unique and useful features. Any cabin size, width, and length could be simulated from a small "commuter" category aircraft cabin through a three aisle, three deck mega-jumbo transport seating 700-1,000 passengers. The simulator sits on a hydraulic positioning system, allowing door sill height to be adjusted. The simulator uses a modular design allowing for the rapid and inexpensive fabrication of cabin components, such as exits, essential to the study of future cabin safety issues. Interior and exterior illumination levels can be controlled, and a non-toxic, vision obscuring theatrical smoke can be introduced into the cabin. A cabin side pool allows the investigation of evacuation into water. The pool can be covered, allowing evacuation from both sides of the cabin.

The proposed simulator would be housed in a building permitting the scheduling and conduct of experiments without regard to the weather. The building is also required, because a weatherproof flexible simulator is not a practical design. The building has a large enough open area at the end of the evacuation slides so that research subjects can safely tumble without impacting building walls while exiting a slide. A large lobby, which can be reconfigured as a subject briefing room, is included in the building as are locker rooms for as many as 250 research subjects of each gender. The building's size is approximately 36,000 ft^2 in the simulator area, and 14,000 ft^2 of administrative space.

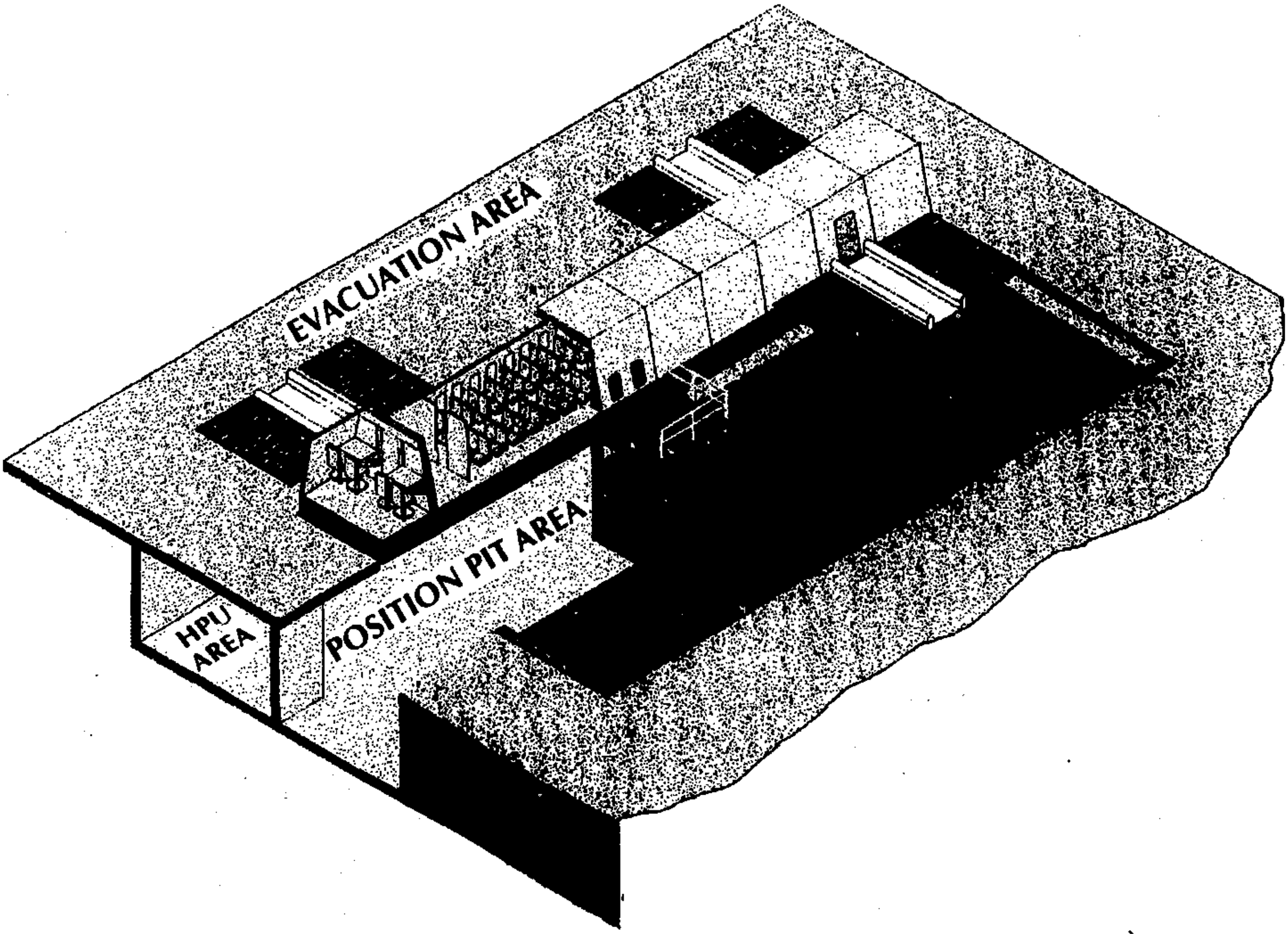

Figure 1. Artist's Concept Commuter Body Simulator (Shown at Rest Position)

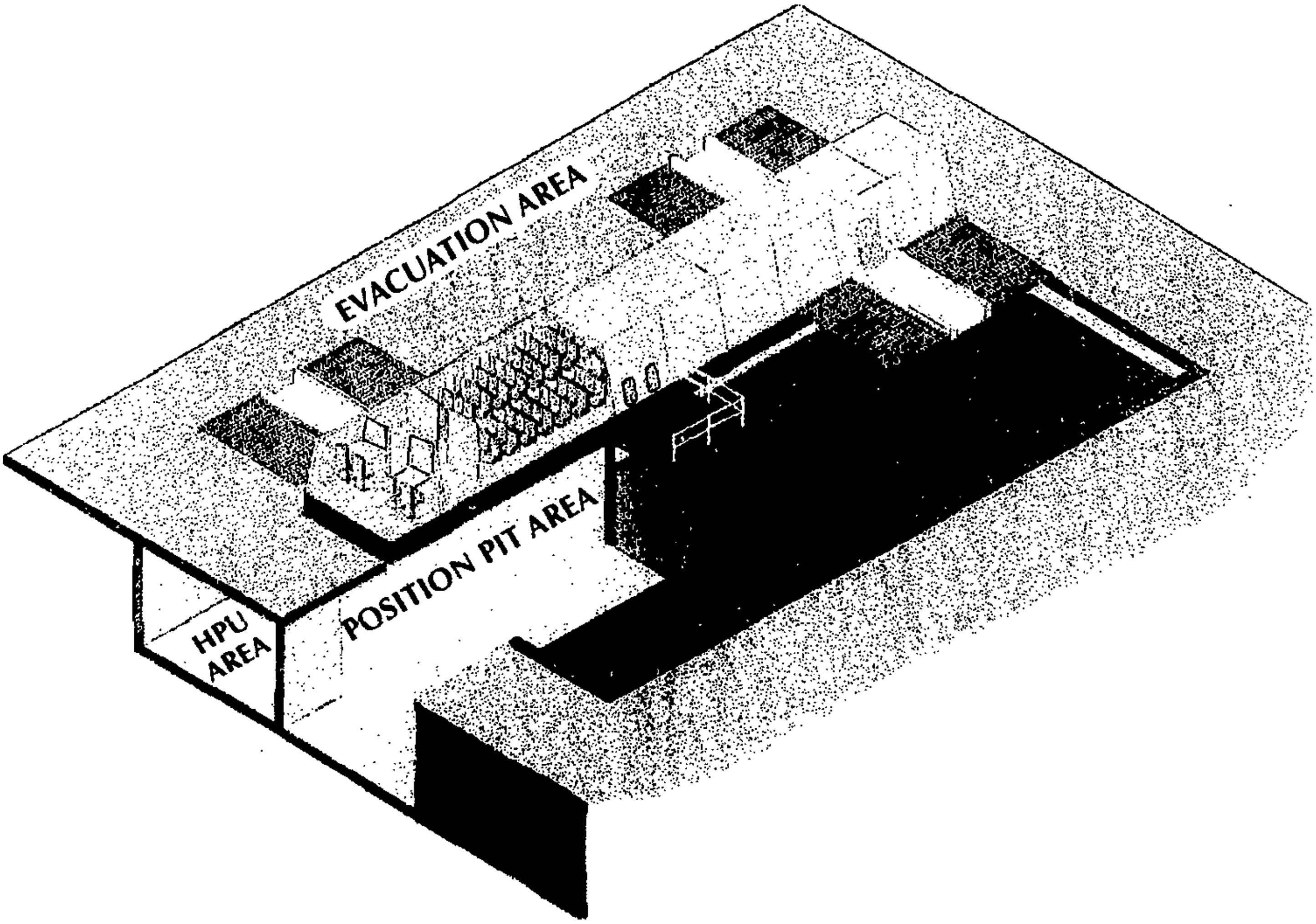

Figure 2. Artist's Concept Narrow Body Simulator (Shown at Rest Position)

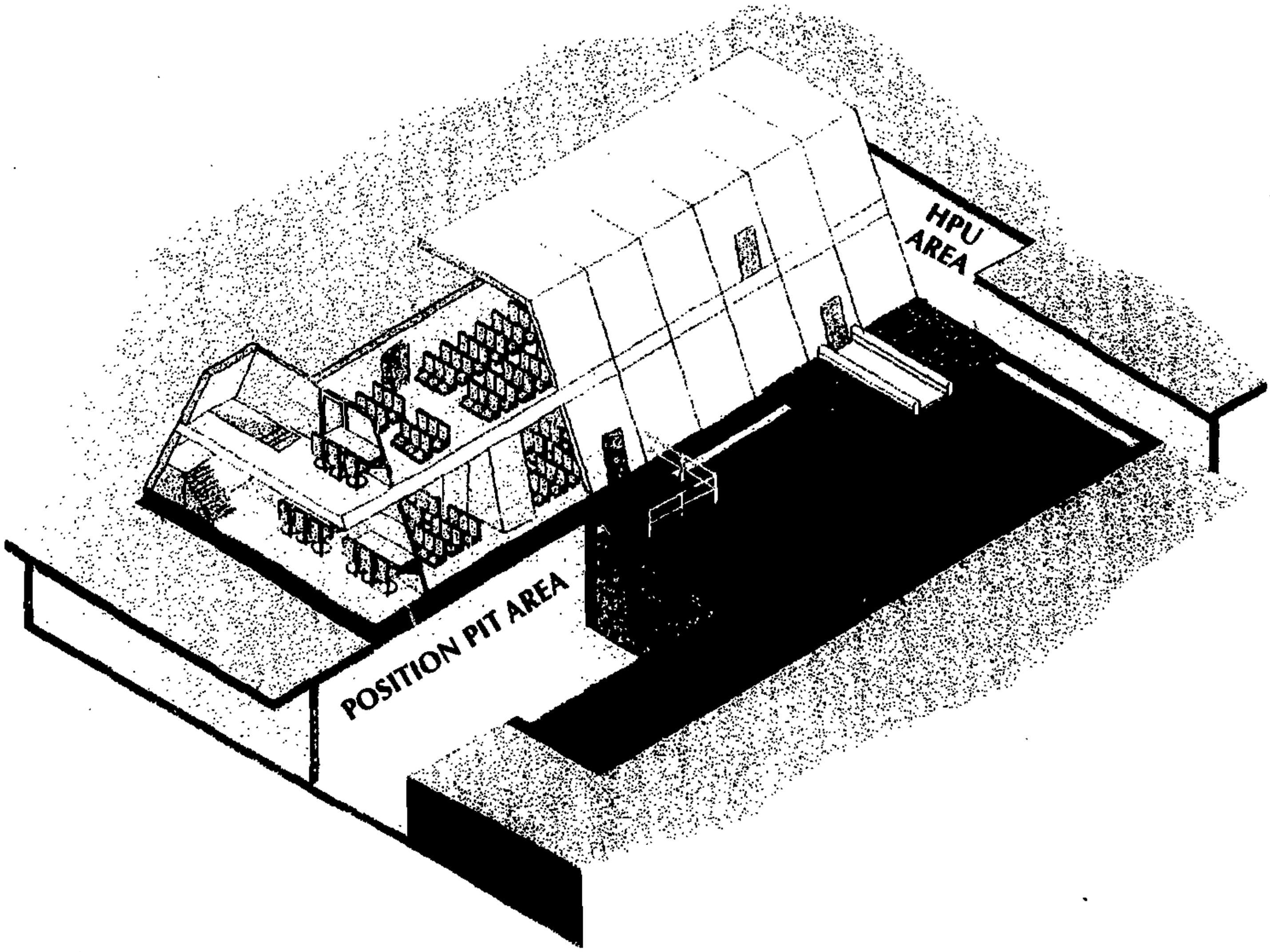

Figure 3. Artist's Concept Wide Body Simulator (Shown at Rest Position)

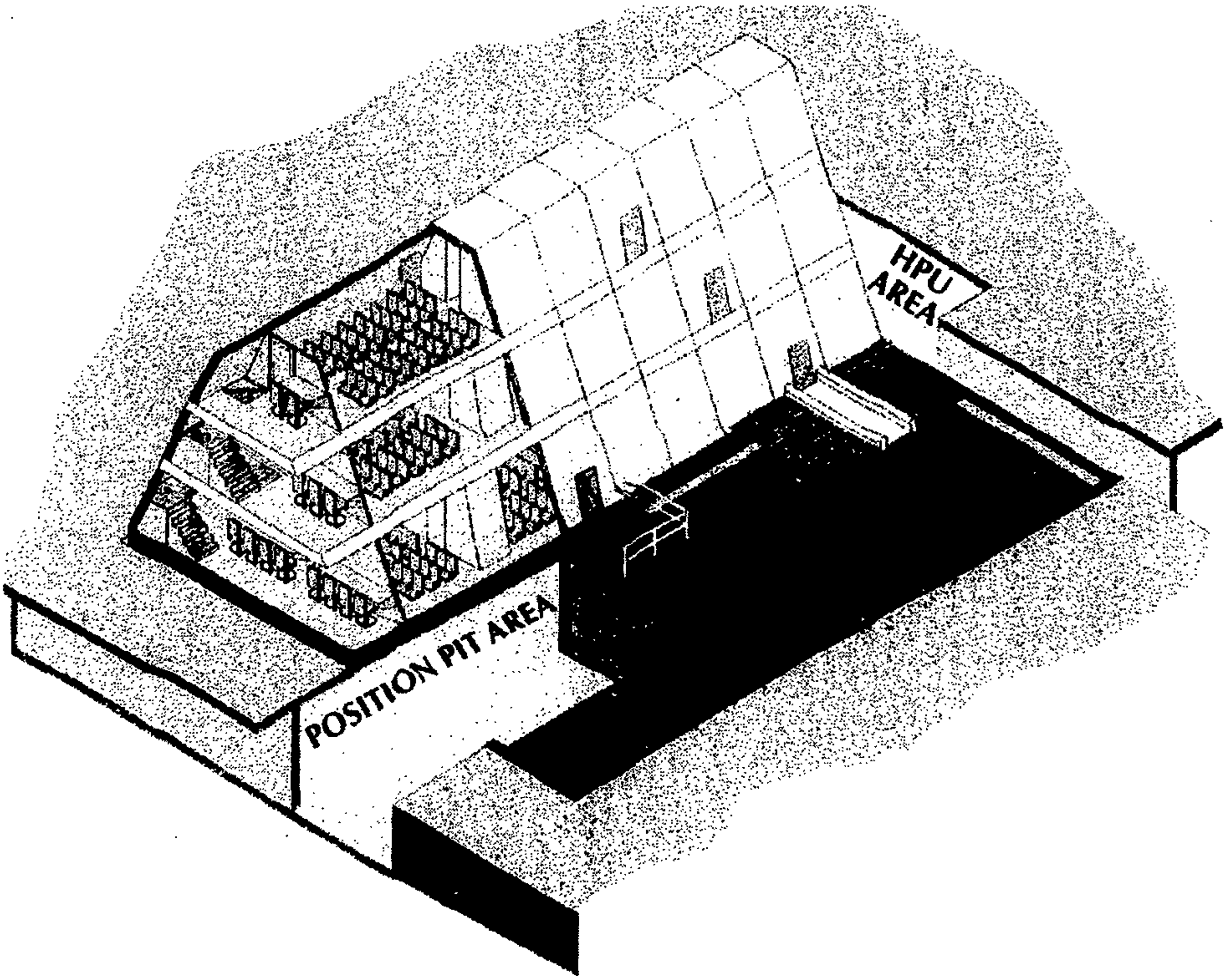

Figure 4. Artist's Concept Mega Body Simulator (Shown at Rest Position)

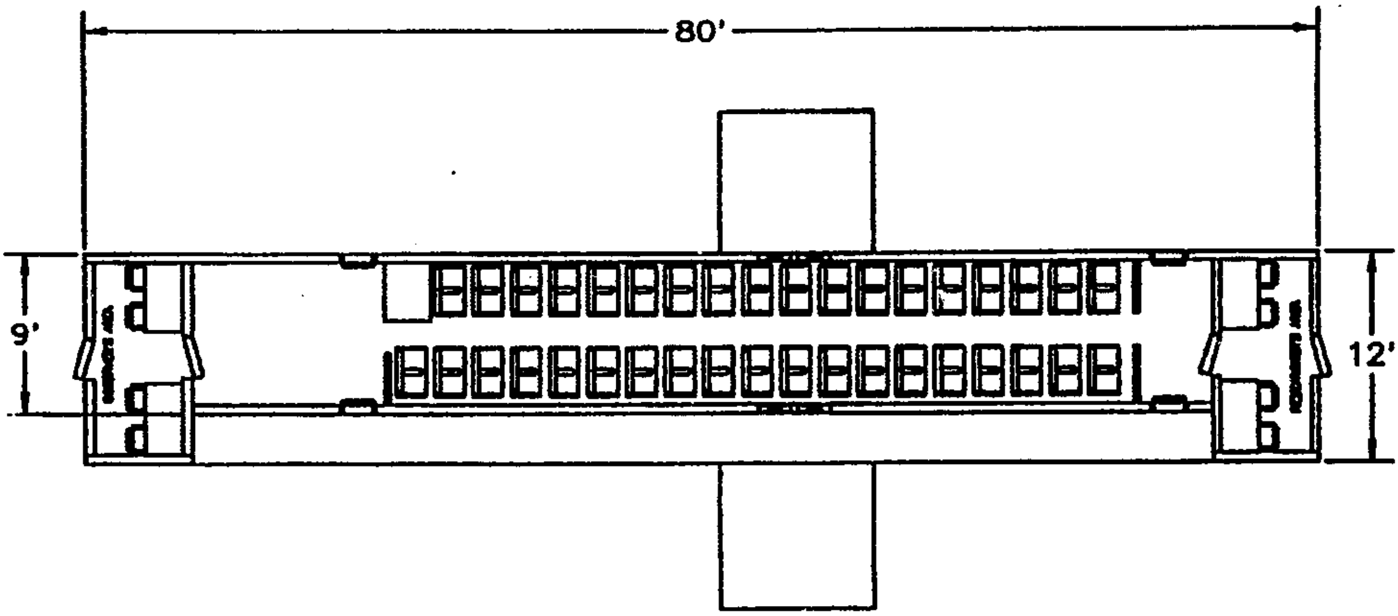

Figure 5. Commuter Body Floor Plan (No Scale)

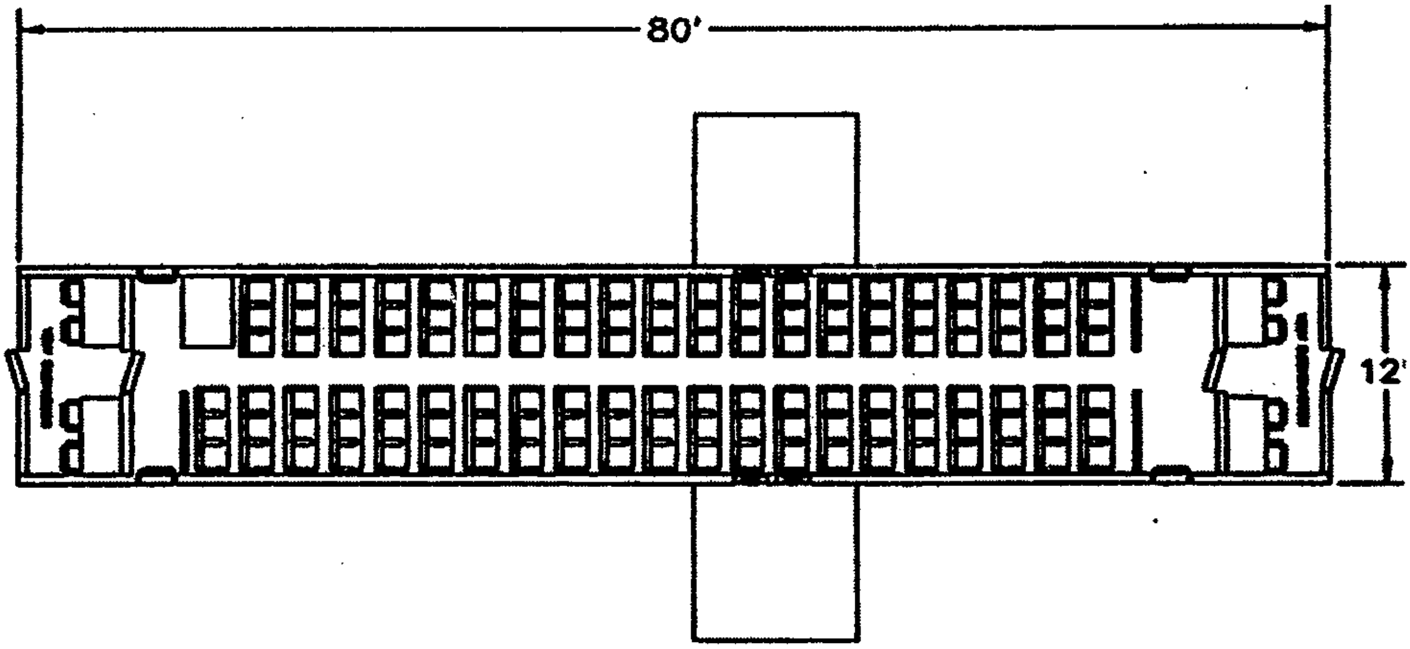

Figure 6. Narrow Body Floor Plan (No Scale)

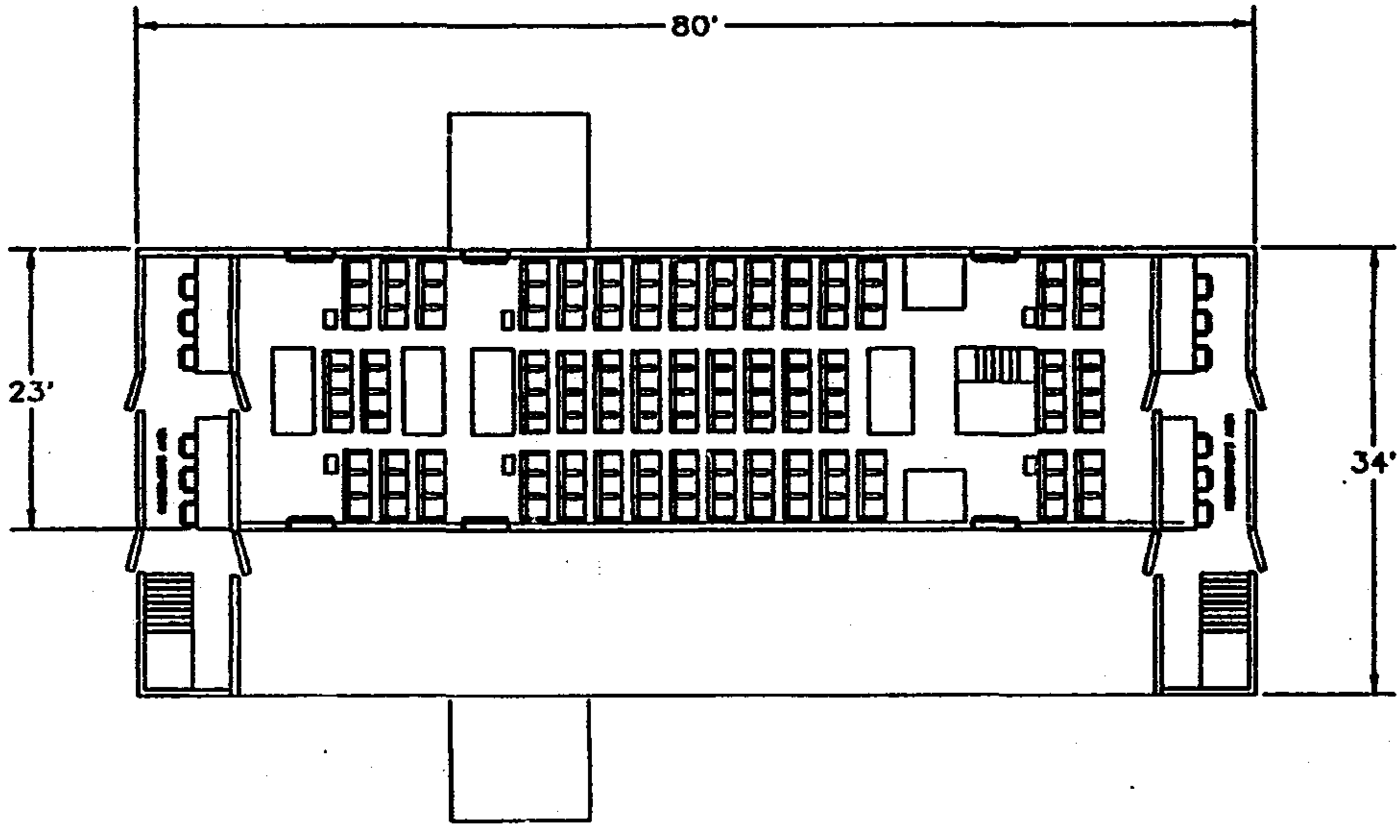

Figure 7. Wide Body Deck Floor Plan (No Scale)

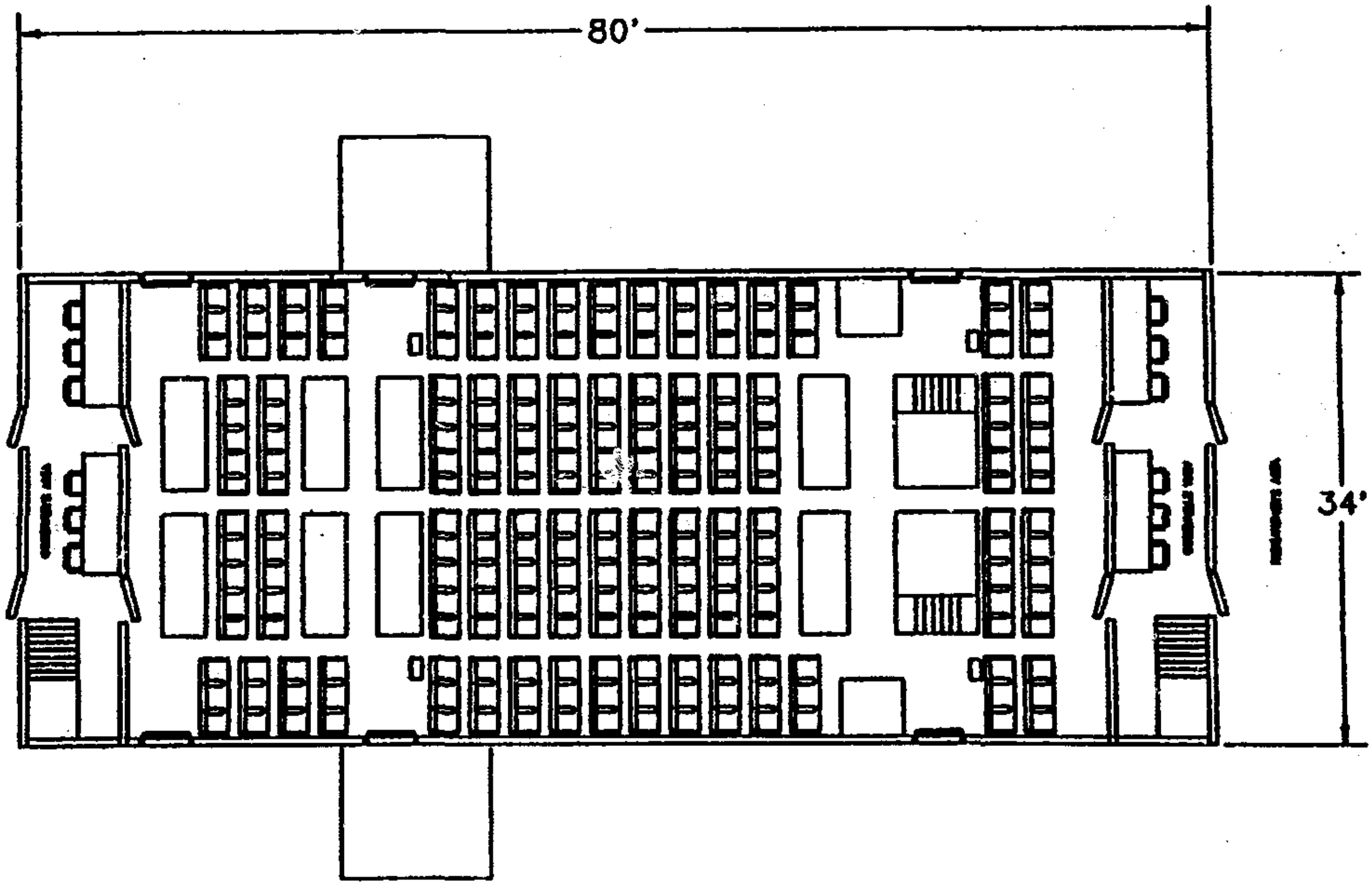

Figure 8. Mega Body Deck Floor Plan (No Scale)

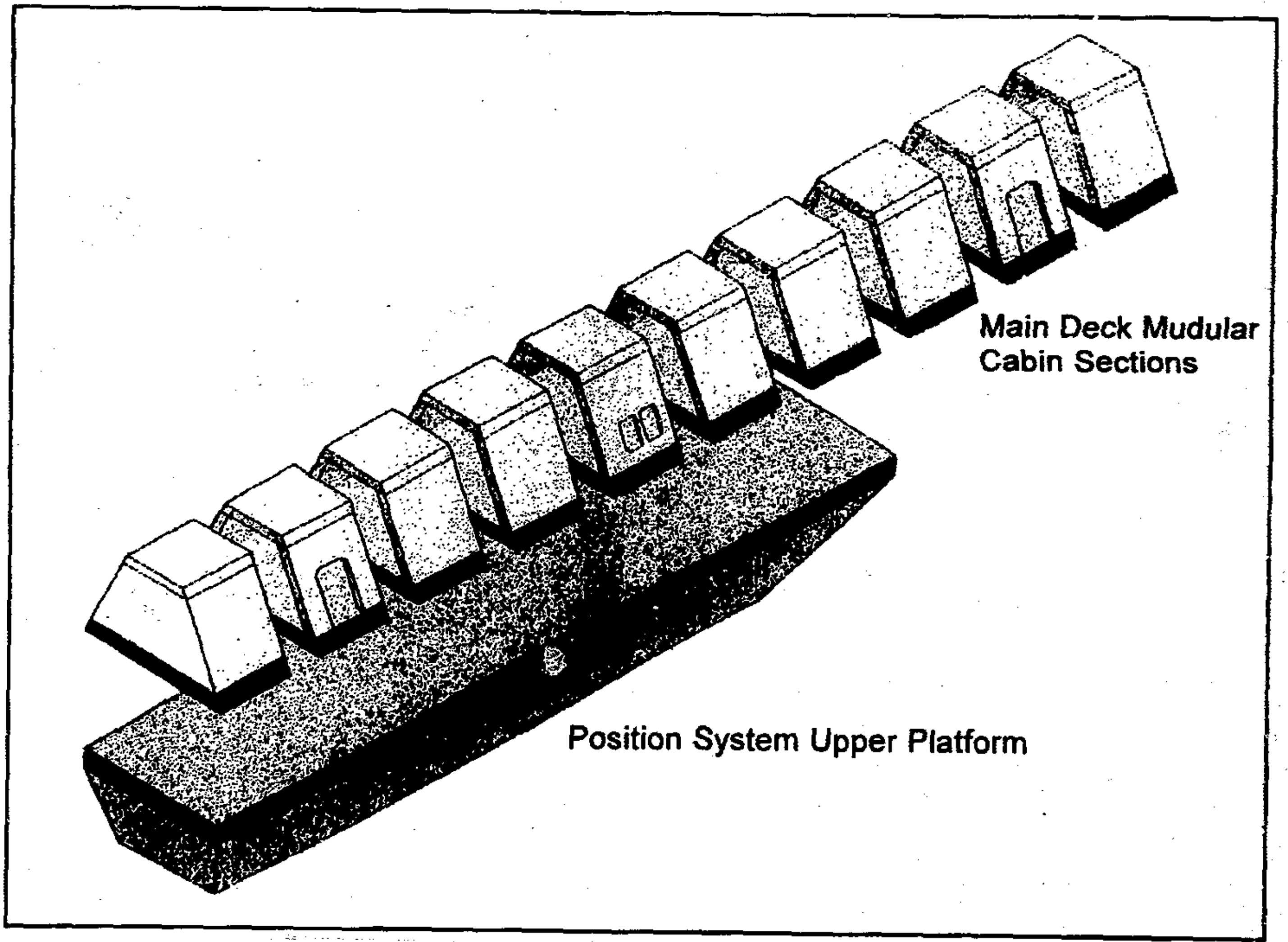

Figure 9. Artist's Concept Commuter/Narrow Body Simulator

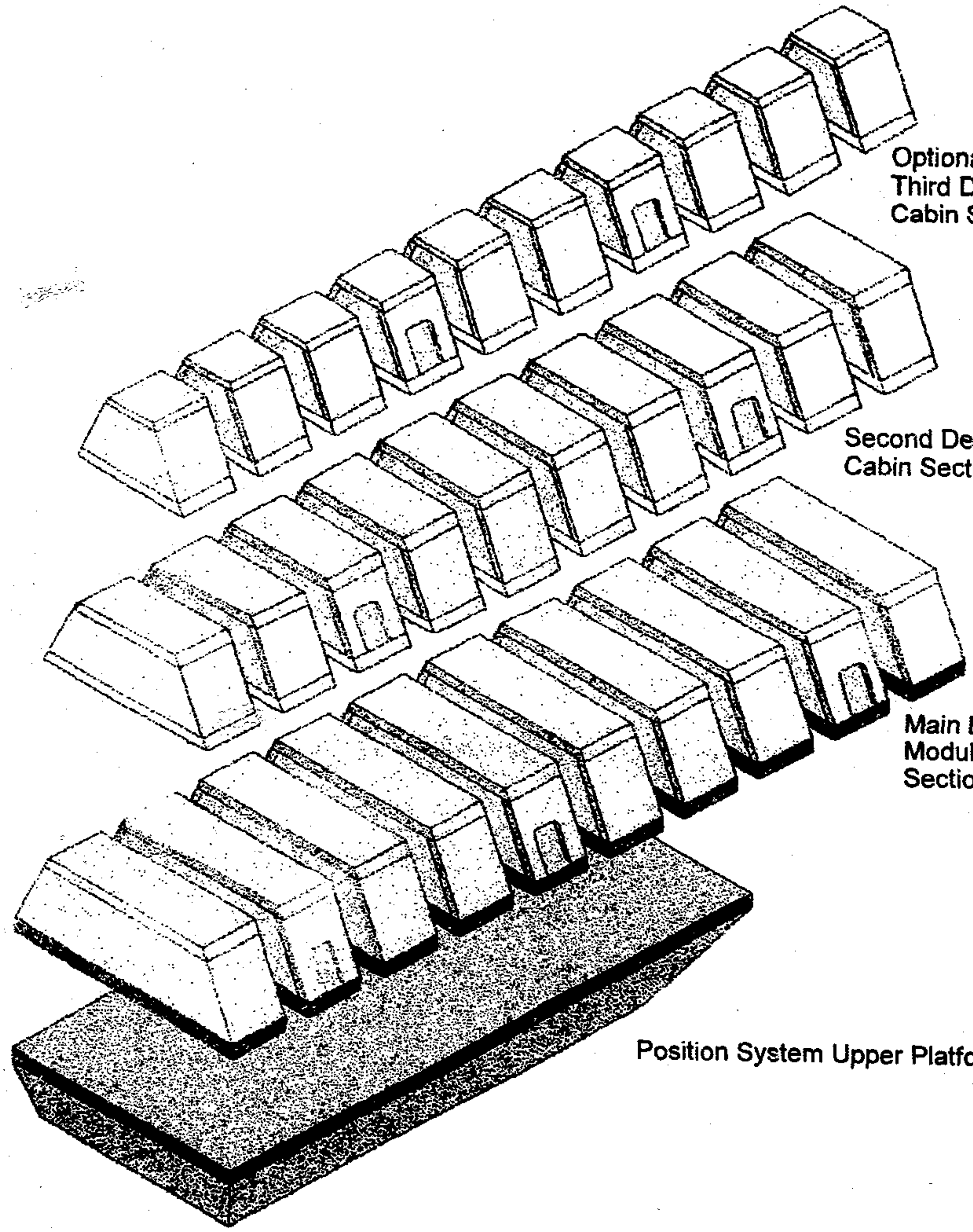

Figure 10. Artist's Concept Wide/Mega Body Simulator

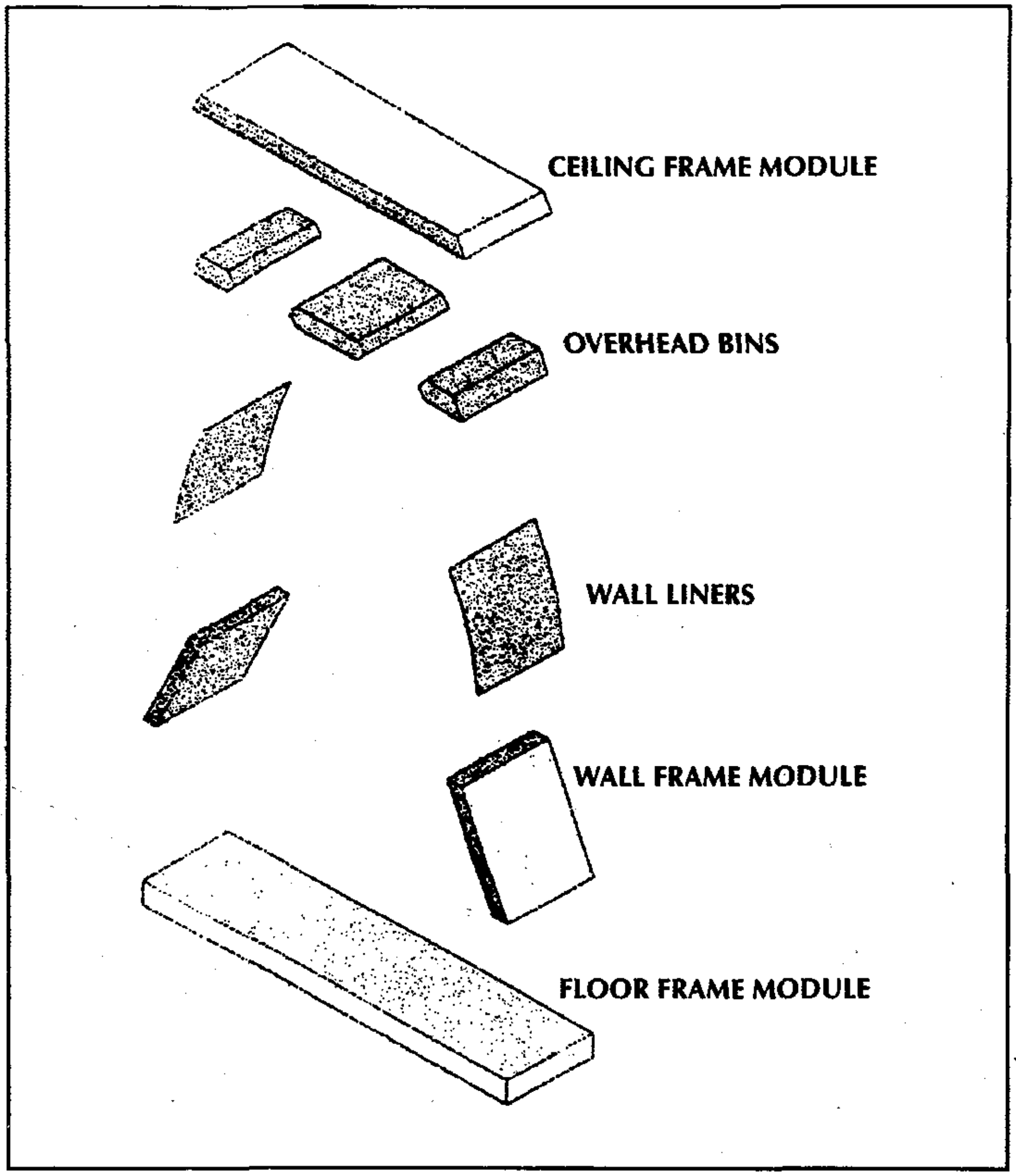

Figure 11. Artist's Concept Typical Cabin Module Assembly (WMBS Shown, CNBS Similar)

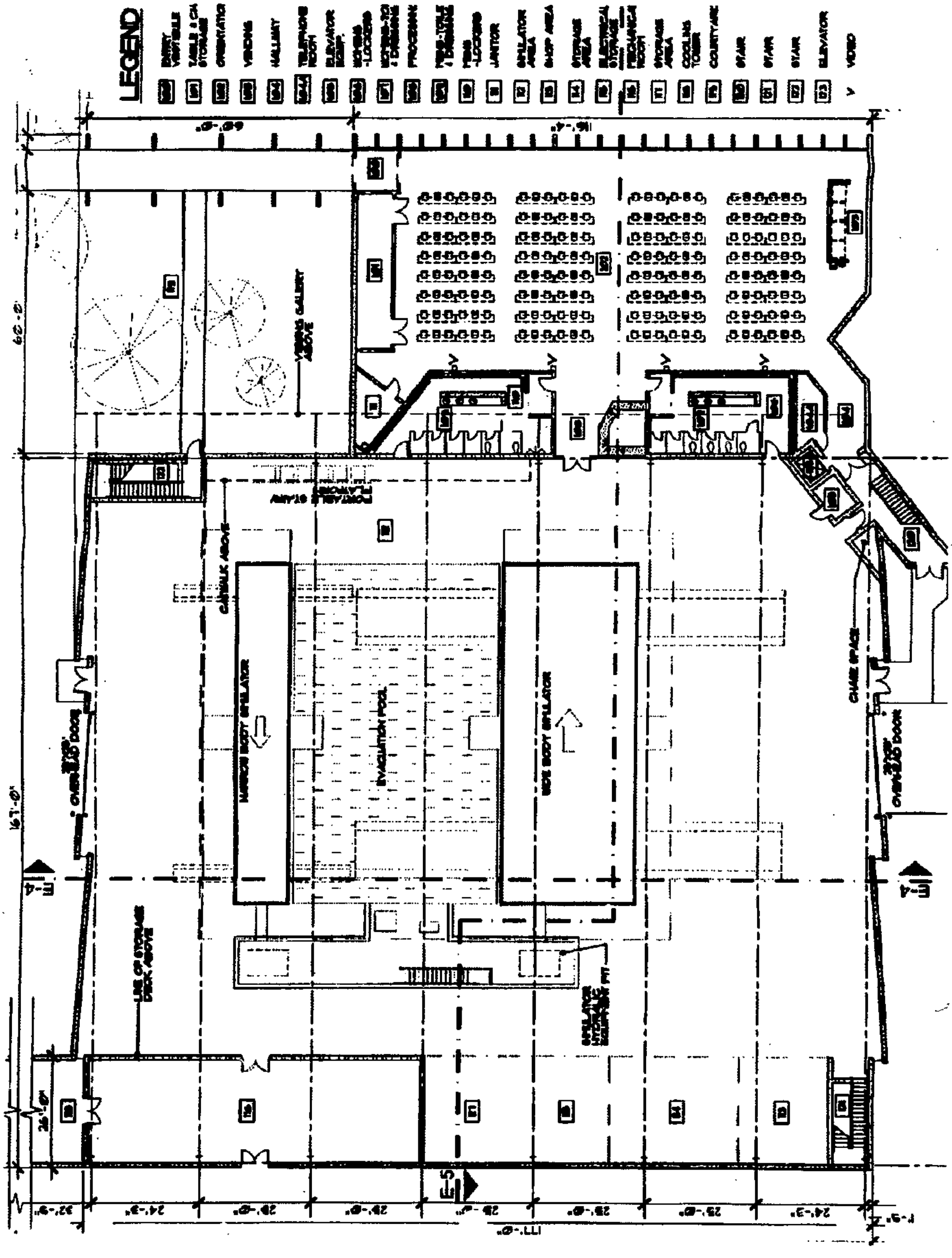

Figure 12. Plan View of Proposed Facility

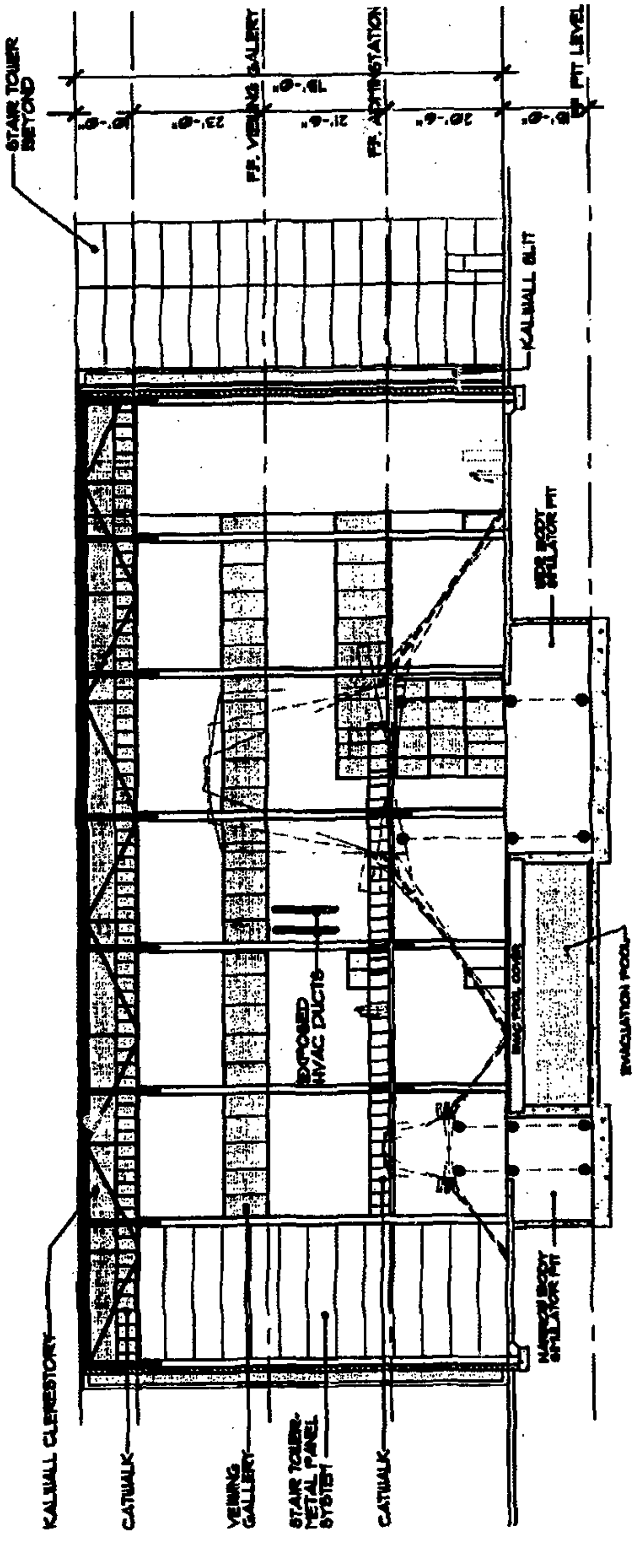

Figure 13. Elevation of Proposed Facility

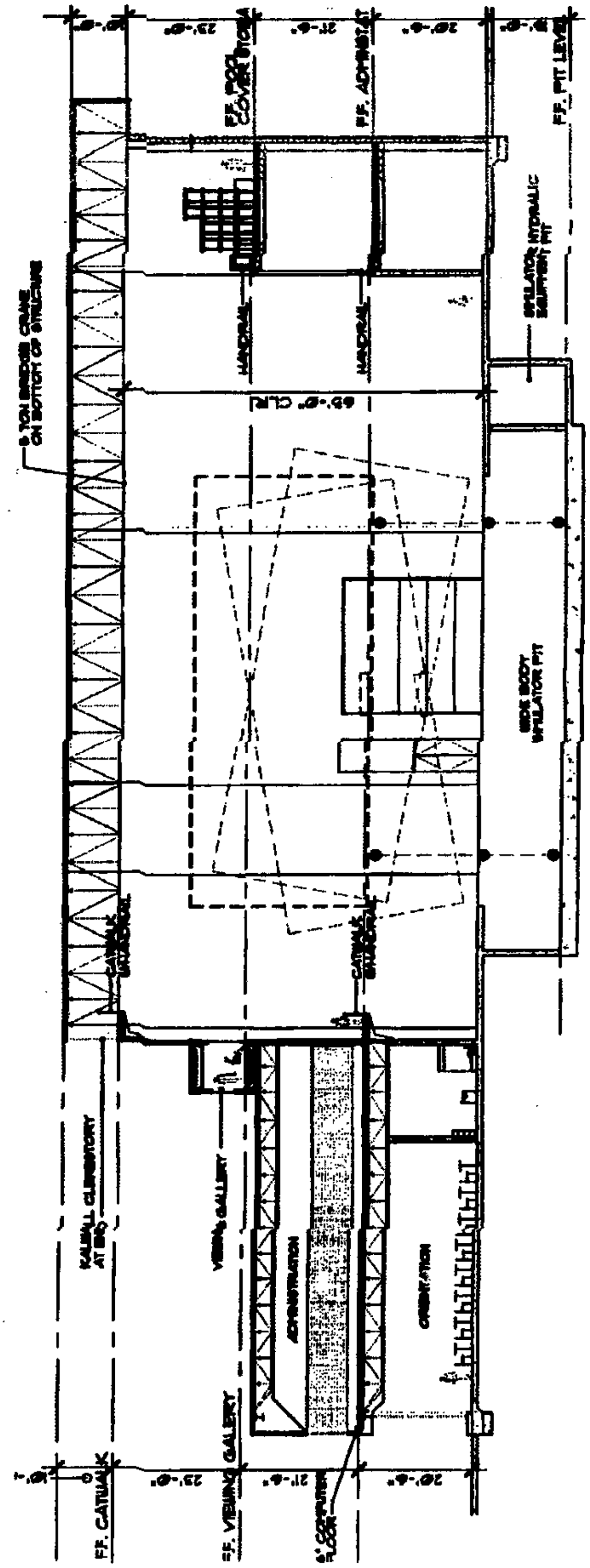

Figure 14. Elevation View of Proposed Facility

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