N88-19884

SPACE STATION ARCHITECTURAL ELEMENTS MODEL STUDY

SPACE STATION HUMAN FACTORS RESEARCH REVIEW

BY

Thomas C. Taylor
Taylor and Associates, Inc.
P.O. Box 1547
Wrightwood, CA 92397
Phone 619-249-6882

Eyoub Khan
Conceptual Design Group
18002 Skypark Circle
Irvine, CA 92714

John Spencer and Carlos Rocha
Design Science
7033 Sunset Blvd, Suite 310
Los Angeles, CA 90028

Ethan Wilson Cliffton, AIA
3435 Army Street, Studio 332
San Francisco, CA 94110

ABSTRACT

The objective of the study is to explore and analyze the interaction of major utilities distribution, generic workstation, and spatial composition of the module interior. The study is approximately half complete with seven different interior models fabricated at a scale of 1" equal 1' - 0". The final output will be a Final Report using the "Inquiry by Design" approach and suggesting an Evaluation Criteria for interior human factors module design.

Taylor and Associates, Inc. study manager is Thomas C. Taylor and previous work includes three years experience in the Alaskan Construction camps. These camps provide a rough analog to the Space Station which includes the severe environment, utility design problems, logistics considerations and the effect of interior human factors design on the workers involved. Other work includes Orbital Assembly Studies, Human Factors Interior Design, Aft Cargo Carrier and entrepreneurial activities such as SPACEHAB.

THE SPACEHAB Module is a 1,000 cubic foot pressurized Middeck Augmentation Module for the STS. It is financed by private funding and expects to sign a M.O.U. with NASA in the near future.

The Flat End Cap research from the 1984 NASA contract led indirectly to the design of the Flat End Caps used on the SPACEHAB Module and the interior design models used similar techniques to the previous NASA Contract. The SPACEHAB Module can provide up to 100 additional Middeck lockers and still have 70% of the interior volume to devote to other manned activities. The potential for the development and orbital testing of Space Station "Lead In" interior hardware, science experiments and commercial process development exists with the SPACEHAB Module and could start six to eight years before the hardware is tranferred to the station. The SPACEHAB organization intends to focus on low cost repeated access to space through a module costing approximately $5 million to lease and 6 about months to integrate.

Two other ideas from the first study were chosen to be expanded and explored in the second contract. The ideas include a Triangular Central Beam and a Workstation for orbital modules. These have been developed into seven scaled models by the three subcontractors listed. The approach has been "Inquiry by Design" which requires an interior design free of the conventions of the one gravity environment. This search has led to a central beam to be used as a testbed. Then the approach develops theoretical interior designs on which to test the variables. The interior configurations test the theoretical human factors variables through the seven designs and explores the Human Factors, commercial and functional issues. The result will be a series of Oppositions/Gradients and produce components of Human Productivity, namely operations, design and human performance.

A variety of issues can be expressed as Oppositions and Gradients. They include Packing Densities vs. circulation, Efficiency of Packing vs. Standardization, Flexibility vs. Diversity, and most importantly the Composition of Interior Volume as Space for Living as a PLACE vs. Residual "Negative" Volume. It is this "SPACE FOR PRODUCTIVE LIVING" we found to be critical in the very commercial and competitive environment of the Alaskan Construction Camps.

The result of the study is expected to be a series of observations and a preliminary evaluation criteria which focuses on the Productive Living Environment for a module in orbit.

Several other aspects have been explored in the study but not covered in depth in the presentation. Utilities for example are a critical design driver. A series of utility rules of thumb are developed to expand on the Alaskan experience and adapt it to the microgravity environment. There is no reason to make the same mistake twice. The workstation for an orbital module can have an impact on both the station operations and surface commercial customers. This is an area where private funding combined with NASA research budgets can create an entrepreneurial thrust similar to the SPACEHAB Module.

Three subcontractors have contributed to the NASA study this year.

Eyoub Khan is the principal force behind the Conceptual Design Group, an Irvine, CA architectural design and planning firm, and created three of the models and most of the renderings for the study. The interior design concepts created include the Hexagonal Beam - Large, Square Beam and H Beam models.

John Spencer is the head of Design Science, a Los Angeles firm specializing on interior human factors design. Previous work includes human factors interiors for an Undersea Lab and Antarctic design projects. John is assisted by Carlos Rocha, and the firm created the Triangular Beam on Center and off Center model. Also created were the Hexagonal - small and the Workstation models.

Ethan Wilson Cliffton, AIA, is an architect in San Francisco and brings to the project a depth of technical knowledge gained in more than ten years experience on complex surface science related projects. These include a major research complex at Lawrence Berkeley Labs. The complex consists of a building to house the world's most powerful Atomic Resolution Microscope, a connecting ARM Support Laboratory and the Surface Science and Catalysis Laboratory. His work also includes a large telescope facility in Hawaii and projects for Cetus and Hewlett-Packard. Ethan created the Center Cluster Beam concept.

INTRODUCTION

- BACKGROUND
- LAST YEARS CONTRACT
- SPACEHAB MODULE
- OBJECTIVES
- APPROACH
- HUMAN FACTORS / HUMAN PRODUCTIVITY VARIABLES
- ISSUES
- CENTRAL BEAM TEST DESIGN
- WORKSTATION TEST DESIGN
- OBSERVATIONS

BACKGROUND

TAI WORK IN SEVERE AND ISOLATED ENVIRONMENTS, ALASKAN CONST CAMPS, UNDERSEA LABS, ANTARCTICA, ETC.

FIRST NASA-AMES SPACE STATION STUDY

- CONCEPTS FOR

  CENTRAL BEAM

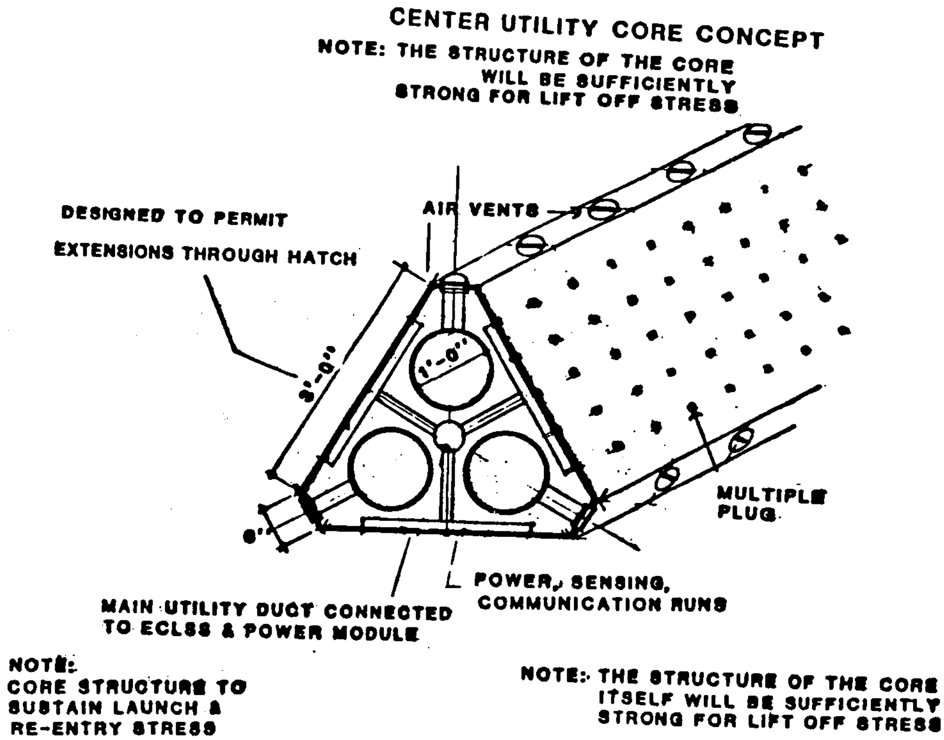
  WORK POD

  FLAT END CAP

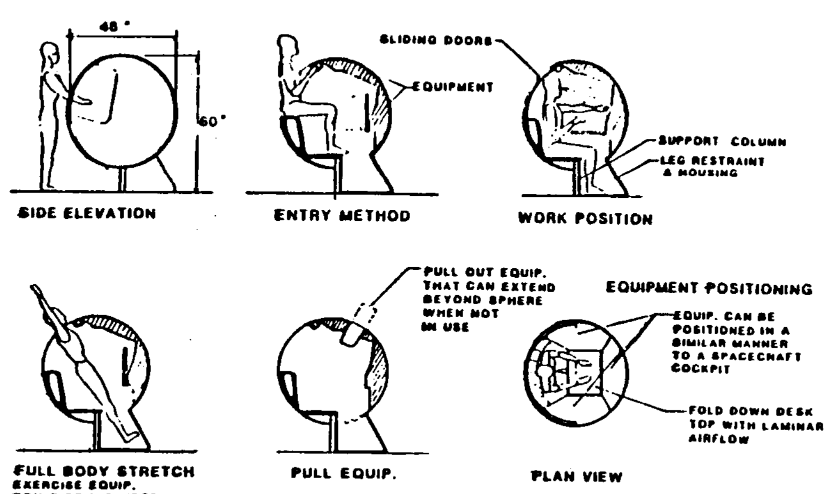
  HUMAN FACTORS FOR FLEXIBLE WORK SPACE

SPACEHAB INITIATIVE - PRIVATELY FINANCED COMMERCIAL VENTURE

GENERIC RESEARCH OF THE FIRST STUDY LED TO THE FLAT END CAP AND WORK POD WHICH EVOLVED INTO THE DEVELOPMENT OF THE SPACEHAB DESIGN



Triangular Central Beam



OBJECTIVE / OUTPUT

OBJECTIVE:

TO EXPLORE AND ANALYZE THE INTERACTION

OF

MAJOR UTILITIES DISTRIBUTION

GENERIC WORKSTATION

SPATIAL COMPOSITION

OF MODULE INTERIOR

OUTPUT: INQUIRY BY DESIGN DERIVED EVALUATION CRITERIA

RESULTS OF THE FIRST STUDY

1. INTERNAL UTILITIES DISTRIBUTION IS A MAJOR DESIGN DRIVER.
2. WORK STATIONS HAVE CRITICAL RELATION TO UTILITY DISTRIBUTION AND COULD BECOME THE INTERFACE TO SPACE STATION FOR SOCIETY THROUGH COMMERCIAL DEVELOPMENT OF THE ENGINEERING WORKSTATION.
3. TOGETHER UTILITIES AND EQUIPMENT INTERACE WITH SPATIAL COMPOSITION.
4. THE FLAT END CAP CAN PROVIDE AN ALTERNATIVE TO THE CONICAL END CAP FOR EFFECTIVE UTILIZATION OF THE STS.
5. THE MODIFICATION AND TECHNICAL UPDATING OF THE MODULE ON ORBIT IS A CRITICAL DESIGN DRIVER.

APPROACH BASICALLY "INQUIRY BY DESIGN"

1. THE STUDY OF WORKSTATION, UTILITIES AND HUMAN FACTORS REQUIRES THAT TEST DESIGNS START WITH AN INTERIOR CONFIGURATION FREE OF ONE GRAVITY CONVENTIONS SUCH AS UP-DOWN, FLOOR/CEILING.

   (BUT DOES NOT PRECLUDE EVOLUTION OF CONVENTIONAL FORMS FROM RESEARCH DESIGNS.)

2. SEARCH OF POSSIBILITIES LED TO SELECTION OF CENTRAL BEAM APPROACH AS MOST FREE OF ARCHITECTURAL CONVENTIONS – TO BE USED AS A 'TEST BED' FOR INQUIRY BY DESIGN.

3. DEVELOP THEORETICAL APPROACHES TO INTERIOR CONFIGURATIONS TO EXPLAIN INTERACTION OF BEAM, WORK POD DERIVATIVE, LOGISTICS SUBMODULES AND SPATIAL COMPOSITION.

4. DEVELOP INTERIOR CONFIGURATIONS TO TEST THEORETICAL VARIABLES:

   - 6 BEAM CONFIGURATIONS, GROUPED IN THREE PAIRS.
   - HUMAN FACTORS/ COMMERCIAL/ FUNCTIONAL

APPROACH BASICALLY "INQUIRY BY DESIGN"

5. THRASH/ WRING OUT HUMAN FACTORS ISSUES AS OPPOSITIONS/GRADIENT AND AS COMPONENTS OF HUMAN PRODUCTIVITY — OPERATION/DESIGN/ HUMAN PERFORMANCE.

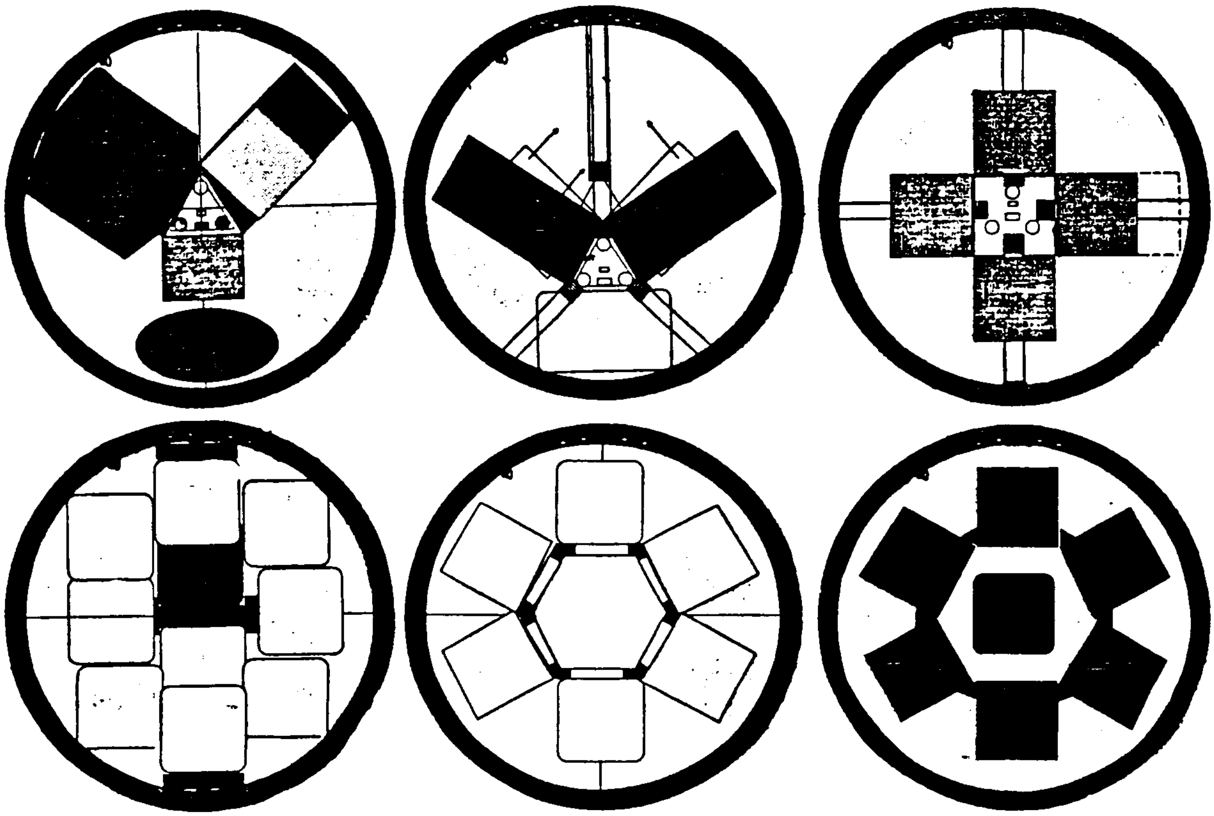
6. OBSERVATIONS

7. FINDINGS

8. RECOMMENDATIONS

   EVALUATION CRITERIA

CENTRAL BEAM TEST DESIGNS



ISSUES: OPPOSITIONS OR GRADIENTS

COMPOSITION OF INTERIOR VOLUME AS A LIVING VOLUME VS RESIDUAL 'NEGATIVE' VOLUME

PACKING DENSITIES VS CIRCULATION

PACKING DENSITIES VS PERCEIVED SPACIOUSNESS

SYMMETRY VS ASYMMETRY

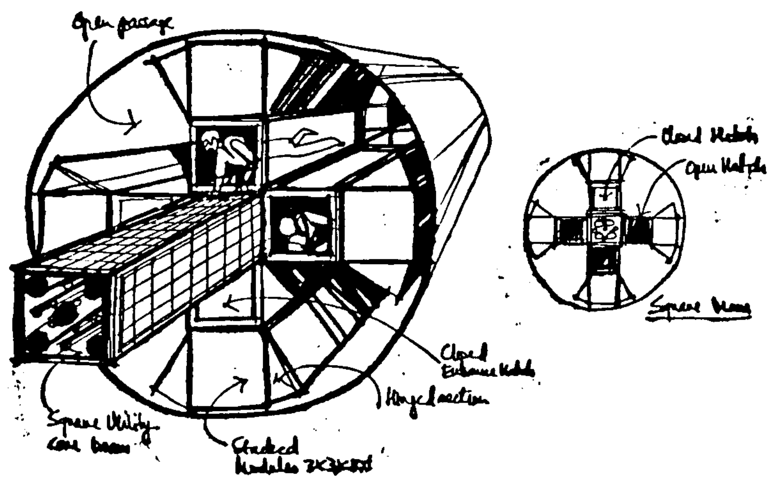
EFFICIENCY OF PACKING / STANDARDIZATION VS FLEXIBILITY / DIVERSITY

STANDARDIZATION OF UTILITY INTERFACES VS DIVERSITY OF ACCOMMODATION REQUIREMENTS

STANDARDIZATION OF STRUCTURAL INTERFACES VS DIVERSITY OF MODULAR PACKAGING

CENTRAL BEAM TEST DESIGNS

SQUARE BEAM ON CENTER

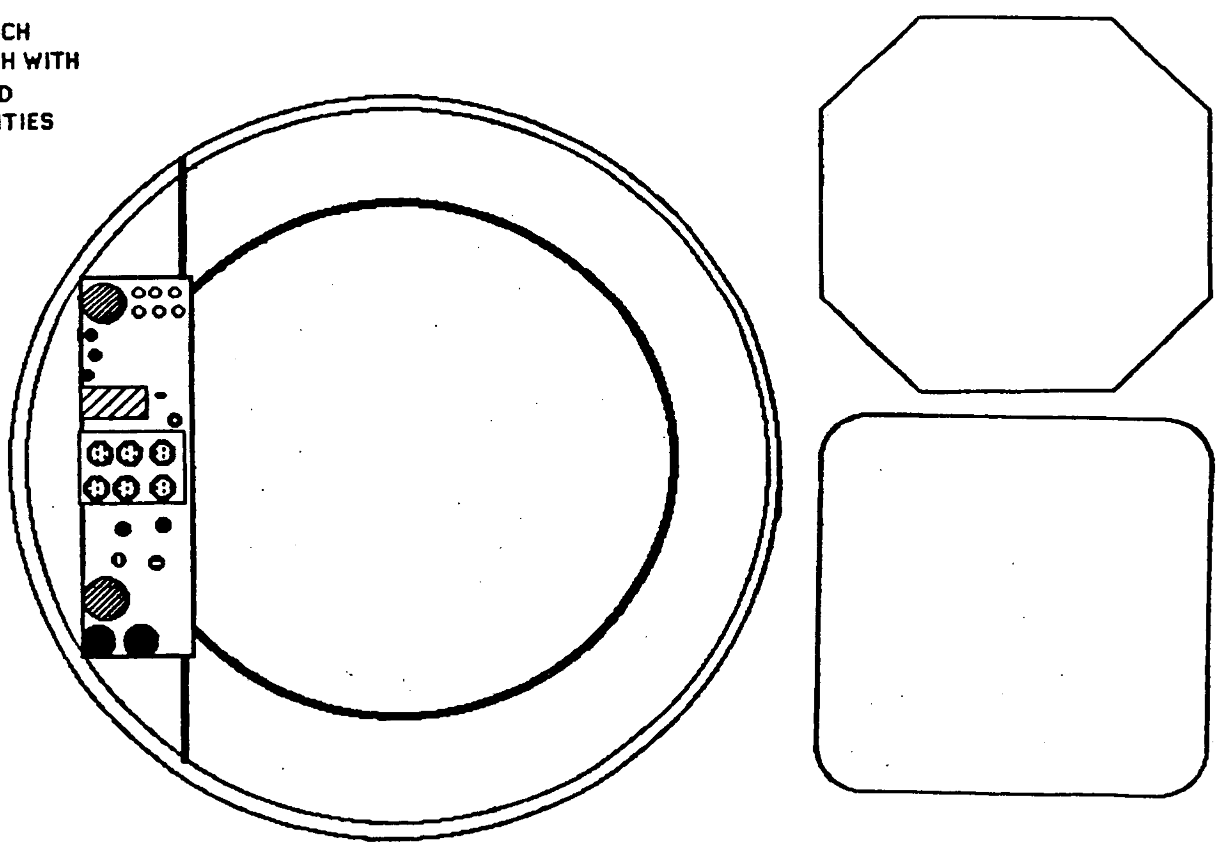


PERMITS TWO AXIS SYMMETRY

MOST PERFECTLY SPACE FILLING BEAM ALLOWS ALIGNMENT OPPOSITE SIDES

Hatch Assumption

50 INCH HATCH WITH BOXED UTILITIES



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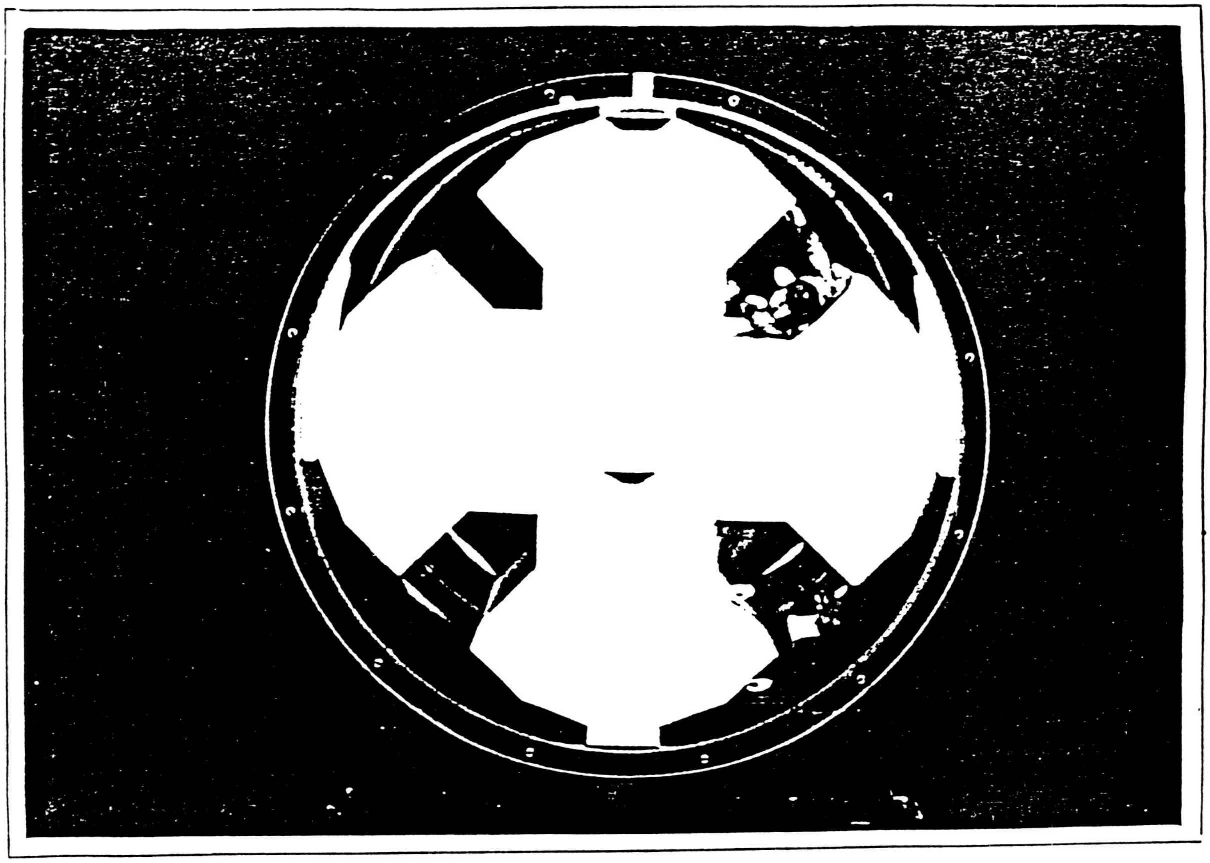
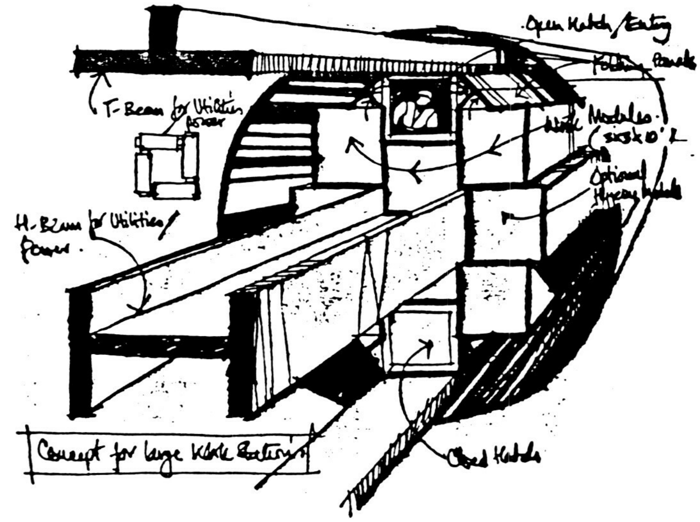


SQUARE BEAM WITH EXPANDED SUBMODULES

CENTRAL BEAM TEST DESIGNS

H BEAM - ON CENTER

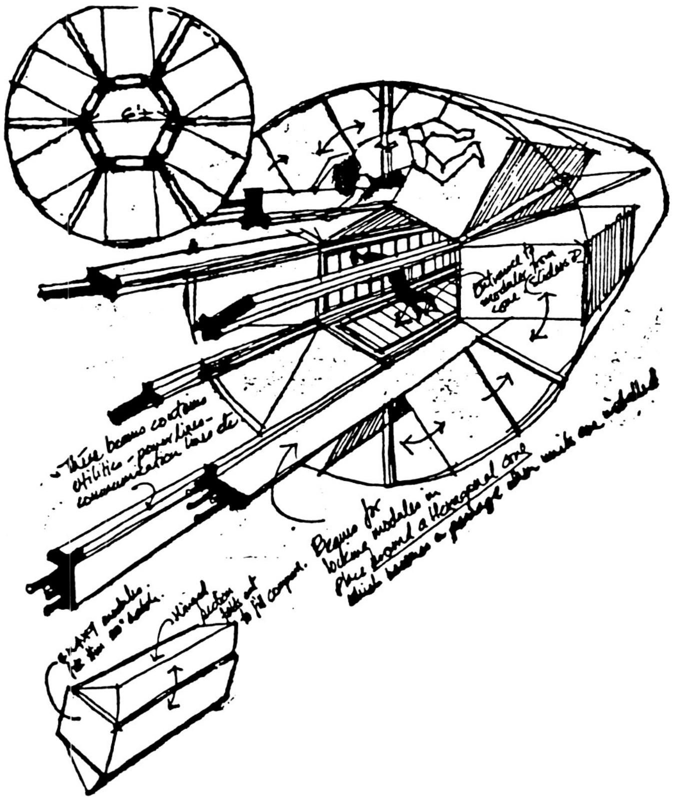


LEAVE ONE SUBMODULE OUT TO PERMIT PASSAGE

DISTRIBUTED UTILITY LOOPS

CENTRAL BEAM TEST DESIGNS

HEXAGONAL BEAM - LARGE



GOOD EFFICIENCY FACTORS

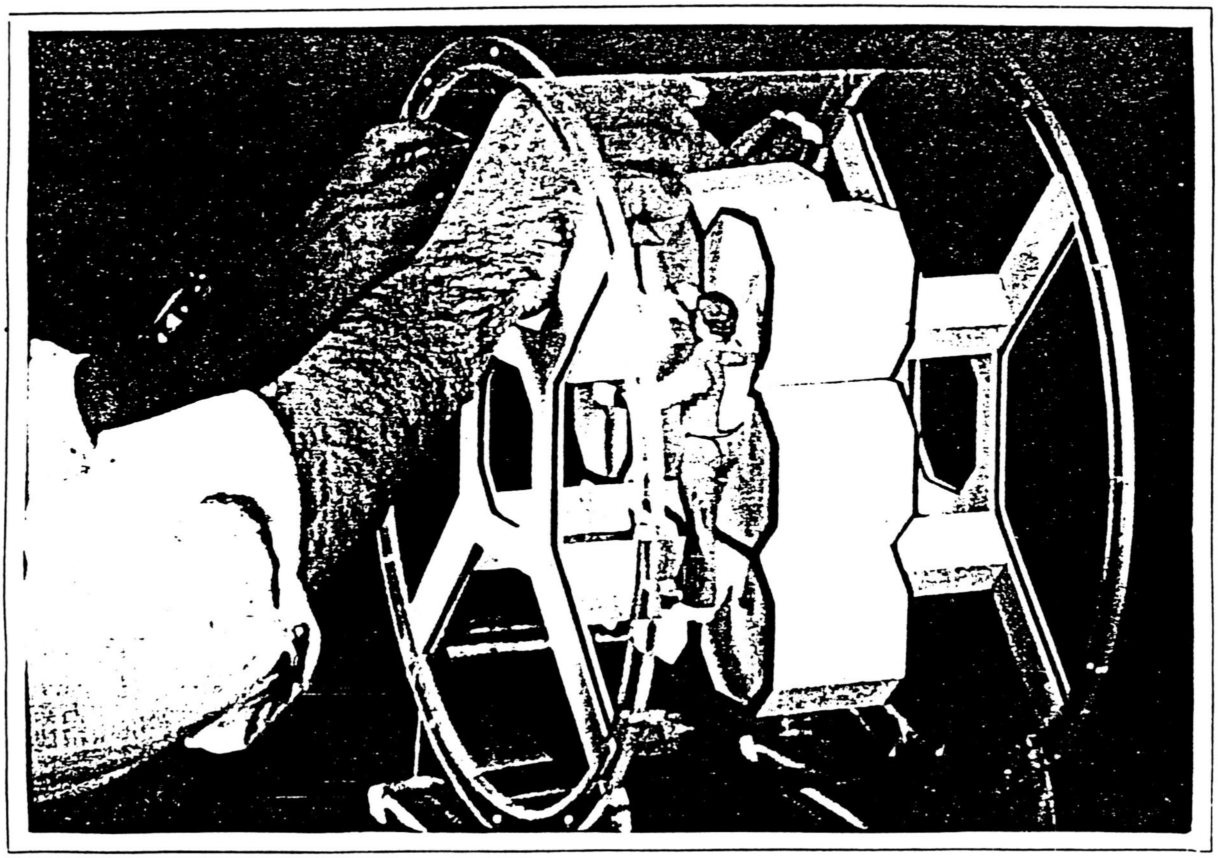
HIGHEST PACKING DENSITY

CENTRAL BEAM TEST DESIGNS

HEXAGONAL BEAM - SMALL WITH CENTER PASSAGE

GOOD LOGISTICS IMPLICATIONS

GOOD CIRCULATION AND ACCESS TO ALL CHANGE OUT UNITS



HEXAGONAL BEAM - SMALL

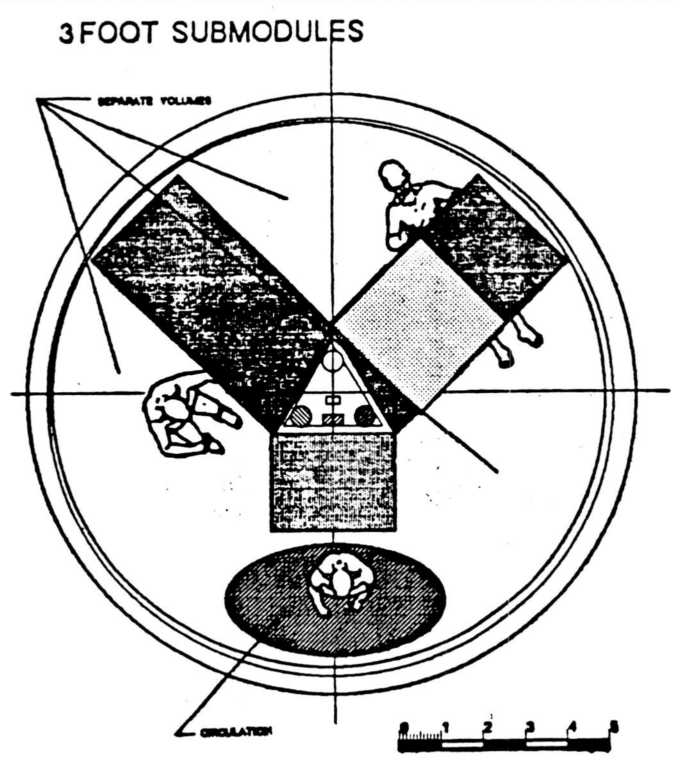
CENTRAL BEAM TEST DESIGNS

TRIANGULAR BEAM
ON CENTER

SYMMETRIC CORE W/ 120 DEGREE BRACE AT THIRD POINTS

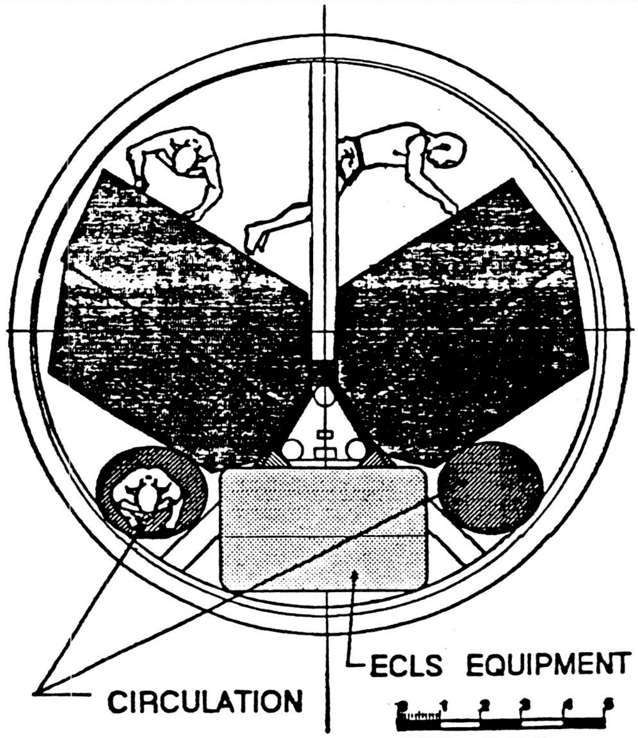
RELATES WELL TO CIRCLE

SUFFICIENT VOLUME FOR UTILITIES



CENTRAL BEAM TEST DESIGNS

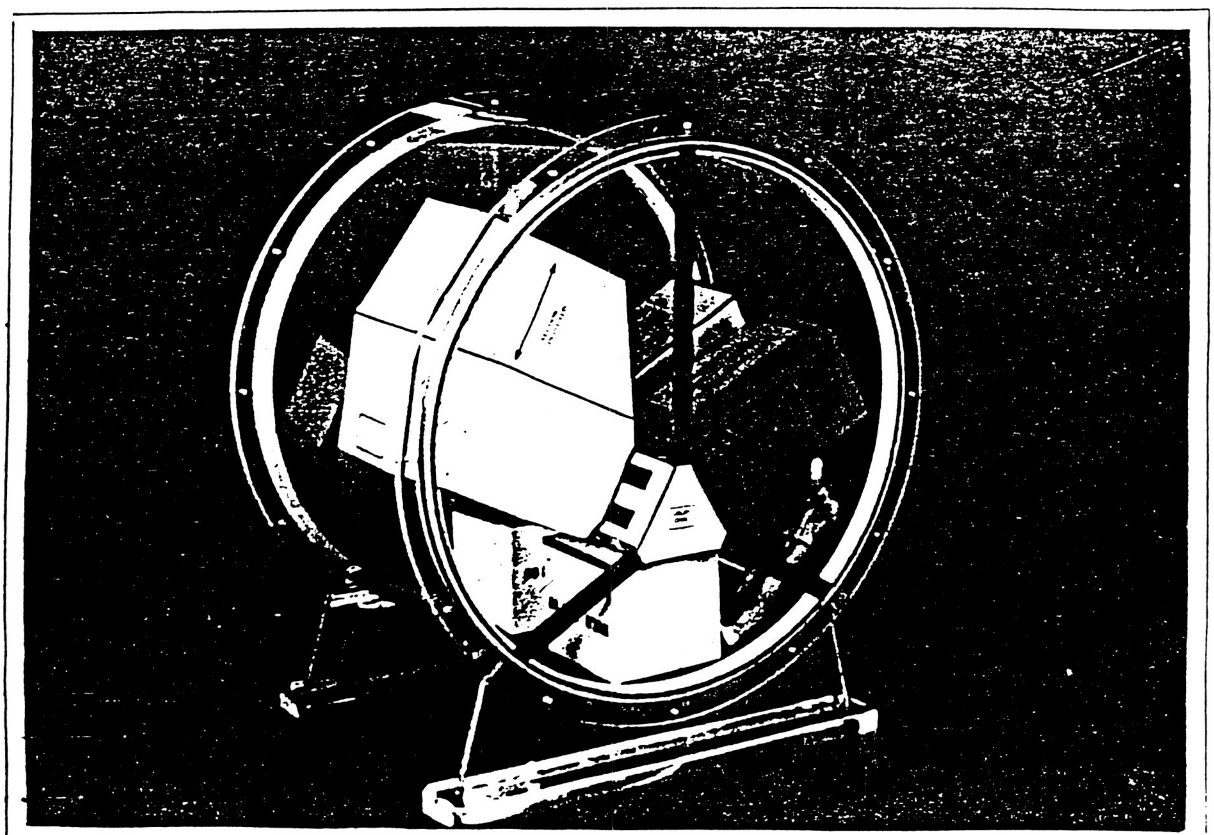
TRIANGULAR BEAM OFF CENTER



MOVING CORE OFF CENTER YIELDS GREATER CROSS SECTIONAL AREA AND DIVERSITY OF FUNCTIONAL ALLOCATIONS

PERMITS USE OF EXPANDABLE SUBMODULES EFFECTIVELY

SUFFICIENT VOLUME FOR UTILITIES

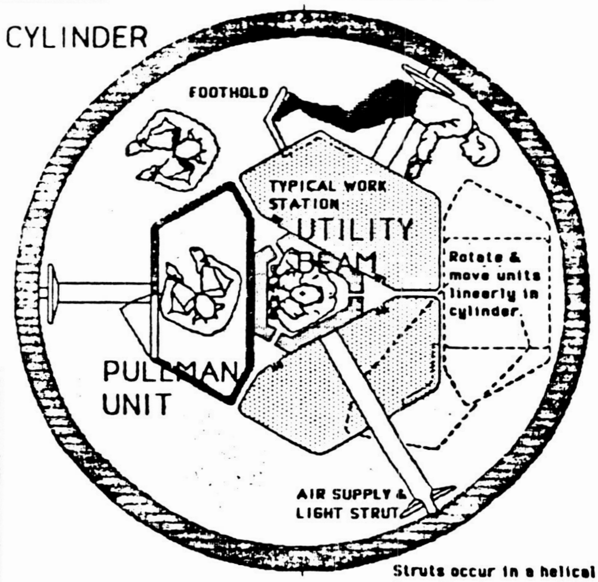


TRIANGULAR BEAM - OFF CENTER

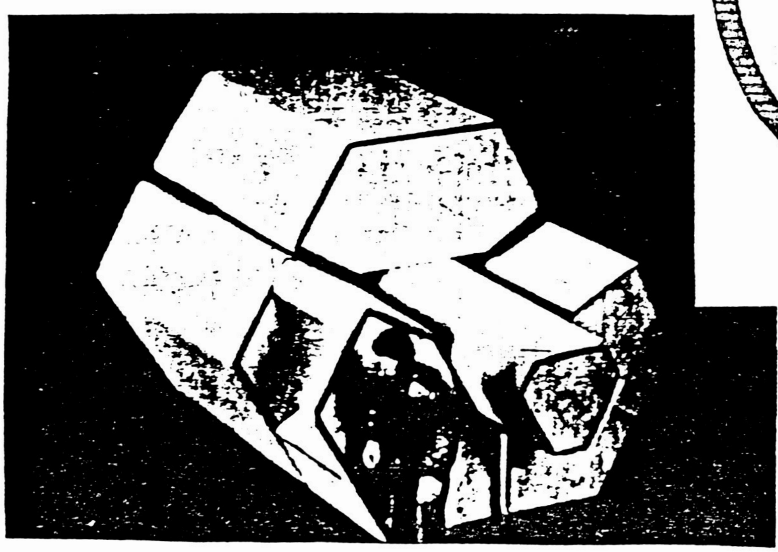
CENTRAL BEAM TEST DESIGNS

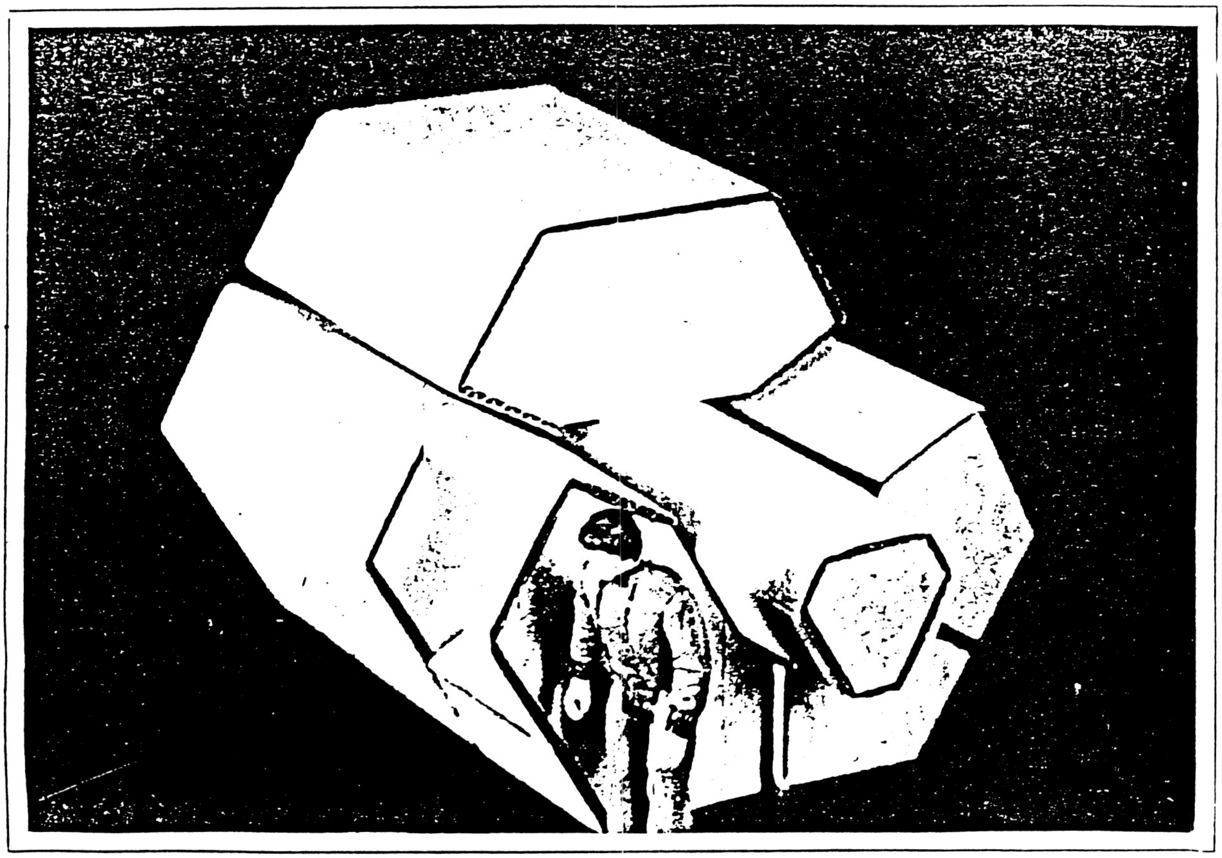
CENTER CLUSTER BEAM WITH EXTERNAL CIRCULATION

MOVEMENT OF CHANGE OUT UNITS IS NEAR THE INNER SURFACE OF THE MODULE



Struts occur in a helical formation to support the Utility Beam on three sides.



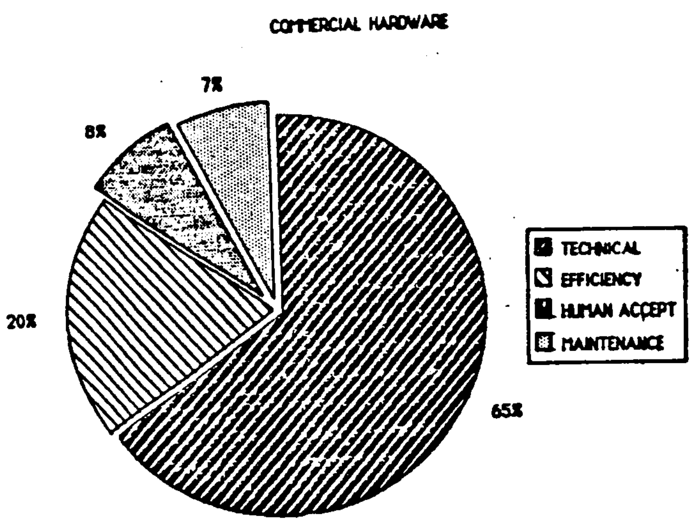


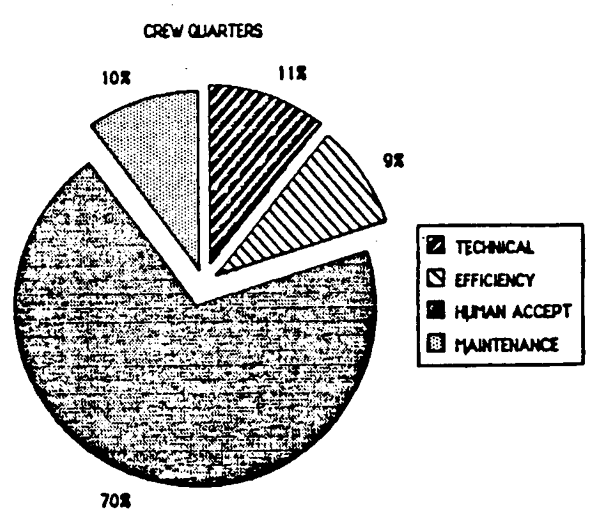
CENTER CLUSTER BEAM

COMPARISONS - VOLUME AND PACKING DENSITY

BEAM	UNEXPANDED VOLUME	EXPANDED VOLUME	PASSAGE WAYS	NEGATIVE VOLUME	%	COMMENTS PACKING DENSITY
SQUARE BEAM	36	89	22.5	26.2	19	65 %
H BEAM	58.5	82.5	9	44.4	32	62 %
HEX LARGE	54	89.2	22.7	15.1	11	73 %
HEX SMALL	TBD					
TRI-ON CENTER	49.5	82.5	50	4.1	3	61 %
TRI-OFF CENTER	54	86.5	37	12.5	9	65 %
CLUSTER BEAM	TBD					
SPACE-LAB	46.9	64	41	21.5	15	56 %

Recommended Evaluation Factor Examples





EVALUATION FACTOR

EXAMPLES OF WEIGHTED COMPONENTS

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Assumed Utilities

UTILITIES

SEE JSC-19989, P. 110, EXCLUDES 30% GROWTH, ESTIMATES ARE IN BOXES

ESTIMATES

ECLSS - 2 EA. 4" DIA. AT HATCH (ONE SUPPLY, ONE EXHAUST),
ASSUME 2 EA. 6" DIA. AT MODULE CENTER

POWER - 2 EA. 3/4" DIA.

OPTIONAL

THERMAL - 2 EA. 1 1/2" COOLANT SUPPLY & RETURN

HOUSEKEEPING DATA - 6 EA. - 1/2" DIA.

PAYLOADS DATA - CABLE TRAY 3" X 6" X MODULE LENGTH

CREW WATER -

DRINK - 2 EA. 1" DIA.

WASTE - 2 EA. 1" DIA.

WASH - 2 EA. 1" DIA.

CONDENSATE - 2 EA. 1" DIA.

OXYGEN - 3/8" DIA.

NITROGEN - 1/2" DIA.

REQ'D

TV FEED - 1 EA. 1/2" DIA.

C & C - 4 EA. 1/2" DIA.

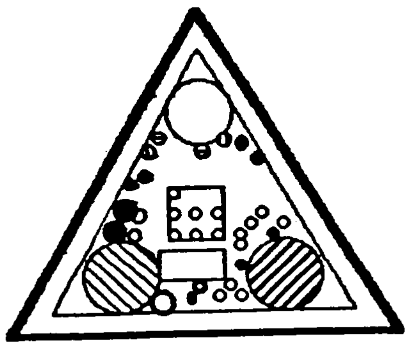
VACUUM HOUSEKEEPING - 1 EA. 6" DIA.

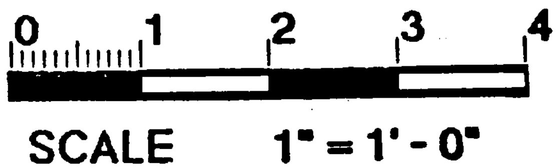
MISC - CONTINGENCY 2 EA. 1" DIA.

GROWTH- 30%

UTILITY PLANNING

TRIANGULAR CENTRAL BEAM





INTERNAL VOLUME

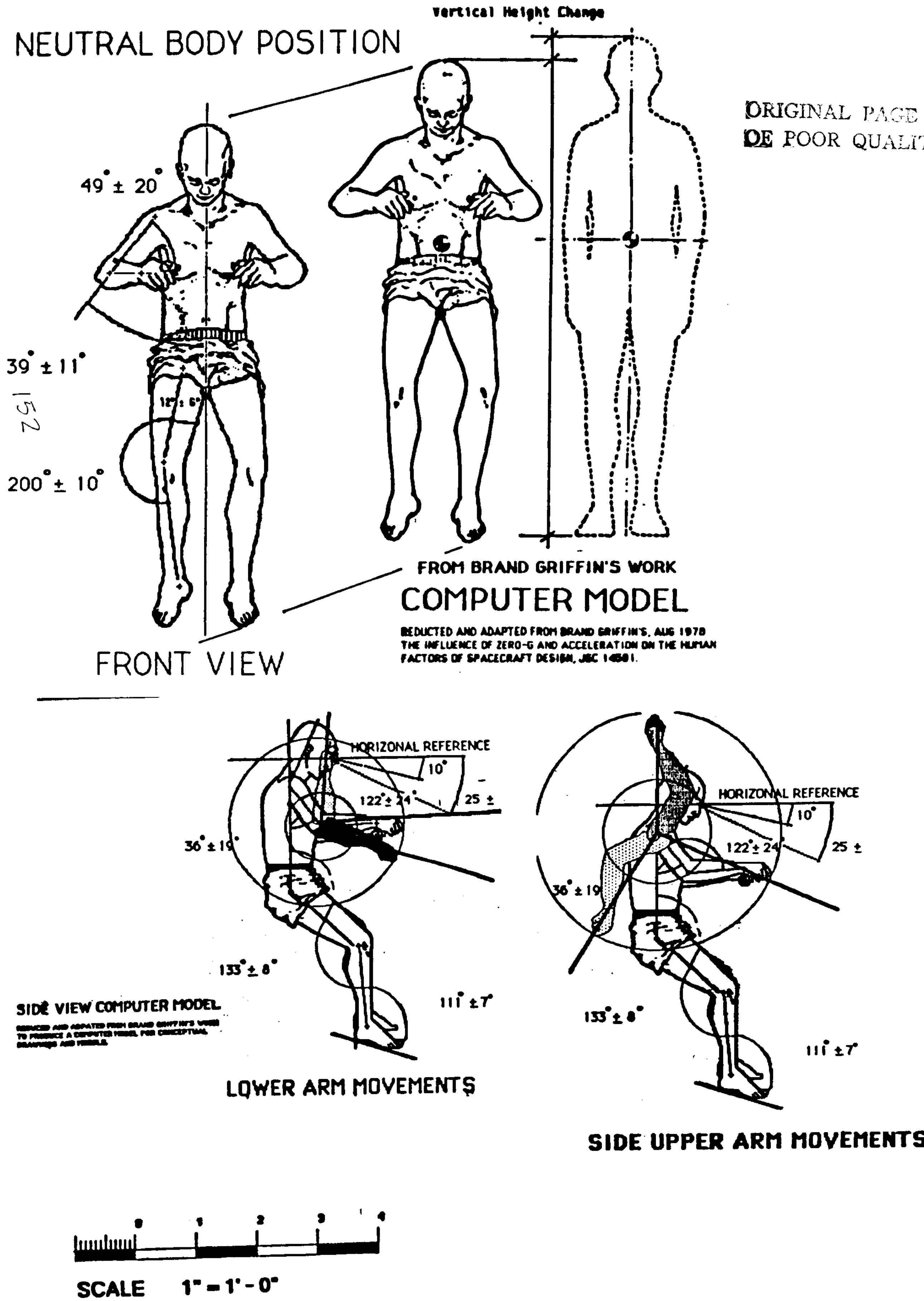
VOLUME W/O 1" 1/2" STRUCTURE

= 2.85 CF X 27" = 77 CF

PLUS TRANSITIONS AND HATCH PASS THROUGHS

7.3 CF ECLSS
35.3 CF OPTICAL, ETC.
17.6 CF INTERNAL UTIL.
10.8 CF HAB

71.0 CF REQUIRED


NEUTRAL BODY POSITION
Vertical Height Change
49° ± 20°
39° ± 11°
12° ± 6°
200° ± 10°
FRONT VIEW
FROM BRAND GRIFFIN'S WORK
COMPUTER MODEL
REDUCTED AND ADAPTED FROM BRAND GRIFFIN'S, AUG 1978
THE INFLUENCE OF ZERO-G AND ACCELERATION ON THE HUMAN
FACTORS OF SPACECRAFT DESIGN, JSC 14581.
HORIZONAL REFERENCE
10°
122° ± 24°
25 ±
36° ± 19°
133° ± 8°
111° ± 7°
SIDE VIEW COMPUTER MODEL
LOWER ARM MOVEMENTS
HORIZONTAL REFERENCE
10°
122° ± 24
25 ±
36° ± 19
133° ± 8°
111° ± 7°
SIDE UPPER ARM MOVEMENTS
0
1
2
3
4
SCALE 1" = 1'-0"