The Role of Habitability Studies in Space Facility and Vehicle Design

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"Habitability is composed of the qualities of the environment or system which support the crew in working and living. ...All the impacts from habitability are interdependent. For instance, impacts to well-being can impact performance, safety or efficiency"-- <u>and vice versa.</u>

[definition: Dr. J. Novak, LM/SP, NASA-JSC Human Engineering Integration Team]

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The primary aspects of "habitability" which affect the design of human environments are:

- **Programming** [allocation of functions; behavior; psychology]
- **Organization** [ergonomics; logistics; location coding]
- **Dimensions** [anthropometry]
- **Aesthetics** [color studies; lighting analysis]
- **Safety** [safety; systems integration]

Additional Human Engineering factors critical to space vehicle design:

- **Orientation** [local vertical]

What does a Space Architect do?

The role of the Architect is to optimize habitability for any facility in a way that is **most appropriate to its purpose** and requirements. In so doing, the Architect must coordinate human engineering with structural and systems engineering by conceiving and developing designs in ways which meet all requirements in an efficient, usable and harmonious fashion.

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SPECIFIC TASKS

– Typology

–What is the purpose of this facility/vehicle?

–What environment must it occupy?

– Structural Integration

–What technologies are most appropriate to the construction of this facility/vehicle?

– Systems Integration

–What systems must be accommodated to support this facility/vehicle, and

–How can each one be optimized in performance of its function?

– Human Engineering/Outfitting Design:

–How can interior outfitting be designed to optimize crew comfort and

–sustain crew performance?

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These activities can be broken down to the next level of detail...

Impacts on Architecture due to:

TYPOLOGY

- **Environment** or **Context**
  - –relationship between interior and exterior
  - –mission duration
- **Program**--(activities and adjacency)
  - –How much room is needed (volume, functionality)
  - –what kinds of spaces are appropriate (eg. Parliament vs. Congress; kitchens)
  - –balance of group, personal and private functions

–*In response*: hypothesize needs;

–perform studies (behavior, statistics, socioergonomic analysis)

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Impacts on Architecture due to:

STRUCTURAL INTEGRATION

- **Primary** (*e.g.: shell, main supports*)--determines primary volume for site of facility
  - –<u>hard shell/exoskeletal:</u> ISS module, "tuna cans"
  - –<u>complex or inflatable/endoskeletal:</u> TransHab

- **Secondary** (*walls, floors, partitions and closeouts*)--how the available volume is subdivided into "rooms"

- **Subsidiary** (*attachments*)--"Less is more"

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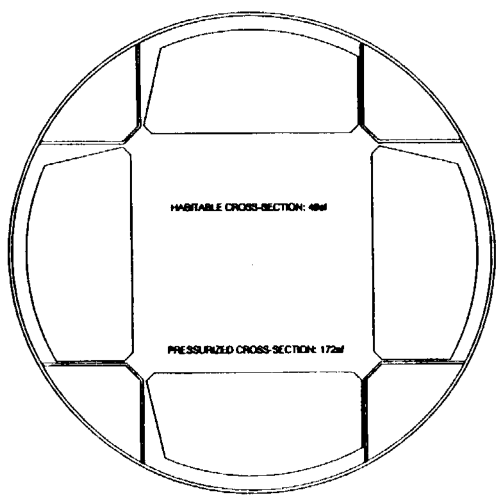
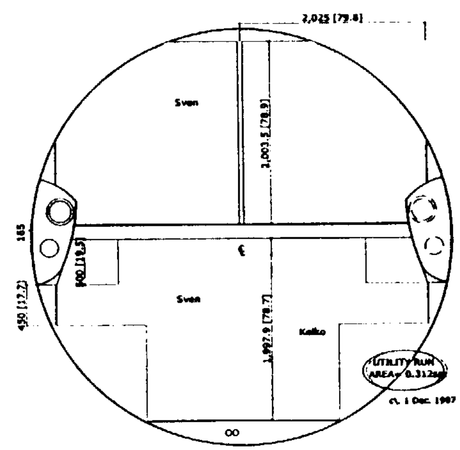
Impacts on Architecture due to:

SYSTEMS INTEGRATION

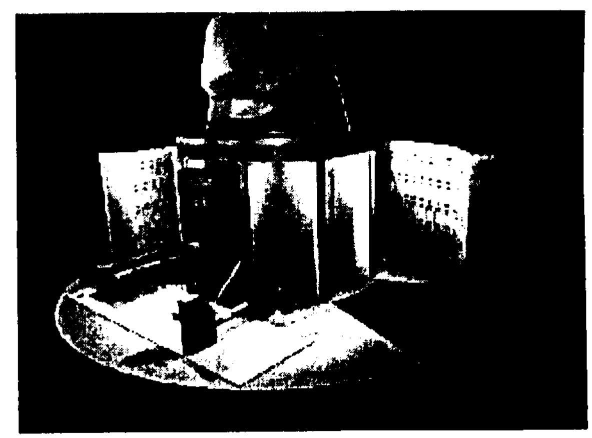
- **Air and Thermal**--ducting, chases, "flow" of open volumes
- **Water/Hygiene**--location of wet lines = location of stations
- **Power**--lighting and cabling
- **Data**--location of equipment; cabling



ISS STANDARD MODULE SECTION
RATIO: 28%



BIO-Plex HAB: UTILITY SECTION @ GALLEY
PRESSURIZED CROSS-SECTIONAL AREA: 16.5 sm
HABITABLE CROSS-SECTIONAL AREA: 10.9 sm
RATIO: 66%



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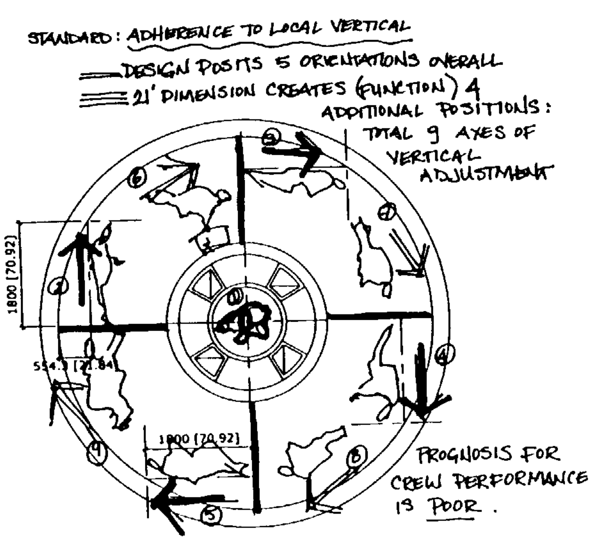
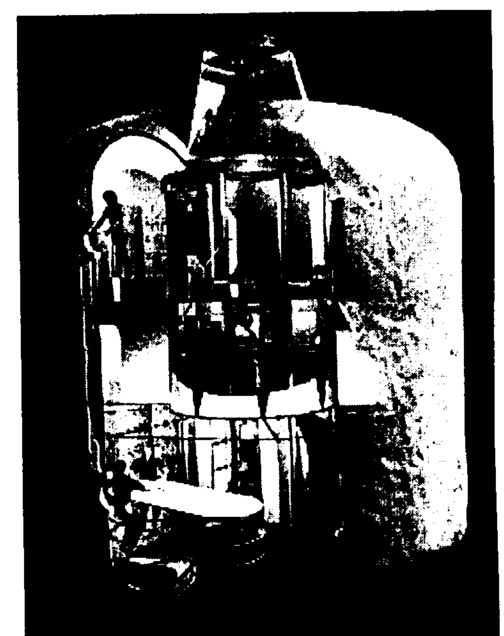
Impacts on Architecture due to:

HUMAN ENGINEERING

- **Spatial Orientation**--grouping, claustrophobia
- **Shape of Outfitting Units**--accessibility, user-friendliness
- **Layout and Location Coding**--orientation
- **Color**--local vertical, stress reduction, performance





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Application of these in Space Facility Design (Case One):

BIO-Plex Hab Chamber

- **Typology**--
  - Environment: planetary habitation module, part of a multi-chamber ground-based ALS testbed (JSC); duration: up to 425 days
  - Program: function--4 crew; activities--undetermined; balance of spaces--undetermined
- **Structure**--
  - Primary: horizontally oriented cylinder, hard shell, 15-foot (4.5m) diameter, 36' (11.2m) long
  - Secondary: open
  - Subsidiary: open
- **Systems**--Since this is part of a systems testbed, all systems data was in flux; design must allow for maximum systems changeout and flexibility.

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Issue: **BIO-Plex Typology**

How to determine the appropriate functional allocation of space for TBD activities?

NEED to develop and perform related tests

Resolution: **socioergonomic analysis**;

- passive testing: LMLSTP Phase III data;
- active testing: BIO-Plex Hab Chamber modularity
  - designed-in reconfigurability so as to test effectiveness of different layouts
  - variations in ratio of group space : personal space : private space

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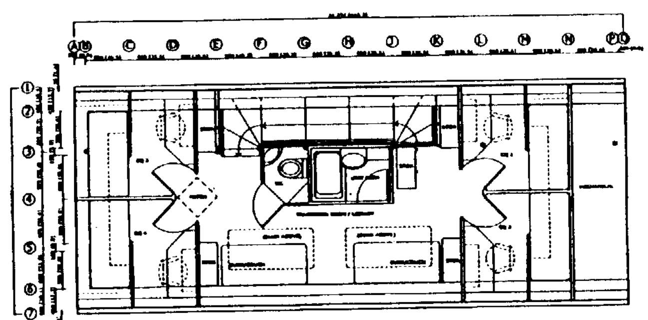
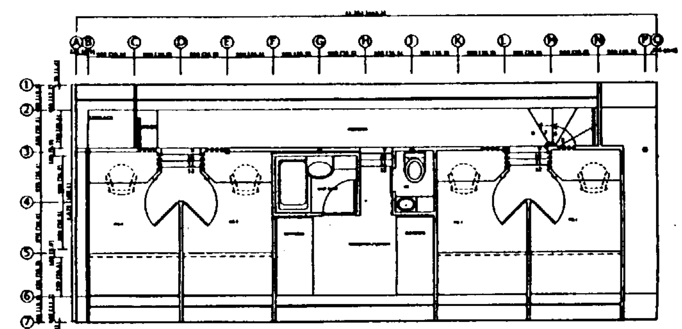
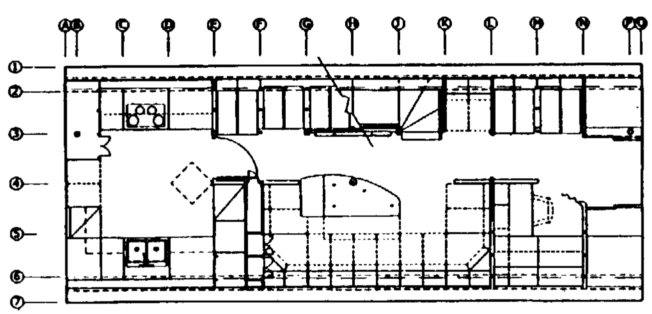


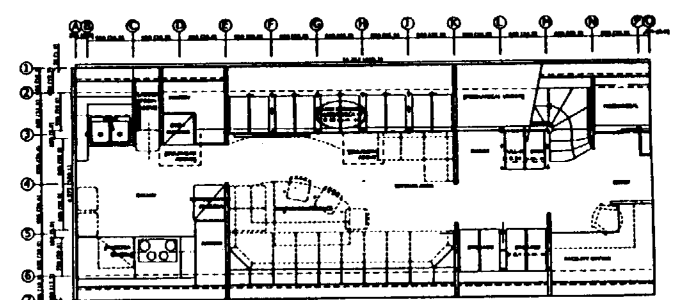
ALT. B, UPPER LEVEL PLAN



ALT. C, UPPER LEVEL PLAN



ALT. B, LOWER LEVEL PLAN



ALT. C, LOWER LEVEL PLAN

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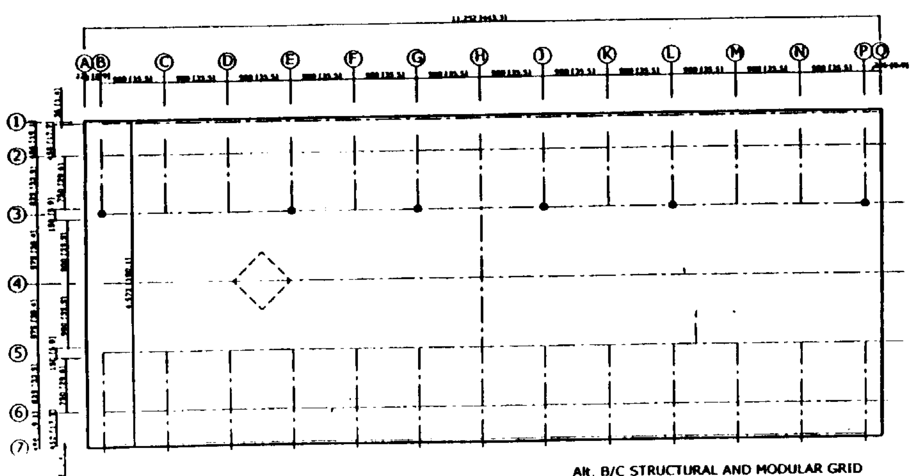
Issue: **BIO-Plex Structures**

How to design subsidiary structures to

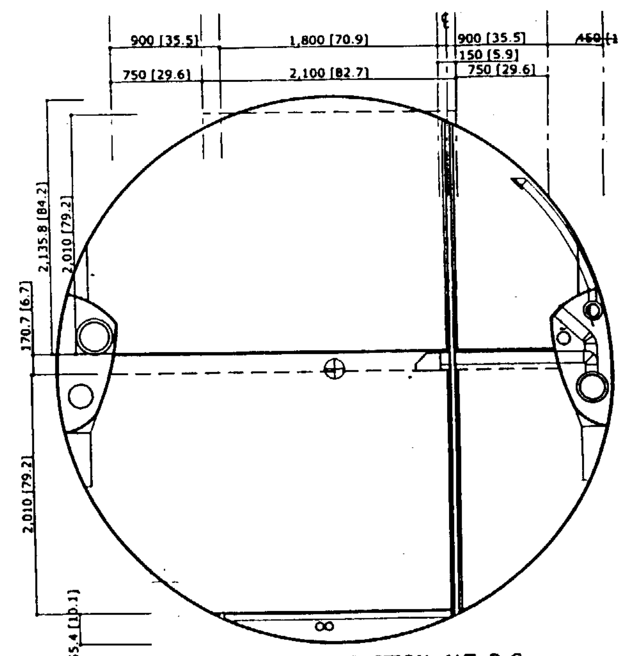
1.) Optimize human accommodations; and

2.) Support reconfigurability?

Solution: **BIO-Plex Hab modular grid**



Alt. B/C STRUCTURAL AND MODULAR GRID



STRUCTURAL SECTION, ALT. B-C

SCALE= 1:25

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Issue: **BIO-Plex Systems**

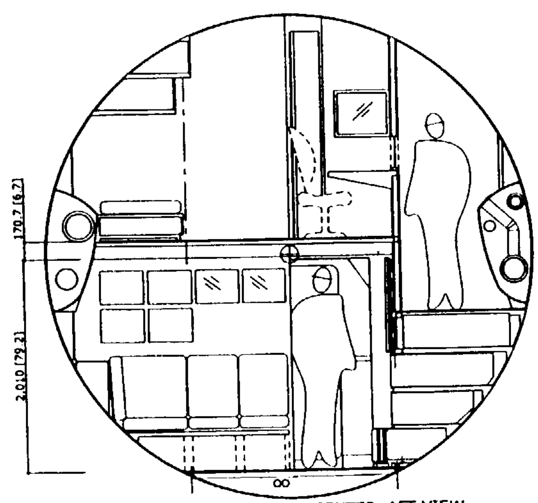
How to accommodate utilities and systems in a manner that

1.) is nonobtrusive and volumetrically efficient; and

2.) supports easy maintenance and systems reconfiguration?

Solution: **BIO-Plex Utility Chase design**

ergonomic and anthropometric study; usable volume optimization



Alt. C., SECTION 3: CENTER, AFT VIEW
SCALE=1:25
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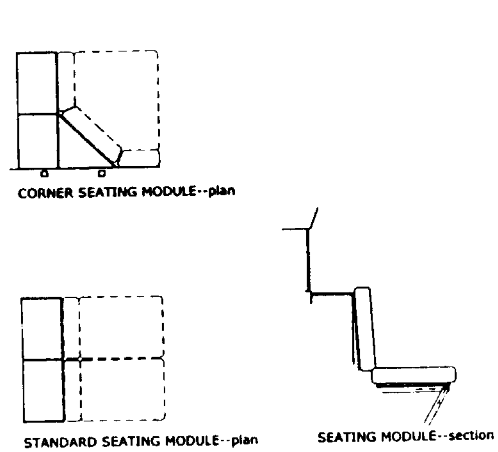
Issue: **BIO-Plex Outfitting Design**

How to develop strategies for outfitting, furnishings,lighting, color and location coding that optimize crew comfort and performance?

NEED to develop BIO-Plex HAB as a testbed for behavioral tests

Resolution: **Reconfigurability** test new objects



DETAIL SHEET 1: MODULAR SEATING UNITS
SCALE: 1=20
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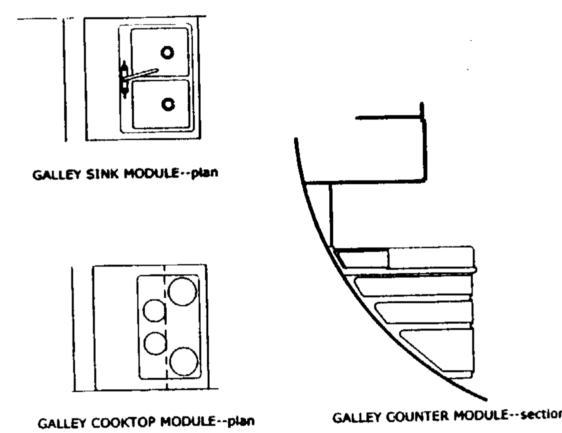

DETAIL SHEET 2: MODULAR GALLEY UNITS
SCALE: 1=20
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Application of these in Space Facility Design (Case Two):

ISS-TransHab

- **Typology--**
  - Environment: microgravity, LOE hab module, prototype for Mars transit (342 cu.m); duration: 6 months minimum
  - Program: function--6 crew; activities--exercise, hygiene, medical, personal work and sleep, dining, galley, conferencing, stowage and inventory management; balance of spaces--single group volume Level One (galley, wardroom, inventory); personal spaces Level 3 (Exercise, hygiene, medical); private space Level 2 core (CQs); separate mechanical/maintenance volume Level 2 external ring
- **Structure--**
  - Primary: 25' ID inflatable shell on composite core, 11' OD x 23' long
  - Secondary: reconfigured composite core segments; composite floor struts deployed from core fairing; acoustic sandwich (fabric) floor; deployable stowage array structure; inflated compression rings
  - Subsidiary: partly THab-unique, partly ISS-standard attachment H/W
- **Systems**--Life Support, Power, Avionics and Inflation Systems conceptually defined.

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Issue: **TransHab Typology**

How to determine the appropriate functional allocation of space for crew hab activities?

NEED to perform related tests (including socioergonomic analysis)

Resolution: **Habitability Studies; Phase I. And Skylab Lessons Learned**

- passive testing: Skylab and Mir data accumulated by Ops/Hab;
- active testing:
  - BIO-Plex Hab Chamber tests will help verify choices made for TransHab;
  - continued habitability debriefing from ISS-TransHab to verify design for Mars unit

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