

SEMINAR ON  
SPACE STATION HUMAN PRODUCTIVITY

OVERVIEW:  
HUMAN FACTORS ISSUES IN  
SPACE STATION ARCHITECTURE

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# SPACE STATION PROGRAM STATUS

"NO DESIGN DECISIONS  
HAVE BEEN MADE"

3/1/84

Hans Mark 2/10/84

TWO YEARS OF INTENSIVE STUDY  
1984 - 1985

TARGET FIRST LAUNCH DATE: 1991

JOHNSON SPACE CENTER (JSC):  
LEAD CENTER FOR DEVELOPMENT

AMES RESEARCH CENTER (ARC):

- SPACE HUMAN FACTORS OFFICE FORMED (9/83)
- AERO-SPACE HUMAN FACTORS DIVISION  
FORMED IN REORGANIZATION OF MVSORD  
(2/84)

## SPACE STATION PROGRAM ASSUMPTIONS

1. ALL PARTS OF STATION WILL BE LAUNCHED  
IN SHUTTLE PAYLOAD BAY -  
~14'-0" MAX. O.D. X ~45' MAX. LENGTH.
2. STATION WILL FLY IN LOW EARTH ORBIT,  
(LEO) ~200-300 MILE ALTITUDE AT  
LOW INCLINATION, ~28.5°
3. SOLAR PHOTOVOLTAIC POWER, ~75 KW.
4. ZERO-GRAVITY (NO ARTIFICIAL G.).
5. BUDGET FOR INITIAL OPERATING  
CAPABILITY (I.O.C.) IS \$8.0 BILLION  
OVER ~8 YEARS, AND INCLUDES  
2 UNMANNED PLATFORMS, SVCE. STRUCT.  
EVA, MMLIS & OMS/TMS

## CONCEPT DEVELOPMENT GROUP I.O.C. MODEL:

### 1. AUTONOMY:

90 DAYS WITHOUT STS REVISIT  
5 DAYS W/O ROUTINE GROUND SUPPORT  
24 HOURS W/O ANY COMM. FROM GROUND

### 2. CREW:

6-8 PEOPLE ON 90 DAY TOURS  
MIXTURE OF PILOT, MISSION & PAYLOAD TYPES

### 3. COMMAND & CONTROL:

COMPLETELY DISTRIBUTED TO EACH MODULE  
NO "BRIDGE"

### 4. SAFETY:

"SINGLE PERCEIVED LEVEL", WITH DISTR.  
SAFE HAVENS TO SUPPORT ENTIRE CREW  
FOR 21 DAYS.

# 1) SPACE HUMAN FACTORS

- FOR WORKING & LMING ENVIRONMENTS
- "MAXIMIZE HUMAN PRODUCTIVITY":
  - CREW PERFORMANCE
  - IVA TIME AVAILABLE FOR PAYLOADS
  - ROUTINE EVA → 1,000 HOURS/YEAR
- NEW SPACE MISSION CHARACTERISTICS:
  - LONG DURATION, REPEATED TOURS OF DUTY
  - PERMANENT HABITATION WITH AUTONOMY
  - HIGH LEVELS OF AUTOMATION, MAN/MACHINE INTERACTION & USE OF ROBOTICS
- COMMERCIALIZATION:
  - COTTAGE INDUSTRY OR MASS PRODUCTION?
  - DIVERSE ACTIVITIES

## 2) ARCHITECTURE

"Architecture is a social art. It becomes an instrument of fate because it not only caters to requirements but also shapes and conditions our responses. It can be called reflective because it mirrors a program of conduct and living. At the same time this art of a planned environment does more, it also programs our daily conduct and our entire civilized life. It modifies and often breaks earlier established habit."

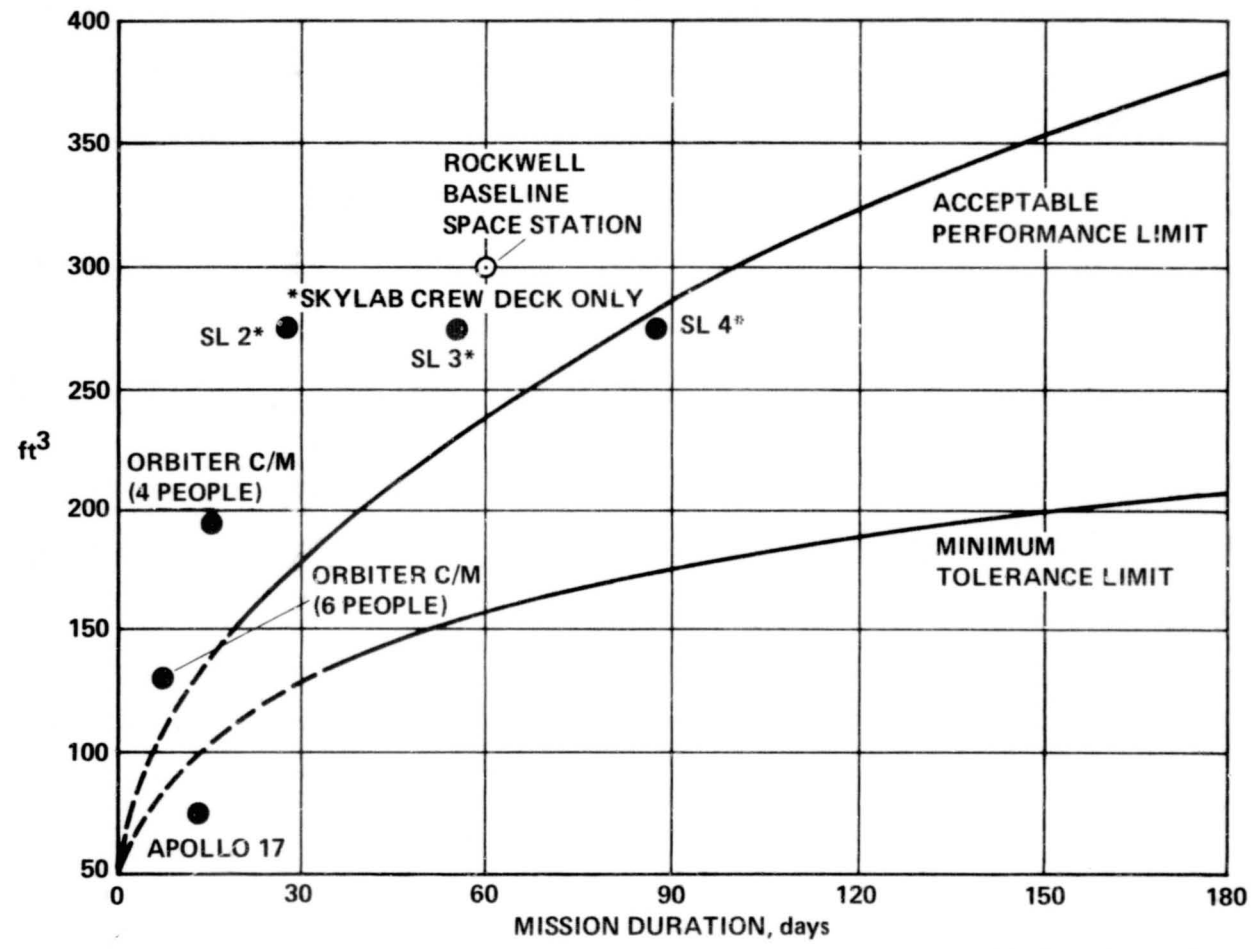
- Richard Neutra, SURVIVAL THROUGH DESIGN, (Oxford University Press) 1954. Page 314.

### 3) VOLUME

- MOST CRITICAL SINGLE H.F. ISSUE:
  - MOST CONSTRAINED BY EXTERNAL LIMITS.
  - AFFECTS ENTIRE HABITABILITY BASELINE.
  - CELENTANO CURVES.
- EFFORTS TO REDUCE COSTS BY MINIMISING VOLUME PRESENT A FALSE ECONOMY.
- EFFECTS OF INADEQUATE VOLUME:
  - FORCE MINIATURIZATION OF MANY ITEMS.
  - PRECLUDE MUCH "OFF-THE-SHELF" HARDWARE.
  - IMPEDE, IMPAIR OR PREVENT ON-ORBIT MAINTENANCE.
  - DRIVE UP DESIGN, ENGINEERING, FABRICATION & INTEGRATION COSTS BEYOND THE INITIAL SAVINGS.
  - DIMINISH CREW PERFORMANCE & COMFORT.

# J. T. CELENTANO: HABITABLE VOLUME REQUIREMENTS PER PERSON

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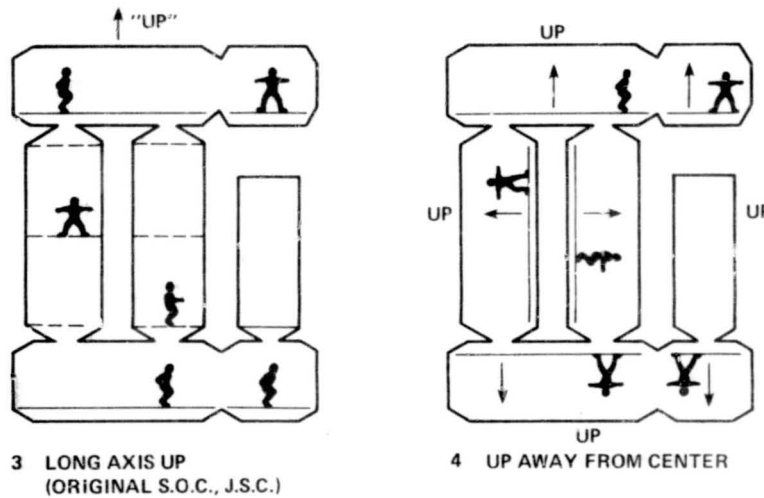
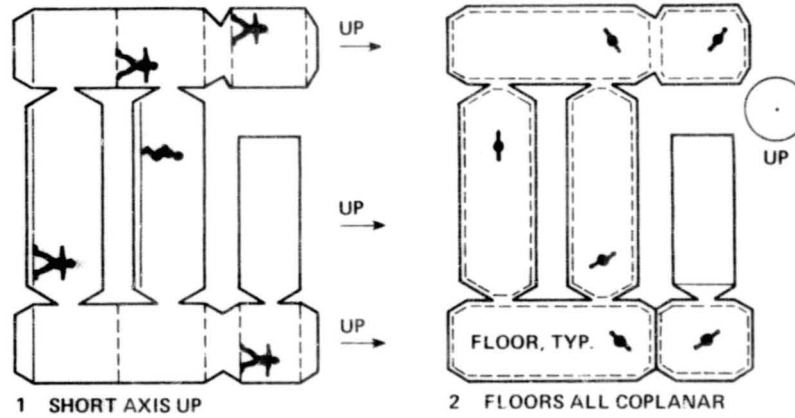
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## 4) REFERENCE ORIENTATION

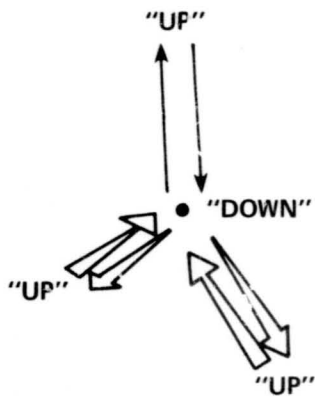
- ONE POINT  
(SOVIET EVA PROTOCOL)
- TWO POINT  
(LOCAL VERTICAL IN SKYLAB OWS, SPACELAB)
- THREE POINT (2-D)  
(RAFT TYPE STATION ASSEMBLY)
- FOUR POINT (3-D)  
("DELTA" CONFIGURATION)
- PLANAR (S.O.C. TYPE) STATION OPTIONS

PLANAR SPACE STATION  
REFERENCE ORIENTATION OPTIONS

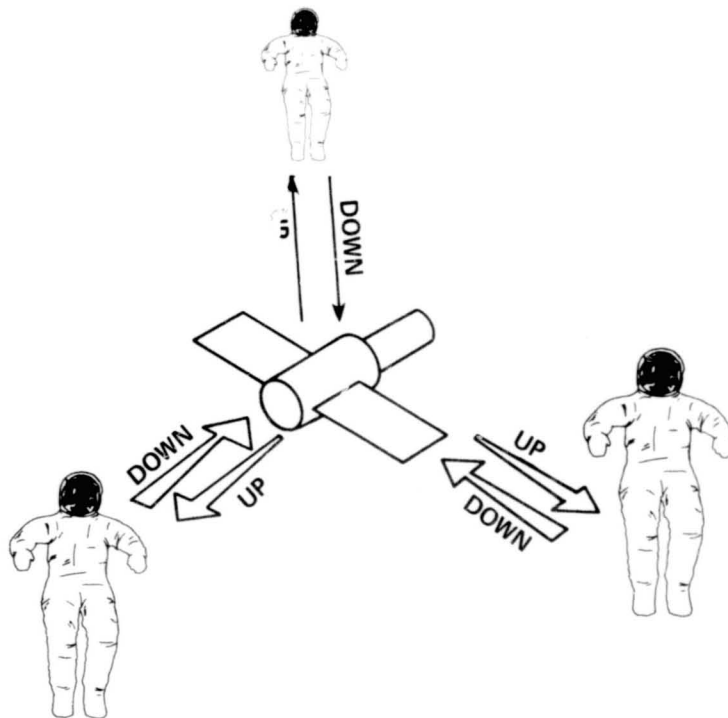


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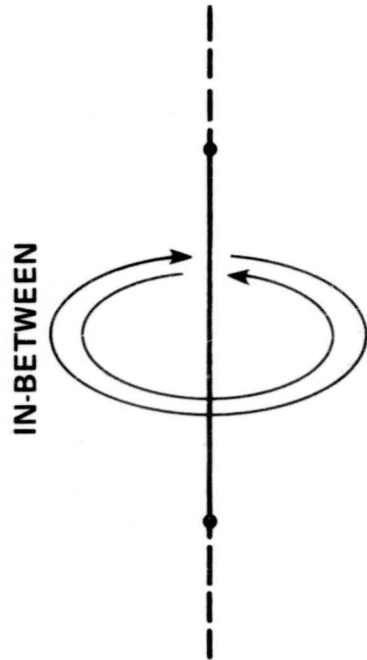
ONE POINT  
REFERENCE ORIENTATION



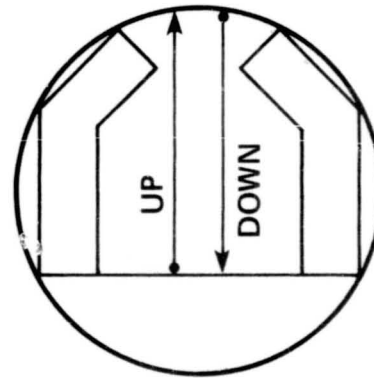
REPORTED SOVIET EVA PROTOCOL  
FOR TETHERED OPERATIONS

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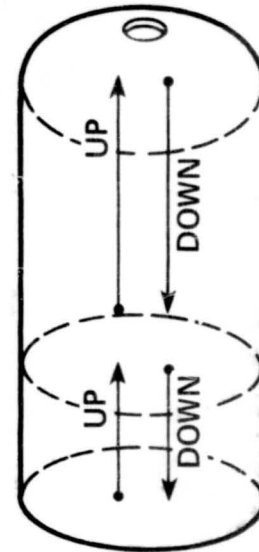
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**TWO POINT  
REFERENCE ORIENTATION**



**SPACELAB**

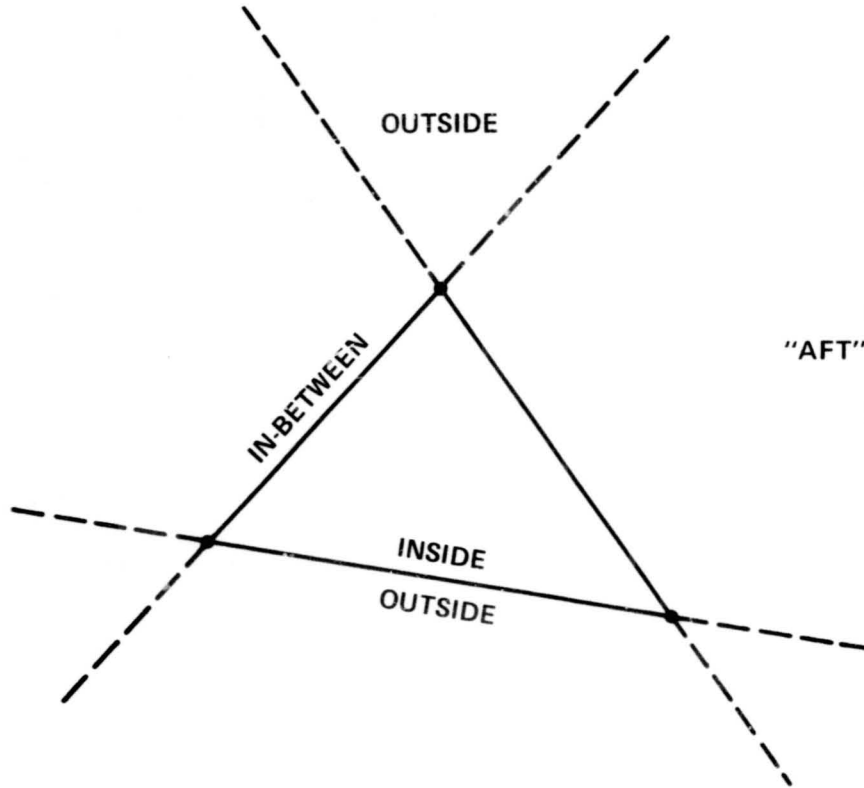


**SKYLAB**

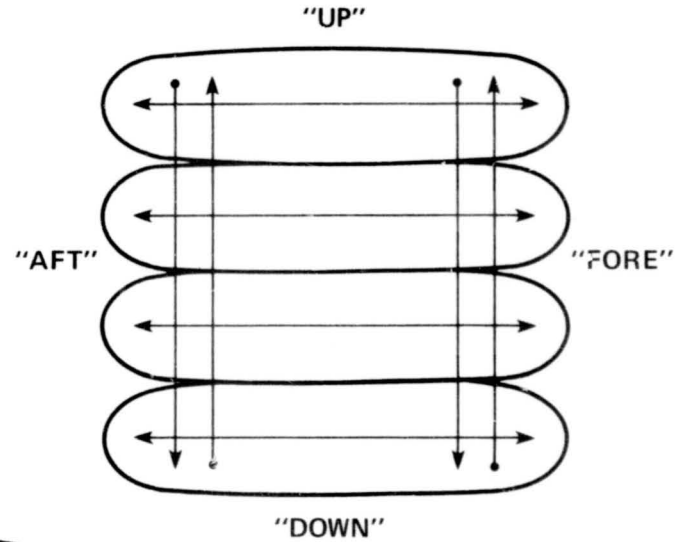
**"LOCAL VERTICAL"  
IN SKYLAB AND  
SPACELAB**

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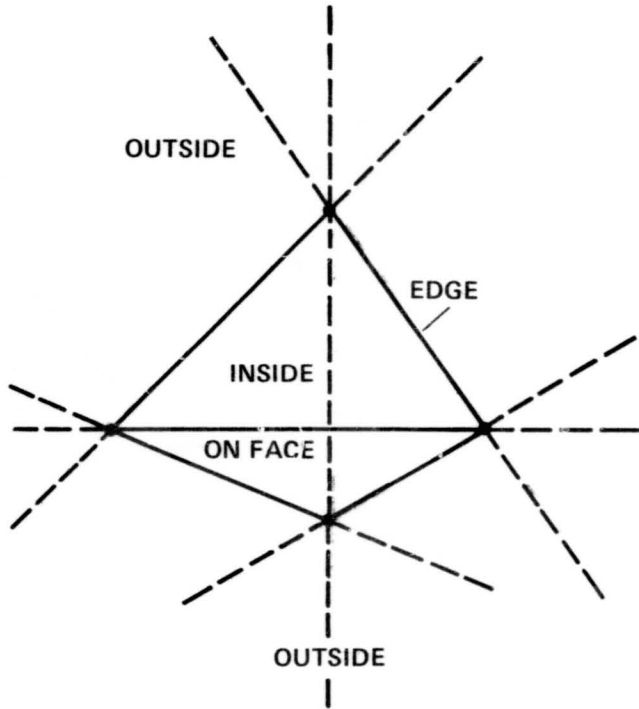
**THREE POINT  
REFERENCE ORIENTATION**



**"VERTICAL RAFT"  
SPACE STATION**

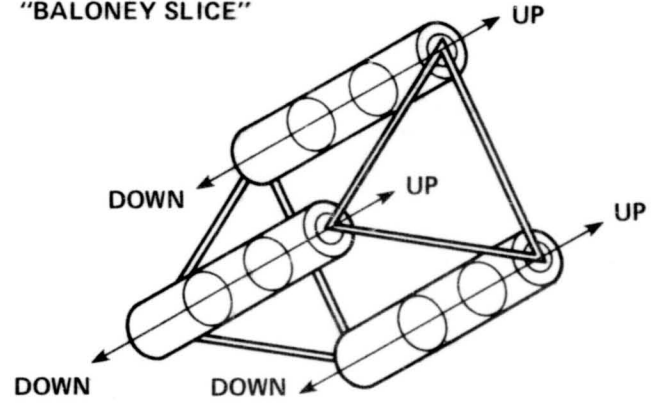
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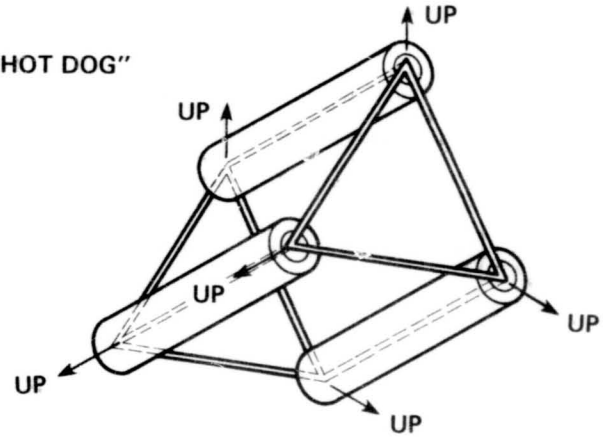


FOUR POINT  
REFERENCE ORIENTATION

"BALONEY SLICE"



"HOT DOG"



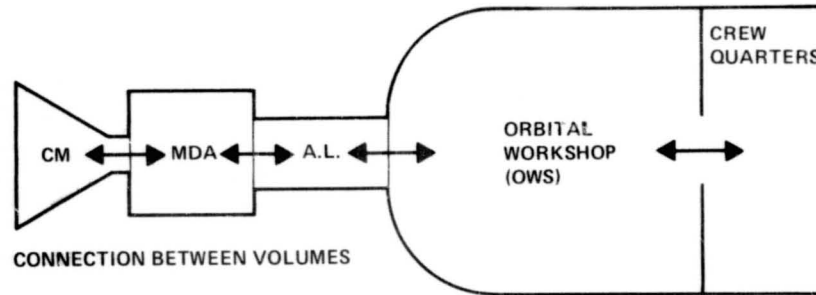
JSC "DELTA"  
CONFIGURATION

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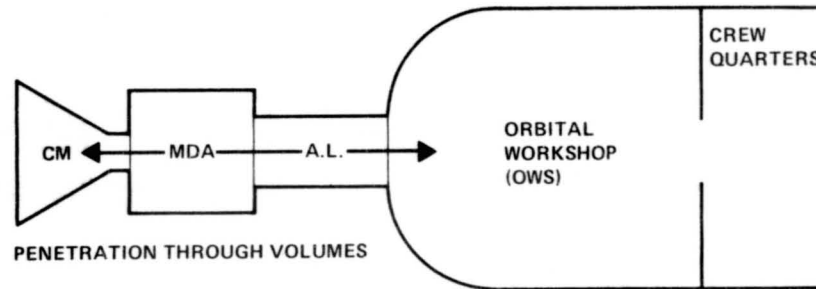
## 5) CIRCULATION

- SKYLAB EXPERIENCE SHOWS 3 ASPECTS:
  1. CONNECTION BETWEEN VOLUMES
  2. PENETRATION THROUGH VOLUMES
  3. DIVISION OR SEPERATION OF VOLUMES
- BIOLOGICAL ANALOGIES -  
TRADITION IN CITY PLANNING
  - SCALELESSNESS & COMPLEXITY
  - FIGURE/GROUND AMBIGUITY
  - CENTER/END VS CENTER/PARTS CIRCULATION
- FIVE CIRCULATION CONDITIONS - DEFINITIONS
  1. ACCESS
  2. MULTIPLE ACCESS
  3. EGRESS
  4. DUAL EGRESS
  5. DUAL REMOTE EGRESS

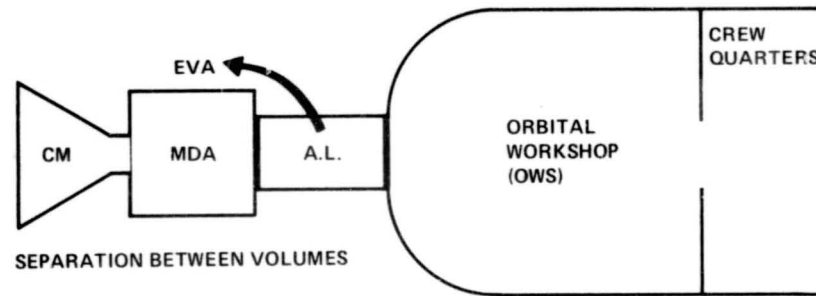
# SKYLAB CIRCULATION CHARACTERISTICS



CONNECTION BETWEEN VOLUMES



PENETRATION THROUGH VOLUMES

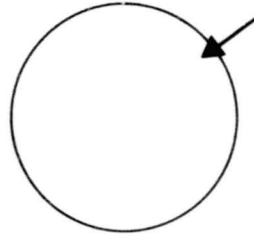


SEPARATION BETWEEN VOLUMES

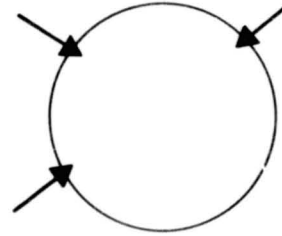
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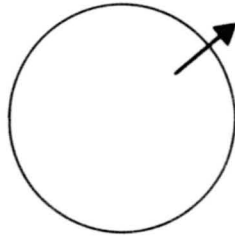
# ACCESS AND EGRESS DEFINITIONS



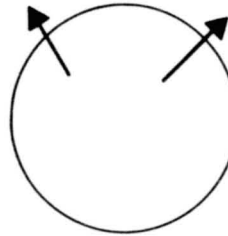
(a) ACCESS



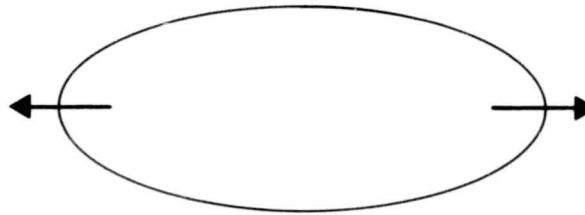
(b) MULTIPLE ACCESS



(c) EGRESS



(d) DUAL EGRESS



(e) DUAL REMOTE EGRESS

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## 6) PRIVACY

- MANDATORY FOR "STAYING SAFE IN SPACE"
- INDIVIDUAL CONTROL (PERSONAL DOMAIN)  
VITRUVIUS'S DEFINITION: "INVITATION"
- COMMUNITY CONTROL BY  
"LOCKS" & SEPERATIONS BETWEEN DOMAINS
  1. ENTRY LOCK
  2. DIRECT EVA ACCESS TO EXTERIOR
  3. BUFFER BETWEEN PRIVATE DOMAINS
  4. LOCK TO PRIVATE CREW QUARTERS
  5. LOCK TO COMMON AREAS
  6. EXTERIOR SEPERATIONS & CLEARANCES  
- INFLUENCE ON INTERIOR FUNCTIONS

## 7) GROUP GATHERING PLACES

### 1. WARDROOM

- GALLEY?
- DINING
- RECREATION / ENTERTAINMENT
- WORK AREA

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### 2. GROUP WORK STATIONS

- STS RMS & AFT PILOT STATION
- NEED FOR OFFICE ON SKYLAB
- LABORATORY MODULES

### 3. EXERCISE / HEALTH FACILITY

### 4. SMALL GROUP / CONFERENCE / DEN

- DOUBLE AS SOLAR STORM RADIATION SHELTER?

## 8) VISUAL SYSTEMS 1

- WINDOWS FOR WORK
  - RENDEZ-VOUS & DOCKING
  - CELESTIAL OBSERVATION
  - EARTH OBSERVATION
- WINDOWS FOR ENTERTAINMENT
  - MOST POPULAR PASTIME ON SKYLAB WAS WATCHING EARTH SLIP BY.
- WINDOW LOCATION, TYPE, SIZE, SHAPE & OPTICAL QUALITY - CRITICAL
- CLOSED CIRCUIT T.V. & VIDEO
  - TO WHAT EXTENT CAN THEY SUBSTITUTE FOR WINDOWS?
- WINDOWS ADMIT UNWANTED RADIATION

# VISUAL SYSTEMS 2

- LIGHTING:

- SPECIFIC TASK LIGHTING
- AMBIENT BACKGROUND LIGHTING

- ARTIFICIAL LIGHTING:

- SOME STUDIES SHOW LONG TERM EXPOSURE CONTRIBUTES TO FATIGUE & IRRITABILITY.
- USE OF SUNLIGHT FOR INTERIOR ILLUMINATION

- EXTERIOR ILLUMINATION:

- SUPPORT EVA WORK CONTINUOUSLY THROUGH NIGHTSIDE?
- EVA CONTROL OF LUMINAIRES?

## 9) VIBROACOUSTICS

- SKYLAB WAS SO QUIET, THE SLIGHTEST NOISE WOULD AWAKEN SLEEPING CREWMEN, FORCING SINGLE SHIFT OPERATION.
- SHUTTLE FLIGHT DECK IS SO LOUD, HEADSETS MUST BE WORN FOR CONVERSATION.
- COUNTERMEASURES:
  - ISOLATION OR ATTENUATION AT SOURCE
  - ABSORBANT SURFACES
  - SOUND BARRIERS/BULKHEADS BETWEEN COMPARTMENTS IN A MODULE
  - POSITIVE ISOLATION BETWEEN MODULES.
- AUDIO SYSTEMS

# 10) STRUCTURES: SHELLS

- MODULE PRESSURE SHELL CONSTRUCTION CAN INFLUENCE HABITABILITY AND H.F.
  - RIBBED VS. SMOOTH INTERIOR WALL
    - CONNECTIONS FOR INTERIOR STRUCTURE
    - WINDOW FRAMING, SIZE, SHAPE, LOCATION
    - DUST & CONTAMINANT ACCUMULATION
- END CAP GEOMETRY
  - SUPPORT BERTHING PORTS, MECHANISMS, WINDOWS, TANKS
  - METHOD OF FABRICATION
    - SHEAR SPLIN SECTION
    - TRAPAZOIDAL GORES
    - HEXAGONAL GORES
  - FORM: ELLIPTICAL, CONICAL OR SPHERICAL

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# 11) MECHANISMS

- BERTHING MECHANISM IMPORTANCE CANNOT BE IGNORED, IT IS PROFOUND.
- CURRENT BERTHING MECH. CONCEPT WAS DEVELOPED AT JSC FOR APOLLO/SOYUZ (ASTP):
  - SINGLE-VECTOR, SIMULTANEOUS ALIGNMENT
  - WORKED WELL FOR APOLLO

## BLT

- SPACE STATION MECHANISM MUST PERFORM MORE & DIFFERENT FUNCTIONS:
  - GEOMETRIC FLEXIBILITY
  - 15-20 VARIED UTILITY CONNECTIONS
  - SYSTEM OF BERTHING LOGIC
  - MAINTENANCE & UPGRADES BETWEEN PORTS





# 12 UTILITIES

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- DISTRIBUTION & CONNECTION WILL BE THE MOST DIFFICULT INTERIOR DESIGN & PHYSICAL SYSTEM INTEGRATION PROBLEM.
- CASE STUDY OF PLUMBING JOINTS (POTENTIAL LEAK & MAINTENANCE POINTS)
  - MANUAL CHANNEL: 2 JOINT UNITS/PIECES
  - REMOTE ACTUATED: 5 JOINT UNITS/PIECES
- LDR CASE STUDY (MDAC) 3-D TRUSSES
  - ASSEMBLED (MANUAL) EVA
  - DEPLOYED (AUTOMATED)
- REMOTE/AUTOMATIC CONNECTIONS MAY BE APPROPRIATE ONLY FOR FREQUENT OR HAZARDOUS UNITS OR MODULES OR OPERATIONS

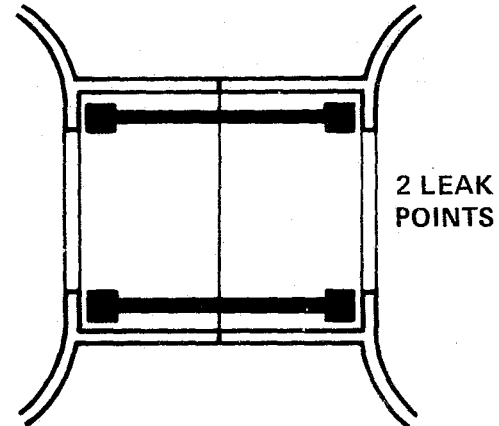
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## UTILITY CONNECTION CASE STUDY

### RESULTS OF TRIANGULAR-TETRAHEDRAL SPACE STATION STUDY:

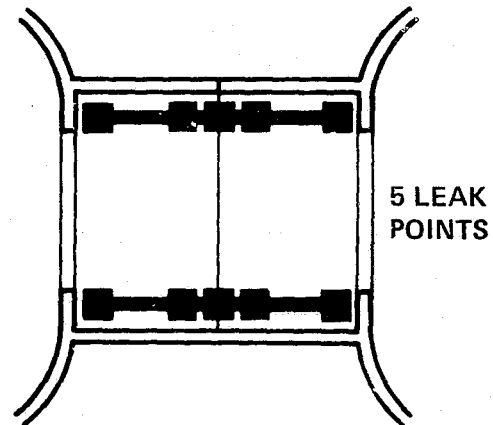
#### MANUAL CHANNEL CONNECTION:

2 JOINT UNITS/PIECES – PREASSEMBLED  
CHANNEL INSTALLED BY HAND



#### REMOTE ACTUATED CONNECTION:

5 JOINT UNITS/PIECES – PREINSTALLED  
UTILITIES DEPLOYED AUTOMATICALLY



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