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"

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 NVORD (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, MMUS & OMS/TMS
CONCEPT DEVELOPMENT GROUP  I.O.C. MODEL:

1. AUTONOMY:
   90 DAYS WITHOUT STS VISIT
   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 & LMNG 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 requirement 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."

3) **VOLUME**

- **Most Critical Single H.E. Issue:**
  - Most constrained by external limits.
  - Affects entire habitability baseline.
  - Celentano curves.

- **Efforts to reduce costs by minimizing 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. Celetano: Habitable Volume Requirements Per Person

- **Rockwell Baseline Space Station Performance Limit**
- **Acceptable Performance Limit**
- **Minimum Tolerance Limit**

**Mission Duration, days**
- 0
- 30
- 60
- 90
- 120
- 150
- 180

**ft³**
- 50
- 100
- 150
- 200
- 250
- 300
- 350
- 400

**Orbiter C/M**
- (4 People)
- (6 People)

**Skylab Crew Deck Only**

**Mission Duration**
- Apollo 17
- Skylab Crew Deck Only
- SL 2* (4 People)
- SL 3* (4 People)
- SL 4* (4 People)

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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

1 SHORT AXIS UP
2 FLOORS ALL COPLANAR

3 LONG AXIS UP
(ORIGINAL S.O.C., J.S.C.)
4 UP AWAY FROM CENTER

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ONE POINT
REFERENCE ORIENTATION

REPORTED SOVIET EVA PROTOCOL
FOR TETHERED OPERATIONS

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Two Point Reference Orientation

"Local Vertical" in Skylab and Spacelab

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THREE POINT REFERENCE ORIENTATION

"VERTICAL RAFT" SPACE STATION

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OUTSIDE

INSIDE

ON FACE

EDGE

FOUR POINT REFERENCE ORIENTATION

"BALONEY SLICE"

"HOT DOG"

"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 separation 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 SANE 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

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

- WINDOWS FOR WORK
  - RENDEZ-VOUS & DOKING
  - 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
  - Absorptive surfaces
  - Sound barriers/bulkheads between compartments in a module
  - Positive isolation between modules.

* Audio systems
STRUCTURES: SHELLS

- MODULE PRESSURE SHELL CONSTRUCTION CAN INFLUENCE HABITABILITY AND H.E
  - 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 SPUN SECTION
    - TRAPEZOIDAL GORES
    - HEXAGONAL GORES
  - FORM: ELLIPTICAL, CONICAL OR SPHERICAL
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

  BUT

- 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

- 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
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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13) **FUNCTION**

- **DEFINITION OF FUNCTION**
- **CLARITY OF FUNCTION**
- **ORGANIZATION OF FUNCTIONS**

- **DO FUNCTIONS EQUATE TO MODULES?**
- **CAN FUNCTION DICTATE GEOMETRY?**