SPACE STATION CREW SAFETY
HUMAN FACTORS INTERACTION MODEL

Abstract by Marc M. Cohen and Maria K. Junge
Space Human Factors Office
NASA-Ames Research Center
Presented at NASA HQ, May 8, 1984

As NASA prepares plans to develop a space station, one of the major Human Factors study tasks is to develop an approach to Crew Safety. NASA has always been a paradigm of safety consciousness and recognizes that safety will be a key to reliability and human productivity on the space station.

In evaluating safety strategies, it is also necessary to recognize both qualitatively and quantitatively how this space station will be different from all other spacecraft. During the initial phase of this study, it was recognized that the major difference between space station and previous spacecraft is the role of human factors and extra-vehicular activity (EVA). In this project, a model of the various human factors issues and interactions that might affect crew safety is developed.

The first step addressed systematically the central question: How is this space station different from all other spacecraft? A wide range of possible issues was identified and researched. Five major topics of human factors issues that interacted with crew safety resulted: Protocols, Critical Habitability, Work Related Issues, Crew Incapacitation and Personal Choice.

Second, an interaction model was developed that would show some degree of cause and effect between objective environmental or operational conditions and the creation of potential safety hazards. The intermediary steps between these two extremes of causality were the effects on human performance and the results of degraded performance. The model contains three milestones: stressor, human performance (degraded) and safety hazard threshold. Between these milestones are two countermeasure intervention points. The first opportunity for intervention is the countermeasure against stress. If this countermeasure fails, performance degrades. The second opportunity for intervention is the countermeasure against error. If this second countermeasure fails, the threshold of a potential safety hazard may be crossed.

An example of how this interaction model works can be demonstrated. Under Critical Habitability, the primary environmental stressors include confinement, isolation and separation from earth. There are two subgroups of within the first countermeasure against these stressors, social and architectural interventions. The social factors are communication with family and friends, visitors to the station and recreation. The architectural factors are design, station geometry and "local vertical" reference orientations and windows. When these social and architectural design level countermeasures against stress are not effective, crew performance may degrade in the form of morale deterioration, impaired
judgement or faulty perceptions. The second set of countermeasures, against errors are operational or group social activities plus personal existential actions. These social subset countermeasures include group activities, hobbies and time for personal interests. The design/physical countermeasure sub-group includes color coding on interior functions, lighting and video systems. To the extent that this second defense of countermeasures is not successful, the threshold of potential safety hazards may be crossed. In this instance, potential safety hazards include a breakdown in group process and teamwork, and mistakes occurring in judgement, perception or action.

The third step, which is now in progress, is to apply a system of weighting to the various stressors and countermeasures in order to be able to evaluate their relative importance. This weighting will also require an element of time duration to identify which stressors or countermeasures are relevant at the beginning, middle or end of missions, and which are short-lived or chronic in nature.
SPACE STATION CREW SAFETY
HUMAN FACTORS CONCERNS

1. PROTOCOLS
   - AUTONOMY FROM GROUND

2. WORK RELATED ISSUES
   - TASK ASSIGNMENT
   - ROLE DEFINITION

3. CRITICAL HABITABILITY

4. CREW INCAPACITATION

5. PERSONAL CHOICE
   - INDIVIDUAL SCHEDULE CHANGES
   - OPERATIONAL CHANGES
   - WORK PROCEDURE CHANGES

NASA—Ames Research Center
Space Human Factors Office
SPACE STATION CREW SAFETY
HUMAN FACTORS INTERACTION MODEL

STRESSORS

STRESSED CREW

DEGRADED PERFORMANCE

ERRORS

SAFETY HAZARD

COUNTER-MEASURES

COUNTER-MEASURES

NASA—Ames Research Center
Space Human Factors Office
SPACE STATION CREW SAFETY
HUMAN FACTORS INTERACTION MODEL

1. PROTOCOLS

<table>
<thead>
<tr>
<th>STRESSORS</th>
<th>DEGRADED PERFORMANCE</th>
<th>SAFETY HAZARD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>COUNTER-MEASURES</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AGAINST STRESS</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AUTONOMY FROM</td>
<td>GROUND</td>
<td></td>
</tr>
<tr>
<td>SCHEDULING OVERLOAD</td>
<td>SCHEDULING CONFLICTS</td>
<td>DAILY SCHEDULING</td>
</tr>
<tr>
<td></td>
<td>CHANGES</td>
<td>POST-FLIGHT DEBRIEFING</td>
</tr>
<tr>
<td></td>
<td>CREW ROTATION</td>
<td></td>
</tr>
<tr>
<td>FAMILY PROBLEMS</td>
<td>FAMILY INTERACTION/SECURE COMMUNICATIONS</td>
<td>DISCIPLINE</td>
</tr>
<tr>
<td></td>
<td>BEHAVIOR? DEPRESSION</td>
<td></td>
</tr>
<tr>
<td>DISAGREEMENTS WITH GROUND CONTROL</td>
<td>CONFLICTING OBJECTIVES</td>
<td>DELIBERATE CONFLICT</td>
</tr>
<tr>
<td>TERRITORIALITY</td>
<td>AUTONOMY FROM GROUND</td>
<td>CHANGES IN MISSION OBJECTIVES</td>
</tr>
<tr>
<td></td>
<td>ACCESS/ NON-ACCESS</td>
<td>VIOLATION OF SAFETY CRITERION</td>
</tr>
<tr>
<td>INCOMPATIBILITIES</td>
<td>CREW SELECTION/CREW TRAINING</td>
<td>NEGOTIATIONS</td>
</tr>
<tr>
<td></td>
<td>INCOMPATIBILITIES</td>
<td>TRAINING GROUP PROCESS CRISIS MANAGEMENT (FOR ALL OF THE ABOVE)</td>
</tr>
</tbody>
</table>

LACK OF
COORDINATION
MISUNDERSTANDING

DISCREPANCY
CONFLICT

VIOLATION OF
SAFETY CRITERION

IMPROPER ENTRY
OR INADEQUATE ACCESS

LACK OF COOPERATION

NASA—Ames Research Center
Space Human Factors Office
## 2. CRITICAL HABITABILITY

<table>
<thead>
<tr>
<th>STRESSORS</th>
<th>DEGRADED PERFORMANCE</th>
<th>SAFETY HAZARD</th>
</tr>
</thead>
<tbody>
<tr>
<td>COUNTER-MEASURES AGAINST STRESS</td>
<td>COUNTER-MEASURES AGAINST ERRORS</td>
<td></td>
</tr>
</tbody>
</table>

### VOLUME LIMITATIONS
- ARCHITECTURE: DESIGN
- PRIVACY, WINDOWS
- FEELINGS OF CLAUSTROPHOBIA
- LACK OF PRIVACY

### NOISE
- VIBRATION, ISOLATION AND CONTROL
- SLEEP DISTURBANCES
- POOR COMMUNICATION

### HOUSEKEEPING
- ROUTINES \& TRAINING
- ENVIRONMENT QUALITY
- DETERIORATION

### HYGIENE CLEANLINESS
- PERSONAL PRACTICES
- DISCOMFORT TO OTHERS
- ILLNESS DISEASE

### PRIVACY OR EVACUATION
- EARMUFFS, HEADSETS, DRUGS
- COMMUNICATION DEVICES

### IRRITABILITY PARANOID
- FAILURE TO RESPOND
- FAILURE TO COMMUNICATE OR COORDINATE

### BREAKDOWN IN LIFE SUPPORT
- PERSONAL ILLNESS
- OR IMPAIRMENT
- INABILITY TO PERFORM TASKS

---

NASA—Ames Research Center
Space Human Factors Office
CRITICAL HABITABILITY II

SPACE STATION CREW SAFETY
HUMAN FACTORS INTERACTION MODEL

STRESSORS
- THERMAL/HUMIDITY
- CLOSED ATMOSPHERE
- CONFINEMENT
- ISOLATION
- SEPARATION
- ARTIFICIAL LIGHTING
  - LIGHTING DESIGN, "NATURAL LIGHT"

DEGRADED PERFORMANCE
- ENVIRONMENTAL CONTROLS
- COMMUNICATION WITH FAMILY AND FRIENDS
- VISITORS
- SOCIAL EVENTS
- RECREATION
- COUNSELING
- ARCHITECTURE
- GEOMETRY
- STOWAGE AND RETRIEVAL "LOCAL VERTICAL"
- DISCOMFORT
- IRRITABILITY
- LONELINESS
- MORALE
- DETERIORATION
- IMPAIRED
- JUDGMENT
- PERCEPTION UNDER STRESS
- Claustrophobia

COUNTER-MEASURES AGAINST STRESS
- AIR MOVEMENT
- GAS COMPOSITION
- CONTROL
- TEMPERATURE AND HUMIDITY
- CONTROL
- GROUP ACTIVITIES
- HOBBIES
- PERSONAL INTERESTS
- JUDGMENT
- PERCEPTION AND JUDGMENT CHECKS
- COLOR CODING
- LIGHTING
- MULTIPLE ACCESS
- CHOICES
- MOBILITY AIDS
- PERSONAL RESTRAINTS
- SPECIAL TASK
- LIGHTING

COUNTER-MEASURES AGAINST ERRORS
- INCREASED ANXIETY
- IMPAIRED RESPONSE
- BREAKDOWN IN GROUP PROCESS, TEAMWORK
- MISTAKES IN JUDGMENT, PERCEPTION OR ACTION
- PARANOIA
- MISTAKEN PERCEPTION

NASA—Ames Research Center
Space Human Factors Office
### 3. TASK RELATED ISSUES

**Space Station Crew Safety**  
**Human Factors Interaction Model**

<table>
<thead>
<tr>
<th>STRESSORS</th>
<th>DEGRADED PERFORMANCE</th>
<th>SAFETY HAZARD</th>
</tr>
</thead>
<tbody>
<tr>
<td>COUNTER-MEASURES AGAINST STRESS</td>
<td>COUNTER-MEASURES AGAINST ERRORS</td>
<td></td>
</tr>
</tbody>
</table>

#### Task Assignment/Role Definition

<table>
<thead>
<tr>
<th>Work Environment Problems</th>
<th>Work Organization/Leadership</th>
<th>Task Assignment</th>
<th>Physical Limitations</th>
<th>Scheduling and Coordination Conflicts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station Organization/Design</td>
<td>Leadership Training Consensus</td>
<td>Task Selection</td>
<td>Crew Selection Physical Endurance</td>
<td>Group Meals and Meetings</td>
</tr>
<tr>
<td>Fatigue Factors</td>
<td>Conflicts with Leadership</td>
<td>Monotony, Boredom</td>
<td>Strain on Endurance</td>
<td>Blame Assignment</td>
</tr>
<tr>
<td>Work Station Design</td>
<td>Crisis Resolution/Chain of Command</td>
<td>Task Rotation</td>
<td>MANDATORY PHYSICAL EXERCISE REGIMEN</td>
<td>CREW/Buddy Checks and Drills</td>
</tr>
<tr>
<td>Mistake/Inadvertent Action</td>
<td>Conflicting Actions</td>
<td>&quot;FAMILIARITY BREEDS CONTEMPT LACK OF CAUTION&quot;</td>
<td>&quot;CUTTING CORNERS&quot; PHYSICAL INABILITY TO PERFORM TASKS</td>
<td>LACK OF EFFECTIVE CREW INTER-ACTION</td>
</tr>
</tbody>
</table>

#### EVA Routines and Procedures

NASA—Ames Research Center  
Space Human Factors Office
SPACE STATION CREW SAFETY
HUMAN FACTORS INTERACTION MODEL

4. CREW INCAPACITATION

<table>
<thead>
<tr>
<th>STRESSORS</th>
<th>COUNTER-MEASURES AGAINST STRESS</th>
<th>DEGRADED PERFORMANCE</th>
<th>COUNTER-MEASURES AGAINST ERRORS</th>
<th>SAFETY HAZARD</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPACE SICKNESS</td>
<td>SELECTION/ADJUSTMENT</td>
<td>RELIABILITY</td>
<td>TREATMENT</td>
<td>CREW FAILURE TO</td>
</tr>
<tr>
<td>GAS BUBBLES IN WATER</td>
<td>MAINTAIN/CHECK FUEL CELLS</td>
<td>GAS PAINS</td>
<td>SLING WATER TO SEPARATE GAS</td>
<td>RESPOND</td>
</tr>
<tr>
<td>ILLNESS</td>
<td>EXAMINATIONS AND HEALTH</td>
<td>SHORT TERM</td>
<td>TREATMENT</td>
<td>CONTAGION?</td>
</tr>
<tr>
<td>MAINTENANCE PROGRAM</td>
<td>INCAPACITATION</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INJURY</td>
<td>SPACE INDUSTRIAL SAFETY</td>
<td>LONG TERM INCAPACITATION</td>
<td>RETURN TO EARTH? STABILIZE ON ORBIT?</td>
<td>DISTRACTION OF OTHER CREW MEMBERS</td>
</tr>
<tr>
<td>EMOTIONAL/MENTAL PROBLEM</td>
<td>CREW SELECTION GROUP TRAINING</td>
<td>STRAIN ON OTHERS/</td>
<td>RELIEF FROM DUTY</td>
<td>SOcially deviant BEHAVIOR?</td>
</tr>
<tr>
<td>FAILURE IN LIFE SUPPORT SYSTEM</td>
<td>ABANDON, EVACUATE ONE MODULE</td>
<td>LACK OF TRUST</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DEATH</td>
<td>COUNSELING</td>
<td>CONFINEMENT, TRAUMA</td>
<td>REPAIRS, REPLACE-MENT</td>
<td>LOSS OF ACCESS TO CRITICAL FUNCT JNS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TRAUMA TO CREW DISRUPTION OF TEAMWORK</td>
<td>COUNSELING</td>
<td>PRESERVATION OR DISPOSAL OF BODY LACK OF EXPERTISE ON BOARD</td>
</tr>
</tbody>
</table>

NASA—Ames Research Center
Space Human Factors Office
## 5. PERSONAL CHOICE

<table>
<thead>
<tr>
<th>STRESSORS</th>
<th>DEGRADED PERFORMANCE</th>
<th>SAFETY HAZARD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COOKING/EATING HABITS</strong></td>
<td>IRRITATION</td>
<td>ADEQUATE TRAINING</td>
</tr>
<tr>
<td></td>
<td>DEPRESSION</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>INDIVIDUAL PROPERTY</strong></td>
<td>PERSONAL AUTONOMY DIMINISHED</td>
<td>MONITORING AND CONTROL</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Boredom, Monotony</strong></td>
<td>LACK OF VIGILANCE</td>
<td>ADEQUATE CREW ACTIVITIES PLANNING AND SCHEDULING</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CLOTHING</strong></td>
<td>IRRITATION, DISCOMFORT LESS PERSONAL FREEDOM</td>
<td>CLEAN FILTERS</td>
</tr>
<tr>
<td></td>
<td>VARIETY, LAUNDRY CREW PREFERENCE</td>
<td></td>
</tr>
</tbody>
</table>

### Individual Schedule Changes

<table>
<thead>
<tr>
<th>WORK PROCEDURE CHANGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>CREW SELECTION</td>
</tr>
<tr>
<td>CREW TRAINING</td>
</tr>
</tbody>
</table>

### Operational Changes

<table>
<thead>
<tr>
<th>PERSONAL HABITS: SMOKING ALCOHOL DRUGS</th>
<th>CREW SELECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>REASONS FOR CONCEALMENT</td>
<td></td>
</tr>
<tr>
<td>WITHDRAWAL SYMPTOMS</td>
<td></td>
</tr>
<tr>
<td>POOR HEALTH INTERFERENCE WITH DUTIES</td>
<td></td>
</tr>
<tr>
<td>COUNSELING?</td>
<td></td>
</tr>
<tr>
<td>EVACUATION</td>
<td></td>
</tr>
<tr>
<td>EARLY CREW CHANGEOUT</td>
<td></td>
</tr>
<tr>
<td>FIRE</td>
<td></td>
</tr>
<tr>
<td>IMPAIRED</td>
<td></td>
</tr>
<tr>
<td>JUDGMENT</td>
<td></td>
</tr>
<tr>
<td>DESTRUCTION OF &quot;TEAM&quot;</td>
<td></td>
</tr>
</tbody>
</table>

NASA Ames Research Center
Space Human Factors Office