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SPACE STATION CREW SAFETY

HUMAN FACTORS INTERACTION MODEL

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As NASA prepares plans to devlop 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 seperation 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

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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 subgroup 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 occuring 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.

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SPACE STATION CREW SAFETY HUMAN FACTORS CONCERNS

- **1. PROTOCOLS**
- AUTONOMY FROM GROUND
- 2. WORK RELATED ISSUES
- TASK ASSIGNMENT
- ROLE DEFINITION
- 3. CRITICAL HABITABILITY

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- 4. CREW INCAPACITATION
- 5. PERSONAL CHOICE
- INDIVIDUAL SCHEDULE CHANGES
- OPERATIONAL CHANGES
- WORK PROCEDURE CHANGES

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## **1. PROTOCOLS**

| SAFETY<br>HAZARD        |                                        |         | IG LACK OF<br>COORDINATION<br>MISUNDERSTANDING | DELIBERATE<br>CONFLICT                           | VIOLATION OF<br>SAFETY CRITERION        | IMPROPER ENTRY<br>OR INADEQUATE<br>ACCESS | LACK OF COOPERA-<br>TION                                                     | NASAAmes Research Center<br>Space Human Factors Office |
|-------------------------|----------------------------------------|---------|------------------------------------------------|--------------------------------------------------|-----------------------------------------|-------------------------------------------|------------------------------------------------------------------------------|--------------------------------------------------------|
|                         | COUNTER-<br>MEASURES<br>AGAINST ERRORS | GROUND  | DAILY SCHEDULIN<br>POST-FLIGHT<br>DEBRIEFING   | DISCIPLINE                                       | CHANGES IN<br>MISSION OBJEC-<br>TIVES   | NEGOTIATIONS                              | TRAINING<br>GROUP PROCESS<br>CRISIS MANAGE-<br>MENT (FOR ALL C<br>THE ABOVE) |                                                        |
| DEGRADED<br>PERFORMANCE |                                        | MY FROM | SCHEDULING<br>CONFLICTS                        | SOCIALLY DEVIANT<br>BEHAVIOR?<br>DEPRESSION      | CONFLICTING<br>OBJECTIVES               | TURF CONFLICTS                            | INCOMPATIBILITIES                                                            |                                                        |
|                         | COUNIER-<br>MEASURES<br>AGAINST STRESS | AUTONO  | SCHEDULING<br>CHANGES<br>CREW ROTATION         | FAMILY INTER-<br>ACTION/SECURE<br>COMMUNICATIONS | AUTONOMY FROM<br>GROUND                 | ACCESS/<br>NON-ACCESS                     | CREW SELECTION<br>CREW TRAINING                                              |                                                        |
| STRESSORS               |                                        |         | SCHEDULING                                     | FAMILY PROBLEMS                                  | DISAGREEMENTS<br>WITH GROUND<br>CONTROL | TERRITORIALITY                            | INCOMPATIBILITIES                                                            |                                                        |

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# 2. CRITICAL HABITABILITY I

|   | ssors            | COUNTER<br>MEASURES<br>AGAINST STR     | TIONS ARCHITECTURE<br>PESIGN<br>PRIVACY<br>WINDOWS | VIBRATION,<br>ISOLATION AN<br>CONTROL                      | EPING ROUTINES JND<br>TRAINING             | VESS PERSONAL<br>PRACTICES                                         |
|---|------------------|----------------------------------------|----------------------------------------------------|------------------------------------------------------------|--------------------------------------------|--------------------------------------------------------------------|
|   | PERFORMANCE      | 8                                      | FEELINGS OF<br>CLAUSTROPHOBIA<br>LACK OF PRIVACY   | SLEEP DISTURB-<br>ANCES<br>POOR COMMUNICA-<br>TION         | ENVIRONMENT<br>QUALITY<br>DETERICRATION    | DISCOMFORT TO<br>OTHERS<br>ILLNESS<br>DISEASE                      |
| ſ |                  | COUNTER-<br>MEASURES<br>AGAINST ERRORS | PRIVACY OR<br>EVACUATION                           | EARMUFFS, HEAD.<br>SETS, DRUGS<br>COMMUNICATION<br>DEVICES | ASSIGNMENT OF<br>RESPONSIBILITIES          | GROUP PRACTICES                                                    |
|   | SAFETY<br>Hazabr |                                        | <br>IRRITABILITY<br>PARANOIL                       | FAILURE TO<br>RESPOND<br>FAILURE TO<br>COMMUNICATE OR      | CUURDINATE<br>BREAKDOWN IN LIFE<br>SUPPORT | PERSONAL ILLNESS<br>OR IMPAIRMENT<br>INABILITY TO<br>PERFORM TASUS |

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## CRITICAL HABITABILITY II

| STRESSORS                                |                                                                                                                                                                                  | DEGRADED<br>PERFORMANCE                                                                                                        |                                                                                                                                                                                  | SAFETY<br>HAZARD                                                                                              |
|------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|
|                                          | COUNTER-<br>MEASURES<br>AGAINST STRESS                                                                                                                                           |                                                                                                                                | COUNTER-<br>MEASURES<br>AGAINST ERRORS                                                                                                                                           |                                                                                                               |
| THERMAL/HUMIDITY<br>CLOSED<br>ATMOSPHERE | ENVIRONMENTAL<br>CONTFOLS                                                                                                                                                        | DISCOMFORT<br>IRRITABILITY                                                                                                     | AIR MOVEMENT<br>GAS COMPOSITION<br>CONTROL<br>TEMPERATURE AND                                                                                                                    | INCREASED<br>ANXIETY<br>IMPAIRED                                                                              |
|                                          |                                                                                                                                                                                  |                                                                                                                                | HUMIDITY<br>CONTROL                                                                                                                                                              | RESPONSE                                                                                                      |
| CONFINEMENT<br>ISOLATION<br>SEPARATION   | COMMUNICATION<br>WITH FAMILY AND<br>FRIENDS<br>VISITORS<br>SOCIAL EVENTS<br>RECREATION<br>COUNSELING<br>ARCHITECTURE<br>GEOMETRY<br>STOWAGE AND<br>RETRIEVAL<br>"LOCAL VERTICAL" | LONELINESS<br>MORALE<br>DETERIORATION<br>DETERIORATION<br>IMPAIRED<br>JUDGMENT<br>PERCEPTION UNDER<br>STRESS<br>CLAUSTROPHOBIA | GROUP ACTIVITIES<br>HOBBIES<br>PERSONAL<br>INTERESTS<br>PERCEPTION AND<br>JUDGMENT CHECKS<br>COLOR CODING<br>LIGHTING<br>MULTIPLE ACCESS<br>CHOICES<br>MOBILITY AIDS<br>PERSONA' | BREAKDOWN IN<br>GROUP PROCESS,<br>TEAMWORK<br>MISTAKES IN<br>JUDGMENT,<br>PERCEPTION OR<br>ACTION<br>PARANOIA |
| ARTIFICIAL<br>LIGHTING                   | LIGHTING DESIGN,<br>"NATURAL LIGHT"                                                                                                                                              | FATIGUE<br>IRRITABILITY<br>BLURRED VISION                                                                                      | RESTRAINTS<br>SPECIAL TASK<br>LIGHTING                                                                                                                                           | MISTAKEN<br>PERCEPTION                                                                                        |

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## **TASK RELATED ISSUES**

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|   | SAFETY   | HAZARD      |           |          |          |                |  |
|---|----------|-------------|-----------|----------|----------|----------------|--|
| _ |          |             | 001111100 | COUNTER- | MEASURES | AGAINST ERRORS |  |
|   | DEGRADED | PERFORMANCE |           |          |          |                |  |
| - |          | •           |           | COUNTER- | MEASURES | AGAINST STRESS |  |
|   |          | - SIRESOURS |           |          |          |                |  |

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| WORK ENVIRON-<br>MENT PROBLEMS              | STATION<br>ORGANIZATION/<br>DESIGN      | FATIGUE FACTORS              | WORK STATION<br>DESIGN                      | MISTAKE/<br>INADVERTENT<br>ACTION                              |
|---------------------------------------------|-----------------------------------------|------------------------------|---------------------------------------------|----------------------------------------------------------------|
| WORK<br>ORGANIZATION/<br>LEADERSHIP         | LEADERSHIP<br>TRAINING<br>CONSENSUS     | CONFLICTS WITH<br>LEADERSHIP | CRISIS RESOLUTION/<br>CHAIN OF<br>COMMAND   | CONFLICTING                                                    |
| TASK ASSIGNMENT                             | TASK SELECTION                          | MONOTONY,<br>BOREDOM         | TASK ROTATION                               | "FAMILIARITY<br>BREEDS<br>CONTEMPT<br>LACK OF CAUTION"         |
| PHYSICAL<br>LIMITATIONS                     | CREW SELECTION<br>PHYSICAL<br>ENDURANCE | STRAIN ON<br>ENDURANCE       | MANDATORY<br>PHYSICAL EXER-<br>CISE REGIMEN | "CUTTING<br>CORNERS"<br>PHYSICAL INABILITY<br>TO PERFORM TASKS |
| SCHEDULING AND<br>COORDINATION<br>CONFLICTS | GROUP MEALS AND<br>MEETINGS             | BLAME ASSIGNMENT             | CREW/BUDDY<br>CHECKS AND<br>DRILLS          | LACK OF EFFECTIVE<br>CREW INTER-<br>ACTION                     |
| _                                           | -                                       | -                            | -<br>-                                      |                                                                |

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## CREW INCAPACITATION

|                                           | 4. CREV                                                  | V INCAPAC                                   | SITATION                                    |                                                                      |
|-------------------------------------------|----------------------------------------------------------|---------------------------------------------|---------------------------------------------|----------------------------------------------------------------------|
| STRESSORS                                 | -                                                        | DEGRADED<br>PERFORMANCE                     |                                             | SAFETY<br>HAZARD                                                     |
|                                           | COUNTER-<br>MEASURES<br>AGAINST STRESS                   |                                             | COUNTER-<br>MEASURES<br>AGAINST ERRORS      |                                                                      |
| SPACE SICKNESS<br>GAS BUBBLES IN<br>WATER | SELECTION/<br>ADJUSTMENT<br>MAINTAIN/CHECK<br>FUEL CELLS | RELIABILITY<br>GAS PAINS                    | TREATMENT<br>SLING WATER TO<br>SEPARATE GAS | CREW FAILURE TO<br>RESPOND                                           |
| ILLNESS                                   | EXAMINATIONS<br>AND HEALTH<br>MAINTENANCE<br>PROGRAM     | SHORT TERM<br>INCAPACITATION                | TREATMENT                                   | CONTAGION?                                                           |
| INJURY                                    | SPACE INDUSTRIAL<br>SAFETY                               | LONG TERM<br>INCAPACITATION                 | RETURN TO EARTH?<br>STABILIZE ON<br>ORBIT?  | DISTRACTION OF<br>OTHER CREW<br>MEMBERS                              |
| EMOTIONAL/<br>MENTAL PROBLEM              | CREW SELECTION<br>GROUP TRAINING                         | STRAIN ON OTHERS/<br>LACK OF TRUST          | RELIEF FROM DUTY                            | SOCIALLY DEVIANT<br>BEHAVIOR?                                        |
| FAILURE IN LIFE<br>SUPPORT SYSTEM         | ABANDON,<br>EVACUATE ONE<br>MODULE                       | CONFINEMENT,<br>TRAUMA                      | REPAIRS, REPLACE.<br>MENT                   | LOSS OF ACCESS<br>TO CRIT'DAL<br>FUNCT JNS                           |
| DEATH                                     | COUNSELING                                               | TRAUMA TO CREW<br>DISRUPTION OF<br>TEAMWORK | COUNSELING                                  | PRESERVATION OR<br>DISPOSAL OF BODY<br>LACK OF EXPERTISE<br>ON BOARD |
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## **PERSONAL CHOICE** <u>ີ</u>.

| STRESSORS                                       |                                                                    | <b><u><u>SEGRADED</u></u></b><br>PERFORMANCE                                                       |                                                           | SAFETY<br>HAZARD                                         |
|-------------------------------------------------|--------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|-----------------------------------------------------------|----------------------------------------------------------|
|                                                 | COUNTER-<br>MEASURES<br>AGAINST STRESS                             |                                                                                                    | COUNTER-<br>MEASURES<br>AGAINST ERRORS                    |                                                          |
|                                                 |                                                                    |                                                                                                    |                                                           |                                                          |
| COOKING/EATING<br>HABITS                        | SHARED MEALS<br>ACCOMMODATION<br>FOR INDIVIDUAL<br>CREW PREFERENCE | IRRITATION<br>DEPRESSION                                                                           | ADEQUATE<br>TRAINING                                      | FIRE<br>SMELLS<br>OUTGASSING                             |
| INDIVIDUAL<br>PROPERTY                          | EDUCATION<br>MONITORING AND<br>CONTROL<br>CREW TRAINING            | PERSONAL AUTON.<br>OMY DIMINISHED                                                                  | MONITORING<br>AND CONTROL                                 | OUTGASSING<br>CONTAMINATION<br>FLAMMABILITY              |
| BOREDOM,<br>MONOTONY                            | ENTERTAINMENT<br>CREW SELECTED<br>ACTIVITIES                       | LACK OF VIGILANCE                                                                                  | ADEQUATE CREW<br>ACTIVITIES<br>PLANNING AND<br>SCHEDULING | PRACTICAL JOKES<br>DISTRACTION<br>ACCIDENTS              |
| CLOTHING                                        | VARIETY, LAUNDRY<br>CREW PREFERENCE                                | IRRITATION,<br>DISCOMFORT<br>LESS PERSONAL<br>FREEDOM                                              | CLEAN FILTERS                                             | LINT PROBLEM                                             |
| <b>Z</b> ,<br><b>-</b> ,<br>,                   | DIVIDUAL<br>Work Pr<br>Opera                                       | SCHEDU<br>OCEDURE<br>TIONAL C                                                                      | LE CHANG<br>CHANGES<br>HANGES                             | S                                                        |
| PERSONAL HABITS:<br>SMOKING<br>ALCOHOL<br>DRUGS | CREW TRAINING<br>CREW TRAINING                                     | REASONS FOR<br>CONCEALMENT<br>WITHDRAWAL<br>SYMPTOMS<br>POOR HEALTH<br>INTERFERENCE<br>WITH DUTIES | COUNSELING?<br>EVACUATION<br>EARLY CREW<br>CHANGEOUT      | FIRE<br>IMPAIRED<br>JUDGMENT<br>DESTRUCTION OF<br>"TEAM" |
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