REPORT OF THE CREW STATION DESIGN WORKING GROUP

Dr. James Lewis, Chairman (NASA/JSC)

R. M. Broussard (Aerospace)
J. R. Goodman (NASA/JSC)
Walter Wierwille (VPI)
K. H. E. Kroemer (VPI)
Keith Miller (Boeing)
Kenneth R. Boff (AFAMRL)
Edward R. Jones (McDonnell Douglas)
R. F. Gabriel (McDonnell Douglas)

CREW STATION DESIGN KEY ISSUES SUMMARY

- ERGONOMIC MODEL OF THE HUMAN OPERATOR
- CREW STATION DESIGN AND DEVELOPMENT TECHNOLOGY
- NATURAL LANGUAGE INTERFACE
- PRIORITY AND INHIBIT LOGIC
- DATA ENTRY
- DATA STORAGE AND RETRIEVAL
- RESTRAINT SYSTEMS
- WORKLOAD EVALUATION METHODS--ZERO G
- OPTIMIZED CREW INTERFACE WITH INFORMATION MANAGEMENT SYSTEMS
- FACILITY HYGIENE
- BULK FOOD SYSTEMS

A summary of the key issues which will be discussed in more detail on the following charts.

ERGONOMIC MODEL OF THE HUMAN OPERATOR

ISSUE

SYSTEMATIC AND COMPREHENSIVE REPRESENTATIONS OF THE HUMAN OPERATOR AND HIS ENVIRONMENTS WHICH ARE INTERACTIVE IN THE DESIGN PROCESS ARE NOT AVAILABLE

APPROACH

- DEFINE DATA REQUIRED
- DEVELOP TECHNOLOGY FOR DATA ACQUISITION SYSTEMS
- DEFINE AND DEVELOP TECHNOLOGY REQUIRED FOR USAGE/ IMPLEMENTATION
- DEVELOP AND IMPLEMENT MODELING CRITERIA
  - ANTHROPOMETRIC MODEL
  - BIOMECHANICAL MODEL, WORK STATION AND ENVIRONMENTAL MODEL
  - INTERFACE AND INTERACTION MODELS

BENEFITS

- IMPROVED AND RESPONSIVE CREW STATION DESIGNS
- LOWERED COST, DECREASED CHANGE TRAFFIC
- IMPROVED CREW EFFICIENCY
- ENHANCED MISSION SUCCESS

We need systematic and comprehensive representations of three separate aspects of the human operator within a technological system:

(a) Model of body dimensions, "Anthropometric Model"

(b) Model of physical activity characteristics, "Biomechanical Model"

(c) Model of operator-equipment interactions, "Interface Model".

These submodels should be integrated for the "Ergonomic Model". This shall be a "proactive" (predictive) model, as compared to existing "reactive" (passive) models.

Many approaches for model subsystems or components of this overall problem exist. However, they do not fit into a common framework, and have different, often noncompatible outputs. Furthermore, the input requiremens are usually different (resulting from analytical or systematic approaches of different disciplines) and do not rely on a common data base.

The lack of a systematic, comprehensive, and quantitative ergonomic model brings about incomplete understanding of the human operator as a system component, who is often the main determiner of the system output. Thus, technological systems relying on the human as a system component may be laid out less than optimal with respect to system performance and, therefore, are suboptimal in their output.

Such systems are military or civilian. Typical examples in the military domain are aircraft cockpits, tank interiors, work stations on surface ships, or submarines. Search and rescue ships used by the US Coast Guard are notorious for the lack of human engineering in their design. Typical civilian applications are in the automobile industry, both in passenger vehicles or trucks, and very prominent in construction and agricultural equipment. Acute industrial problems relate to control rooms, or visual display terminals.

Thus, development of a comprehensive and systematic Ergonomic Model of the Human Operation would benefit military as well as civilian populations and applications.

CREW STATION DESIGN & DEVELOPMENT TECHNOLOGY

APPROACH

- DEVELOP A SYSTEMATIC PROCESS FOR ASSESSMENT OF IMPACTS ON GROUND CONTROL ELEMENTS OF DESIGN ALTERNATIVES WITH RESPECT TO MAN-MACHINE FUNCTIONS

BENEFIT

- YIELDS QUANTITATIVE DATA ON PERFORMANCE AND COMPARATIVE ASSESSMENT CAPABILITY

PLAN

- CONTINUE DEVELOPMENT OF TECHNOLOGY REPRESENTING COMPLEX SINGLE AND MULTIPLE COMPUTER MAN MODELS REPRESENTATIVE OF FLIGHT CREW FUNCTIONAL INTERACTION WITH SPACECRAFT SYSTEMS
- SIMULATOR MEASUREMENT SYSTEM DEVELOPMENT

A systematic process is needed that can be applied to various crew stations aboard the spacecraft/station and those control elements of the ground support system that interface with the spacecraft.

The crew station design technology described below is particularly appropriate for computer-based crew stations as exemplified by the 767 and F-18, as well as certain command and control systems. These systems are characterized by new multi-mode, multifunction displays/controls that are software driven, and thus, changes in logic and format can be introduced readily and without hardware changes.

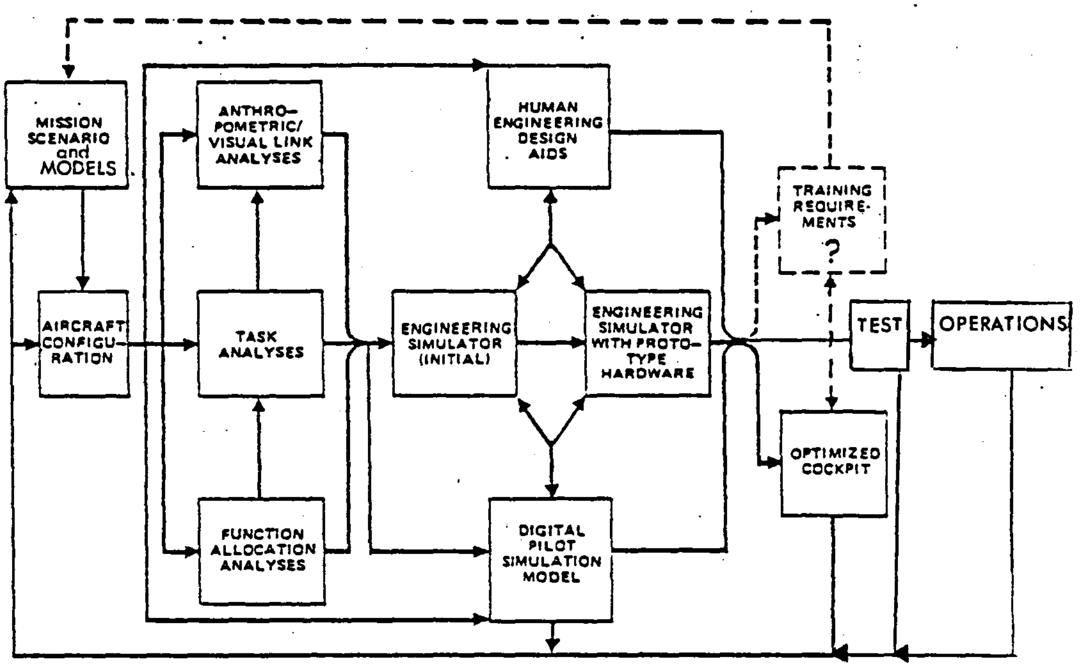
The crew station development process used for several aircraft is shown in the next chart. It should be noted that this process is probably the only way quantitative data can be obtained on the total effectiveness of a given crew station or the impact of a design (e.g., training, procedure, etc.) change on effectiveness. The issues are too complex and interactive to obtain "numbers" in any other way.

This process has been applied to the development of several fighter aircraft but further technology developments are needed to adapt this approach to NASA needs. Examples of further development needs are:

Digital Pilot (and Crew) Simulation Models
These are complex computer models that represent man's function in relation to a specific system. They consider discrete events, decision-making, and continuous control functions. Multiple runs of the models (Monte Carlo) can show the distribution of performance as a function of changes in variables such as a new display, stressors, and malfunctions. These can also interface with mission effectiveness models.

NASA needs require further developments in areas that include multi-man crews, mission control functions, duty cycles, and the effects of the environmental stresses found in space. Techniques must also be developed for inputing data from simulations and flight test and operational results.

Design Simulator Measurement Systems
The use of man-in-the-loop design simulators is an integral part of this process. However, the development of a science of crew station design requires the development of objective measurement systems. These do not exist now in a form that can generate quantitative data on a near real-time basis in a form that is meaningful for the design process. That is, a family of measures are needed that reflect new performance, system performance, and mission performance. They also should be developed in a way that human errors or poor performance basue of design (or training) limitations can be shown to impact safety of flight. Techniques for structuring missions and efficient "experimental" designs must also be developed to maximize data return.



HUMAN FACTORS USE OF ENGINEERING DEVELOPMENT SIMULATORS

Introduction - Simulators are used by many different engineering disciplines alone or in conjunction with other disciplines. These are chiefly the guidance and control mechanics, avionics, aerodynamics, flight test, computer software, operations analysis, and human factors groups. Most of the groups consider the man-machine interface, but the activities of the human factors group are probably most important in terms of impact on training system development.

Human factors studies, as a rule, use service or line pilots and focus on the cockpit to ensure that the aircraft is operable under a variety of mission conditions. Many cockpit configurations are examined during development. The ones used during the later stages of design are very close to the first aircraft. If human engineering has been effective, few changes will occur as a result of the flight test program because of crew operability problems. In the case of one recent fighter, the configuration of the cockpit is today essentially the same as the simulated cockpit established before the first flight.

Human engineering is the complement of training in that attempts are made to produce the most operable system possible in terms of crew use. Maximum operability is sometimes sacrificed in deliberate cost, complexity, and weight tradeoffs, and thus some tasks are identified for special emphasis during training. Consequently, an effective cockpit human engineering program should result in detailed and objective data regarding task difficulty and its various implications for training.

Approach - The iterative process used to develop a new cockpit is illustrated above. The key point is that analytical results are verified empirically in the context of mission scenarios. Current task analytic techniques are not powerful enough to identify, with the necessary certainty and precision, problems in operability. They seem particularly deficient in this regard for complex psychomotor tasks and for tasks involving new task elements found on emerging systems. The high capacity airborne computers and electro-optical displays utilized on newer aircraft led to an overabundance of pilot information presented in changing, complex formats.

Additionally, analytical results can be verified, corrected, and manipulated using digital pilot simulation models that do not require man-in-the-loop. Thus, better tools are now available to compensate for the weakness of the task analysis, particularly for complex interactive crew tasks.

During the concept design phase, preliminary crew functions are defined, operating procedures and tactics are developed, workload measured, the crew performance necessary to meet operational requirements established, and high risk training areas identified. At the same time computer software is being developed for the aircraft and for the engineering simulator.

After preliminary checkouts with engineers and test pilots, design verification is accomplished in the simulator with selected service pilots participating as test subjects and operational experts. Classroom training on the aircraft system is provided by the responsible engineer, and hands-on training is provided in the simulator.

Many planned and briefed mission segments are flown over a period of 5-10 days, with flight assignments based on experimental designs that maximize data utility. Sessions may be specific, such as air-to-air combat or carrier landings, or more encompassing depending on engineering needs. Normal operations and tactical situations are addressed with low and high workload imposed as a test condition. Numerical and graphic data and video recordings are obtained for each mission and detailed pilot debriefings provided.

The data necessary to assess the accuracy and quality of actual task performance is obtained. During early simulator flights, pilot performance is widely variable. The magnitude of this variability decreases, of course, as a function of practice. Tasks are identified which contribute to operating difficulty, such as crosschecking and the relation of switches to multifunction displays, and the use of new multifunction controls. Consequences of improper actions are identified. Target detection probability is examined as a function of mission conditions and display characteristics, and the precision required to meet operational requirements is defined.

Eye movements can be recorded to obtain information on frequency of instrument use, dwell time for each fixation, and scanning patterns. In special cases, physiological measures can be used as supplements to performance measures to indicate how difficult it is for the pilot to perform. In the future, for example, evoked brain potentials might be used in conjunction with eye-movement recordings for assessing workload.

All in all, simulation is a rich source of qualitative and quantitative data on the difficulty and performance requirements for perceptual-motor and cognitive tasks. The lessons learned and the information acquired in designing an aircraft can be of great value in identifying critical and difficult crew functions and defining training simulator configurations.

NATURAL LANGUAGE INTERFACE

ISSUE

- EXCESSIVE TRAINING REQUIRED

APPROACH

- DEVELOP CRITERIA FOR CREW INTERACTION WITH ON-BOARD SYSTEMS

BENEFITS

- REDUCED TRAINING
- GREATER PERFORMANCE ACCURACY
- SAFETY
- MISSION SUCCESS

Computer software should be developed so it does not require extensive operator training to interact with computer. Ideally the interaction with the computer will be "user friendly"--require no learning.

PRIORITY AND INHIBIT LOGIC

ISSUE

- AUTOMATION WILL REQUIRE MAN TO INCREASINGLY ASSUME THE ROLE OF MONITOR/DECISION MAKER/MANAGER--i.e., "THE FINAL REDUNDANCY"
- STRESS AND SYSTEM COMPLEXITY HIGH

APPROACH

- DEFINE CRITERIA FOR PRIORITY LOGIC FOR FAULT ANNUNCIATION
- DEFINE CRITERIA FOR INHIBIT LOGIC FOR RELEVANT TRAFFIC MANAGEMENT
- UTILIZE LOGICAL SYSTEMS ANALYSIS, EXPERT SURVEY AND EMPIRICAL TESTS

BENEFITS

- OPTIMAL USE OF MAN IN SPACE

As automation increases, man's role will become increasingly that of a monitor/decision maker/manager. He will probably always be retained as the final redundancy, reqhired to "take over" in the event of any unprotected system failure. Stress is apt to be high; mental set, familiarity skills are all apt to be low particularly with reliable systems. It is important, therefore, that the operator be unburdened from extraneous or redundant information. The warning system should provide clear, concise, unambiguous guidance for decision making and action. Priority logic would annunciate faults in the order of "most critical first", inhibit logic would not display caution or warning information that was unimportant at that time. Because, however, of the changing priorities resulting from differing phases of flight, environmental or other systems, many combinations of condition will have to be assessed including some requiring information not apt to be available to the computer. Some method of resolving this issue should be developed.

DATA ENTRY

ISSUE

- CURRENT METHODS (KEYBOARD, VOICE, MODE SELECTION, etc.) ALL HAVE SIGNIFICANT LIMITATIONS

APPROACH

- SYSTEMATIC REVIEW OF EXISTING DATA TO ESTABLISH GUIDE-LINES
- SYNTHESIS OF TECHNOLOGY TO SEEK BREAKTHROUGH

BENEFITS

- ERROR POTENTIAL REDUCED
- IMPROVED SAFETY AND MISSION SUCCESS

Interaction with computer requires human input. This can be done in any of a number of ways including keyboards, voice recognition, or mode selector keys. All of the existing methods have significant limitations. Keyboard entry, for example, is subject to high error rate when the operator is stressed, even with a scratch pad. Menu-select has been used to help overcome deficiencies but this approach may require significant time. Voice entry has a number of problems including a slow rate of input, erroneous and recognition or inadvertent activation potential. New methods and/or systematic guidelines of strengths, weaknesses, trade-offs of existing methods should be developed. A subsidiary problem is standardization of keyboard formats.

DATA STORAGE AND RETRIEVAL

APPROACH

- DEVELOP A STATE-OF-THE-ART SYSTEM FOR REPLACEMENT OF CURRENT FLIGHT DATA FILE BY ESTABLISHING CRITERIA AND METHODS FOR COMPRESSION, PRESENTATION, AND EFFECTIVE UTILIZATION OF DATA

BENEFIT

- WEIGHT } SAVINGS
- VOLUME }
- EFFICIENCY IMPROVEMENT

Current practice in spacecraft is to rely heavily on paper documentation for uplink information, experimental procedures, diagnostics, and emergency procedures. This practice, while providing relatively permanent records, is wasteful of crew time because of slow access. It may also be wasteful of space and weight.

A data storage and retrieval system could be substituted. It would probably require less space and would certainly reduce access time if properly diagnosed.

The storage and retrieval system must be optimized for space crew usage. An off-the-shelf approach to hardware or software would probably result in poor performance and poor crew acceptance. Formatting of information should be studied and developed specifically for efficient presentation and use by the crew. Diagrams, text, and data access procedures must be specifically tailored for viewing in the spacecraft environment. A research and development effort should be undertaken to determine the optimum formatting of information and the best types of data entry and display.

WORKLOAD EVALUATION

APPROACH

- DEVELOP METHODS FOR MEASUREMENT OF ZERO-G WORKLOADS, ESTABLISHING CRITERIA FOR ACCEPTABLE WORKLOADS AS A FUNCTION OF TIME
- DEVELOP METHODS FOR ASSESSMENT OF INTERACTION OF SPACEFLIGHT CREW WORKLOADS AS A FUNCTION OF STRESS

BENEFIT

- IMPROVED CREW EFFICIENCY
- AVOID POSSIBLE LOSS OF FLIGHT OBJECTIVES

Research is progressing on understanding and quantifying mental workload in a nominal 1 G environment. Several researchers are currently engaged in developing and validating procedures for aircrew workload assessment. These procedures will aid in determining the mental loads that aircrew stations impose on their operators.

It appears that no similar quantification effort for workload evaluation in spacecrew stations has been undertaken. Furthermore, any guidelines developed for 1 G environments probably could not be directly applied to zero-G environments. Unless procedures are developed, it is likely that spacecrew members may experience unacceptable mental loads, possibly resulting in mistakes and reducing the level of mission success.

Coupled with the problem of mental load is the problem of stress overtime. Acceptable mental load may decline as mission length increases, because of the possible interaction of stress with load. Physical load may also play a role in acceptable mental load.

In many cases, research should be undertaken to develop valid and reliable methods of workload measurement for space crew stations. These methods should then be used to specify acceptable load levels as a function of time in space. This problem will become more important as spacecrews begin to include more individuals not fully accustomed to the rigors of high performance flight.

RESTRAINT SYSTEMS

APPROACH

- ESTABLISH MULTIDISCIPLINARY RESEARCH TEAM TO EXAMINE ISSUES AND HISTORY
- INVESTIGATE ALL POSSIBLE APPROACHES

BENEFITS

- GENERIC SYSTEMS ELIMINATE INDIVIDUALIZED AND STYLIZED DESIGNS, REDUCE COSTS AND IMPROVE EFFICIENCY

While a great deal of effort has already been expanded on restraint systems, it appears that they still are not totally adequate. Restraints appear to fall into two major categories: foot restraints and body (torso) restraints. The need for these restraints arises because spacecrew members are routinely required to exert forces and torques, which must be counter-balanced to avoid unwanted body translations and rotations.

Because so much of the working time of future spacecrews will be spent in fixed, but unseated positions while performing some additional manipulation, efficient forms of restraints should be developed if possible, due to the wide variety of work sites in a Space Station.

A research team having multiple interdisciplinary backgrounds should re-examine the restraint problem. This group should not include those who have worked on the problem previously. However, the group should have access to them. The group should examine every conceivable approach to restraint including mechanical, pneumatic, electrostatic, electromagnetic, and various combinations. The research team should brainstorm prior to developing the most promising approaches, in hopes of achieving the greatest probability of success in evolving a new and better restraint system.

OPTIMIZED CREW INTERFACE WITH INFORMATION MANAGEMENT SYSTEMS

ISSUES

- CURENT I/Fs NOT OPTIMAL AND CAN BE IMPROVED
- SYSTEMATIC AND COHERENT APPROACH REQUIRED FOR SPACE STATION

APPROACH

- REVIEW AND APPLY CURRENT HF DATA BASE TO THE PROBLEM
- SYSTEMATICALLY CAPITALIZE ON DOD AND COMMERCIAL EXPERIENCE

BENEFIT

- IMPROVED CREW EFFICIENCY
- AVOID LOSS OF MISSION OBJECTIVES

Several assumptions stated upfront:

(1) Existing interfaces are not optimal with respect to the user.

(2) These may be optimized with respect to the variables which affect the operator's ability to acquire, process and utilize information from the system.

(3) Areas of concern may be:

a. Determination of what information is necessary to provide given the system, mission, task and previous training and experience of the operator.

b. Quality of information presentation (contrast, intensity, resolution, distortion, etc.) are operator fatique issues and related standards appropriate in zero-g.

c. Spatial/temporal configuration of the information within the display.

d. Spatial configuration of displays within cockpit suite with respect to subtask, task or mission requirements.

e. Portrayal/coding of information in displays. These relate to at least two sets of issues.

   1. Symbolic, pictorial, alphanumeric representations of information.

   2. Use of coping devices to prioritize or emphasize classes of information (issues of priority/inhibit logic and warning attentional directors will be treated elsewhere).

f. Definition of adequate metrics (probably including workload quantification) for system interface performance assessment.

(4) General Approach

a. Consult the existing human factors data base available in the general and technical report literature. Do not re-invent the wheel!

b. Systematically capitalize on the lessons learned from related experience internally and outside the organization.

(5) Less general considerations:

a. In the generally passive mission environment it may be possible to reduce a number of discrete controls and displays into a sort of adpative crewstation on either a "menu select" or automated screening basis. This may be task determined or based on individual operator differences.

b. Given issues of test paint, bi-dextral control requirements should probably be minimized. Use of biocybernetic control techniques involving heat, eye or voice control designation may be useful.

c. Consider deployment of integrated tactite, aural and visual displays.

d. Eliminate/simplify highly coded information. Consider pictorial and mimetic displays where possible. 3-D displays could be used to provide natural spatial analogs such that the location of information relative to the operator has meaning as well as the system symbology which is presented.

FACILITY HYGIENE

ISSUE

- LARGE ORBITAL FACILITY DECONTAMINATION ISSUE NOT HERETOFORE ADDRESSED

APPROACH

- STATUS REVIEW, STATE-OF-THE-ART CONSOLIDATION
- TECHNOLOGY DRIVERS IDENTIFIED
- DESIGN CRITERIA DEVELOPMENT

BENEFITS

- IMPROVED ON-ORBIT EFFICIENCY

Self Explanatory

BULK FOOD SYSTEMS

ISSUE

- BULK FOOD ACQUISITION, STORAGE, PREPARATION FOR LARGE SPACE STATIONS IS NEW TECHNOLOGY

APPROACH

- STATUS REVIEW, STATE-OF-THE-ART CONSOLIDATION
- TECHNOLOGY DRIVERS IDENTIFIED
- DESIGN CRITERIA DEVELOPMENT

BENEFITS

- IMPROVED ON-ORBIT EFFICIENCIES

Self Explanatory

REPORT OF THE EVA WORKING GROUP

Harley L. Stutesman, Chairman (NASA/JSC)

Scott Millican (Scott Sciences & Tech)
Ed Pruett (Essex Corporation)
Gary Johnson (TRW)
Tom Fisher (Lockheed Missiles)
Barry Boswell (McDonnell Douglas)
Joe Goodwin (Grumman Aerospace)
Bill Welch (Aerospace Medical Division)
Charles E. Billings (NASA/ARC)
Jon Zelon (Rockwell)
Dave Akin (MIT)
Ken King (HSD)
Terry Reese (GRC)
Jerry Goodman (NASA/JSC)

EVA WORKING GROUP

ISSUE

- NASA DOES NOT HAVE A CLEARLY STATED POLICY ON EVA

APPROACH

- NASA MUST DEVELOP A POLICY WHICH ACTIVELY SUPPORTS EVA AS AN OPERATIONAL TOOL
- DEVELOP AN INTEGRATED EVA DESIGN GUIDELINE
    - WHAT CAN BE DONE WITH EVA?
    - HOW TO DESIGN PAYLOADS TO USE EVA
    - WHAT DOES EVA COST THE USER?

BENEFIT

- ELIMINATE EXISTING CONFUSION ABOUT EVA CAPABILITY
- SAVE PAYLOAD DESIGNERS MONEY
- IMPROVE SHUTTLE CAPABILITIES

EVA WORKING GROUP

ISSUE

- EVA TIMELINES IS INCREASED SIGNIFICANTLY DUE TO THE CREWMAN'S PRE-BREATH REQUIREMENT

APPROACH

- DEVELOP A HIGHER PRESSURE EMU $\approx$ 8 psi

BENEFIT

- REDUCE EVA OVERHEAD TIME
- ALLOW FOR QUICK CABIN EGRESS
- TECHNICAL IMPROVEMENTS ARE USEFUL AT ALL PRESSURES, i.e., 8 psi OR 4 psi

EVA WORKING GROUP

ISSUE

- SHUTTLE EVA EQUIPMENT DOES NOT INCLUDE THE CAPABILITY TO ANCHOR AN EVA CREWMAN AT AN UNPLANNED WORKSITE--EXTERIOR TO THE PAYLOAD BAY

APPROACH

- DEVELOP A UNIVERSAL WORKSTATION CAPABLE OF HOLDING THE EVA CREWMAN IN LOCATIONS NOT SPECIFICALLY DESIGNED FOR EVA

BENEFITS

- BETTER USE OF MAN AS A TOOL IN SPACE
- SALVAGE MECHANIZED PAYLOADS
- ALLOW EXTERIOR REPAIR OF ORBITER

EVA WORKING GROUP

ISSUE

- EVA TOOLS ARE NOT STANDARD--EACH USER BRINGS HIS OWN SPECIAL TOOLS

APPROACH

- ESTABLISH A STANDARD SET OF EVA TOOLS AND MAKE THEM AVAILABLE TO PAYLOAD DESIGNERS EARLY

BENEFIT

- CARRY LESS OVERHEAD WEIGHT AND STANDARDIZE PAYLOAD DESIGNS TO USE THE SAME TOOLS

EVA WORKING GROUP

ISSUE

- TECHNICAL IMPROVEMENTS IN EVA EQUIPMENT

APPROACH

- IMPROVE EVA GLOVES
- INTEGRATE COMMUNICATIONS IN HELMET
- PROVIDE "HEAD-UP" CWS DISPLAY FOR EMU
- DEVELOP NON-VENTING PORTABLE LIFE SUPPORT SYSTEM
- REGENERABLE CO_2 REMOVAL FOR PORTABLE LIFE SUPPORT
- DEVELOP LI BATTERY FOR LSS
- DEVELOP SUITS WITH QD TYPE ASSEMBLY
- AUTOMATE BETWEEN FLIGHTS, TEST AND CHECKOUT OF EMU

EVA WORKING GROUP

ISSUE

- SHUTTLE ORBITER NOT OPTIMIZED FOR EVA

APPROACH

- FOR THE NEXT NASA PROGRAM WE SHOULD:
  - ESTABLISH EVA AS A SPACECRAFT REPAIR TOOL EARLY
  - SIZE THE AIRLOCK ADEQUATELY (ORBITERS A/L IS TOO SMALL)
  - FACE FACTS ABOUT "CAN'T FAIL DESIGNS"
  - ESTABLISH EVA ENVELOP ROUTES EARLY IN THE DESIGN PHASE AND RETAIN THEM
  - STANDARDIZE GOOD DESIGN PRACTICES TO TAKE ADVANTAGE OF EVA LATER

REPORT OF THE TELEOPERATION WORKING GROUP

Antal Bejczy, Chairman (JPL)

W. E. Bachman (JPL)
Lawrence Stark (University of California)
Jack Pennington (NASA/LARC)
Gerald Malecki (Office of Naval Research)
John Lyman (UCLA)
Nicholas Shields (Essex Corporation)
Wayne Wagnon (NASA/MSFC)
Thomas B. Malone (Carlow Associates)
Bob O'Donnell (AFAMRL)
Sheldon Baron (Bolt Beranek and Newman)
Roger Schappell (Martin Marietta)
Tom Sheridan (MIT)

TELEOPERATION IN SPACE

ISSUES

- GUIDANCE AND CONTROL
- SENSING AND PREPROCESSING
- DISPLAYS
- INFORMATION MANAGEMENT
- WORKLOAD
- SAFETY

APPROACH

- MODELING, SIMULATION, LAB EXPERIMENTS

BENEFITS

- DATA BASE, DEVICES, TECHNIQUES

This viewgraph summarizes the Teleoperator Working Group's views and recommendations. The subsequent viewgraphs present some details of the main topics and issues.

The Working Group's consensus was that, in future systems, the human operator in the teleoperator man-machine interface will require a greater sense of presence of the remote task ("tele-presence"). This in turn requires advances in controllers, sensing, displays and information management. Control systems that allow the operator to interact in varying modes with the remote machine must be developed when the complexity of tasks and the complexity of teleoperator systems increases.

The Working Group endorsed an empirical approach to the R&D issues, supported with appropriate modeling and simulation studies to form a coherent frame for human factors data base development related to teleoperation in space. The consensus was that a space-specific human factors data base does not exist for teleoperation.

GUIDANCE AND CONTROL

- CONTROL MODES
  - MANUAL/BILATERAL
  - COMPUTER/INTERACTIVE/SUPERVISORY
- CONTROL REFERENCING
  - SCALING (KINEMATIC AND DYNAMIC)
  - INDEXING (PROPRIOCEPTION AND VISUAL FRAME)
- CONTROL LANGUAGES
  - ANALOG
  - SYMBOLIC
- COOPERATIVE CONTROL
  - MULTI-ARM SYSTEMS
  - MULTI-OPERATOR SYSTEMS
- GUIDANCE SENSORS
  - VISUAL
  - NON-VISUAL
- TIME DELAY--COMPENSATION

The break-down of the guidance & control issues expresses two major points:

(1) The development and evaluation of controls should be pursued by taking an operator-centered viewpoint.

(2) Relate the human operator's involvement in the control to the sensory (or guidance) information available to the operator.

The human involvement in the control under time-delay conditions was recognized as a major problem area.

SENSING

- VISUAL
    - DISTRIBUTED--COORDINATED
    - SCENE-ENHANCED/SCREEN-ENHANCED
    - STEREOSCOPIC
    - FRAMES FOR CONTROL, STATIC/MOBILE
- NON-VISUAL
    - GEOMETRIC-TYPE
    - FORCEC/TORQUES
    - CONTACT/TACTILE
- HAZARD DETECTION/WARNING
- "SMART" SENSORS
    - PREPROCESSING/COMPRESSING
    - FORMATTING
    - BANDWIDTH

The break-down of the sensing issues reflects two major points:

(1) The visual sensing instrumentation in teleoperation is primarily serving the interest of the human operator's visual perception of the remote task.

(2) For true "telepresence" and safe operation, the non-visual sensors are essential elements of the system.

DISPLAYS

- MULTIFUNCTION
  - FORMATS
  - INTEGRATION
- TASK-RELATED
  - OPERATOR-CONTROLLED
  - EVENT-DRIVEN
- COMPUTER GRAPHICS
  - REFERENCE FRAME
  - 3D-HOLOGRAPHY
- "SMART" DISPLAYS
  - CONTEXT-ORIENTED
  - UNBURDENING, e.g., AURAL, SPEECH-SYNTHESIS

The break-down of the display issues expresses two major points:

(1) The displays primarily convey non-visual information to the operator in visible or audible forms.

(2) The "intelligence" of the displays is a basic requirement in an information-rich control/decision environment.

INFORMATION MANAGEMENT

- TASK STRUCTURE
- STRATEGY/PLANNING
- PROTOCOL
- CONTINGENCIES
- PLAN MODIFICATIONS
- FAULT IDENTIFICATION/EVALUATION

USING APPLICATION OF AI TECHNIQUES

The break-down of the information management issues reflects the need to aid the operator and operation using AI techniques acting on a large data base.

WORKLOAD

- TASK ANALYSIS
- ASSESSMENT/MEASURES
- MANAGEMENT/OPTIMIZATION

The break-down of the workload issues are related to the physical, physiological and psychological conditions of the operator.

APPROACH

- GENERIC SET OF TASKS (INCLUDING TMS)
  - COMPARATIVE PERFORMANCE OF BENCHMARK TESTS
    - EVA VS. TSM
    - TSM VS. TSC/I
    - TSC/I VS. TSS/R
- MODELING
  - STRUCTURES/PARAMETERS (INVOLVING OPERATOR)
  - MATHEMATICAL SIMULATION
- LABORATORY
  - EXPERIMENTAL SIMULATION
    - 1 G - NB - ϕG
  - BENCH-MODELS; DEVICES
  - TECHNIQUES; DEMOS

The development of generic set of tasks should consider the practical implications of conducting benchmark tests in order to compare task performance in alternative man-machine operation modes. The alternative operation modes are:

EVA: suited astronaut

TSM: teleoperator system, in fully manual control mode

TSC/I: teleoperator system, in man-computer interactive control mode

TSS/R: teleoperator system, in high-level supervised robot control mode.

The experimental laboratory work should consider all three working conditions:

Zero-g,

Natural buoyancy,

One-g,

REPORT OF THE
GROUND/SPACE OPERATIONS
WORKING GROUP

Dave Moja, Chairman (NASA/KSC)

Wyckliffe Hoffler (NASA/KSC)
Karen Moe (NASA/GSFC)
Ed Pruitt (Essex Corporation)
John Roebuck (Rockwell)
Ed Shriver (Kinton, Inc.)

TECHNOLOGY REQUIREMENTS FOR GROUND/SPACE OPERATIONS

- CONTROLS/DISPLAYS
- AUTOMATION
- ROLE OF MAN VS. MACHINE
- EXPERT SYSTEMS
- ASSEMBLY/INSTALLATION
- OPERATIONS PLANNING/SCHEDULING
- LEARNING TECHNOLOGIES

CONTROLS/DISPLAYS

- ADAPTIVE INTERFACES
- TEXT/GRAPHICS INTEGRATION
- VISUAL/NON-VISUAL SENSOR INTEGRATION
- VOICE INTERACTION

BENEFITS

- REDUCTION OF HUMAN ERROR
- ENHANCED SAFETY AND EFFICIENCY

RECOMMENDED APPROACH

- SURVEY THE STATE OF THE ART/PARTICIPATE IN OTHER STUDIES
- SPECIALIZED STUDIES

AUTOMATION

- ROBOTICS/REMOTE CONTROL FOR HAZARDOUS OPERATIONS EXAMPLES:
  - PROPELLANT SERVICING
  - UMBILICAL CONNECTIONS
- AUTOMATION FOR ROUTINE OR REPETITIOUS TASKS

BENEFITS

- ENHANCED SAFETY AND EFFICIENCY
- REDUCTION OF HUMAN ERRORS

RECOMMENDED APPROACH

- SURVEY THE STATE OF THE ART/PARTICIPATE IN OTHER STUDIES
- SPECIALIZED STUDIES

THE ROLE OF MAN VS. MACHINE

- SYSTEMS SUPERVISOR VS. OPERATOR
- ROUTINE/SPECIALIZED OPERATIONS
- MAN-TENDED VS. PERMANENTLY MANNED SPACE STATION
- MAINTENANCE OF CONTINGENCY SKILLS

BENEFITS

- EFFICIENCY--RESERVE MAN FOR WHAT HE CAN DO BEST
- ENHANCED SAFETY
- REDUCTION OF HUMAN ERRORS

RECOMMENDED APPROACH

- SPECIALIZED STUDIES

EXPERT SYSTEMS

- DECISION SUPPORT
  - TROUBLESHOOTING AND FAULT ISOLATION
  - CONTINGENCY/EMERGENCY OPERATIONS
  - LAUNCH "REDLINES"
- GENERATION/VERIFICATION OF SOFTWARE
- DATA/TREND ANALYSIS

BENEFITS

- ENHANCED EFFICIENCY AND SAFETY
- REDUCTION OF HUMAN ERRORS

RECOMMENDED APPROACH

- PUSH THE STATE OF THE ART FOR OPERATIONS
- SPECIALIZED STUDIES

ASSEMBLY/INSTALLATION

- SIMPLER, BETTER CONNECTIONS
  - MECHANICAL
  - ELECTRICAL
  - FLUID
- INTERFACE VERIFICATION
  - LEAK CHECKS
- HANDLING AND ALIGNMENT TECHNIQUES

BENEFITS

- SIMPLIFIED OPERATIONS
- PREPARATION FOR SPACE OPERATIONS

RECOMMENDED APPROACH

- SPECIALIZED STUDIES

OPERATIONS PLANNING/SCHEDULING

- PROBLEM TRACKING
- INVENTORY FORECASTING
- STATUS AND CONTROL

BENEFITS

- MORE EFFICIENT OPERATIONS
- HIGHER PROBABILITY OF MEETING MILESTONES

RECOMMENDED APPROACH

- SURVEY THE STATE OF THE ART
- SPECIALIZED STUDIES

LEARNING TECHNOLOGIES

- TRAINING TECHNIQUES
- INDIVIDUALLY ADAPTIVE CAPABILITIES

BENEFITS

- ENHANCED SAFETY AND EFFICIENCY
- REDUCTION OF HUMAN ERRORS

RECOMMENDED APPROACH

- SURVEY THE STATE OF THE ART
- SPECIALIZED STUDIES

GENERAL COMMENTS

- ALL TECHNOLOGY DEVELOPMENT MUST INCLUDE OPERATIONAL CONSIDERATIONS
- RESISTANCE TO CHANGE COULD IMPEDE INCORPORATION OF NEW OPERATIONAL TECHNIQUES
- SPECIALIZED STUDIES SHOULD INCLUDE QUANTIFICATION OF COSTS/BENEFITS
- ARE WE EXPECTED TOO MUCH FROM EXPERT SYSTEM TECHNIQUES?

REPORT OF THE
ROBOTICS/SUPERVISORY CONTROL
WORKING GROUP

Ewald Heer, Chairman (JPL)

Sheldon Barron (Bolt Beranek and Newman)
Max Engert (NASA/JSC)
Greg Kearsley (HUMRO)
Ronald Larsen (NASA HQ)
Tom Sheridan (MIT)
Walter Truskowski (NASA/GSFC)
Leonard Yarborough (NASA/MSFC)

HUMAN FACTORS ISSUES

ISSUE 1

- LACK OF USER ORIENTED LANGUAGE FOR OPERATION OF MACHINES (ROBOTS) IN SPACE

⇨ INVESTIGATE AND ESTABLISH HUMAN/MACHINE REQUIREMENTS

ISSUE 2

- MACHINE CONTROL WITH COMMUNICATION DELAY

⇨ EXTEND EXISTING RESEARCH TO DETERMINE REQUIRED LEVELS OF AUTONOMY

ISSUE 3

- NEED OF COMPUTER BASED MODELS AND GRAPHIC DISPLAYS TO:
  1. HELP OPERATOR TO PLAN AND TEACH MACHINE (ROBOT)
  2. ALLOW VISUAL SIMULATION
  3. ALLOW ANY VISUAL VIEWPOINT OR ZOOM
  4. CAN BE UPDATED RELATIVE TO REAL WORLD
  5. CAN BE USED DIRECTLY FOR MACHINE CONTROL

ISSUE 4

- NEED OF UNDERSTANDING/THEORY ON HOW HUMANS INTEGRATE AND INTERPRET SENSORY FEEDBACK FROM DIFFERENT KINDS OF SENSORS

ISSUE 5

- LEVEL OF SUPERVISION OF MACHINE SYSTEMS SUCH AS SPACE STATION AND/OR ROBOTS BY HUMAN OPERATOR(S)

⇨ DETERMINE THE SUBSYSTEM LEVEL THAT MUST BE REACHABLE

⇨ DETERMINE HUMAN TRAINING REQUIREMENTS

⇨ DETERMINE REQUIRED HUMAN CHARACTERISTICS

ISSUE 6

- VARIABLE/ADAPTIVE CONTROL ACCESS BY HUMAN OPERATOR(S)

⇨ INVESTIGATE AND DETERMINE HUMAN FACTOR REQUIREMENTS

HUMAN FACTORS ISSUES (CONT.)

ISSUE 7

- VARIABLE/ADAPTIVE FUNCTION ALLOCATION BETWEEN HUMAN(S) AND MACHINE(S) OR ROBOT(S)

⇨ INVESTIGATE AND DETERMINE HUMAN FACTOR REQUIREMENTS

ISSUE 8

- TRAINING REQUIREMENTS FOR TOTAL SYSTEM

ISSUE 9

- ORGANIZATIONAL STRUCTURE OF MAN-MACHINE (HUMANS-ROBOTS) SYSTEM CONSIDERING A SPACE STATION CREW OF UP TO 12 PEOPLE AND UP TO SEVERAL SUPERVISED ROBOTS

⇨ STUDY AND DETERMINE OPTIMAL MANAGEMENT (DECISION-MAKING) STRUCTURE

⇨ INVESTIGATE REQUIREMENTS FOR AND DEFINE AUTOMATIC PLANNING AND DECISION MAKING TOOLS TO COPE WITH TIME LIMITATIONS, SYSTEM COMPLEXITY, GROUP DYNAMICS, GROUP COORDINATION, AND GROUP/MACHINE BEHAVIOR

⇨ DEVELOP APPROPRIATE INTERACTIVE DISPLAY TECHNIQUES, BUILT-IN MODELS OF THE SYSTEM, EXPERT SYSTEMS, AUTOMATED PLANNING SYSTEMS, ETC.--DEVELOP HUMAN FACTOR REQUIREMENTS

⇨ DEVELOP STRATEGIES FOR FAIL SAFE AND/OR FAULT TOLERANT OPERATIONS

ISSUE 10

- SYSTEM PERFORMANCE AND VALIDATION

⇨ DEVELOP METHODOLOGY FOR ASSESSING SUPERVISORY SYSTEM PARAMETER SENSITIVITY INCLUDING HUMANS

⇨ DETERMINE SUPERVISORY SYSTEM PERFORMANCE CRITERIA

DEVELOP METHODOLOGY FOR "TEST BED" VALIDATION

⇨ INVESTIGATE APPROACHES FOR PROGRESSIVE VALIDATION OF SUPERVISORY/ROBOT SYSTEM (VALIDATING/LEARNING ON THE JOB)

⇨ ESTABLISH AND DEFINE MEANINGFUL FLIGHT TESTS SCENARIOS

REPORT OF THE
BEHAVIORAL INTERACTIONS AND HABITABILITY FACTORS
WORKING GROUP

Steward Nachtwey, Chairman (NASA/JSC)

Stan Deutsch (Consultant)
Joel Brady (JHU)
Stephan Cheston (Georgetown University)
Steve Hall (NASA/MSFC)
Dave Stephens (NASA/LARC)
Lawrence Young (MIT)

SPACE STATION WILL BE A COMPLEX SYSTEM
REQUIRING ADVANCES IN DESIGN AND OPERATIONS:

- HABITABILITY
- CREW SELECTION
- CREW TRAINING
- OPERATIONAL PROCEDURES

WHY ADVANCES ARE NEEDED:

- LARGER CREW SIZE
- LONGER DURATION
- INCREASED AUTONOMY
- MIXED CREWS
  DISCIPLINES
  SEXES
- NOT TEST PILOTS--CREW WILL BE PASSENGERS
- LESS GLAMOUR--LESS PUBLIC VISIBILITY

HABITABILITY

THAT WHICH INVOLVES THE NATURE AND QUALITY OF AN ENVIRONMENT, MEASURED IN TERMS OF HOW QUICKLY AND COMPLETELY HUMANS CAN ADJUST TO THEM AND HOW SUCCESSFULLY THEY SUPPORT OPERATIONAL EFFECTIVENESS, COMFORT, PERSONAL WELL-BEING, AND MORALE.

HABITABILITY CONSIDERATIONS

INTERNAL ENVIRONMENT

- TEMPERATURE AND HUMIDITY
- AIR MOVEMENT
- GAS COMPOSITION
- ACOUSTIC CHARACTERISTICS
- LIGHTING LEVELS

ARCHITECTURE

- VOLUME AND GEOMETRY OF COMPARTMENTS
- ACCESS AND EGRESS
- COLORS AND TEXTURES
- STOWAGE AND RETRIEVAL

MOBILITY

- LOCOMOTION AIDS
- RESTRAINT MODES
- MECHANICAL AIDS

HABITABILITY CONSIDERATIONS (CONT.)

FOOD

- VARIETY AND TYPES AVAILABLE
- STOWAGE AND RETRIEVAL
- MEAL PREPARATION AND SERVING
- MEAL CONSUMPTION

CLOTHING

- DUTY
- OFF-DUTY
- SLEEP WEAR

PERSONEL HYGIENE

- BATHING
- GROOMING
- BODY WASTE COLLECTION

HOUSEKEEPING

- CLEANING EQUIPMENT, PROCEDURES AND SCHEDULES
- REFUSE COLLECTION AND DISPOSAL

COMMUNICATIONS

- INTRAVEHICULAR (WITHIN FLIGHT CREW)
- OUTSIDE (FAMILY, FRIENDS, AND GROUND CONTROL)

CREW ACTIVITIES

- WORK/REST SCHEDULES
- OFF-DUTY ACTIVITIES
  - --LEISURE AND ENTERTAINMENT
  - --SLEEP
  - --EXERCISE

HABITABILITY ELEMENTS OF CONCERN

NOISE CRITERIA
- SLEEP
- COMMUNICATION
- HEARING IMPAIRMENT
- COMFORT

NOISE AND VIBRATION CONTROL

SPACE MOTION SICKNESS ENHANCERS/REDUCERS

RESTRAINTS/MOBILITY AIDS

ARTIFICIAL G

WASTE MANAGEMENT

ARCHITECTURE
- VOLUME
- PRIVACY
- TRAFFIC PATTERNS

CREW SELECTION CRITERIA

- TECHNICAL COMPETENCE FOR MISSION REQUIREMENTS
- ADAPTIVE SOCIAL COMPETENCE FOR EFFECTIVE INTERACTION WITH A SMALL, DIVERSIFIED GROUP OPERATING IN A STRESSFUL ENVIRONMENT

METHODS OF EVALUATION OF ADAPTIVE COMPETENCE

- PERSONAL DEVELOPMENTAL HISTORY
- FUTURE-SELF ATTITUDES
- STRESS TESTING
- PEER EVALUATIONS

CREW TRAINING

TECHNICAL TRAINING

SOCIAL SENSITIVITY TRAINING

- IMPROVE UNDERSTANDING OF OTHERS IN CIRCUMSTANCES THAT INTERMIX SEXES, EDUCATIONAL LEVELS, SOCIAL CLASSES, CULTURES, AND WORLD VIEWS

COMMUNICATION SKILLS

- TRAIN TO ARTICULATE ANXIETIES AND FRUSTRATIONS TO AVOID BUILD-UP AND DEVIANT BEHAVIOR

GROUP PERFORMANCE

- TRAIN LEADING, FOLLOWING, AND FACILITATING COMPROMISE

SIMULATIONS OF SPACE STATION GROUP DYNAMICS

CREW BEHAVIOR/OPERATIONS

- ON-STATION DURATION AND CREW ROTATION
- COMMAND ORGANIZATIONS/RESPONSIBILITIES
- WORK/REST CYCLES
- OFF DUTY ACTIVITIES
- MALE/FEMALE RELATIONS
- FAMILY RELATIONS
- INDIVIDUAL/GROUP COMMUNICATIONS AND SECURITY
- BEHAVIORAL CRISIS MANAGEMENT/STRESS REDUCTION
- GROUP DYNAMICS
- SENSORY MODALITIES MODIFICATION
- MAINTENANCE SUPPORT

APPROACHES

- REDUCE VOLUMINOUS LITERATURE TO USABLE HAND-BOOKS (SPACE STATION ORIENTED)

- INTERVIEW ASTRONAUTS

- SYSTEMATICALLY STUDY DURING SPACE SHUTTLE AND SPACELAB MISSIONS

- EARTH BASED SIMULATIONS

REPORT OF THE SIMULATION/TRAINING WORKING GROUP

Jack Stokes, Chairman (NASA/MSFC)

Byron Lichtenberg (MIT)
Hersh Liebowitz (Penn State)
Ed Stark (Singer Corporation)
Scott Millican (Scott Science and Engineering)
Bob Sugarman (RCS)
Bob Hennessy (NRC)
Ed Shriver (Kinton, Inc.)
Dave Akin (MIT)

SIMULATION/TRAINING

- ASSUME 90-DAY TOURS; APPROXIMATELY 10-YR LIFETIME
- TRAINING INCLUDES GROUND AND FLIGHT
- SUGGEST UTILIZATION OF CAREER TRAINING TECHNOLOGISTS

- In order to scope the boundaries for simulation and training, we assumed a target of a Space Station mission with a 10-year lifetime, and crew rotations every 90 days.
- We further assumed that training considerations were for all people involved in a mission, including ground support, maintenance support, and flight and launch control personnel.
- It is recommended that, in order to fully perform training to the level required, it is beneficial to incorporate career training technologists.

SIMULATION/TRAINING

ISSUE	PROGRESS APPROACHES/ TECHNIQUES	BENEFITS
1. CURRENT SIMULATION/ TRAINING PROBLEM - SIM/TRG REQMTS INCREASING - SIM/TRG FACILITY TIME DECREASING	1. EVALUATE CURRENT TRG CAPABILITY (US) - MAXIMIZE UTILIZATION OF TRG/ENG FACILITIES - DEFINE TRG ALTERNATIVES	1. SIM/TRG DATA BASE - IMPROVE TRG EFFICIENCY
2. ARE WE USING STATE-OF-THE-ART TRG TECHNOLOGY?	2. SURVEY INDUSTRY - TECHNIQUES FOR ANALYSIS - SOLUTIONS	2. DEFINES TRG OPTIONS - SIM/TRG DATA BASE
3. CAN NASA TRG BE IMPROVED?	3. ANALYZE/SELECT FROM APPROACH (ITEM 2) AND APPLY	3. LOWER LIFE CYCLE COSTS - ABILITY TO MEET SCHEDULES - SIM/TRG DATA BASE

Item 1: The first issue identified was that we have a basic problem in simulation/training. That is that the simulation and training requirements are steadily increasing, while the available time on the various simulators is decreasing.

The approach or technique for making progress toward a solution includes a comprehensive evaluation of the current capabilities throughout the United States, in government, industrial, and academic facilities. To be addressed are those systems which may be incomplete or in moth balls.

Once identified, we must maximize the utilization of training and simulation facilities. This means to update or bring on-line facilities which are not up currently. Likewise, we must consider or use multiple shift operations.

In conjunction with the above, we must also creatively define training alternatives in order to work around those problems that the existing simulation/training capabilities do not meet.

The benefits of this approach will be to establish a simulation/training data base. It will also improve training efficiency for the current training system.

Item 2: The question was raised: Is NASA using state-of-the-art training technology? It is suspected that this is not the case due to procurement cycles, uneducated training personnel (due to intense involvement with ongoing simulation activities), and lack of available information from other training designs. This question can also be applied to developmental simulation.

The answer to the question may be found by performing a survey of industry (including industry, academia, other government agencies). The survey should address techniques for performing training analysis, and the determination of solutions for answering the question.

The benefit should be the provision of the training options that could be used by NASA based on training requirements. It will also add to the simulation/training base established from Item 1.

Item 3: The question was raised: Can NASA training be improved? The thought behind the question is self-evident. The approach for the answer is to analyze and then select an approach(es) from Item 2 and apply this technique to the future simulation and training requirements.

The benefits will be the reduction of simulator life cycle costs. It will likewise permit us to better meet mission and training schedules. Finally, it will add to the simulation/training base.

SIMULATION/TRAINING

ISSUE	PROGRESS APPROACHES/ TECHNIQUES	BENEFITS
4. PAYLOAD HARD-WARE TRAINING REQMTS	4. CREATE GUIDELINES FOR PAYLOAD TRAINING: - CONCEPTS - HARDWARE	4. STANDARDIZE AND IMPROVE USER-SUPPLIED SYSTEMS
5. SPACE STATION SIMULATION AND TRG REQMTS - OPERATIONAL - SOCIAL	5. DEFINE PLAN FOR DEVELOPING TRG REQUIREMENTS	5. STATE-OF-THE-ART TRG OF MULTIPLE FOLLOW-ON CREWS: - CONSIDER SPACE STATION AS SIMULATOR/ TRAINER - HARMONIOUS CREW

Item 4: It was determined that there is a need to develop a comprehensive standard set of training requirements for the various payloads upcoming on Space Station, Spacelab, etc.

The technique recommended for correcting the problem is to create guidelines for payload training. The thrust should be for training concepts as well as for hardware.

Benefits to the payload and carrier personnel will be the standardization and improvement of user-supplied systems.

Item 5: There is a need to define Space Station simulation and training requirements, including operational and social requirements. Space Station provides a unique situation (for NASA) in that crews will be kept in a relatively small environment with a small group for relatively long time periods (up to 90 days). Further, the personnel may not be as homogeneous as previous crews and the motivation of work may not be astrong as on previous missions. This portion should be transferred to the Habitability Working Group.

The approach to define the Space Station requirements is to define a plan for developing training requirements as an initial start. It is required early in the program in order to best and most efficiently define the training portion of the mission. The program will then use this plan to develop simulation requirements.

The benefits will then provision state-of-the-art training of the various Space Station crews. It will also result in a more harmonious crew.

An additional benefit would be that with planning the Space Station itself might be used for both developmental simulation and training of flight personnel because it provides the best simulation environment.