Space Station Preprototype Space Suit TEST PROGRAM

- Test Program Background
- Test Matrix Overview
- Evaluation Plan
Test Program Background

Background:

- To accommodate Space Station Freedom budget constraints, and without incurring management risk, Project Office:
  - Deferred EMU activity at Prime (Phase C/D) Contractor
  - Asked CTSD to continue supporting development activities

Goal:

- Develop best possible 8.3 psi space suit for Space Station Freedom Program based on selected advanced suit technology

Objective:

- Establish quantitative measures of various performance characteristics as compared to Shuttle space suit:
  - Objective evaluations
  - Subjective evaluations
  - Typical task performance
ADVANCED SPACE SUIT ASSEMBLY EVALUATION ACTIVITIES

Advanced Space Suit Assembly Evaluation Plan

- WETF Evaluation
- Zero Gravity Evaluation
- Torque Measurement System (Unmanned)
- Component Cycle Verification
"Why" The Breadth of Program?

- **WETF Evaluation Activities**: 
  - Simulation represents "hi-fidelity", real-time performance activities of actual EVA operations and tasks.
  - Establishes a "user" input comparison baseline developed over long-duration test exercises.

- **Zero-Gravity Evaluation (KC-135 Aircraft)**: 
  - Provides proper environment for don/doff evaluation activities.
  - Eliminates water inertia influencing factors.

- **Torque/Range Measurement (Unmanned)**: 
  - Establishes ultimate performance characteristics.
  - Provides absolute/non-subjective data-base.

- **Component Cycle Verification (Selected Joint Elements)**: 
  - Establishes design confidence level.
  - Identifies if design compromised due to material selection or fabrication/assembly process.
TEST MATRIX
DESCRIPTION

SET-UP
PROCEDURES
REPRESENTATIVE DATA
WETF
EVALUATION

OBJECTIVE EVALUATIONS

- MOBILITY (RANGE OF MOTION)
- REACH ENVELOPE
- MAXIMUM FORCE TRANSMISSION

SUBJECTIVE EVALUATIONS

- MOBILITY (PERFORMANCE INDEX)
- EVA TASKS I
- EVA TASKS II
FORWARD AND UPWARD REACH FROM SIDE OF BODY (BOTH ARMS)

BACKWARD TORSO BENDING USING ANKLE, KNEE, AND TORSO

FORWARD TORSO BENDING USING ANKLE, KNEE, AND TORSO

OVERHEAD REACH FROM SIDE OF BODY (BOTH ARMS)

INBOARD CHEST REACH (BOTH ARMS)
<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>MOBILITY</th>
<th>REACH ENVELOPE</th>
<th>MAXIMUM FORCE TRANSMISSION</th>
</tr>
</thead>
<tbody>
<tr>
<td>OBJECTIVES</td>
<td>Objectively evaluate SSA performance by maximum joint angle measurement during various movements</td>
<td>Objectively evaluate SSA by defining shape and volume of one and two handed functional reach envelopes</td>
<td>Objectively evaluate SSA by measuring maximum force transmission for movements</td>
</tr>
<tr>
<td></td>
<td>Subjectively evaluate SSA using performance index</td>
<td>Familiarize crewmember with SSA while performing isolated joint motions</td>
<td>1) Frequently used during EVA</td>
</tr>
<tr>
<td></td>
<td>Familiarize crewmember with integrated mobility of SSA</td>
<td></td>
<td>2) Defined for joint isolation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Familiarize crewmember with SSA mobility under heavy work loads</td>
</tr>
</tbody>
</table>
ARM SWEEPING MOTIONS (RIGHT TO LEFT, LEFT TO RIGHT)

TORSO ROTATION (ARMS EXTENDED)

FORWARD TORSO BENDING WITH TORSO ROTATED

SIDE-TO-SIDE ANKLE FLEXION/REACH (RIGHT AND LEFT, BOTH FEET IN FOOT RESTRAINTS)

SIDE-TO-SIDE ANKLE FLEXION/REACH (RIGHT AND LEFT, ONE FOOT IN FOOT RESTRAINT)

SIDE-TO-SIDE ANKLE FLEXION/REACH (RIGHT AND LEFT, OTHER FOOT IN FOOT RESTRAINT)
STRAIGHT LEG HIP FLEXION (BOTH LEGS)

BENT KNEE HIP FLEXION (BOTH LEGS)

HIP ABDUCTION (BOTH LEGS)
RIGHT SIDE ONE-HAND REACH ENVELOPE

LEFT SIDE ONE-HAND REACH ENVELOPE
FUNCTIONAL REACH ENVELOPE

ONE-HANDED
SHOULDER ABDUCTION

SHOULDER FLEXION

SHOULDER FLEXION/ABDUCTION
(combination of first two)

EVA RATCHET TOOL CRANK

EVA RATCHET TOOL PUSH / PULL

ELBOW FLEXION / EXTENSION

SHOULDER ROTATION Y-AXIS

SHOULDER ROTATION MEDIAL INTERNAL
SHOULDER FLEXION/ABDUCTION
DYNAMIC

DROP LOW
DROP HIGH
AVERAGE = 66.27

TORQUE OUTPUT (FT-LBS)

56.85 FT-LB
65.70 FT-LB
69.13 FT-LB
72.54 FT-LB
63.99 FT-LB

ELAPSED EXERCISE TIME (SECONDS)
## WETF EVALUATION (CONTINUED)

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>EVA TASKS I</td>
<td>Subjectively evaluate SSA using Cooper-Harper rating scale while performing common EVA tasks</td>
</tr>
<tr>
<td></td>
<td>Familiarize crewmember with SSA mobility as used on practical applications - precursor for EVA tasks II</td>
</tr>
<tr>
<td>EVA TASKS II (EASE/ACCESS)</td>
<td>Subjectively evaluate SSA using Cooper-Harper rating scale while performing EASE/ACCESS assemblies and disassemblies - best representation of unrestricted complex movements while performing typical Space Station assembly tasks</td>
</tr>
<tr>
<td>ACTIVITY</td>
<td>OBJECTIVES</td>
</tr>
<tr>
<td>----------</td>
<td>------------</td>
</tr>
<tr>
<td>DON/DOFF</td>
<td>Cooper-Harper rating scale</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TRANSLATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjectively evaluate differences in SSA performance between neutral buoyancy (WETF) and zero-g</td>
</tr>
<tr>
<td>- Ease of operation</td>
</tr>
<tr>
<td>- Fit</td>
</tr>
<tr>
<td>- Comfort</td>
</tr>
</tbody>
</table>
# TORQUE / RANGE MEASUREMENT EVALUATION

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>OBJECTIVES</th>
</tr>
</thead>
</table>
| TORQUE VERSUS RANGE OF MOTION MAPPING | Objectively determine  
  1) Torque required to move the joint through a given range of motion  
  2) Maximum joint range of motion |
SHOULDER JOINT COMPARISONS

(Torque vs. Angle)

ADDITION/ABDUCTION
(HORIZONTAL REACH)

-400
-300
-200
-100
0
100
200
300
400

Torque (in-lb)

ROLLING CONVOLUTE

- EMU a 4.0 PSI

- ZPS a 8.0 PSI

Flexure Angle (deg)

NUDE BODY RANGE
FORWARD - 182° - BACKWARD
<table>
<thead>
<tr>
<th>CYCLE JOINTS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verify joint operational capability for one year on orbit life (plus a safety factor of two and based on 52 eva's per year)</td>
<td></td>
</tr>
</tbody>
</table>
SSA JOINT CYCLE MACHINE

AIR CYLINDER (INDUCES SIMULATED MAN-LOADS)

ROCKING MOTION (JOINT AND CRADLE)

GUIDE

ROLLER

CRADLE

SUIT JOINT

DRIVE CHAIN

ROCKER ARM

SPEED REDUCER

OFF CENTER PIVOT

DRIVE MOTOR

DRIVE BELT

SPROCKET (GROUND PIVOT)
# Task Completion Matrix

**Manned Test Activities**

<table>
<thead>
<tr>
<th>WETF</th>
<th>Crewmember A</th>
<th>Crewmember B</th>
<th>Crewmember C</th>
<th>Crewmember D</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Suit Mobility</strong></td>
<td>STS</td>
<td>AX-5</td>
<td>Mk. III</td>
<td>STS</td>
</tr>
<tr>
<td><strong>Reach Envelope</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Max. Force</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>EVA Tasks 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>EVA Tasks 2</strong></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
EVALUATION PLAN

EVALUATION PLAN COORDINATION MEETINGS
- ARC
- JSC
- Wk. Pkg. II Phase C/D Contractor
  (McDAC / LOCKHEED)

SELECTION CRITERIA PRIORITIES

TECHNOLOGY SELECTION PANEL

SELECTION PROCESS
SELECTION CRITERIA
PRIORITIES

FIRST ORDER SELECTION CRITERIA
MANNED PERFORMANCE

OBJECTIVE
MOBILITY (RANGE OF MOTION)
REACH ENVELOPE
MAX. FORCE TRANSMISSION

SUBJECTIVE
EVA TASKS I & II
MOBILITY (PERFORMANCE INDEX)
ZERO - G

SECOND ORDER SELECTION CRITERIA
ENGINEERING TEST AND ANALYSIS

TORQUE MEASUREMENT
CYCLE VERIFICATION
ENVIRONMENTAL PROTECTION

THIRD ORDER SELECTION CRITERIA
PROGRAMMATIC ISSUES

LIFE CYCLE COSTS
TECHNOLOGY SELECTION PANEL

PURPOSE

- REVIEW ALL TEST DATA
- MAKE TECHNOLOGY SELECTION RECOMMENDATION

MEMBERSHIP

- CHAIR: EMU SYSTEM DEVELOPMENT MANAGER (SDM) ROUEN
- TECHNICAL EXPERTS
  - KOSMO/JSC
  - VYKUKAL/ARC
- ASTRONAUT OFFICE
  - ROSS
- SPACE STATION PROJECT OFFICE (Wk. Pkg. II)
  - KISSINGER
- SYSTEMS ENGINEER
  - WEBBON/ARC
  - WEST/JSC
- PHASE C/D CONTRACTOR (Wk. Pkg. II)
  - RAFFAELLI/Mc DONNELL DOUGLAS
  - WILKINSON/LOCKHEED
TECHNOLOGY SELECTION PROCESS SUMMARY

SOW

PROJECT MANAGER APPROVAL (WORK PACKAGE)

CENTER DIRECTOR REVIEW

CONFIGURATION RECOMMENDATION

TECHNOLOGY SELECTION PANEL REVIEW

DATA REDUCTION

ESTABLISH SELECTION CRITERIA AND PROCESS AR/C/J/G/MDAC/LOCKHEED
AX-5 ADVANCED SPACE SUIT DESIGN OVERVIEW

Captain A. Reinhardt
NASA/Ames Research Center

(Paper not provided by publication date.)