

N90 - 25506

**S O A R 89**

Space Station

Space Suit Test Program

Nasa - Jsc

Crew & Thermal Systems Division

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# **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

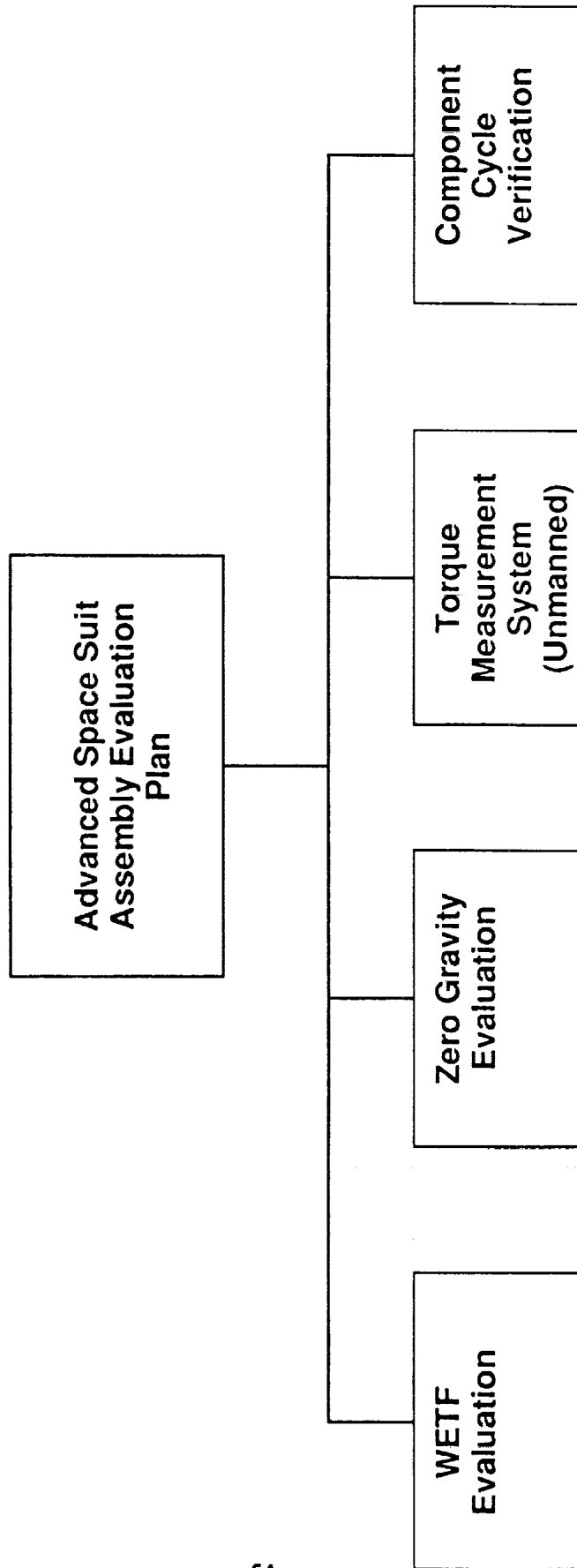
## Goal:

- 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



## **"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**

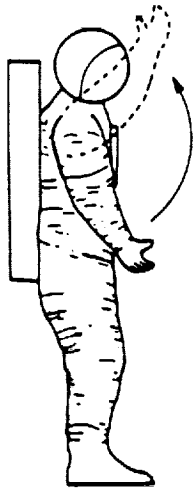
# **WETF EVALUATION**

## **OBJECTIVE EVALUATIONS**

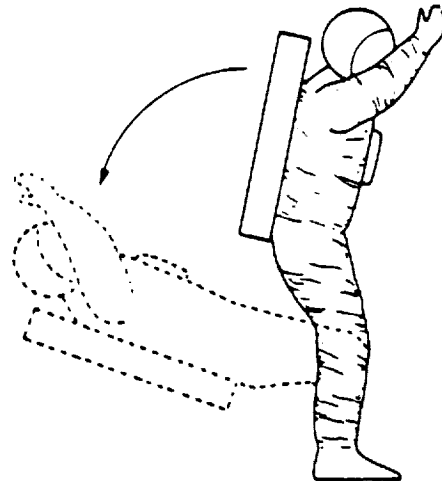
- **MOBILITY (RANGE OF MOTION)**
- **REACH ENVELOPE**
- **MAXIMUM FORCE TRANSMISSION**

## **SUBJECTIVE EVALUATIONS**

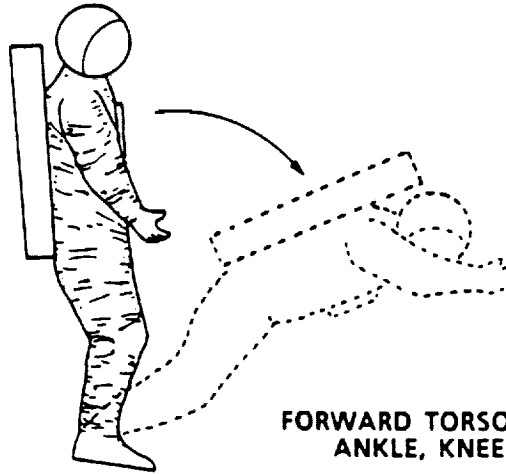
- **MOBILITY (PERFORMANCE INDEX)**
- **EVA TASKS I**
- **EVA TASKS II**



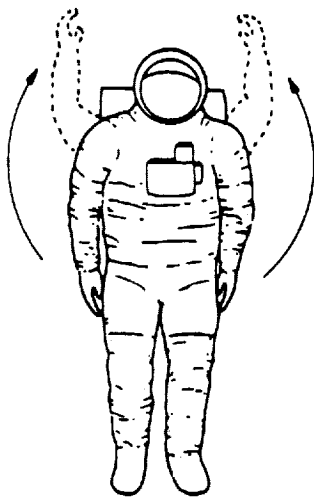
**FORWARD AND UPWARD REACH FROM SIDE OF BODY (BOTH ARMS)**



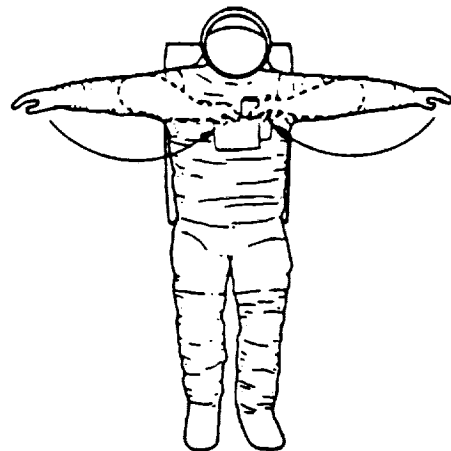
**BACKWARD TORSO BENDING USING ANKLE, KNEE, AND TORSO**



**FORWARD TORSO BENDING USING ANKLE, KNEE, AND TORSO**



**OVERHEAD REACH FROM SIDE OF BODY (BOTH ARMS)**

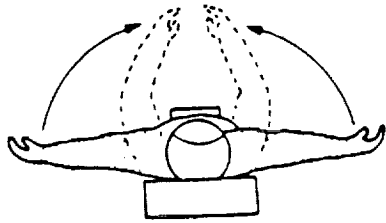


**INBOARD CHEST REACH (BOTH ARMS)**

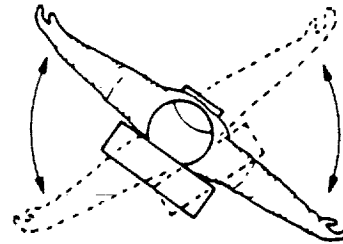


# WETF EVALUATION

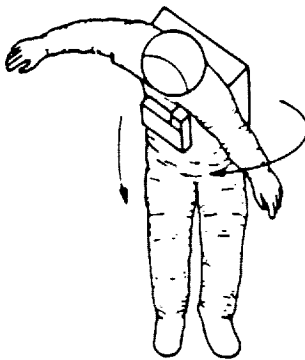
ACTIVITY	OBJECTIVES
<p><b>MOBILITY</b></p>	<p>Objectively evaluate SSA performance by maximum joint angle measurement during various movements</p> <p>Subjectively evaluate SSA using performance index throughout motion</p> <p>Familiarize crewmember with SSA while performing isolated joint motions</p>
<p><b>REACH ENVELOPE</b></p>	<p>Objectively evaluate SSA by defining shape and volume of one and two handed functional reach envelopes</p> <p>Familiarize crewmember with integrated mobility of SSA</p>
<p><b>MAXIMUM FORCE TRANSMISSION</b></p>	<p>Objectively evaluate SSA by measuring maximum force transmission for movements</p> <p>1) Frequently used during EVA</p> <p>2) Defined for joint isolation</p> <p>Familiarize crewmember with SSA mobility under heavy work loads</p>



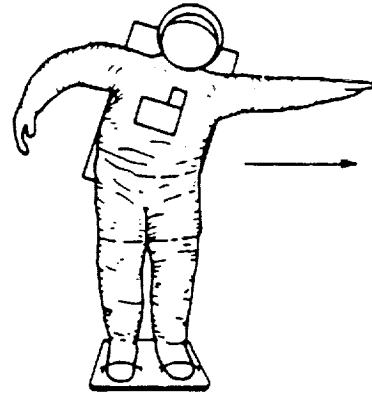
**ARM SWEEPING MOTIONS (RIGHT TO LEFT, LEFT TO RIGHT)**



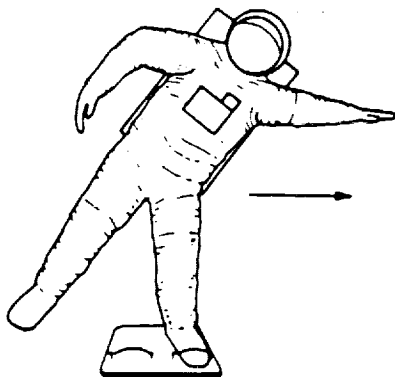
**TORSO ROTATION (ARMS EXTENDED)**



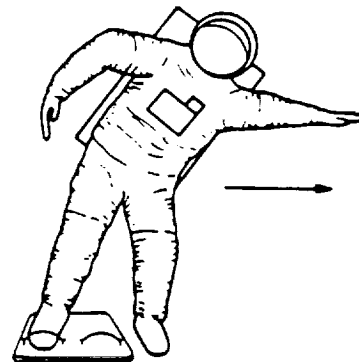
**FORWARD TORSO BENDING WITH TORSO ROTATED**



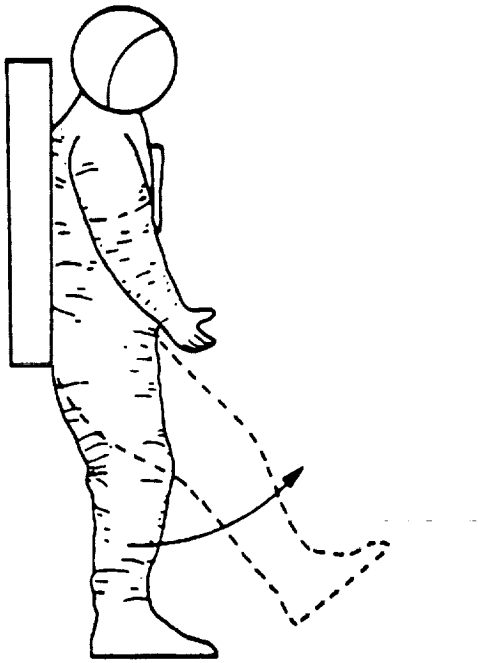
**SIDE-TO-SIDE ANKLE FLEXION / REACH (RIGHT AND LEFT, BOTH FEET IN FOOT RESTRAINTS)**



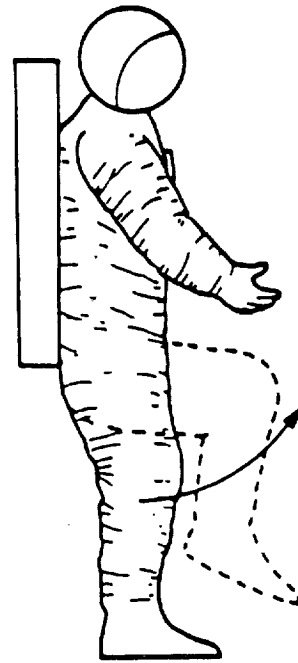
**SIDE-TO-SIDE ANKLE FLEXION / REACH (RIGHT AND LEFT, ONE FOOT IN FOOT RESTRAINT)**



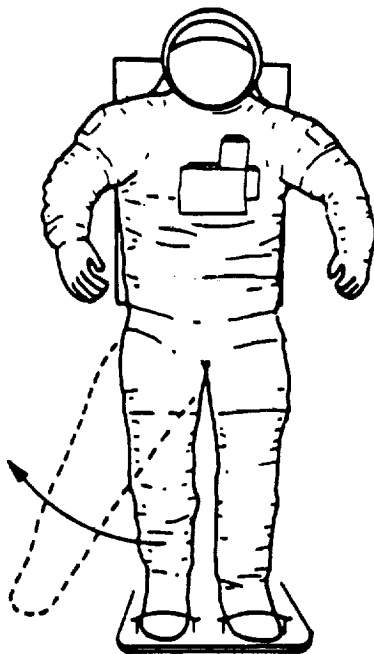
**SIDE-TO-SIDE ANKLE FLEXION / REACH (RIGHT AND LEFT, OTHER FOOT IN FOOT RESTRAINT)**



**STRAIGHT LEG HIP FLEXION  
(BOTH LEGS)**



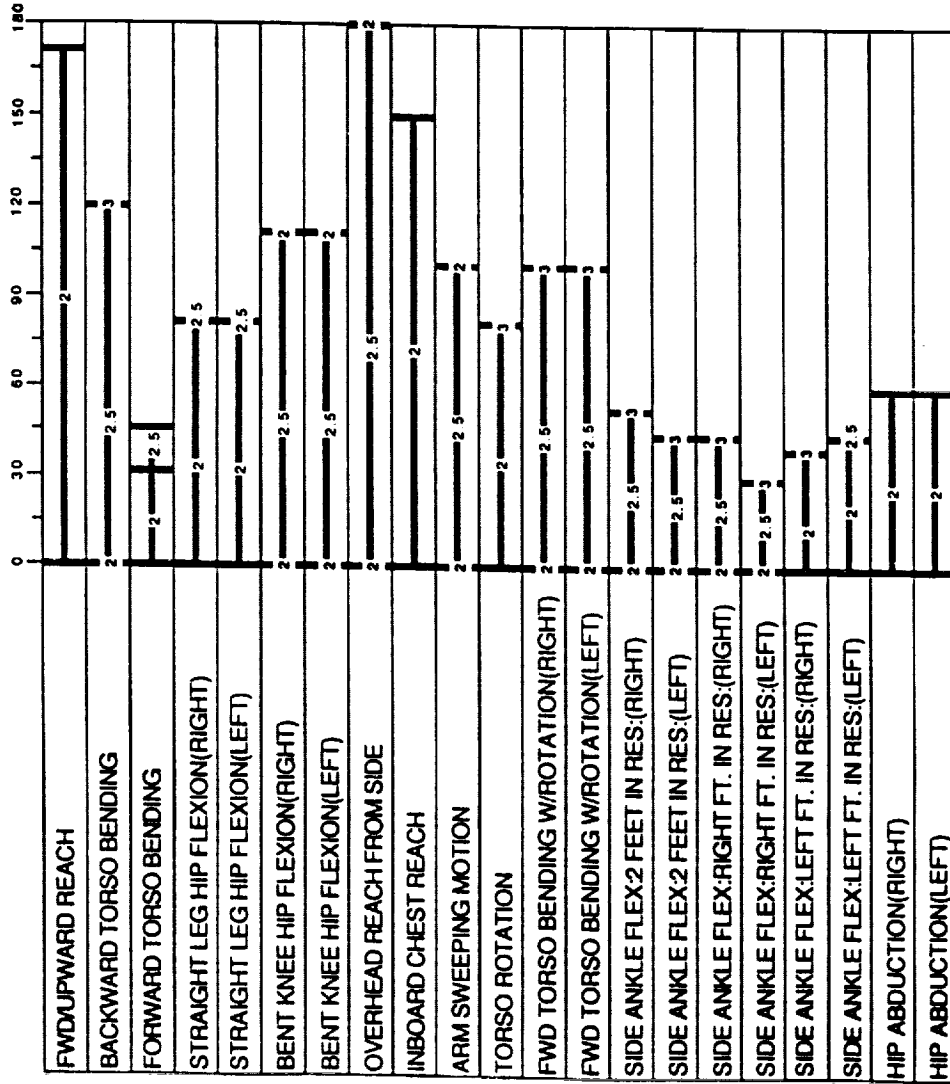
**BENT KNEE HIP FLEXION  
(BOTH LEGS)**

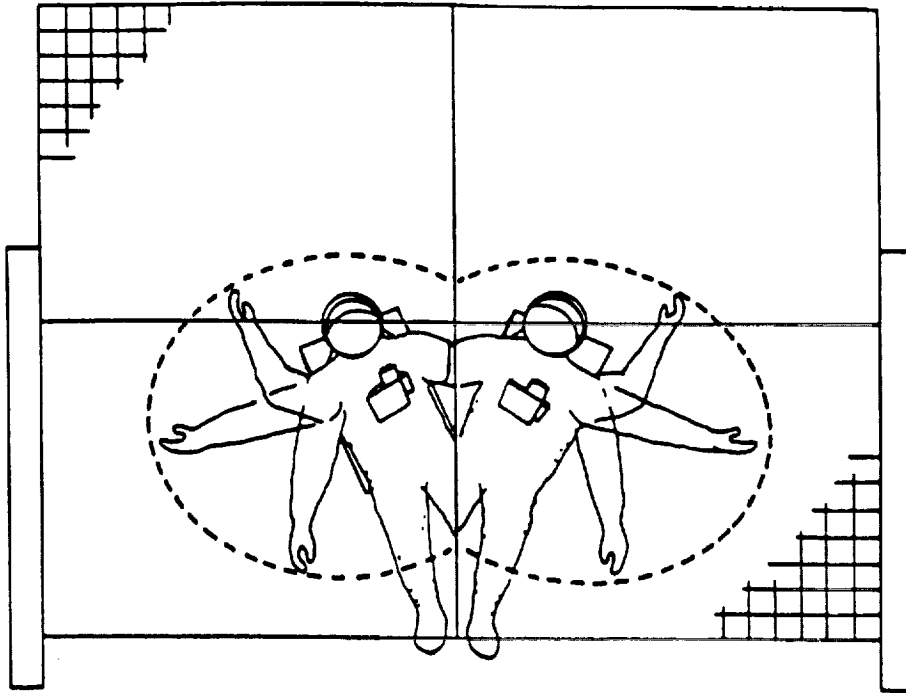


**HIP ABDUCTION (BOTH LEGS)**

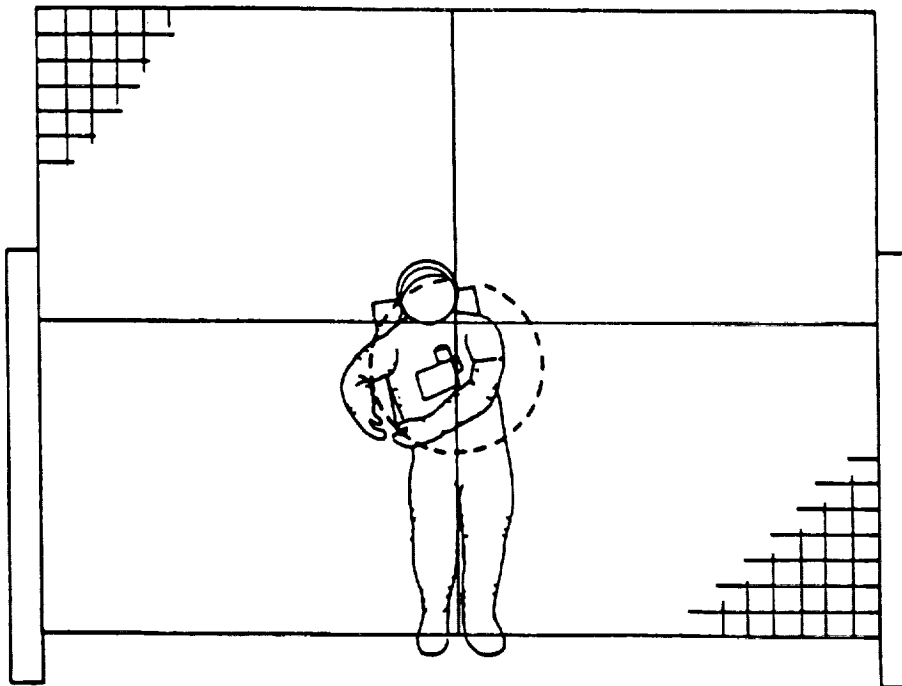
SUIT MOBILITY EVALUATION

LIMITING FACTORS

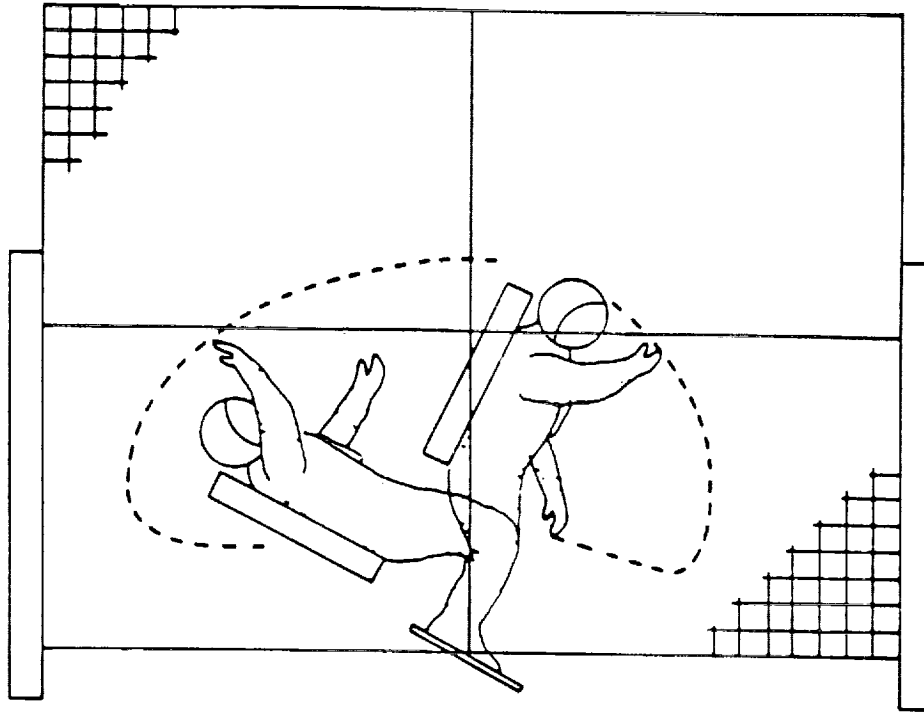




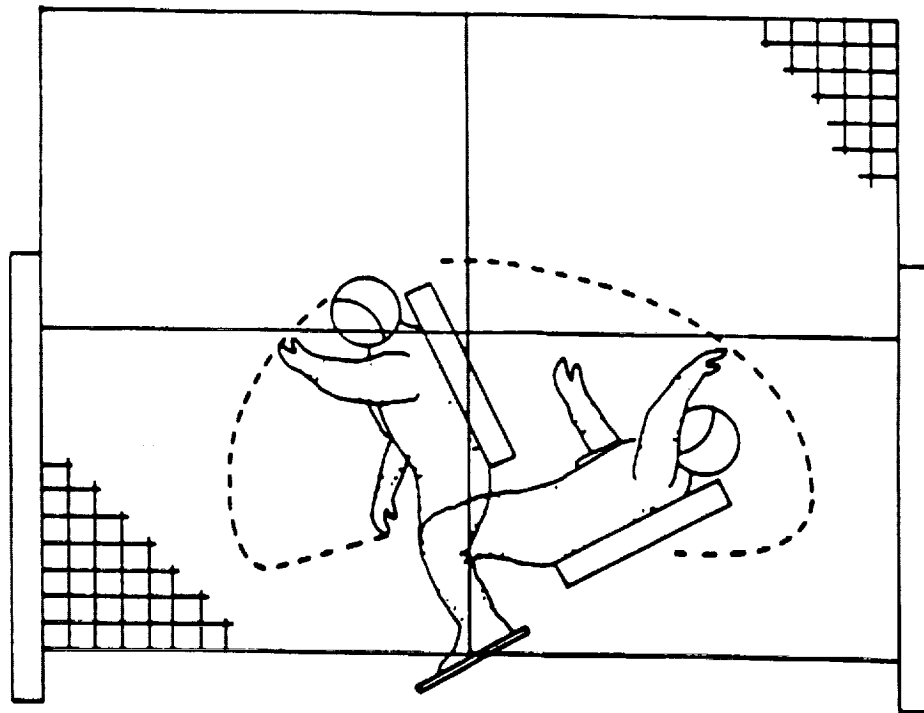
**FRONT RIGHT- AND LEFT-HAND  
REACH ENVELOPE**



**TWO-HAND REACH ENVELOPE**



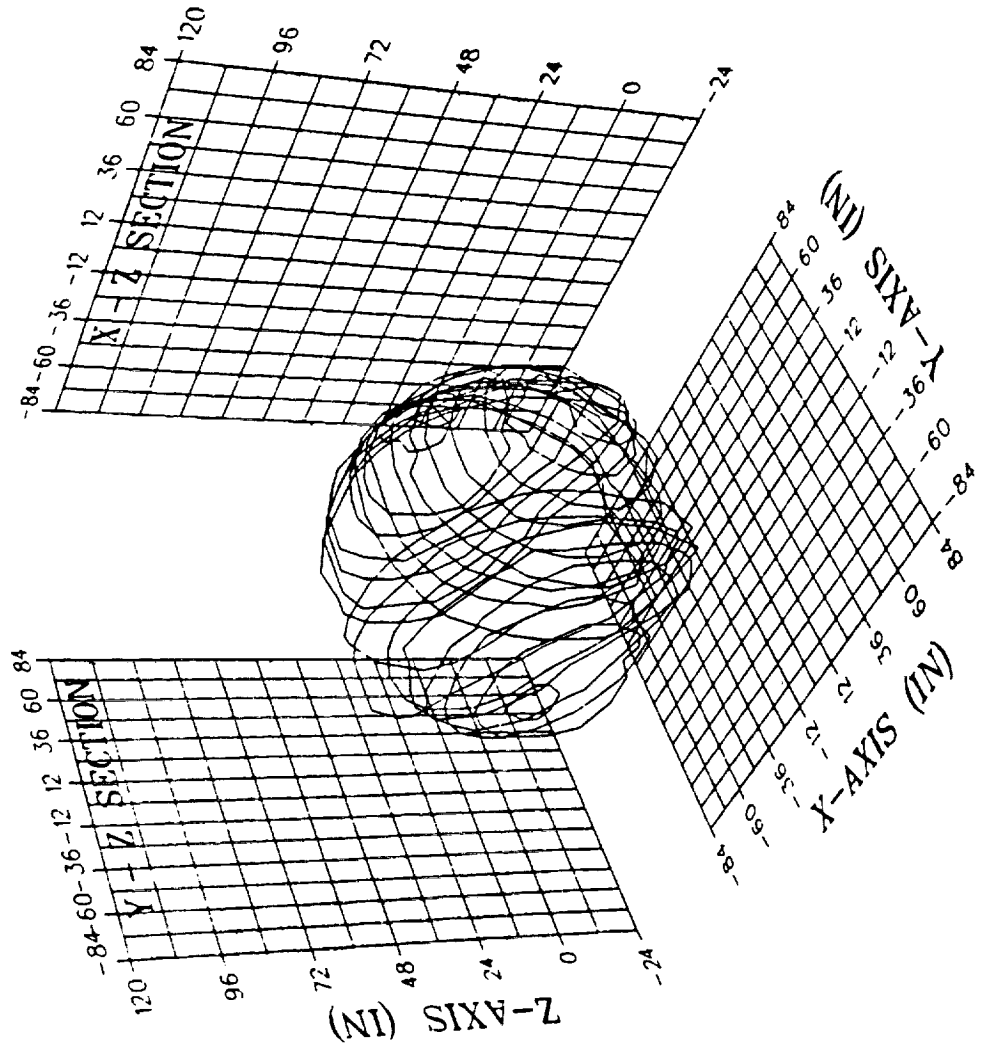
**RIGHT SIDE ONE-HAND REACH ENVELOPE**

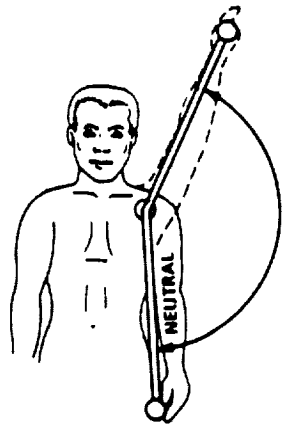


**LEFT SIDE ONE-HAND REACH ENVELOPE**

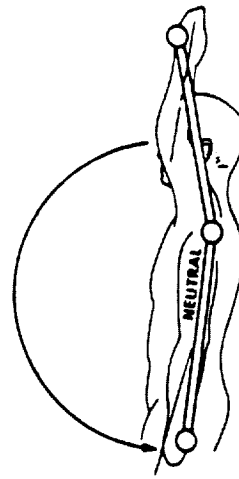
# FUNCTIONAL REACH ENVELOPE

ONE-HANDED



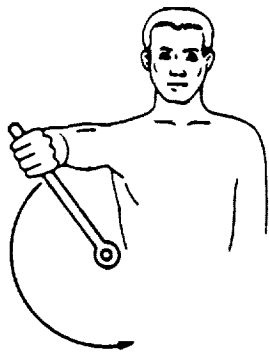


**SHOULDER ABDUCTION**

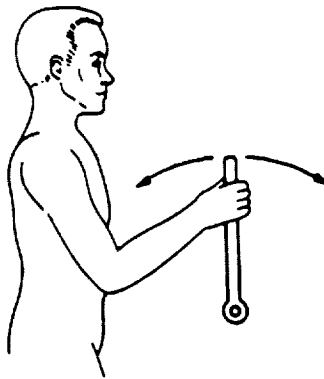


**SHOULDER FLEXION**

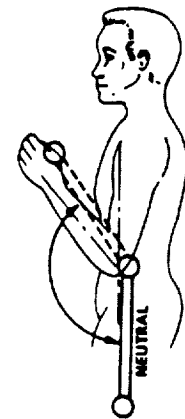
**SHOULDER FLEXION/ABDUCTION**  
(combination of first two)



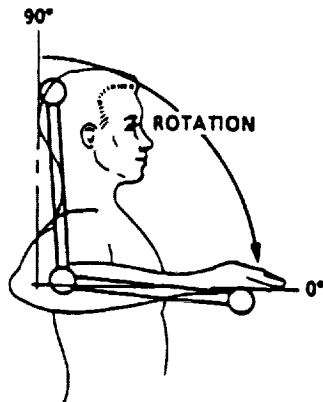
**EVA RATCHET TOOL  
CRANK**



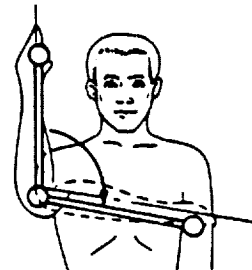
**EVA RATCHET TOOL  
PUSH / PULL**



**ELBOW  
FLEXION / EXTENSION**



**SHOULDER ROTATION  
Y - AXIS**

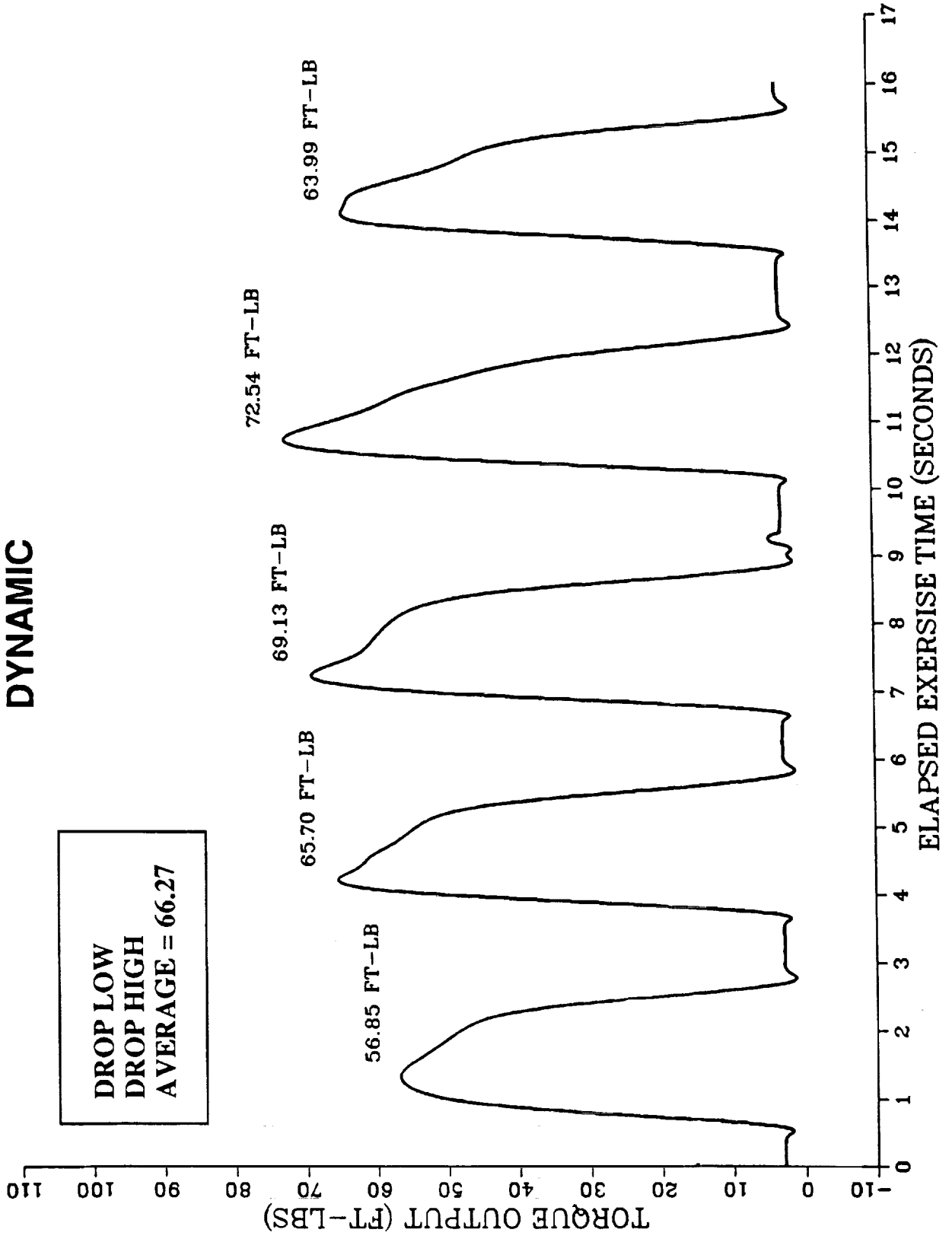


**SHOULDER ROTATION  
MEDIAL INTERNAL**



# SHOULDER FLEXION/ABDUCTION

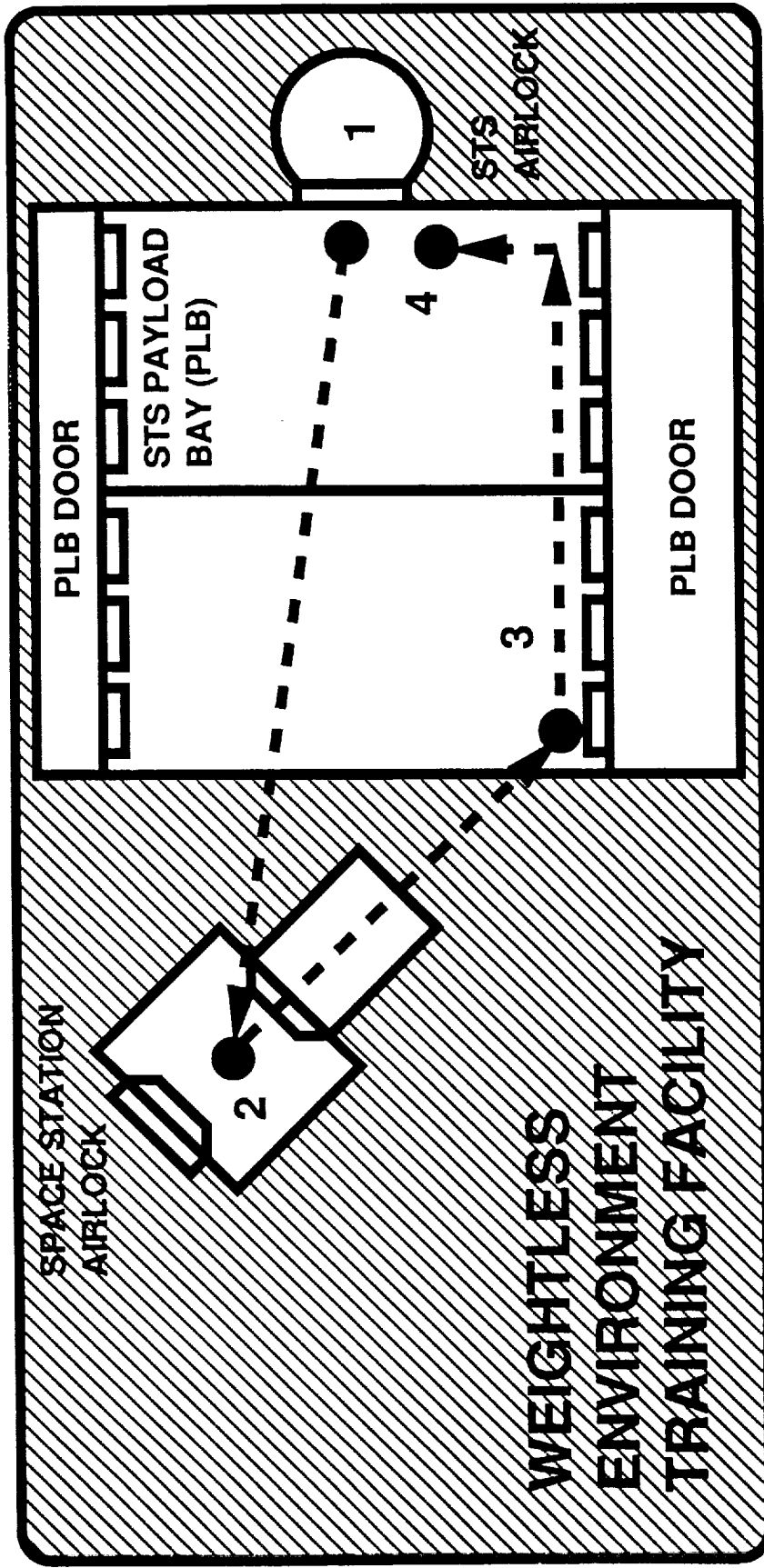
## DYNAMIC



# WETF EVALUATION (CONTINUED)

ACTIVITY	OBJECTIVES
EVA TASKS I	<p>Subjectively evaluate SSA using Cooper-Harper rating scale while performing common EVA tasks</p> <p>Familiarize crewmember with SSA mobility as used on practical applications - precursor for EVA tasks II</p>
EVA TASKS II (EASE/ACCESS)	<p>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</p>

# EVA TASKS I



- 1 STS AIRLOCK OPS
- 2 SPACE STATION AIRLOCK OPS
- 3 STS PAYLOAD BAY TRANSLATION WINCH
- 4 STS CONTINGENCY EVA OPS THREE POINT TOOL

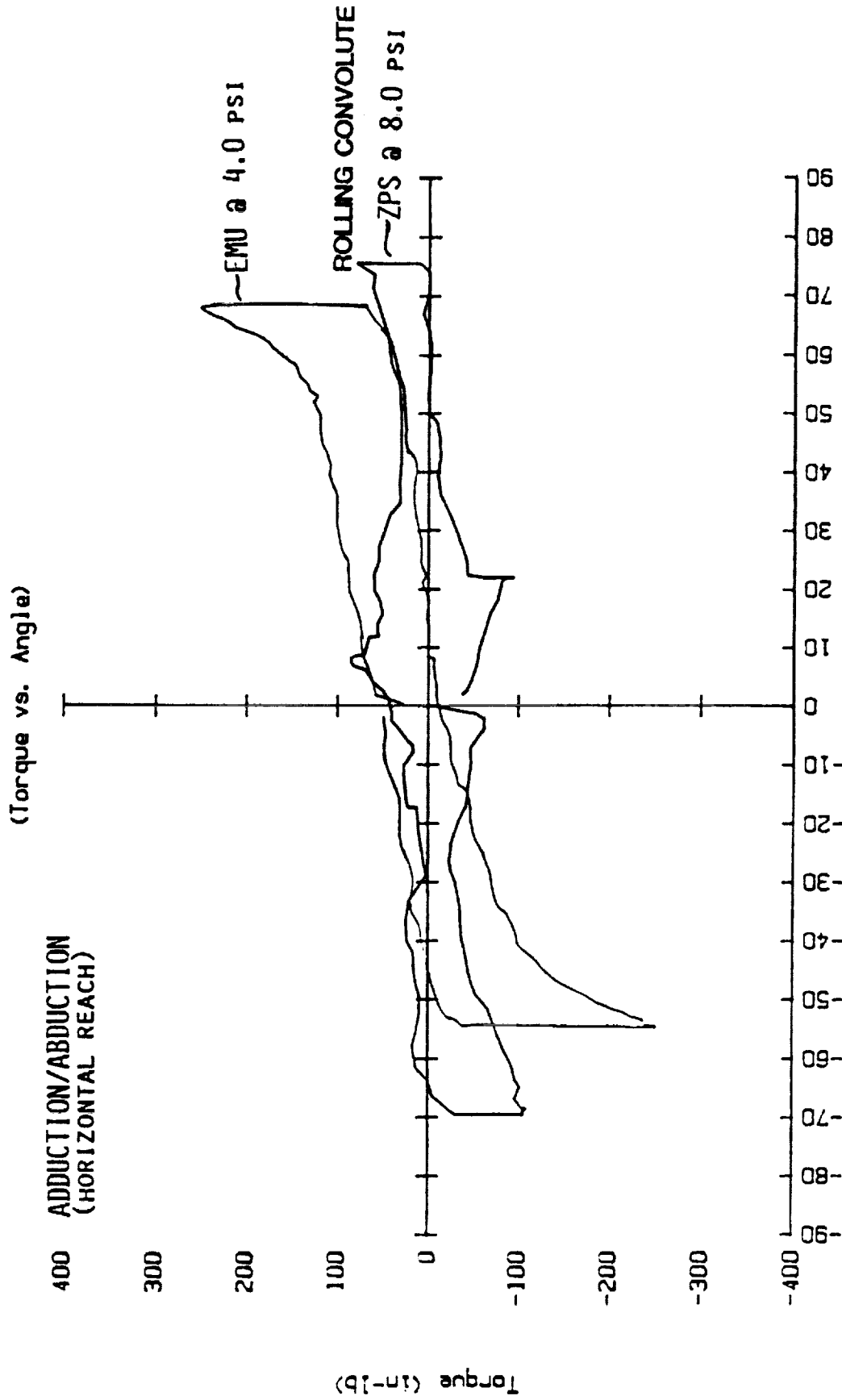
# KC-135 EVALUATION

ACTIVITY	OBJECTIVES
DON/DOFF	Subjectively evaluate SSA don/doff operations using Cooper-Harper rating scale
TRANSLATION	Subjectively evaluate differences in SSA performance between neutral buoyancy (WETF) and zero - g <ul style="list-style-type: none"> <li>- Ease of operation</li> <li>- Fit</li> <li>- Comfort</li> </ul>

# TORQUE / RANGE MEASUREMENT EVALUATION

ACTIVITY	OBJECTIVES
<p style="text-align: center;"><b>TORQUE VERSUS RANGE OF MOTION MAPPING</b></p>	<p>Objectively determine</p> <ol style="list-style-type: none"> <li>1) Torque required to move the joint through a given range of motion</li> <li>2) Maximum joint range of motion</li> </ol>

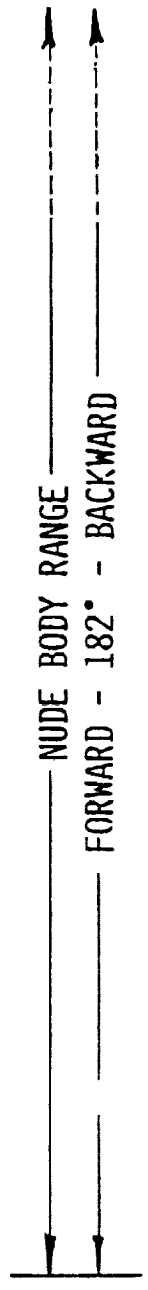
# SHOULDER JOINT COMPARISONS



13

Flexure Angle (deg)

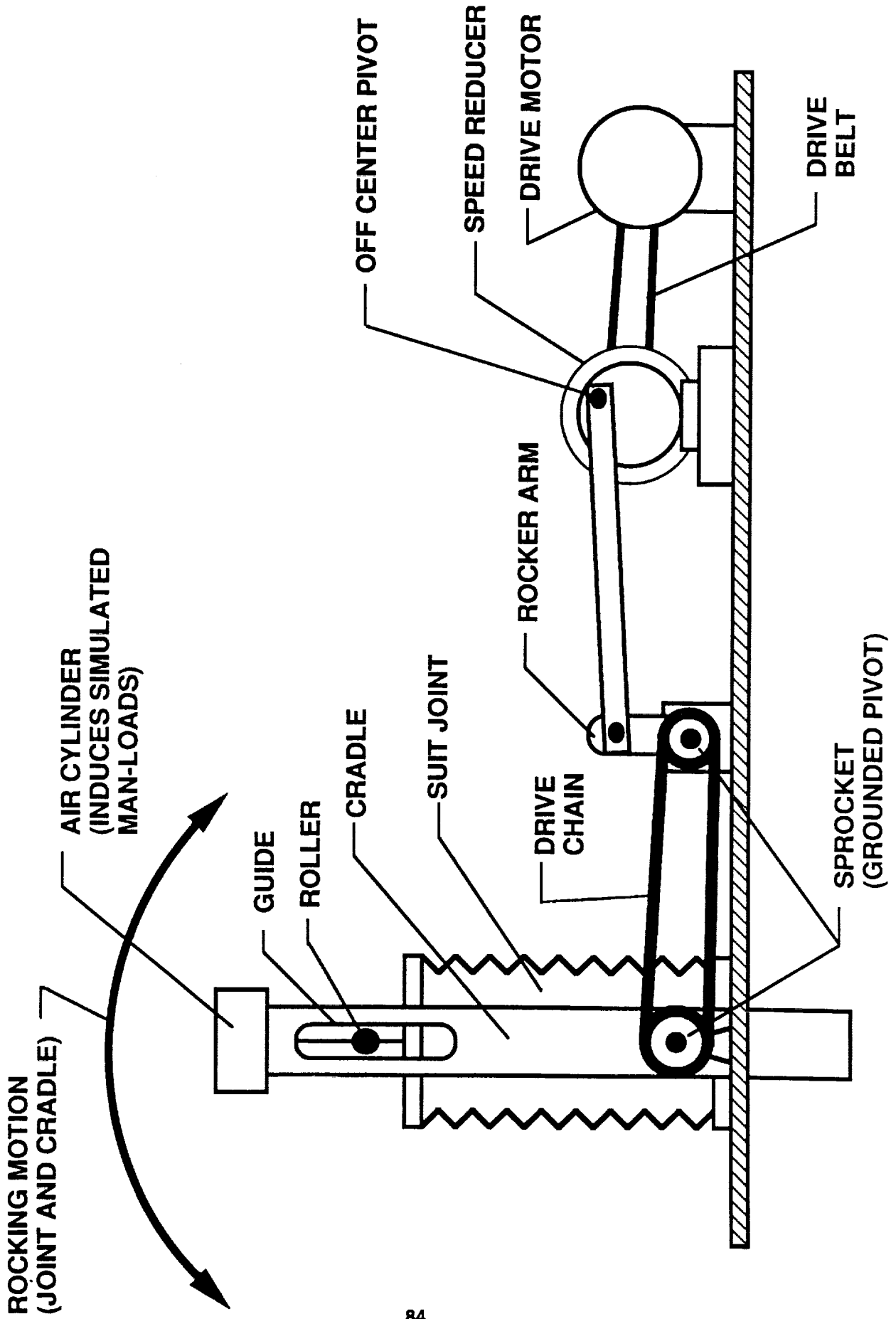
-48°



# CYCLE VERIFICATION EVALUATION

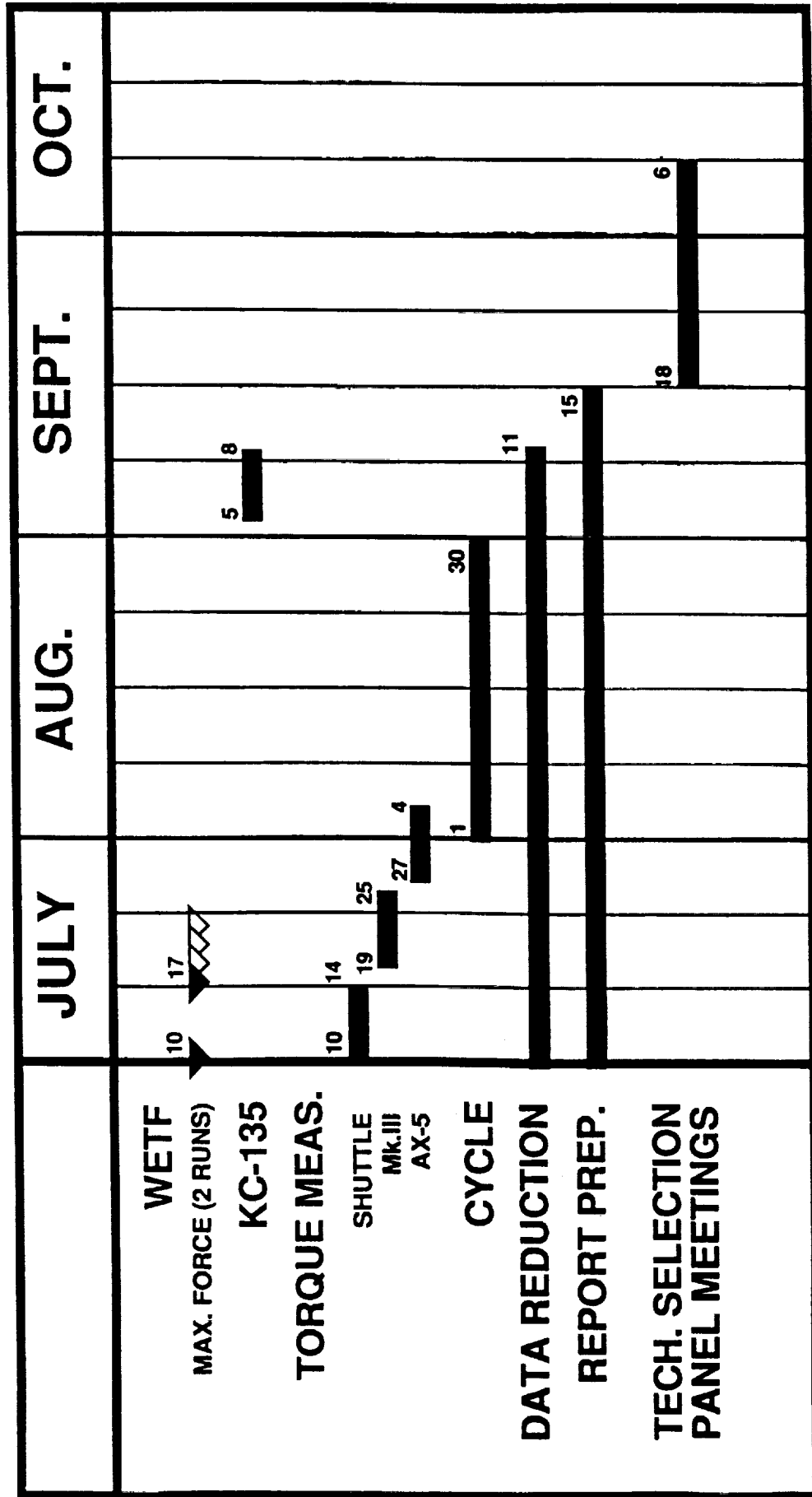
ACTIVITY	OBJECTIVES
CYCLE JOINTS	Verify joint operational capability for one year on orbit life (plus a safety factor of two and based on 52 eva's per year)

# SSA JOINT CYCLE MACHINE





# SUIT TEST PROGRAM SCHEDULE



# TASK COMPLETION MATRIX

## MANNED TEST ACTIVITIES

	CREWMEMBER A			CREWMEMBER B			CREWMEMBER C			CREWMEMBER D		
	STS	AX-5	Mk. III	STS	AX-5	Mk. III	STS	AX-5	Mk. III	STS	AX-5	Mk. III
<b>WETF</b>												
SUIT MOBILITY												
REACH ENVELOPE												
MAX. FORCE												
EVA TASKS 1												
EVA TASKS 2												
<b>KC-135</b>	AX-5		Mk. III	AX-5		Mk. III	AX-5		Mk. III	AX-5		Mk. III

# **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

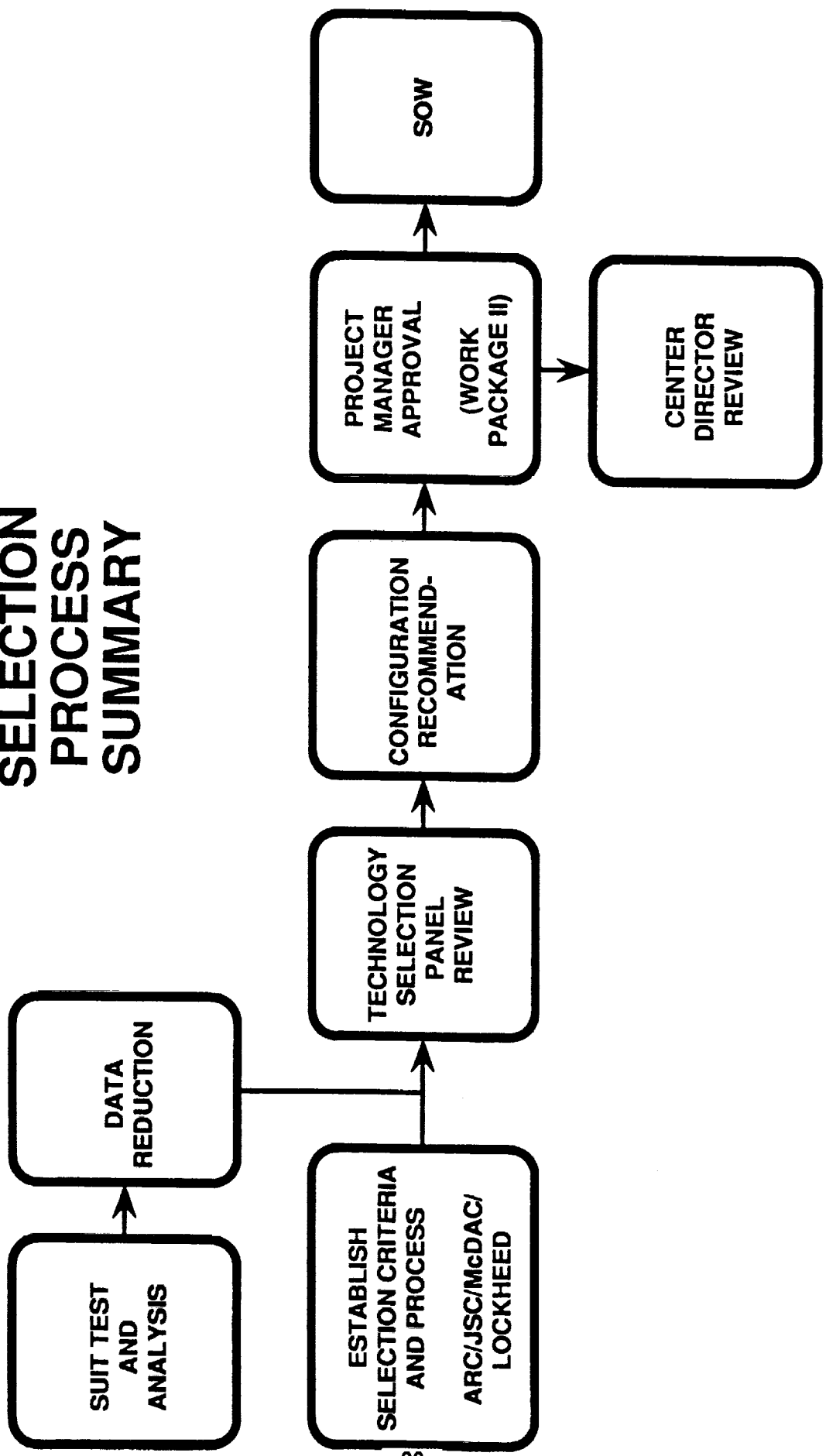
## PURPOSE

- 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



**AX-5 ADVANCED SPACE SUIT DESIGN OVERVIEW**

Captain A. Reinhardt  
NASA/Ames Research Center

(Paper not provided by publication date.)

