The features of the advanced EMU which make it an effective EVA system are:

1. Quick reaction--no pre-breathing is required to transfer from sea level habitat pressures to EVA operations. This requires an EMU operational pressure of approximately 8 psi.

2. Full mobility--the advanced EMU implements a complete mobility system which closely simulates the full nude mobility range of its user. The mobility techniques are passively stable and exhibit extremely low torques to minimize the energy expenditures and assure productive and extended EVA work cycles.

3. Long life components--the construction of large space stations will require extensive numbers of EVA workers who will be on the work site for months at a time. This will require highly reliable and long life components (greater than one million cycles).

4. Extended modularity sizing and maintenance systems--by designing the improved EMU as a series of standard components which are "length" sized to fit individual workers by quick connect components, "shift" assembly of EMU components to fit workers on alternate 8-hour shifts will significantly reduce the in-orbit inventory of suit components and the attendent volume required for storage. The improved EMU will make EVA so efficient that the most effective way to handle many in-orbit satellite launches and recoveries will be through the use of EVA rather than fully automated systems.

GUIDELINES

"THE OPTIMIZED EVA SYSTEM IS CONSIDERED FOR THE YEAR 2000 OPERATIONAL REQUIREMENTS."

"LOGICAL TRANSITION FROM THE CURRENT EMU TO THE OPTIMUM (CIRCA 2000) SYSTEM WILL BE DEFINED."

RESULTS

THE OPTIMUM EVA SYSTEM WILL MEET THE FOLLOWING REQUIREMENTS:

- NO PRE-BREATH AND MIXED O_2/N_2 EMU ENVIRONMENT
- FULL MOBILITY
- IN-ORBIT MINIMUM SERVICING
- EXTENDED MODULARITY TO ENHANCE SERVICING AND LOGISTICS
- USEFUL IN-ORBIT LIFE PER OPERATIONAL CYCLE IS ; 1M
- RADIATION PROTECTION (UP TO 300 NM @ 60^0 INCLINATION)

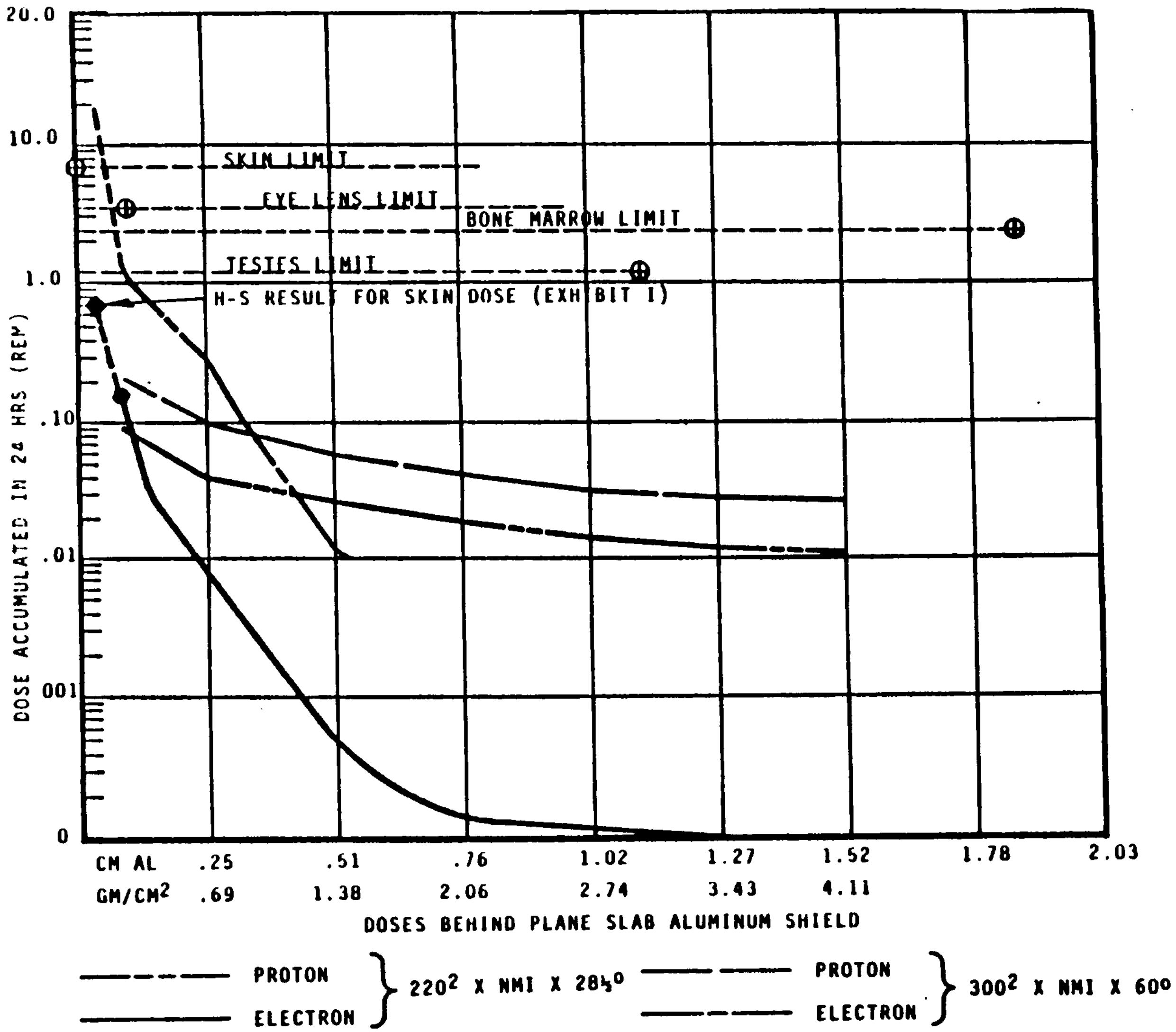
GENERAL

TASKS--EVA CONSTRUCTION, DEPLOYMENT, STOWAGE, OPERATION, MAINTNEANCE, AND REPAIR
PERSONNEL--EVA-TRAINED ONLY
SORTIE--WORK CYCLE 6 HOURS CONTINUOUS EVA; SINGLE OR MULTIPLE SHIFT
--NO PRE-BREATHING
RESTRAINT--FOOT AND/OR TORSO
--TETHERED EQUIPMENT
EVA TRANSLATION--HAND RAILS, HAND HOLDS, CRANE, PERSONAL PROPULSION SYSTEM, FOOT RAILS
STOWAGE--IN HABITAT
LIGHTING--AREA AND EMU INTEGRAL

ADVANCED EMU RADIATION PROTECTION

- VAN ALLEN BELT RADIATION USED FOR ANALYSIS
  - -- SOLAR FLARES AND EXOATMOSPHERIC NUCLEAR BLASTS NOT CONSIDERED
  - -- COSMIC RAY INSIGNIFICANT
- CONCLUSION:
  - -- NORMAL EVA SYSTEM DENSITIES SUFFICIENT FOR LEO RADIATION PROTECTION
  - -- NOT TRUE FOR GEO

ADVANCED EMU RADIATION PROTECTION (CONT'D)



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ADVANCED EMU OPERATIONAL PRESSURE

- Recommend--sea level pressure in habitat (14.7 psia)
  - 8 psia suit pressure with 50% N_2 - 50% O_2 mix
- No pre-breathe of O_2 required
- Long-term exposure to high O_2 concentrations undesirable
- Habitat pressure affects
  - cooling power requirements
  - avionics reliability
  - flammability hazards
  - O_2 toxicity
  - biological/physiological and material process experiments

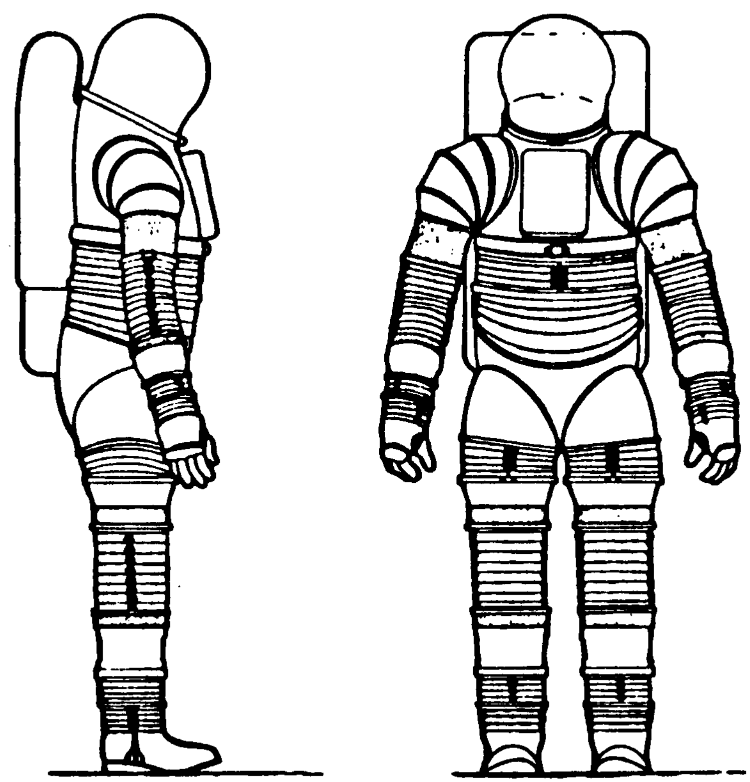
ADVANCED EMU OPERATIONAL PRESSURE (CONT'D)

- 8 PSI TECHNOLOGY IS AVAILABLE
- ON-GOING PROGRAM TO DEMONSTRATE ADVANCED EMU FEASIBILITY
- POTENTIAL FOR NEAR-TERM IMPLEMENTATION

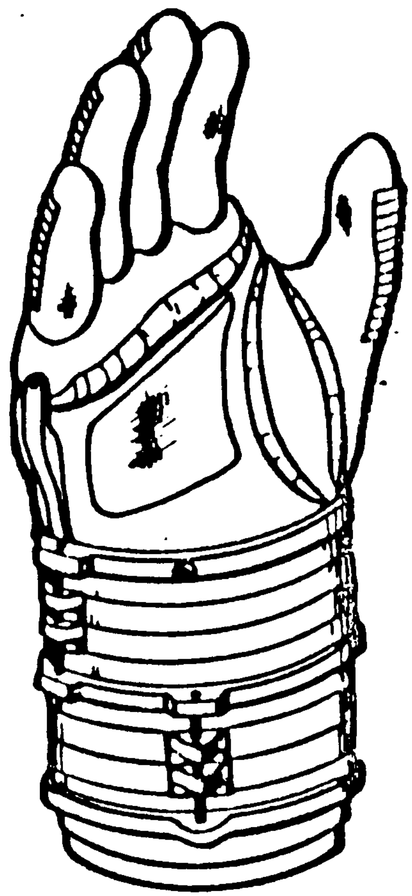
ADVANCED EMU MOBILITY EFFECTS

- THE ADVANCED EMU WILL IMPLEMENT NON-PROGRAMMED FLEXIBLE JOINTS AS FOLLOWS:
  - SHOULDER 3-AXIS
  - ELBOW SINGLE-AXIS
  - WRIST 3-AXIS
  - WAIST 2-AXIS
  - HIP 3-AXIS
  - KNEE SINGLE-AXIS
  - ANKLE 2-AXIS

- FULL MOBILITY FAVORABLE AFFECTS
  - TRAINING TIME
  - EVA AID COMPLEXITY
  - TASK TIME LINES



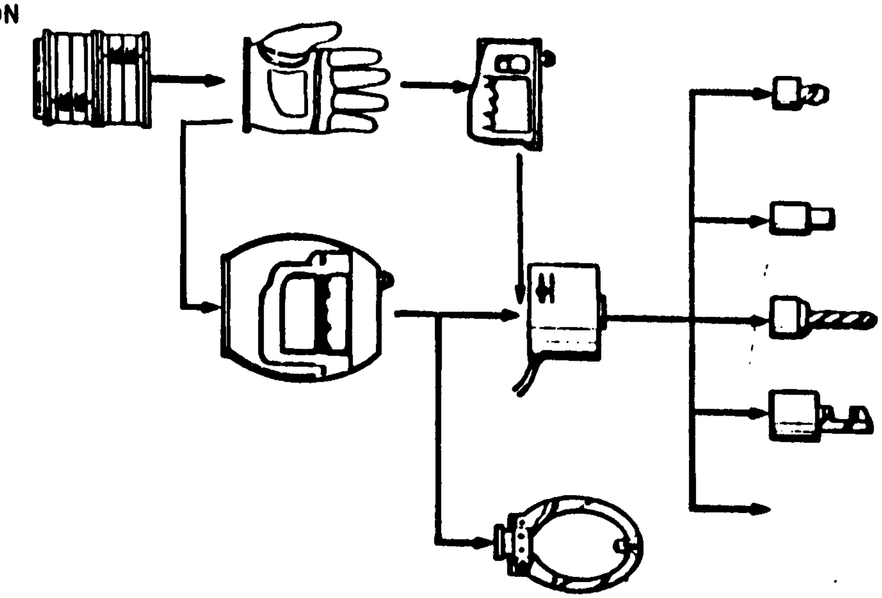
ADVANCED EMU TOOL/GLOVE/EFFECTOR



- For orbits considered, radiation is not a serious problem
  - -- Glove used for LEO
  - -- Future GEO will require increased hand protection/effector system
- Glove requires
  - -- 1st metacarpal joint implementation
  - -- Good tool "grip interface"
  - -- Thumb-finger opposition
  - -- In-orbit replacement of glove element to wrist

ADVANCED EMU TOOL/GLOVE/EFFECTOR (CONT'D)

- o NEED FOR MULTI-PURPOSE POWER ELEMENT FOR
  - -- VARIABLE TORQUE MULTI-ROTATION
  - -- RECIPROCAL MOVEMENT
- o INTERFACE TO GLOVE OR TO RADIATION PROTECTIVE "CAN"



EVA SYSTEM ANTHROPOMETRICS

Early space suits were designed as derivations of emergency pressure flight suits. Such suits were never intended for use while pressurized except under emergency conditions for short periods of time. The demand for mobility while pressurized grew with the advent of Extravehicular Activity (EVA) and lunar exploration.

A group of developmental space suits which began with the JSC-Litton hard space suits approached the problem of pressurized mobility from a new direction. Those suits were conceived and designed as articulated anthropomorphic structures instead of as specialized articles of clothing. Such an articulated structure is constructed of an assembly of specially formed elements connected to flexible joint elements.

It was apparent that the only way such an assembly could be sized to a range of subject sizes was to provide different sized elements that could be assembled in combination to fit an individual.

This sizing approach was explored in the JSC-Litton RX-3 program and in the JSC-AiResearch AES program. In both cases, the concept was to provide suit element cross sections that would accommodate the largest individual and vary the length of the element for fit.

The sizing matrix presented here offers a fit to a wider range of subject sizes by varying both cross sections and lengths of selected elements.

Anthropometric data from several sources has been utilized to define the sizes for each pressure garment element. The 5th to 95th percentile range of each group was selected as the range that should be covered by the modular sizing matrix.

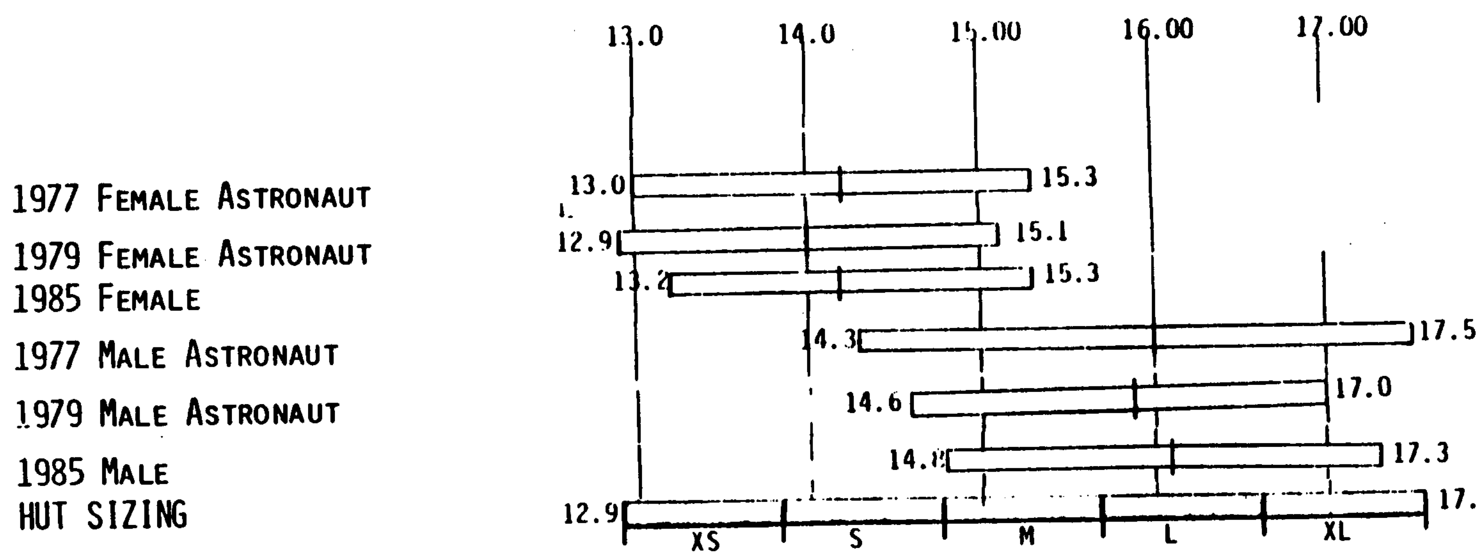
SIZING CONSIDERATIONS

Definition of a rational modular sizing system is based on selected anthropometric measurement for each modular element. Data from several sources has been extracted to define the ranges needed in each sized element. It should be noted that because of inconsistencies in the types of measurements taken in different surveys, not all measurements required for this sizing study were available. In most cases, the missing data has been projected by simple regression equations based on stature.

- o Bi-modal distribution of male and female poplation complicates modular sizing system
  - -- Feasible modular sizing system proposed
  - -- Two ranges of circumferential sizing components
  - -- Intermediate length inserts

- o More stringent selection of astronaut could significantly affect system costs

SIZING CRITERION: Biacromial Breadth



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SIZING CONSIDERATIONS (cont'd)

NASA Reference Publication 1024 provides projections for measurements of 1985 males based on population growth curves. Similar data is provided as 1985 female measurements. However, due to lack of data on growth curves of the female Air Force population, the information provided is an estimate based on the officer sub-series from Anthropometry of Air Force Women by Clauser, et. al.

Since it seems reasonable to assume that the female population will undergo the same rate of growth as the male, we have prepared projections for the 1985 female based on the 1968 Air Force data and assuming the same growth rate in weight and stature as that projected for men. Other measurements for 1985 females were then derived by multiple regression equations.

Data derived from male Air Force flight personnel are skewed by preselection due to screening during earlier selections. The data on Air Force women while also skewed by preselection is probably less so since it does not represent flight personnel only.

As the selection of workers for long term construction and maintenance tasks in orbit takes place, it is possible that both male and female candidates will cover a wider range of measurements than the current data allows. The sizing matrix can be enlarged or shifted for certain measurements, but there will be limits to the sizes of subjects that it is possible to fit. Once the sizing matrix is established it may be necessary to select EVA worker candidates who fit within the measurements defined. The production and inventory costs of fitting a nonconforming subject would be extremely high.

ELEMENT: UPPER ARM

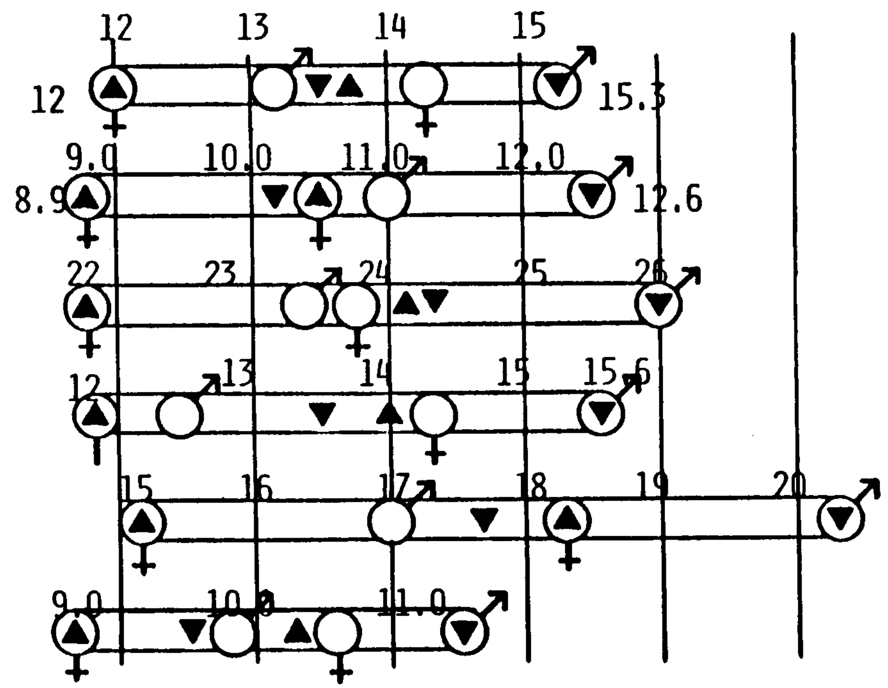
FOREARM

TORSO LENGTH

UPPER LEG

LOWER LEG

FOOT LENGTH



LEGEND

○♀ FEMALE LIMITS

○♂ MALE LIMITS

▲▲ SMALL MODULE RANGE

▼▼ LARGE MODULE RANGE

EVA tasks, both planned and contingent, would be greatly enhanced by the suggested EMU. Modular yet reliable, and having a design goal of ten operational cycles, this unit would provide a means of mobile protection for several crewmembers on rotating shifts.

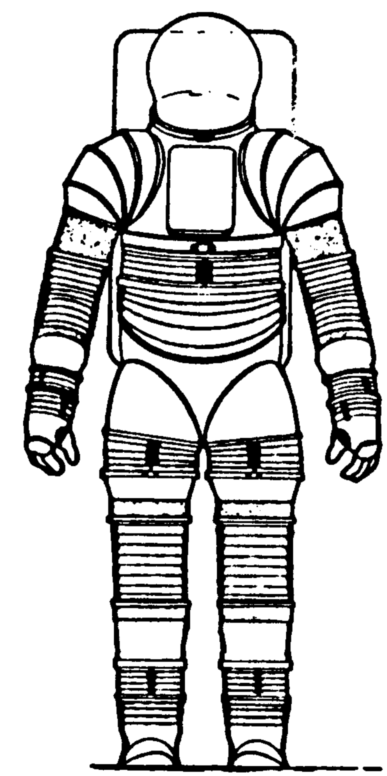
Two of the proposed EMUs would service four crewmembers working sequential six-hour shifts. Upon completion of their six-hour sortie, the first team would return to the ship, go through any required decontamination procedures, and doff the unit. The EMU would quickly and easily break down for cleaning and/or resizing. Each element of the EMU would have an identifier so that a computer log could be kept on component use rather than total suit life. The total sortie time and task would be logged in for the unit being worn. The computer would then automatically record wear values for each element of the total EMU. This would allow extended life items to be used to their fullest capacity. Additional front and back identification would be provided for those segments of the suit that are constructed in a toroidal joint configuration. After each sortie, these joints would be rotated 180° so that the front would then become the back and vice versa, thus maximizing their useful life. Using the computer log system, any wear trends which might develop would be quickly discovered and brought to the attention of the design department for corrective action. It is envisioned that a complete resizing, donning, and donned check-out could be per-foremd within a period of forty minutes. With man-induced loads associated with occupancy of the EMU, a pressure slightly higher than normal test pressure should be used prior to EVA.

The high reliability built into the EMU limits the amount of required in-orbit maintenance. Outside of normal freshening of the garment, maintenance tasks consist of lubricating bearings and sealing gaskets, visual inspection, and some limited testing.

More extensive testing performed on a periodic (six-month) basis would be handled by maintenance crews stationed on earth. Bearings and bearing races would be torn down, cleaned, soft goods replaced, reassembled, and evaluated. X-ray examination of hardware and rigid structures would be one means of determining their relative repair status. Upon evaluation, the element would either be returned to service in orbit, or retained on earth for training purposes. All elements not meeting the evaluation criteria would be scrapped.

ADVANCED EMU EQUIPMENT TURNAROUND

- o EXTENDED MODULARITY LONG LIFE COMPONENTS YIELD
  - -- MINIMUM NUMBER OF EMU COMPONENTS IN ORBIT
  - -- EASE OF COMPONENT INSPECTION/REPLACEMENT
- o COMPUTER AIDED IN-ORBIT COMPONENT MAINTENANCE AND EMU ASSIGNMENT
  - -- EARTH MAINTENANCE AND ASSIGNMENT OF COMPONENTS
  - -- FAILURE/TROUBLE STATISTICS AND FLAGGING OF MARGINAL ELEMENTS



ADVANCED EMU SUMMARY

- ADVANCED EMU UTILIZES AVAILABLE TECHNOLOGY
  - -- RADIATION--MINIMUM IMPACT ON DESIGN FOR LEO
    - --GEO NOT ADDRESSED
  - -- OPERATIONAL PRESSURE--~8 PSI MIXED GAS
  - -- MOBILITY EFFECTS--FULL MOBILITY, LOW TORQUE
  - -- TOOL/GLOVE/EFFECTOR--MODULAR GLOVE FOR LEO
    - --EFFECTOR PRESSURE VESSEL FOR GEO
    - --MODULAR POWER TOOL INTERFACE
  - -- ANTHROPOMETRICS--BI-MODAL EXTENDED MODULARITY SYSTEM
  - -- EVA LIGHTING--SERVOED INTENSITY AND ARTICULATION FOR FILL-IN LIGHTING
  - -- EQUIPMENT TURNAROUND--MODULAR COMPONENT BUILD UP IN ORBIT
    - --COMPUTER AIDED TRACKING AND TROUBLE IDENTIFICATION