NASA-STD-3000-Vol 3

NASA-STD-3000

*AC62512

NASA
National Aeronautics and
Space Administration

MAN-SYSTEMS INTEGRATION STANDARDS

NASA-STD-3000 HANDBOOK

VOLUME III

AUGUST 1994

NASA
National Aeronautics and
Space Administration

FORWARD

This booklet provides basic, quantitative human engineering design requirements in pictorial, tabular, and graphical format. It is to be used as a small portable handbook reference for users of NASA-STD-3000, Volume I. Since the primary purpose is to provide a portable reference, the principles, explanations, limitations, and application techniques associated with the data are intentionally omitted. In addition, while the headings for all requirements have been included, top-level requirements headings, the text for non-specific requirements and those requirements considered inappropriate for *"field use"* have been omitted. Accordingly, this abbreviated presentation assumes that the user is familiar with the bases and limitations of the given data or will consult applicable references to insure appropriate application of the data.

Within the context of this handbook, "*field use*" is defined as the application of human performance standards relative to space module features, environments, hardware, and software. The "*field*" includes but is not limited to meetings, design reviews, crewstation reviews, sketch evaluations, software architecture reviews, demonstrations, etc. The data contained herein should be used to remind or point out applicable standards or requirements and aid in the inspection of environments, systems, and subsystems.

In general, this booklet is a digest of material appearing in NASA-STD-3000, Volume I. The data herein is intended for field reference only. The user is therefore referred to that document and its references for required supplementary information.

Comments or suggestions regarding this Handbook can be forwarded to Mr. John Jackson, Book Manager, Mail Code SP2, Johnson Space Center, Houston, TX 77058.

Copies of this document can be obtained from the Book Manager at Johnson Space Center or from the CSERIAC Program Office, AL/CFH/CSERIAC Bldg. 248, 2255 H Street, Wright-Patterson AFB, OH 45433-7022.

This document is the result of the collaborative efforts of NASA, CSERIAC, and CAMUS, Inc.

ABOUT CSERIAC

The Crew System Ergonomics Information Analysis Center **(CSERIAC)** is the central source for up-to-date human factors information and technologies. CSERIAC provides a variety of products and services to government, industry, and academia promoting the use of ergonomics in the design of human-operated equipment and manned systems. On a cost recovery basis, **CSERIAC** will:

- Distribute ergonomic technologies and publications.
- Perform customized bibliographic searches and reviews.
- Prepare state-of-the-art reports and critical reviews.
- Conduct specialized analyses and evaluations.
- Provide workshop administration support.

CSERIAC is a Department of Defense organization sponsored by the Defense Technical Information Center. It is managed by the Human Engineering Division of the Armstrong Laboratory, and operated by the University of Dayton Research Institute.

To obtain further information, contact:

CSERIAC Program Office

AL/CFH/CSERIAC Bldg 248

2255 H Street

Wright-Patterson AFB OH 45433-7022

Phone: (513)255-4842

Fax: (513)255-4823

TABLE OF CONTENTS

NOTE: Handbook contains only boldfaced material

ERRATA

3.3.1.3 Body Size Data Design Requirements

3.3.2.3 Joint Motion Data Design Requirements

3.3.2.3.1 Joint Motion Data For Single Joint Design Requirements

3.3.2.3.2 Joint Motion Data For Two Joint Design Requirements

3.3.3.3 Reach Data Design Requirements

3.3.3.3.1 Functional Reach Design Requirements

3.3.3.3.2 Strike Reach Envelope Data Design Requirements

3.3.4.3 Neutral Body Posture Data Design Requirements

Parameter	Anthropometric Change		
	Short-term mission (1 to 14 days)	Long-term mission (more than 14 days)	
		Pre vs. during mission	Pre vs. during mission
Height	Slight increase during first week (~ 1.3 cm or 0.5 in). Height returns to normal * R+0 Increases caused by spine lengthening	Increases during first two weeks then stabilizes at approximately 3% of pre-mission baseline. Increases caused by spine lenthening	Returns to normal on R + 0
Circumferences	Circumference changes in chest, waist, and limbs. See Figure 3.2.3.1-2 for chest and waist changes. Changes due primarily to fluid shifts		
Mass	Postflight weight losses average 3.4%; about 2/3 of the loss is due to water loss, the remainder due to loss of lean body mass and fat. Center of mass shifts headward approximately 3 - 4 cm (1 - 2 in). See Paragraph 3.3.7.3.2.1 for details	Inflight weight losses average 3 - 4% during first 6 days, thereafter, weight gradually declines for the remainder of the mission. Early inflight losses are probably due to loss of fluids; later losses are metabolic. Center of mass shifts hea approximately 3 - 4 cm (1 - 2 in)	Rapid weight gain during first 5 days postflight, mainly due to replinishment of fluids. Slower weight gain from R + 5 days to R + 2 or 3 weeks
Limb Volume	Inflight leg volume decreases exponentially during first mission day; thereafter, rate of decrease declines until reaching a plateau within 3 - 5 days. Postflight decrements in leg volume up to 3%; rapid increase immediately followed by slower return to return to pre-mission baseline	Early inflight period same as short missions. Leg volume may continue to decrease slightly throughout mission. Arm volume decreases slightly.	Rapid increase in leg volume immediately postflight, followed by slower return to pre-mission baseline.
Posture	Immediate assumption of neutral body posture (see Paragraph 3.3.4)	Immediate assumption of neutral body posture (see Paragraph 3.3.4)	Rapid return to pre-mission posture.

* Recovery day plus post mission days

MSIS 265
Figure 3.2.3.1-1 Anthropometric Changes in Weightlessness

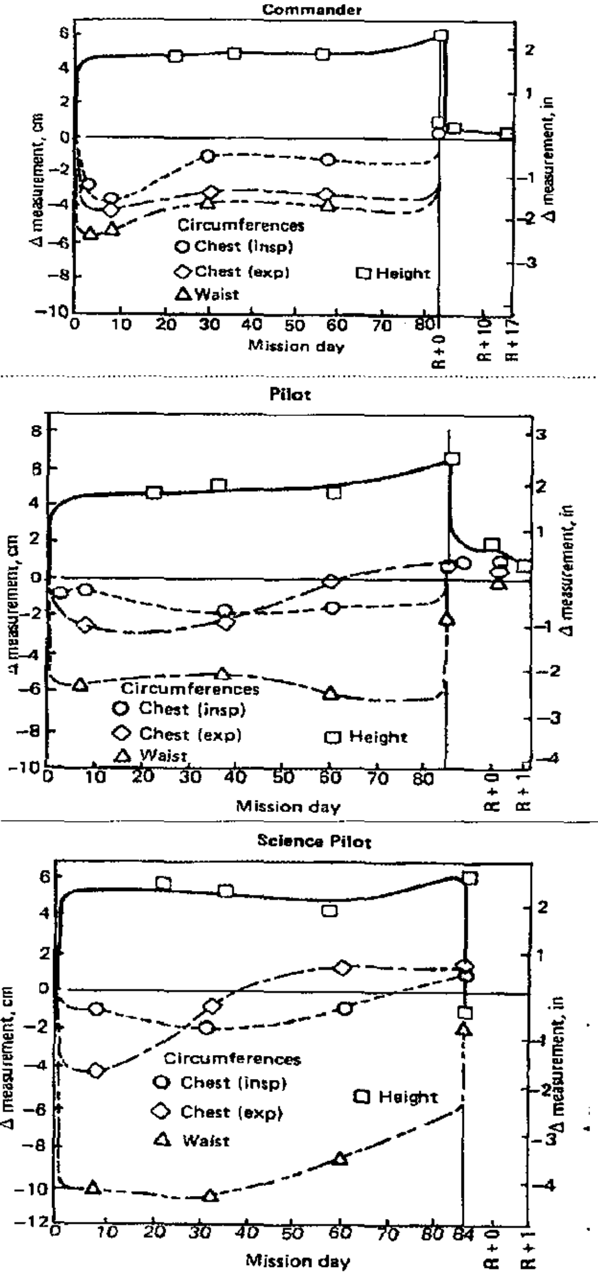


Figure 3.2.3.1-2 Micro-Gravity Changes in Height, Waist, and Chest Measured in Skylab Crewmen. One-G Measurements as a Baseline

MSIS 266

	Stature secular growth rate (per decade)
American male	1.0 cm (0.4 in)
Japanese female	2.6 cm (1.0 in)

MSIS-267

Figure 3.2.3.3-1 Assumed Secular Growth Rate of Stature

Figure	Joint movement (note b)	Range of motion (degrees) Males (note a) 5th percentile	Males (note a) 95th percentile	Females (note a) 5th percentile	Females (note a) 95th percentile
1	Neck, rotation right	73.3	99.6	74.9	108.8
	Neck, rotation left	74.3	99.1	72.2	109.0
2	Neck, flexion	34.5	71.0	46.0	84.4
	Neck, extension	65.4	103.0	64.9	103.0
3	Neck, lateral right	34.9	63.5	37.0	63.2
	Neck, lateral left	35.5	63.5	29.1	77.2
4	Shoulder, abduction	173.2	188.7	172.6	192.9
5	Shoulder, rotation lat	46.3	96.7	53.8	85.8
	Shoulder, rotation med	90.5	126.6	95.8	130.9
6	Shoulder, flexion	164.4	210.9	152.0	217.0
	Shoulder, extension	39.6	83.3	33.7	87.9
7	Elbow, flexion	140.5	159.0	144.9	165.9
8	Forearm, pronation	78.2	116.1	82.3	118.9
	Forearm, supination	83.4	125.8	90.4	139.5
9	Wrist, radial	16.9	36.7	16.1	36.1
	Wrist, ulnar	18.6	47.9	21.5	43.0
10	Wrist, flexion	61.5	94.8	68.3	98.1
	Wrist, extension	40.1	78.0	42.3	74.7
11	Hip, flexion	116.5	148.0	118.5	145.0
12	Hip, abduction	26.8	53.5	27.2	55.9
13	Knee, flexion	118.4	145.6	125.2	145.2
14	Ankle, plantar	36.1	79.6	44.2	91.1
	Ankle, dorsi	8.1	19.9	6.9	17.4

Notes: a. Data was taken 1979 and 1980 at NASA-JSC by Dr. William Thornton and John Jackson. The study was made using 192 males (mean age 33) 22 females (mean age 30) astronaut candidates (see Reference 365)
b. Limb range is average of right and left limb movement.

MSIS-340
1 of 3

Figure 3.3.2.3.1-1 Joint Movement Ranges for Males and Females

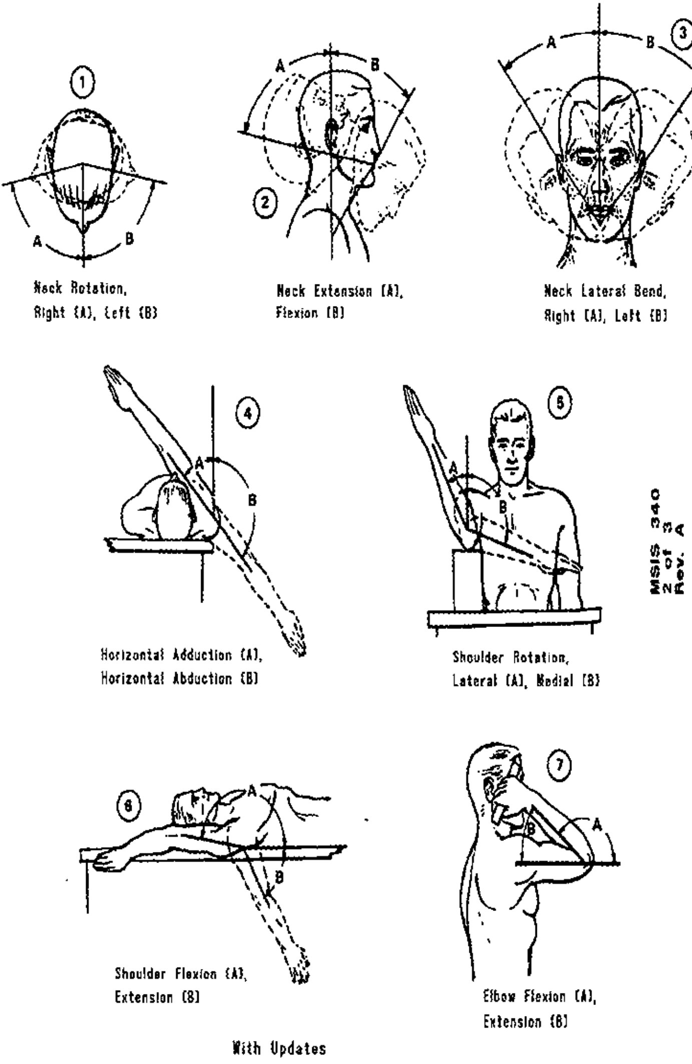


Figure 3.3.2.3.3-1 Joint Movement Ranges for Males and Females (Continued)

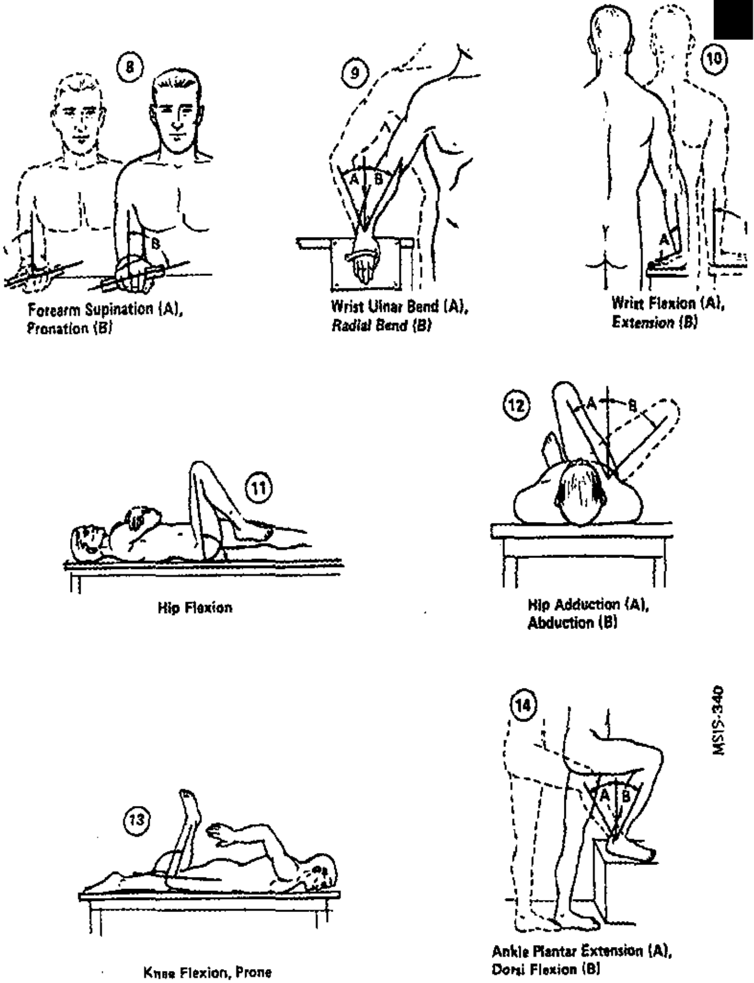
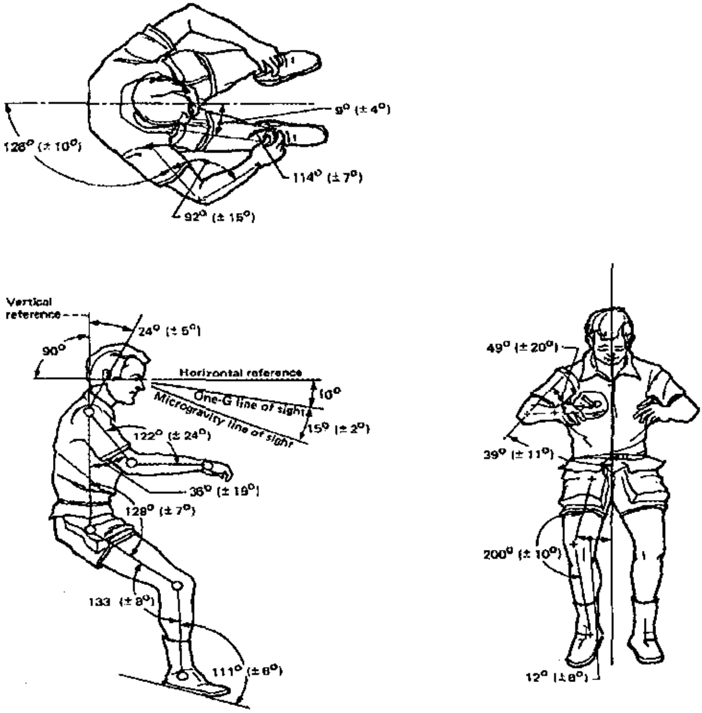


Figure 3.3.2.3.1-1 Joint Movement Ranges for Males and Females (Continued)



Note:
The segment angles shown are means. Values in parentheses are standard deviations about the mean. The data was developed in Skylab and is based on the measurement of 3 subjects.

Figure 3.3.4.3-1 Neutral Body Posture

MSIS 285

3.3.5.3 Body Surface Area Data Design Requirements

3.3.6.3 Body Volume Data Design Requirements

3.3.6.3.1 Whole-Body Volume Data Design Requirements

3.3.6.3.2 Body Segment Volume Data Design Requirements

3.3.7.3 Body Mass Properties Data Design Requirements

3.3.7.3.1 Body Mass Data Design Requirements

3.3.7.3.1.1 Whole-Body Mass Data Design Requirements

3.3.7.3.1.2 Body Segment Mass Data Design Requirements

3.3.7.3.2 Center of Mass Data Design Requirements

3.3.7.3.2.1 Whole-Body Center of Mass Data Design Requirements

3.3.7.3.2.2 Body Segments Center of Mass Data Design Requirements

3.3.7.3.3 Moment of Inertia Data Design Requirements

3.3.7.3.3.1 Whole-Body Moment of Inertia Data Design Requirements

3.3.7.3.3.2 Body Segments Moment of Inertia Data Design Requirements

NOTES

NOTES

4.9.3 Strength Design Requirements

Strength data that shall be used to guide design work are provided below. The weakest crew member in the specified design population shall be accommodated.

(Refer to Ref. 16 for additional data on 1-G strength.)

a. Grip Force:
   1. Grip strength, as a function of the size of the gripped object, is provided for men in Figure 4.9.3-1.

   2. Maximum grip strength for men (5th, 50th, and 95th percentile) is given in Figure 4.9.3-2.

   3. Grip strength for females is shown in Figure 4.9.3-3.

b. Arm, Hand, and Thumb/Finger Strength - Figure 4.9.3-4 presents arm, hand and thumb/finger strength for fifth percentile males. These figures must be corrected for females (see Figure 4.9.3-5).

c. Male/Female Muscular Strength - Figure 4.9.3-5 provides a comparison of male and female muscular strength for different muscle groups. These data allow a more accurate extrapolation from male to female strength data than is provided by the old method of assuming females have two thirds the strength of men.
(Refer to Ref. 16 for more detailed male/female comparison data.)

d. Static Push Force - Maximal static push forces for adult males are shown in Figure 4.9.3-6. While these data were collected in a 1-G situation, the fact that they do not depend on friction resulting from body weight makes them applicable to microgravity. Corrections will have to be made for females (see Figure 4.9.3-5).

e. Leg Strength - Leg strength for the 5th percentile male as a function of various thigh and knee angles is reported in Figure 4.9.3-7. Estimates of female leg strength can be made from these data using the correction factors provided in Figure 4.9.3-5.

f. Torque Strength - Maximum hand torque data are provided in Figure 4.9.3-8.

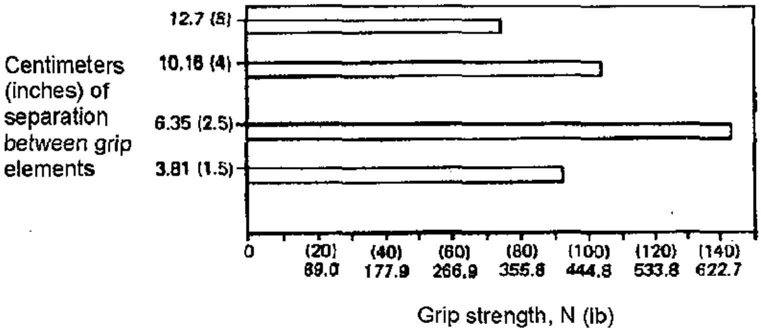


Figure 4.9.3-1 Male Grip Strength as a Function of the Separation Between Grip Elements

MSIS 200

Population	Percentiles, N (lb)			
	5th	50th or mean	95th	Population S.D.
U.S. Air Force personnel, aircrewmen:				
Right hand	467 (105)	596 (134)	729 (164)	80.1 (18.0)
Left hand	427 (96)	552 (124)	685 (154)	71.2 (16.0)

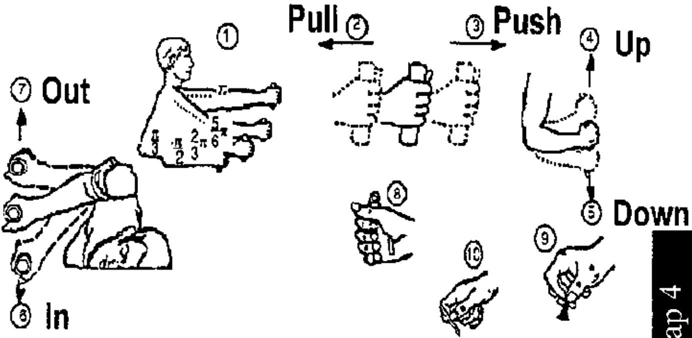
Figure 4.9.3-2 Grip Strength for Males

MSIS 201

Population	Percentiles, N (lb)			Population S.D.
	5th	50th	95th	
U. S. Navy personnel Mean of both hands	258 (58)	325 (73)	387 (87)	39.1 (8.8)
U. S. Industrial workers: Preferred hand	254 (57)	329 (74)	405 (91)	45.8 (10.3)

Figure 4.9.3-3 Grip Strength for Females

MSIS 202



Arm Strength (N)														
(1)	(2)		(3)		(4)		(5)		(6)		(7)	
degree of elbow flexion (rad)	Pull		Push		Up		Down		In		Out	
	L**	R**	L	R	L	R	L	R	L	R	L	R
π	222	231	187	222	40	62	58	76	58	89	36	62
5/6 π	187	249	133	187	67	80	80	89	67	89	36	67
2/3 π	151	187	116	160	76	107	93	116	89	98	45	67
1/2 π	142	155	98	160	76	89	93	116	71	80	45	71
1/3 π	116	107	96	151	67	89	80	89	76	89	53	76

Hand and Thumb- Finger Strength (N)				
	(8)		(9)	(10)
	Hand Grip		Thumb-Finger Grip (Palmer)	Thumb-Finger Grip (Tips)
	L	R		
Momentary Hold	250	260	60	60
Sustained Hold	145	155	35	35

* Elbow angle shown in radians
** L=Left; R=Right

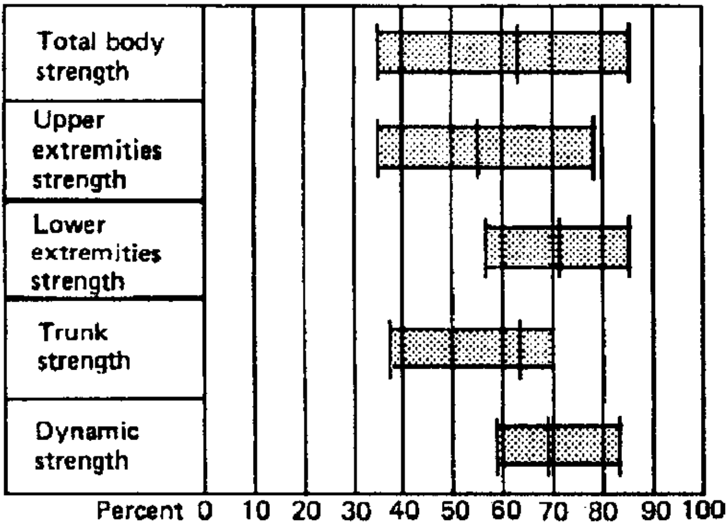
Arm Strength (lb)														
(1)	(2)		(3)		(4)		(5)		(6)		(7)	
degree of elbow flexion deg	Pull		Push		Up		Down		In		Out	
	L**	R**	L	R	L	R	L	R	L	R	L	R
180	50	52	42	50	9	14	13	17	13	20	8	14
150	42	56	30	42	15	18	18	20	15	20	8	15
120	34	42	26	36	17	24	21	26	20	22	10	15
90	32	37	22	36	17	20	21	26	16	18	10	16
60	26	24	22	34	15	20	18	20	17	20	12	17

Hand and Thumb- Finger Strength (lb)				
	(8)		(9)	(10)
	Hand Grip		Thumb-Finger Grip (Palmer)	Thumb-Finger Grip (Tips)
	L	R		
Momentary Hold	56	59	13	13
Sustained Hold	33	35	8	8

** L=Left; R=Right

Figure 4.9.3-4 Arm, Hand, and Thumb/Finger Strength (5th Percentile Male Data)

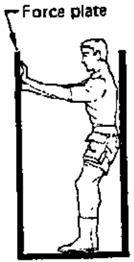
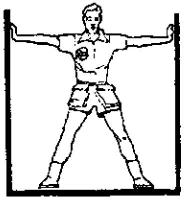
MSIS 203



Note:
Female strength as a percentage of male strength for different conditions. The vertical line within each shaded bar indicates the mean percentage difference. The end points of the shaded bars indicate the range.

Figure 4.9.3-5 Comparison of Female vs. Male Muscular Strength

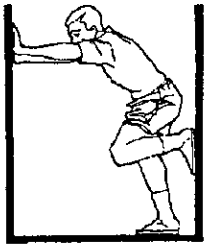
MSIS 204

	Force-plate (1) height	Distances (2)	Force, N (lbf) Means	Force, N (lbf) SD
	100 percent of shoulder height		Both hands	
		50	583 (131)	142 (32)
		60	667 (150)	160 (36)
		70	983 (221)	271 (61)
		80	1285 (289)	400 (90)
		90	979 (220)	302 (68)
		100	645 (145)	254 (57)
			Preferred hand	
		50	262 (59)	67 (15)
		60	298 (67)	71 (16)
		70	360 (81)	98 (22)
		80	520 (117)	142 (32)
		90	494 (111)	169 (38)
		100	427 (96)	173 (39)
		Percent of thumb-tip reach *		
	100 percent of shoulder height	50	369 (83)	138 (31)
		60	347 (78)	125 (28)
		70	520 (117)	165 (37)
		80	707 (159)	191 (32)
		90	325 (73)	133 (30)
		Percent of span **		

Chap 4

Figure 4.9.3-6 Maximal Static Push Forces

MSIS 205, 1 of 2

	Force-plate (1) height	Distances (2)	Force, N (lbf)	
			Means	SD
	50 50 70	100 120 120	774 (174) 778 (175) 818 (184)	214 (48) 165 (37) 138 (31)
	Percent of shoulder height		1-g applicable data	

Notes:

(1) Height of the center of the force plate — 200 mm (8 in.) high by 254 mm (10 in.) long — upon which force is applied.

(2) Horizontal distance between the vertical surface of the force plate and the opposing vertical surface (wall or footrest, respectively) against which the subject brace themselves.

* Thumb-tip reach — distance from backrest to tip of subject's thumb as thumb and fingertips are pressed together.

** Span - the maximal distance betwen a person's fingertips as he extends his arms and hands to each side.

(3) 1-g data

Figure 4.9.3-6 Maximal Static Push Forces (continued)

MSIS 205, 2 of 2

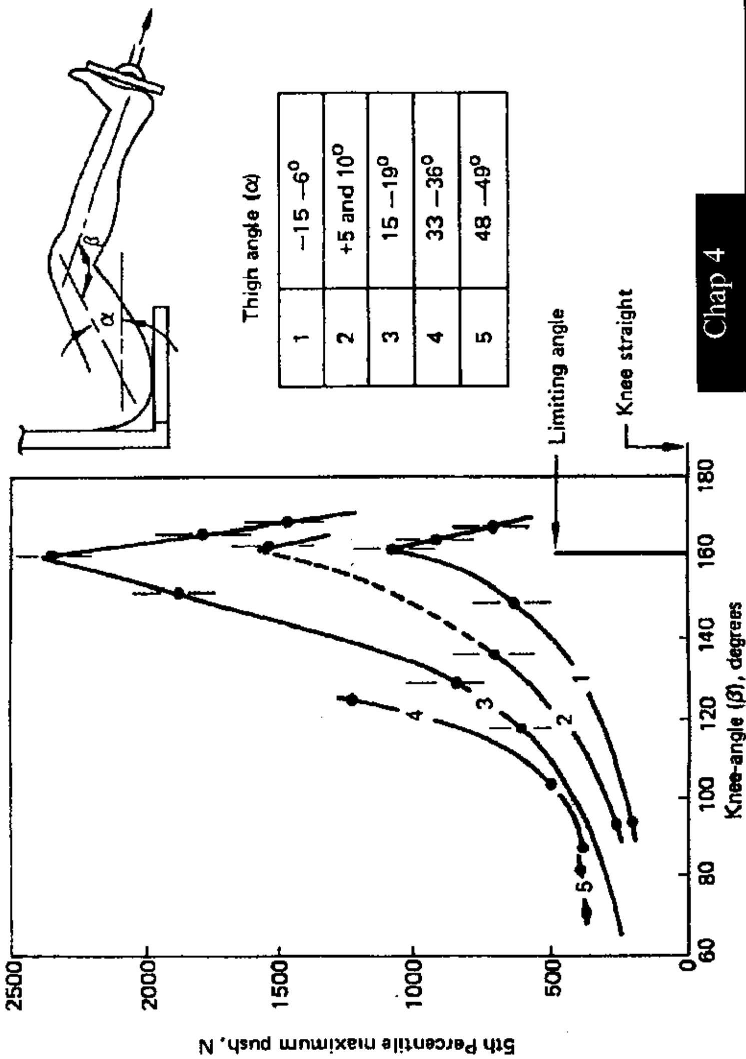


Figure 4.9.3-7 Leg Strength at Various Knee and Thigh Angles (5th Percentile Male Data)

MSIS 206

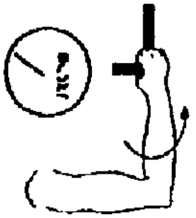
	Unpressurized suit, bare handed	
	Mean	SD
 Maximum torque: Suppination, Nm (lb-in.)	13.73 (121.5)	3.41 (30.1)
 Maximum torque: Pronation, Nm (lb-in.)	17.39 (153.9)	5.08 (45.0)

Figure 4.9.3-8 Torque Strength

MSIS 207

NOTES

NOTES

5.1.3.1 Long-Term Mission Atmosphere Composition and Pressure Design Requirements

The following design considerations shall apply to the composition and pressure of the space module cabin atmosphere:

a. Internal Environment - An internal environment shall be provided adequate to support and maintain crew comfort, convenience, health, and well being throughout all operational phases in accordance with the requirements given in Figure 5.1.3.1-1.

(Refer to Paragraph 5.8.3.1, Temperature, Humidity, and Ventilation Design Requirements, for other atmosphere related design requirements.)

c. Atmosphere Control and Supply :

2. The total pressure of the module shall be maintained at the pressure levels defined in Figure 5.1.3.1-1.

3. The controls shall be provided in each isotable volume of the module and shall be operable by a crewmember in a shirt sleeve environment or by a crewmember wearing a pressure suit or by a remote operator.

4. Normally, the controls shall operate autonomously with limited or no crew intervention necessary.

d. ECLSS Design Requirements :

1. The systems of the ECLSS will provide atmospheric pressure and composition control, module temperature and humidity control, atmospheric revitalization, water management, EVA support, and fire and contamination monitoring and control.

2. The ECLSS shall accommodate whatever phased evolutionary growth is anticipated for the space module.

3. The ECLSS shall embody regenerative concepts to minimize the use of expendables.

e. Hyperbaric Treatment - Where altitude decompression sickness may occur as a result of operational activity or contingency operation, access to a hyperbaric treatment facility is required.

5.1.3.2 Long Term Mission Atmosphere Monitoring Design Requirements

Atmospheric monitoring instruments shall require as little crew time as possible for operation and maintenance.

5.1.3.3 Long Term Mission Atmosphere Toxicological Monitoring Design Requirements

Design considerations for monitors of volatile organics, airborne particulate matter, and compound-specific monitors are as follows:

a. Monitoring Volatile Organics - The monitoring of volatile organics shall be accomplished.

1. The overall organic concentration in the atmosphere of all habitable areas shall be monitored. Continuous real time indication of total organic contamination in the air shall be provided.

2. An additional monitor shall be available. The ability to unequivocally identify and quantify each organic compound and take measurements at regularly scheduled intervals shall be available.

Parameter	Units	Operational	90-day degraded (1)	28-day emergency
CO_2 partial press	mmHg	3.0 max	7.6 max	12 max
Temperature (7)	deg. F	65-80	65-80	60-85
Dew point (2)	deg. F	40-60	35-70	35-70
Ventilation	ft/min	15-40	10-100	10-200
O_2 partial pressure (3)	psia	2.83-3.35	2.4-3.45	2.3-3.45
Total pressure	psia	14.5-14.9	14.5-14.9	14.5-14.9
Diluent gas		N_2	N_2	N_2
Trace contaminants (6)	ppm	TBD	TBD	TBD
Micro-organisms	CFU/m^3 (4)	500 (5)	750 (5)	1000 (5)
Particulates > 0.5 micron	counts/ft^3	100,000 max	TBD	TBD

(a) Respirable Atmosphere Requirements (Customary Units)

Figure 5.1.3.1-1 Requirements for Space Module Respirable Atmosphere

MSIS 72, 1 of 2

Parameter	Units	Operational	90-day degraded (1)	28-day emergency
CO_2 partial press	N/m^2	400 max	1013 max	1600 max
Temperature (7)	deg. K	291.5-299.9	288.8-302.6	288.8-305.4
Dew point (2)	deg. K	277.6-288.7	273.9-294.3	273.9-294.3
Ventilation	m/sec	.076-.203	.051-.508	.050-1.016
O2 partial pressure (3)	kP_2	19.5-23.1	16.5-23.8	15.9-23.8
Total pressure	kP_2	100-101.4	100 -101.4	100-101.4
Dilute gas	———	N_2	N_2	N_2
Trace contaminants (6)	mg/m^3	TBD	TBD	TBD
Micro-organisms	CFU/m^3 (4)	500 (5)	750 (5)	1000 (5)
Particulates > 0.5 micron	$counts/m^3$	3,530,000 max	TBD	TBD

(b) Respirable Atmosphere Requirements (SI Units)

Notes:

(1) Degraded levels meet "fail operational" criteria.

(2) Reletive humidity shall not exceed 70% in the operational mode or 75% in the degraded mode or 75% in the degraded or emergency moode and shall not be less than 25%

(3) In no case shall the O_2 partial pressure be below 15.9 kP_2 (2.3 psia) or the O_2 concentration exceed 23.8 % of the total pressure at 14.7 psia

(4) CFU- Colony Forming Units

(5) These values reflect a limited base. No widely sanctioned standards are available

(6) Will be based on NHB 8060.1B, (J8400003)

(7) In the operational mode temperature will be selectable to ± 1.1°C (±2°F) throughout the range

Figure 5.1.3.1-1 Requirements for Space Module Respirable Atmosphere

MSIS 72, 2 of 2

b. Compound-Specific Monitoring:

1. The capability to monitor specific compounds shall be provided near equipment, chemical operations and processing activities which are potential sources of chemical contamination of the space module.

2. This monitoring capability shall include audible and visible alarms to alert crewmembers when contaminant concentrations exceed maximum acceptable levels.

c. Particulate Size Ranges - Real-time particulate matter monitoring shall be provided for detection of the following size ranges:

1. Respirable particles in the 0.5-10 micron range.

2. Large visible particles.

5.1.3.4 Atmosphere Microbiological-Monitoring & Control Design Considerations

The microbiological monitoring and control design considerations are as follows.

a. Limits - The limits given in Figure 5.1.3.4-1 shall be observed.

b. Air Sampler - Monitoring of the air will be conducted. An air sampler shall monitor air throughout the habitable areas of the facility. It shall be capable of monitoring for the presence of bacteria, yeast and molds.

5.1.3.4.1 Microbial Decontamination Design Requirements

Decontamination is needed when acceptability limits are exceeded or sensory factors indicate microbial contamination has occurred.

5.3.3 Acceleration Design Requirements

(Refer to Figure 5.3.2.4-1 for impact acceleration survival)

5.3.3.1 Linear Acceleration Design Requirements

The following linear acceleration design requirements shall be observed:

a. Linear Acceleration Limits for Unconditioned and Suitably Restrained Crewmembers - The accelerations in any vector shall not exceed those magnitudes and durations specified in Figure 5.3.3.1-1.

b. Linear Acceleration Limits for Preconditioned and Suitably Restrained Crewmembers - Accelerations shall not exceed those magnitudes and durations specified in Figure 5.3.3.1-2.

(Refer to Paragraph 11.7.2.3.3.2, Body Restraint Loads, for seat belt and shoulder harness design loads.)

5.3.3.2 Rotational Acceleration Design Requirements

The following rotational acceleration design requirements for rotation about the pitch axis shall be observed:

a. Rotational Acceleration Limits With Center of Rotation at the Heart - Accelerations shall not exceed the limits specified in Figure 5.3.3.2-1.

b. Rotational Acceleration Limits with a G Field Decaying from 35 to 15 G's - Accelerations shall not exceed the limits specified in Figure 5.3.3.2-2.

Sample source	Monitoring Requirements		Postflight	Acceptability Limit
	Preflight	Inflight		
Air	Prior to closeout	Weekly intervals and within 12 hrs of crew exchange	—	Levels of airborne microorganisms may not exceed 500 CFU per cubic meter

Figure 5.1.3.4-1 Atmosphere Microbiological Limits and Monitoring Requirements

MSIS 73

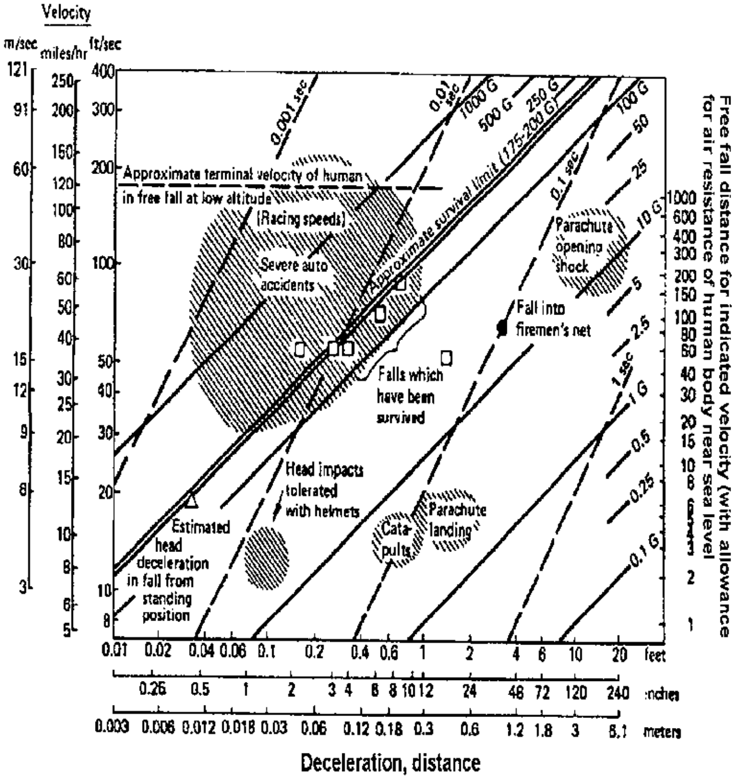


Figure 5.3.2.4-1 Impact Survival Experience

MSIS 49

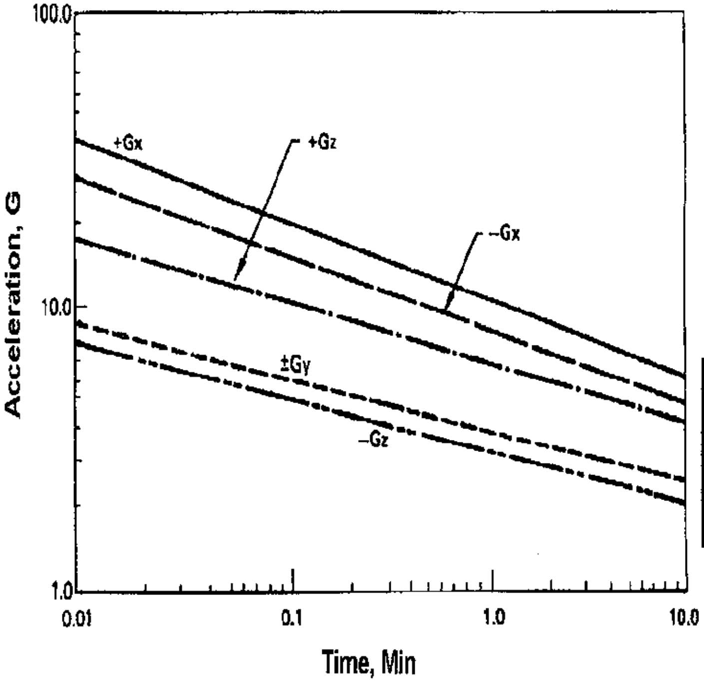


Figure 5.3.3.1-1 Linear Acceleration Limits for Unconditioned and Suitably Restrained Crewmembers

MSIS 50

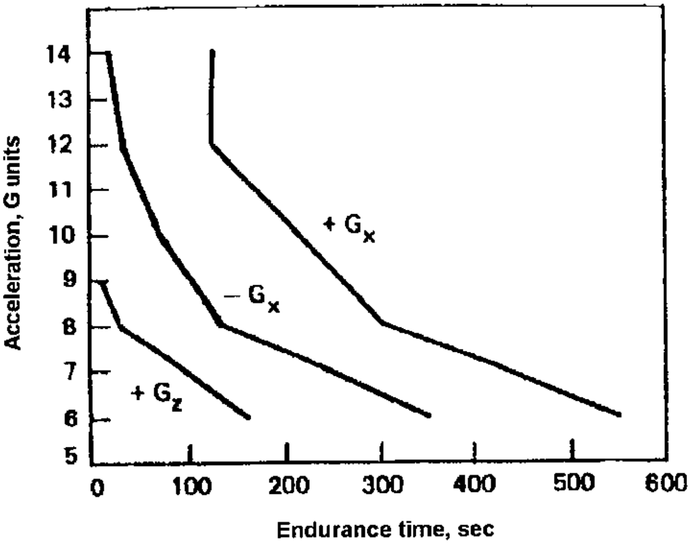


Figure 5.3.3.1-2 Linear Acceleration Limits for Pre-Conditioned and Suitably Restrained Crewmembers

MSIS 51

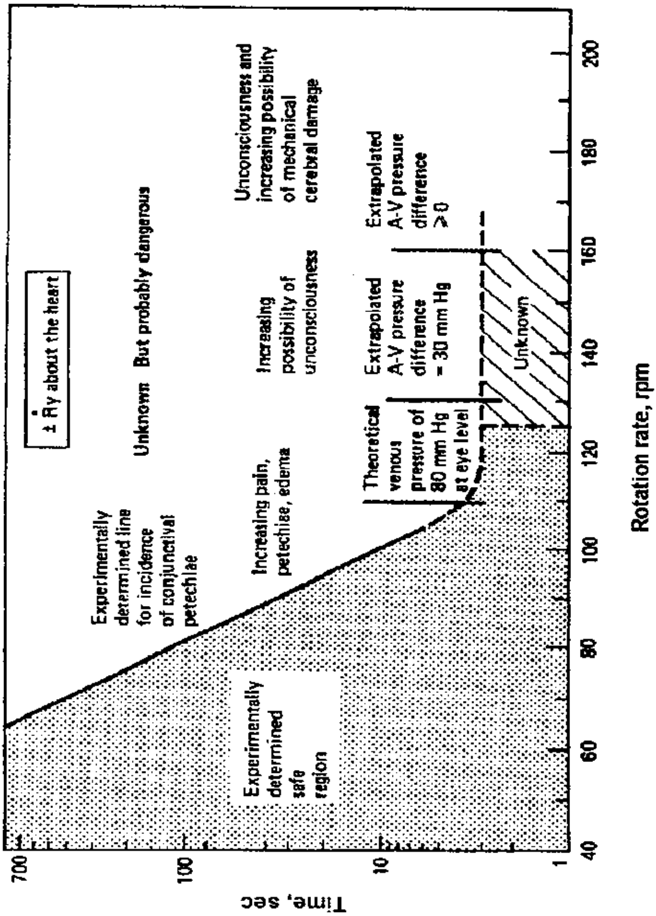


Figure 5.3.3.2-1 Rotational Acceleration Limits for Rotation About the Pitch Axis With No Superimposed Deceleration Field With Center of Rotation at the Heart

MSIS 52

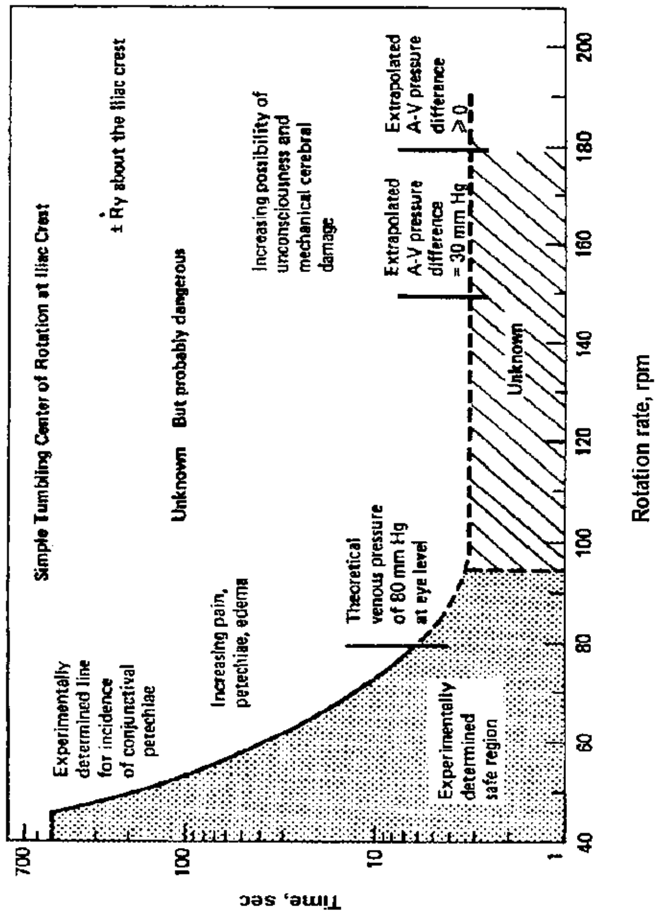


Figure 5.3.3.2-2 Rotational Acceleration Limits for Rotation About the Pitch Axis With No Superimposed Deceleration Field With Center of Rotation at the Iliac Crest

MSIS 53

5.4.3 Acoustics Design Requirements

This section defines the basic environmental limitations and criteria that the designer shall apply to the design of crew stations and other habitable compartment areas.

Noise levels shall be specified in terms of A-weighted sound level, L(A). Noise exposure over 24 hour periods shall be specified in terms of the equivalent A-weighted sound level La eq. The maximum allowable on orbit continuous broad band sound pressure exposure limits produced by the summation of all individual sound pressures from all sources, including all operating systems, subsystems and payloads, considered over a 24 hour period are defined in the following paragraphs.

5.4.3.1 General Acoustic Design Requirements

The following general acoustic design requirements shall be observed:

a. General Acoustic Design - Noise generation and penetration shall be controlled to the extent that acoustic energy will not cause personnel injury, interfere with voice or any other communications, induce fatigue, or contribute to the degradation of overall man-machine effectiveness.

   (All sound pressure levels in decibels are referenced to 20 u-Pascals unless otherwise stated and are to be measured at or translated to the outer ears of crewmembers.)

b. Equipment Noise:

   1. Equipment shall be designed to meet noise requirements of MIL-STD-1474B.

   2. All noisy equipment shall be mounted and located to reduce noise at crewmember stations.

   3. System designs shall include noise control provisions.

   4. Means shall be provided on-board to facilitate measurement of acoustic noise levels to verify that exposure limits are not being exceeded.

5.4.3.2 Noise Exposure Requirements

The following types of noise shall be taken into account:

a. Wide-band random noise (22.4 to 11,200 Hz).

b. Narrow-band noise and tones.

c. Impulse noise.

d. Infrasonic and ultrasonic noise.

There are three sets of noise requirements that shall be satisfied depending on crewmember task and acceleration regimes: 1) hearing conservation, 2) voice communication, and 3) annoyance.

5.4.3.2.1 Hearing Conservation Noise Exposure Requirements

a. Maximum Noise Exposure - A maximum noise exposure of 115 dB(A) is allowable, providing the duration does not exceed two minutes during a 24-hour period.

b. Hearing Protection Devices - Hearing protection devices shall be provided for use during exposure to noise levels of 85 dB(A) or greater.

5.4.3.2.1.1 Wide-Band, Long-Term Hearing Conservation Noise Exposure Requirements

The following long-term, wide-band hearing conservation noise exposure criteria shall apply:

a. Hazard Level - Noise of constant sound levels of 85 dB(A) and greater are considered hazardous regardless of the duration of exposure. Total exposure during a 24-hour period shall not exceed an average of 80dB(A).

b. Allowable Noise Exposure - A noise exposure below 84 dB(A) for up to eight hours duration without hearing protection is allowable but not desirable.

c. Unacceptable Noise Levels - Crewmembers shall not be exposed to continuous noise levels that exceed 120 dB in any octave band or 135 dB OASPL under any circumstances.

5.4.3.2.1.2 Narrow-Band, Long-Term Hearing Conservation Noise Exposure Requirements

The relative sound pressure levels of narrow-band components, pure-tones, and beat frequencies shall be limited to a level at least 10 dB lower than the allowed maximum sound pressure level of the octave-band that contains the component.

5.4.3.2.1.3 Impulse Hearing Conservation Noise Exposure Requirements

Maximum Noise Level (Hearing Conservation Criteria) - Impulse sound is a change in sound pressure level of more than 10 dB in one second or less. Impulse noise shall not exceed 140 dB peak pressure level to meet hearing conservation criteria for unprotected ears.

(See MIL-STD-1474B regarding the relationship between the number of daily exposures, the corresponding peak levels, B-duration values, and the required hearing protection devices when impulse peak pressure levels exceed 140 dB.)

5.4.3.2.1.4 Infrasonic, Long-Term Annoyance Noise Exposure Requirements

The following infrasonic noise annoyance criteria shall apply:

a. Infrasound Sound Pressure Level - Infrasound sound pressure level shall be less than 120 dB in the frequency range of 1 to 16 Hz for 24-hour exposure.

b. Hearing Protection - Passive hearing protection devices shall not be a method for low-frequency infrasound noise control.

5.4.3.2.1.5 Ultrasonic, Long-Term Annoyance Noise Exposure Requirements

The following ultrasonic noise annoyance criteria shall apply:

a. Hearing Conservation Measures - Hearing conservation measures shall be initiated when the ultrasonic criteria provided in Figure 5.4.3.2.1.5-1 are exceeded.

b. Hearing Protection - Ultrasonic noise hearing protection shall be provided where overexposure is possible in contingency cases in a way that communication is not hampered.

5.4.3.2.2 Voice Communication Noise Exposure Requirements

5.4.3.2.2.1 Direct Voice Communications Noise Exposure Requirements

The following noise level criteria shall apply to areas where voice communications are necessary:

One-third octave band center frequency, kHz	One-third octave band level in dB
10	80
12.5	80
16	80
20	105
25	110
31.5	115
40	115

Figure 5.4.3.2.1.5-1 Airborne High Frequency and Ultrasonic Hazard Noise Limits

MSIS 401

a. Voice Communication Criteria - The communication criteria shown in Figure 5.4.3.2.2.1-1 shall be used to define maximum noise level based on voice communication requirements.

b. Background Noise Level - Background noise for work areas shall not exceed the NC- 50 contour unless otherwise specified. (Refer to Figure 5.4.3.2.3.1-1).

c. Room reverberation time -

1. The reverberation time of a spacecraft compartment shall be adjusted according to room volume and the criterion for conversational speech as shown in Figure 5.4.3.2.2.1-2.

2. In areas where crewmember display users must communicate by voice, provide a room reverberation time of approximately 0.5 seconds.

3. Reverberation time shall be verified utilizing the natural frequency of the system.

5.4.3.2.2.2 Indirect Voice Communications Noise Exposure Requirements

The following intelligibility criteria for Articulation Index (AI) shall apply:

a. Very Good to Excellent Intelligibility - AI = 0.7 to 1.0.

b. Good Intelligibility - AI = 0.5 to 0.7.

c. Generally Acceptable Intelligibility - AI = 0.3 to 0.5.

d. Unsatisfactory or Only Marginally Satisfactory - AI = 0.0 to 0.3.

Reference Figure 5.4.2.4.2.2-1.

5.4.3.2.3 Annoyance Noise Exposure Requirements

5.4.3.2.3.1 Wide-Band, Long-Term Annoyance Noise Exposure Requirements

The following long-term, wide-band annoyance noise criteria shall apply:

a. Maximum Continuous Noise - The maximum allowable continuous broad band sound pressure levels produced by the summation of all the individual sound pressure levels from all operating systems and subsystems considered at a given time shall not exceed the Noise Criteria (NC) 50 contour for work periods and the NC 40 contour for sleep compartments shown in Figure 5.4.3.2.3.1-1. Also see Figure 5.4.3.2.3.1-2 for correlation of the NCcurves to the A-Weighted sound pressure levels

b. Sleep Compartment Noise Level

1. In sleep areas, the continuous broad-band noise level shall not be less than NC25 contour.

2. Hearing protection devices shall be available in sleep areas to provide aural isolation as needed.

5.4.3.2.3.2 Narrow-Band Annoyance Noise Exposure Requirements

The maximum SPL of any narrow-band continuous component or tone shall be at least 10 dB less than the broad-band SPL of the octave-band which contains the component.

5.4.3.2.3.3 Wide-Band, Short-Term Annoyance Noise Exposure Requirements

The wide-band annoyance noise level as a result of long-term and short-term (less than five minutes) noise shall not exceed an L_{eq} (8-hours) of 32 dB during the sleep period. Intermittent noises shall be minimized.

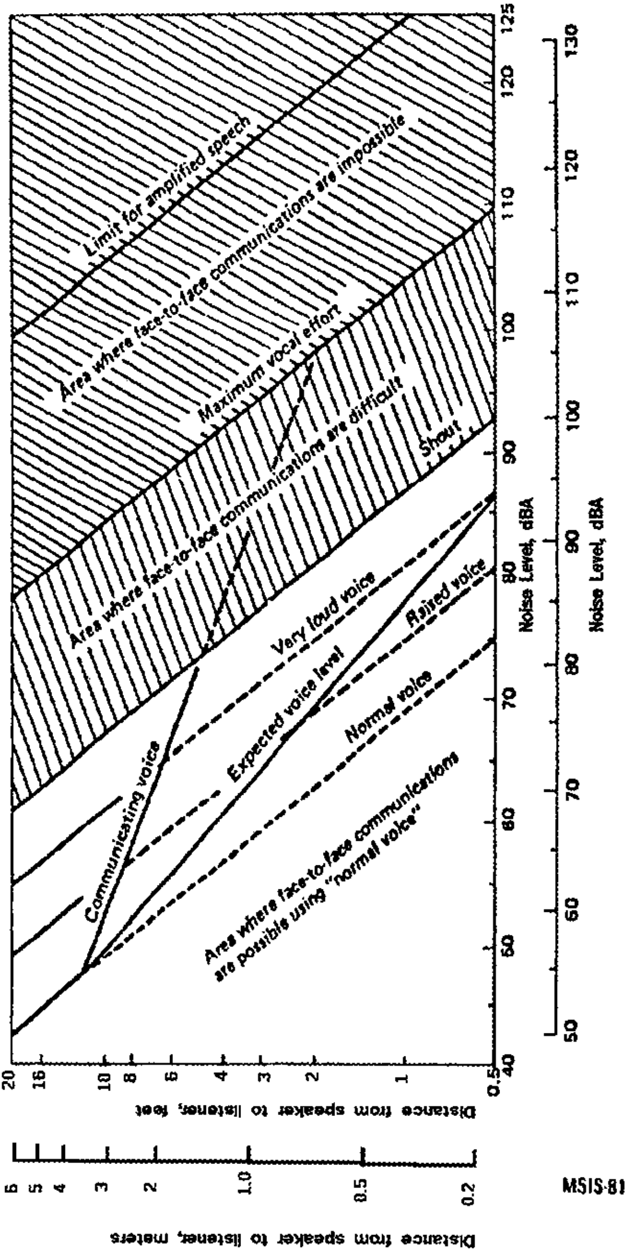


Figure 5.4.3.2.2.1-1. PSIL and Effective Communication Distance

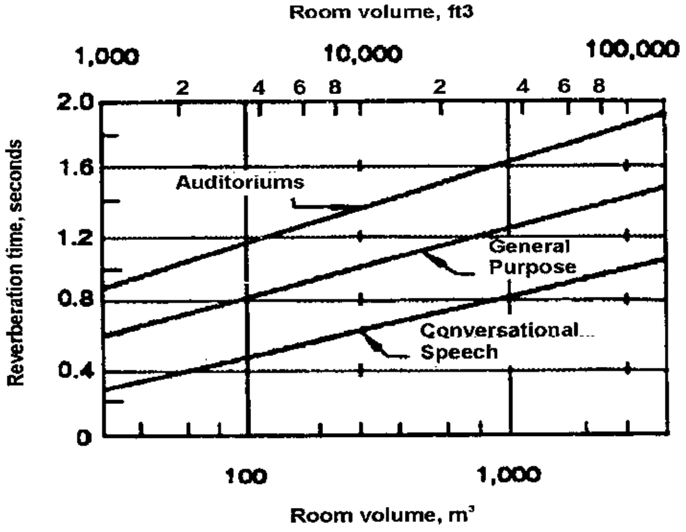


Figure 5.4.3.2.2.1-2 Preferred Reverberation Time

MSIS 82

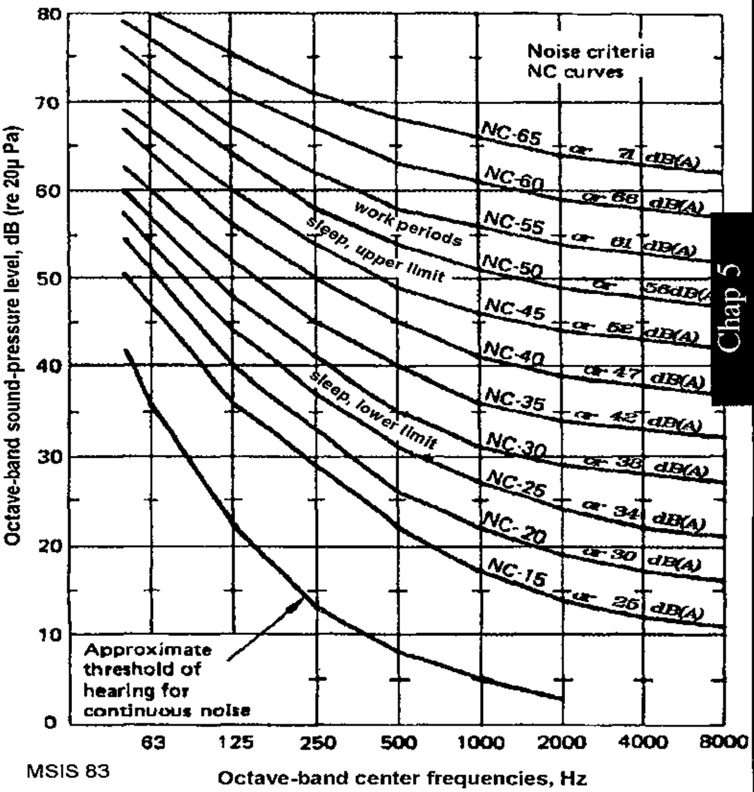
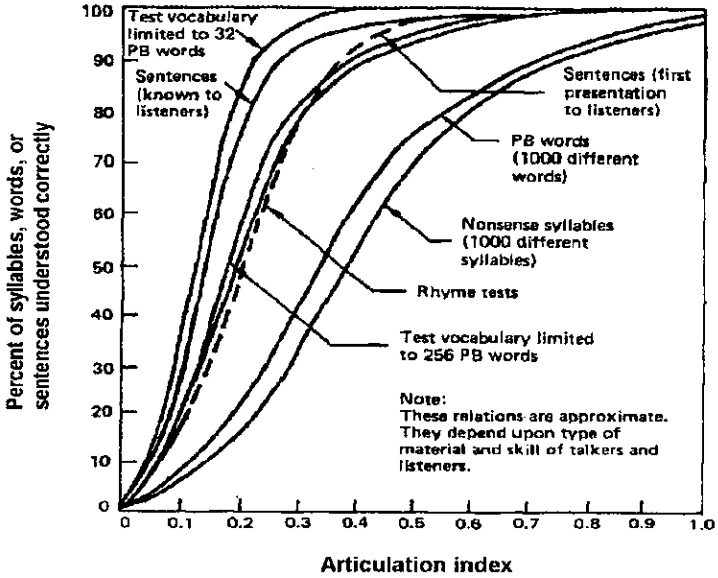


Figure 5.4.3.2.3.1-1 Indoor Noise Criteria (NC) Curves



PB=Phonetically Balanced
(see Paragraph 5.4.3.2.2.2 for AI Criteria)

Figure 5.4.2.4.2.2-1 Articulation Index and Speech Intelligibility

MSIS 79

NC Curve	A-Weighted Sound Pressure Level dB(A)
70	78
65	71
60	66
55	61
50	56
45	52
40	47
35	42
30	38
25	34
20	30
15	25

Figure 5.4.3.2.3.1-2 A-Weighted Sound Pressure Level as Weighted to the NC Curve

MSIS 432

5.4.3.2.3.4 Impulse Annoyance Noise Exposure Requirements

The following impulse noise annoyance criteria shall apply:

a. Sleep/Rest Periods - Anticipated impulse or transient noises shall not exceed background noise by more than 10 dB during sleep/rest periods.

b. Masking Noise:

1. Masking noise generation to cover-up impulse or fluctuating noise is not a preferred solution but, where utilized, it shall not exceed 55 dB(A) at the crewmember's ear.

2. Masking noise level and spectrum shape shall be under the control of crewmembers.

5.7.2.2.2 Ionizing Radiation Protection Design Requirements

Polar Platform servicing missions will be conducted using the NSTS orbiter so NSTS flight rules will prevail.

The following strategies shall be used to implement radiation protection features for crewmembers on the space module at 28.5 deg:

a. Radiation Protection - The design of the space module shall include the necessary radiation protection features (shielding, radiation monitoring and dosimetry, etc.) for all expected missions to ensure that the crew dose rates are kept as low as reasonably achievable (ALARA levels) and that the maximum allowable dose limits are not exceeded.

b. Use of Onboard Mass - The design and layout of the space module shall make optimal use of onboard mass as radiation shielding.

c. Radiation Contingency Plans - Contingency plans for crew protection during radiation emergencies shall be provided.

d. Mission Radiation Control Program - A mission radiation control program shall be omstituted to establish procedures and responsibilities consistent with the expected mission environment and duration of orbital stay in order to keep radiation exposures to crew at ALARA levels and within the established radiation exposure limits.

e. Radioactive Substances - Safe procedures shall be established for the handling, containment and disposal of radioactive substances or radioactively contaminated materials.

f. Cumulative Crewmember Radiation Dose - The radiation dose equivalent accumulated by each space module crewmember shall be monitored throughout the active career of all crewmembers. Thus, career, as well as mission dose equivalent levels shall be kept ALARA, thereby ensuring that the maximum career dose equivalent limit shall not be exceeded.

5.7.2.2.3 Ionizing Radiation Monitoring and Dosimetry Design Requirements

The following design requirements shall be observed to limit the radiation dose that the crewmembers could acquire during a given mission on the space module:

a. Radiation Monitoring - The accumulated radiation dose within the occupied areas of the space module shall be monitored and recorded for all missions. Radiation dose rates within the spacecraft shall also be monitored and recorded.

b. Crewmember Radiation Dose Monitoring - For each crewmember the radiation dose shall be measured, recorded, the effective dose equivalent calculated and stored as part of the crew's radiation exposure history.

c. Charged Particle Monitoring - Proton and other particle fluxes and their energy spectrum within the space module shall be monitored and recorded. Particle radiation characteristics such as particle direction and secondary particle flux, (i.e., neutrons) shall be monitored.

d. Location of Radiation Detectors - The location and characteristics of the onboard radiation detectors shall be consistent with the expected radiation environment.

e. Radiation Dose Management System - A radiation dose management system shall be provided for keeping track of crew cumulative radiation exposure records, scheduling and assigning crew activities and alerting personnel that are approaching their radiation dose limits.

f. Radiation Event Warning - A radiation detection system shall be provided which continuosly monitors the interior radiation levels, records the accumulated dose, and can be read ouit on command from Mission Control and provides clear notification of radiation conditions within the space module.

5.7.2.2.4 Ionizing Radiation Personnel Protection Design Requirements

The following personnel protective equipment shall be provided, or be available, to assist and protect crewmembers during their mission:

a. EVA Radiation Protection - EVA shall not be scheduled during orbits passing through the South Atlantic Anomaly unless space suits and helmets incorporate radiation shielding.

b. Protective IVA Garmets - Personal shielding devices, which are to be worn if and when the crew encounters high radiation conditions, are being considered for each space module crewmember.

c. Radioactive Contamination Control - Protective garments, equipment and procedures shall be established for dealing with possible radioactive contamination associated with any of the manmade radiation sources onboard.

5.8.3 Thermal Environment Design Requirements

Paragraphs 5.8.3.1 and 5.8.3.2 provide the design requirements for spacecraft cabin thermal environments.

5.8.3.1 Temperature, Humidity, and Ventilation Design Requirements

See Paragraph 5.1.3.1

5.8.3.2 **Thermal Monitoring and Control Design Requirements**

The following requirements shall apply to the monitoring and control of the space cabin thermal environment:

(Refer to Paragraph 9.3, Controls, and Paragraph 9.4, Displays, for specific details on control and display requirements)

a. Monitoring of Thermal Environment -

1. Monitoring of cabin temperature and relative humidity shall be provided.

2. Monitoring of the thermal environment shall be fully automatic. The number, type, and location of temperature sensors and the frequency of monitoring shall be such as to ensure measurement of representative cabin temperature and to allow stable control of those temperatures.

3. Visual and audible alarms shall be automatically initiated when thermal parameters exceed the limits given in Paragraph 5.8.3.1.

(Refer to Paragraph 9.4.4, Caution and Warning Displays, for specific requirements for implementing the caution and warning system.)

b. Adjustment of Thermal Environment by the Crew - Crewmembers shall be provided with controls that allow them to modify temperatures, humidity, and ventilation rates inside the space module within the ranges for these parameters as specified in Paragraph 5.8.3.1.

c. Sleep Compartment, Personal Hygiene Area, and Waste Management Compartment Thermal Environment Controls - Temperature and ventilation shall be maintained in each of the private crew quarters, the personal hygiene area, and the waste management compartment, and shall be controlled in each of these areas within the range of these parameters.

d. Portable Fans - If activity stations are isolated from the module air circulation systems, auxiliary airflow and/or portable fans shall be provided.

e. Exercise Station Perspiration Control - Each exercise station shall be provided with a method of sweat removal and collection.

NOTES

NOTES

6.2 GENERAL SAFETY

6.2.2. General Safety Design Considerations

6.2.3 General Safety Design Requirements

6.3.3 Mechanical Hazards Design Requirements

Design requirements for the elimination of burrs, corners, edges, protrusions, pinching, snagging, and cutting for IVA are given in this section:

(Refer to Paragraph 14.1.3, EVA Safety Requirements, for comparable EVA requirements.)

6.3.3.1 Corner and Edge Requirements

a. Exposed edges 6.4 mm (0.25 in.) thick or greater shall be rounded to a minimum radius of 3.0 mm (0.12 in.) as shown in Figure 6.3.3.1-1.

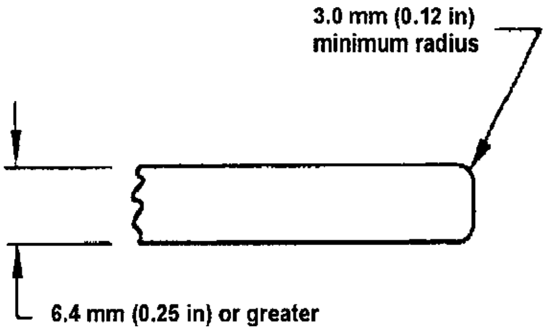


Figure 6.3.3.1-1 Requirements for Rounding Exposed Edges 6.4 mm (0.25 in) Thick or Thicker

MSIS 4

b. Exposed edges 3.0 to 6.4 mm (0.12 to 0.25 in.) thick shall be rounded to a minimum radius of 1.5 mm (0.06 in.) as shown in Figure 6.3.3.1-2.

c. Exposed edges 0.6 to 3.0 mm (0.02 to 0.12 in.) thick shall be rounded to a full radius as shown in Figure 6.3.3.1-3.

d. The edges of thin sheets less than 0.5 mm (0.02 in.) thick shall be rolled or curled as shown in Figure 6.3.3.1-4.

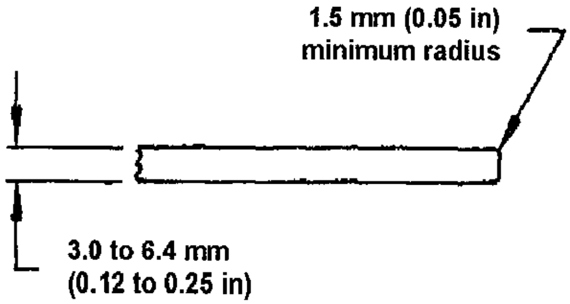


Figure 6.3.3.1-2 Requirements for Rounding Exposed Edges 3.0 to 6.4 mm (0.12 to 0.25 in) Thick

MSIS 5

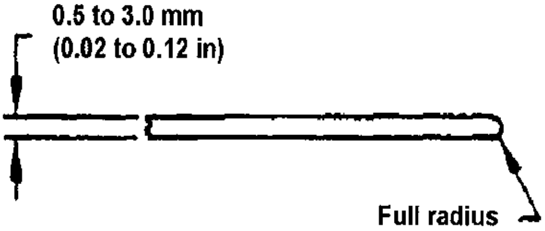


Figure 6.3.3.1-3 Requirements for Rounding Exposed Edges 0.5 to 3.0 mm (0.02 to 0.12 in) Thick

MSIS 6

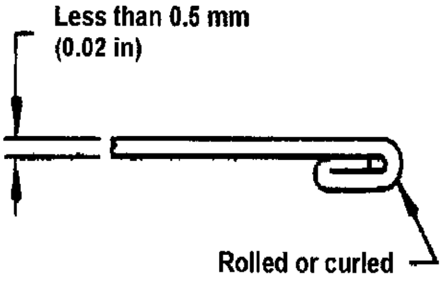


Figure 6.3.3.1-4 Requirements for Curling of Sheets Less Than 0.5 mm (0.02 in) Thick

MSIS 7

6.3.3.2 Exposed Corner Requirements

a. Exposed corners of materials less than 25 mm (1.0 in.) thick shall be rounded to a minimum radius of 13 mm (0.5 in.), as shown in Figure 6.3.3.2-1.

b. Exposed corners of materials which exceed 25 mm (1.0 in.) thickness shall be rounded to 13 mm (0.5 in.) spherical radius, as shown in Figure 6.3.3.2-2.

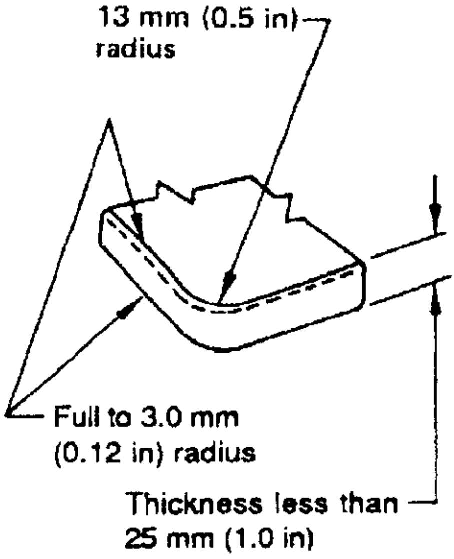


Figure 6.3.3.2-1 Requirements for Rounding of Corners Less Than 25 mm (1.0 in) Thick

MSIS 8

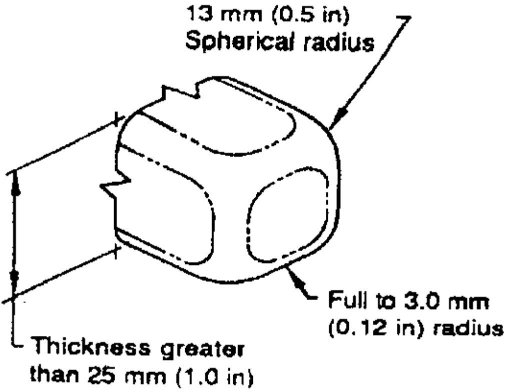


Figure 6.3.3.2-2 Requirements for Rounding of Corners Greater Than 25 mm (1.0 in) Thick

MSIS 9

6.3.3.3 Protective Covers on Exposed Protrusions Requirements

Protective covers, cases, or padding shall be used on protrusions or other hazardous objects that cannot be made completely hazard free.

6.3.3.4 Holes Requirements

Holes that are uncovered and are round or slotted in the range of 10.0 to 25.0 mm (0.4 to 1.0 in) shall be avoided.

6.3.3.5 Latches Requirements

Latches or similar devices that can pinch fingers shall not be used. A protective guard or cover shall be used where suitable substitutes cannot be found.

6.3.3.6 Screws and Bolts Requirements

Screws or bolts with more than two exposed threads shall be capped to protect against the sharp threads.

6.3.3.7 Securing Pins Requirements

Securing pins in handrails shall be designed to prevent their inadvertently backing out above the handhold surface.

6.3.3.8 Levers, Cranks, Hooks, and Controls Requirements

Levers, cranks, hooks, and controls shall not be located where they can pinch, snag, or cut the crewmember or clothing.

6.3.3.9 Burrs Requirements

Exposed surfaces that can be grasped by the bare hand shall be free of burrs.

6.3.3.10 Mechanically Stored Energy Requirements

Mechanical devices capable of storing energy (such as springs, levers, and torsion bars) shall be avoided in spacecraft design. Bungee cords are acceptable.

a. Safety Features - Where stored energy devices are necessary, safety features such as removal tabs, locks, protective devices, and warning placards shall be provided.

b. Stored Energy Release - Spring-loaded devices (i.e., bungee restraints) shall provide means for releasing stored energy forces.

c. Backlash - Stored energy devices shall not generate a backlash.

6.4.3 Electrical Hazards Design Requirements

Equipment design shall protect the crewmembers from electrical hazards. See Figure 6.4.3-1 for general information regarding electrical voltage, current, and frequency exposure criteria and the range of physiological effects thereof.

6.4.3.1 Chassis Leak Current Requirements

Crewmembers shall not be exposed to excessive levels of leak current from contact with the exterior of electrically powered equipment. The maximum chassis leak current shall not exceed 100 microamperes rms for frequencies from dc to 1000 Hz. For frequencies above 1000 Hz, the limit is increased in accordance with Figure 6.4 .3.1-1. Electrical equipment shall meet this maximum current limitation for any combination of the following conditions:

1. Electrical supply polarity normal and reversed.
2. Power switch on and off.
3. Ground open and intact.

6.4.3.2 Crewmember Applied Current Requirements

Crewmembers shall not be exposed to excessive levels of current from electrically powered equipment attached to the crewmember's body. The maximum applied current shall not exceed 50 microamperes rms for frequencies from DC to 1000 Hz for external skin surface or invasive (readily accessible mucous membranes and breached skin) crewmember connections. For frequencies above 1000 Hz, the limit is increased in accordance with Figure 6.4.3.1-1. Electrical equipment shall meet this maximum current limitation for any combination of the following conditions:

1. Electrical supply polarity normal and reversed.
2. Power switch on and off.
3. Ground open and intact.

6.4.3.3 Crewmember Protection Requirements

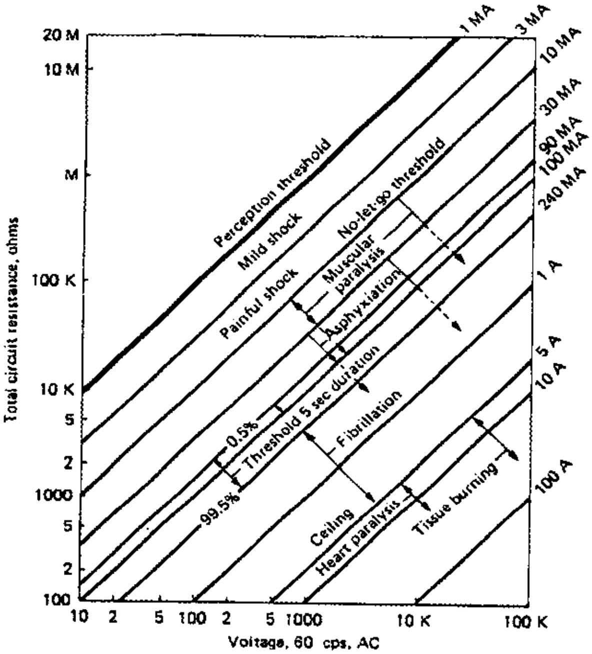
Crewmembers shall be protected from electrical hazards by one or more of the following methods:

6.4.3.3.1 Grounding Requirements

External metal parts subject to crew contact shall be at ground potential.

6.4.3.3.2 Protective Cover Requirements

Equipment shall provide grounded or nonconductive protective covers for all *electrical hardware*.



MSIS 11
Rev. A

Notes:
1. Data are based on current flow from arm-to-arm or arm-to-leg of 60 Hz AC on 150 lb human.

Figure 6.4.3-1 Voltage/Current/Frequency Exposure Criteria and Range of Physiological Effects

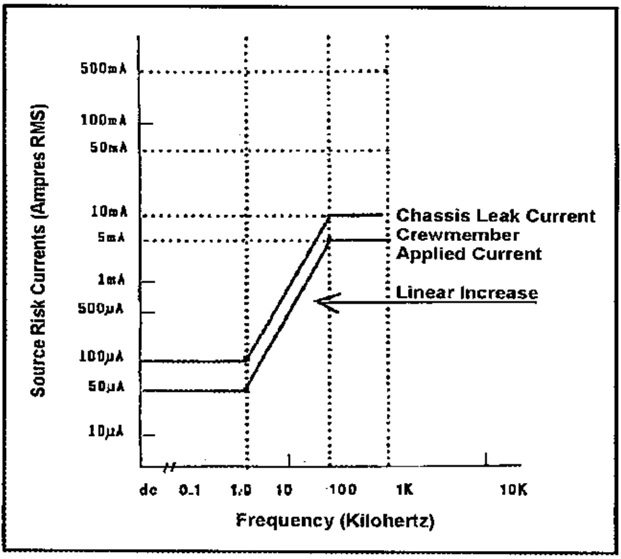


Figure 6.4.3.1-1 Current Limits Versus Frequency

MSIS 402

6.4.3.3.3 Interlocks Requirements

Equipment access doors or covers shall incorporate interlocks to remove all potentials in excess of 150 V when open.

6.4.3.3.4 Warning Labels Requirements

Warning labels shall be provided where potentials are hazardous to crewmembers.

6.4.3.3.5 Warning Labels Plus Recessed Connectors Requirements

Provide warning labels and recessed connectors or other protective measures where potentials exceed 150 V.

6.4.3.3.6 Plugs and Receptacles Requirements

a. Plugs and receptacles design shall prevent a plug of one voltage rating from being inserted into a receptacle of another rating.

b. All hot contacts shall be female receptacles.

c. Provide means to ensure proper pin connections of all critical electrical connectors prior to the application of system power.

d. Provide means to ensure that all pin connections exist as designed, no pin-to-pin shorts exist, and that no pin-to-shell shorts exist.

e. Unless connectors are specifically designed and approved for mating or demating in the existing environment under the loads being carried, they shall not be mated or demated until voltages have been removed from the powered side(s) of the connector.

6.4.3.3.7 Insulation Requirements

a. All exposed electrical conductors shall be insulated.

b. All power tools to be used near high voltages shall have insulated handles.

6.4.3.3.8 Power Cords Requirements

Portable equipment shall be designed with three-wire power cords with one wire at ground potential. A system of double insulation or its equivalent when approved by the procuring agency, may be used without a ground wire.

6.4.3.3.9 Moisture Protection Requirements

Equipment shall be designed so that moisture cannot collect near electrically operated controls.

6.4.3.3.10 Static Discharge Protection Requirements

Equipment design shall ensure that crewmembers are protected from static charge buildup.

6.4.3.3.11 Spacing Between Connectors Requirements

Equipment shall be designed so that a connector installation/removal tool will not make contact between the adjacent connectors.

6.4.3.3.12. Bio-Instrumentation System Shock Protection Requirements

All bio-instrumentation system design shall provide sufficient resistance in series with each body electrode to limit to safe levels electrical shock currents that could flow through an instrumented crewmember as a result of contact with available voltage sources.

6.5.3 Touch Temperature Design Requirements

Surface touch temperature design requirements for minimizing crewmember discomfort and injury are as follows:

a. The deisgn goal for the maximum surface temperatures which can come into contact with bare skin shall be 40°C (104°F).

b. The maximum allowable surface temperature for continuous contact with bare skin shall be 45°C (113°F).

c. Incidential or momentary bare skin contact with surface temperatures from 46° - 49°C (114° - 120°F) is permissible. Warning labels shall be provided to alert crewmembers to these excessive temperature levels. Guards or insulation shall be provided to prevent crewmember contact with surface temperatures in excess of 49°C (120°F). Where contact with surfaces above this limit is required, adequate warning labels and protective equipment are required.

d. For surfaces that must be touched wtih bare skin, the minimum temperature shall not be below 4°C (39°F). Where contact with surfaces below this limit is required, adequate warning labels and protective equipment are required.

(Refer to Paragraph 14.2.3.11, EVA Touch Temperature and Pressure Design Requirements, for EVA-unique touch temperature requirements.)

6.6.3 Fire Protection and Control Design Requirements

Fire protection and control design requirements are given below.

6.6.3.1 General Requirements

6.6.3.1.1 Fire Protection System

A fire protection system comprising detection, warning, and extinguishing devices shall be provided during all mission phases.

6.6.3.1.2 Material Selection

Only approved fire-retardant materials shall be used.

6.6.3.2 Detection Requirements

6.6.3.2.1 Detection System Signals

The fire detection system shall provide signals to the vehicle warning system.

6.6.3.2.2 Reset and Self-test

The fire detection system shall have reset and self-test capabilities.

6.6.3.2.3 Sensor Replacement

All sensors shall be replaceable and accessible.

6.6.3.3 Warning System Requirements

Warning - General requirements for the fire warning system are as follows:

(Refer to Paragraph 9.4, Caution and Warnings, for complete description of design considerations and requirements.)

a. The caution and warning system shall include a fire warning system to alert the crew in case of a fire.

b. The fire warning system shall be capable of operating independently.

c. Warnings shall be both visual and auditory to provide maximum information to the crew for timely action.

d. The visual fire warning display shall be aviation red in accordance with MIL-STD-25050.

6.6.3.4 Extinguishing Requirements

b. Design of the vehicle and its components shall provide for rapid access with fire fighting equipment.

c. Chemical agents used for fire extinguishing shall be compatible with the toxicity requirements of the spacecraft.

d. Portable fire extinguishers shall be provided for open areas and a fixed fire extinguishing system shall be provided for enclosed inaccessible areas.

e. Capability for removal of expended fire extinguishing material during post-fire cleanup shall be provided.

f. Automatic extinguishing systems shall incorporate a disabling feature to prevent inadvertent activation during servicing.

NOTES

NOTES

7.2.2.3 Nutrition Design Requirements

7.2.2.3.1 Food Design Requirements

7.2.2.3.2 Potable Water Design Requirements

7.2.2.3.2.1 Potable Water Quality Design Requirements

Potable water shall meet the quality requirements defined in Figure 7.2.2.3.2.1-1. Provisions shall be made to prevent accidental use of nonpotable water for drinking or food preparation.

Parameter		MCL
Physical		
Total solids (Suspended/Dissolved) mg/l		100
Color True	Pt/Co	15
Taste and Odor	TTN/TON	3
pH		6.0-8.0
Particulates (maximum size - μ)		40
Turbidity	NTU	1
Dissolved Gas	(Free @ 35°F)	None
Free Gas	(@ STP)	None
Inorganic Constituents (mg/l)		
Ammonia		0.5
Arsenic		0.01
Barium		1.0
Cadmium		0.01
Calcium		30
Chloride		250
Chromium		0.05
Copper		1.0
Iodine (Total)		15
Iron		0.3
Lead		0.05
Manganese		0.05
Magnesium		50
Mercury		0.002
Nickel		0.05
Nitrate	(NO_3-N)	10
Potassium		340
Selenium		0.01
Silver		0.05
Sulfate		250

Figure 7.2.2.3.2.1-1 Maximum Contaminant Levels (MCL) for Potable Water

MSIS 186
1 of 2

Chap 7

Parameter	MCL
Inorganic Constituents (mg/l)-Concluded	
Sulfide	0.05
Zinc	5.0
Bactericides (mg/L)	
Residual Iodine (Minimum)	0.5
Residual Iodine (Maximum)	4.0
Aesthetics (mg/)	
Cations	30
Anions	30
CO_2	15
Microbial	
Bacteria (CFU/100 ml)	
Total Count	1
Anaerobes	1
Aerobes	1
Gram Positive	1
Gram Negative	1
E. coli	1
Enteric	1
Viruses (PFU/100ml)	1
Yeasts and Molds (CFU/100ml)	1
Radioactive Constituents (pCi/l)	See Note
Organics (µ/l)	
Total Acids	500
Cyanide	200
Halogenated Hydrocarbons	10
Phenols	1
Total Organic Carbon (TOC)	500
TOC (Less Non-Toxicants)	100
Total Alcohols	500
Organic Constituents (mg/l)	
Specific Toxicants	TBD

Note:
The maximum levels for radioactive material in potable water shall conform to Nuclear Regulatory Commission (NRC) (10CRF20, et. al.) to control the dose to the public from the extant 1200+ man-made radionuclides. These maximum contaminant levels are listed in the Federal Register, Vol. 51, No. 6, 1986, Appendix B, as Table 2 (Reference Level Concentrations), Column 2 (Water).

Figure 7.2.2.3.2.1-1 Continued

MSIS 186
2 of 2

7.2.2.3.2.2 Potable Water Quantity Design Requirements

The supply of available water for drinking and rehydration of food is listed below:

a. Operational Mode - 2.84 to 5.16 Kg per person-day (6.26 to 11.35 lbs per person-day)

b. Degraded and Emergency Mode - 2.84 Kg per person-day (6.26 lbs per person-day)

7.2.2.3.2.3 Potable Water Temperature Design Requirements

Drinking Water requirements shall meet the following requirements:

a. Cold Water - Cold water temperature shall be 4 +/- 3°C (40 +/- 5°F).

b. Ambient Water - Ambient water temperature shall be 21 +/- 5°C (70 +/- 10°F).

c. Hot Water - Means shall be provided for heating water up to 65.6°C (150°F).

7.2.3.3.3 Exercise Countermeasure Design Requirements

Exercise countermeasure requirements apply to space missions that expose crewmembers to microgravity conditions for longer than 10 days. For missions of 10 days or less, exercise countermeasures shall be available for crewmembers as necessary to maintain performance during the mission on entry to 1-G. The following are the exercise countermeasure design requirements:

a. Types of Exercise - The space module shall provide facilities for the following types of exercise:

   1. Equipment for placing tension stress, isotonic and isometric, upon the major muscle groups of the body shall be provided in order to counter "disuse atrophy" caused by microgravity.

   2. Devices for exercising the cardiorespiratory system by engaging large skeletal muscle masses (i.e., aerobic exercises) as partial countermeasure to cardiovascular deconditioning shall be provided.

b. Duration of Exercise - Facilities and scheduling shall provide the capability for all crewmembers to exercise not less than 1 hour per day.

c. Exercise Regimens - Capability shall be provided for establishing and updating individualized exercise routines and goals for each crewmember.

d. Motivation and Training - Appropriate motivational devices and/or incentives *shall be provided. Crewmembers shall be trained in the importance of* exercise and how to use the equipment.

e. Data Monitoring of Exercise - There shall be the capability to monitor physiological parameters during exercise, store the data, and downlink this information to Earth. The following physiological parameters shall be monitored:

   1. Routine Monitoring.

      (a) Heart Rate.

      (b) Duration of Exercise Period

      (c) Power Output From Instrumented Exercise Device

2. Periodic Monitoring
   (a) Electrocardiogram
   (b) Blood Pressure
   (c) Maximal and Submaximal Oxygen Uptake
   (d) Muscle Strength

7.2.3.4.3 Nonexercise Countermeasures Design Requirements

7.2.4.3 Sleep Design Requirements

The following are design requirements for crew sleep:

a. Facilities - Adequate sleep facilities shall be provided.

   (Refer to Paragraph 10.4.3, Crew Quarters, for sleep facility design requirements.)

b. Duration - Scheduling should allow a minimum sleep period of 8 hours per day with minimum of 6 hours of uninterrupted sleep.

c. Pharmaceuticals - Appropriate sleep aid medication shall be made available to crewmembers via a controlled access system.

7.2.5.3 Personal Hygiene Design Requirements

7.2.5.3.1 Body Grooming Design Requirements

The following body grooming measures shall be provided in the space modules.

a. Skin Care - The capability shall be provided for crewmembers to condition their skin sufficiently to prevent drying and/or cracking.

b. Shaving - Provisions shall be made for crewmembers to shave body hair.

c. Hair Grooming - Provisions shall be made for crewmembers to cut hair to maintain the length within mission and/or personal requirements.

d. Nail Care - Provisions shall be made for crew members to trim nails.

e. Body Deodorant - The capability shall be provided for crewmembers to control body odor.

f. Menstruation - Provisions shall be provided for the collection and disposal of menstrual discharge.

   (Refer to Paragraph 10.2.3.4, Hair Cutting Design Requirements, and Paragraph 10.2.3.5, Grooming & Shaving Design Requirements, for facility design requirements.)

7.2.5.3.2 Partial Body Cleansing Design Requirements

The capability shall be provided for crewmembers to perform selected body area cleansing as needed.

(Refer to Paragraph 10.2.3.1, Partial Body Cleansing Design Requirements, for facility design requirements.)

7.2.5.3.3 Oral Hygiene Design Requirements

The capability shall be provided for crewmembers to maintain proper oral hygiene. *Proper oral hygiene includes tooth, mouth, and gum care.*

Water for oral hygiene shall meet potable water quality standards defined in Paragraph 7.2.2.3.2.1.

(Refer to Paragraph 10.2.3.3, Oral Hygiene Design Requirements, for facility design requirements.)

7.2.5.3.4 Whole Body Cleansing Design Requirements

The capability shall be provided for crewmembers to perform whole body skin and hair cleansing.

(Refer to Paragraph 10.2.3.2, Whole Body Cleansing Design Requirements, for facility design requirements.)

7.2.5.3.5 Personal Clothing & Equipment Cleansing Design Requirements

The capability shall be provided to supply each crewmember with clean clothing and other washable items, including bedding and linens, over the duration of the mission.

(Refer to Paragraph 11.13.1.3, Clothing Design Requirements, and Paragraph 10.10.3, Laundry Facility - Design Requirements, for additional requirements.)

7.2.5.3.6 Personal Hygiene Water Design Requirements

Personal hygiene water is water that is used for external body cleansing. Personal hygiene water requirements are listed below:

a. Quality - Minimum personal hygiene water quality requirements are given in Figure 7.2.5.3.6-1.

b. Quantity - Personal hygiene water quantity requirements are given in Figure 7.2.5.3.6-2. This figure does not include requirements for laundry and dishwashing which are system dependent.

c. Temperature - Temperature shall be adjustable from 21°C(70°F) to 45°C(113°F).

	MODE		
UNITS	Operational	90 dAY Degraded (1)	Emergency (3)
lb/ person-day	51.5 (2)	16.0 (4)	12 0 (5)
kg/ person-day	23.4	8.18	5.45

Notes:
(1) Degrade levels meet "fail operational criteria."
(2) Based on 12 lb minimum capacity for hygiene and 25 lb used in a 90 day chamber test. Includes laundry (27.5 lb/person-day) and dishwashing (12 lb/person-day) quantities.
(3) Safe Haven conditions shall be maintained for up to 45 days.
(4) Based on 12 lb/person-day capacity for hygiene and 4 lb/person-day for laundry.
(5) Based on 12 lb/person-day minimum capacity for hygiene only.

Figure 7.2.5.3.6-2 Minimum Presonal Hygiene Quantity Requirements

MSIS 400

Property		Limit
Total solids (suspended/dissolved) mg/ℓ		500
Color, true	Pt/Co	15
Taste and odor	TTN/TON	<3
pH		5.0-8.0
Particulate (maximum size)		40 µ
Turbidity	NTU	1
Dissolved gas	Free @ 35°C	None
Free gas	STP	None
Ionic (inorganic) (mg/ℓ)		
Ammonia		0.5
Arsenic		0.01
Barium		1.0
Cadmium		0.01
Calcium		100
Chloride		250
Chromium		0.05
Copper		1.0
Fluoride		1.0
Iodide		15
Iron		0.3
Lead		0.05
Manganese		0.05
Magnesium		0.05
Mercury		0.002
Nickel		0.05
Nitrate (NO_3-N)		10
Potassium		340
Selenium		0.01
Silver		0.05
Sulfide		0.05
Sulfate		250
Zinc		5.0

Figure 7.2.5.3.6-1 Maximum Contaminant Levels (MCL) for Personal Hygiene Water

MSIS 190
1 of 2

Parameter	MCL
Organics (ug/l)	
Total Organic Carbon (TOC)	10,000
TOC (Less Non-Toxicants)	1,000
Cyanide	TBD
Phenols	1
Acids	TBD
Specific Toxicants	TBD
Halogenated Hydrocarbons	TBD
Alcohols	TBD
Microorganisms	
Bacteria CFU/100ml	
Total Count	1
Anaerobes	1
Aerobes	1
Gram Positive	1
Gram Negative	1
E. coli	1
Enteric	1
Viruses (PFU/100ml)	1
Yeasts and Molds (CFU/100ml)	1
Bactericide (mg/l)	
Residual (Halogens) (Minimum)	0.5
Residual (Halogens) (Maximum)	6.0
Radiological (pCi/l)	See Note

Note:
The maximum contaminant levels for radioactive material in potable and personal hygiene water shall conform to Nuclear Regulatory Commission (NRC) regulations (10CFR20, et. al.) for control of dose to the public from the extant 1200+ man-made radionuclides. These maximum contaminant levels are listed in the Federal Register Vol. 51, No. 6, 1986, Appendix B, a Table 2 (Refereance Level Concentrations) Column 2 (Water).

Figure 7.2.5.3.6-1 Concluded

MSIS 190
2 of 2

7.2.6.3 Pre/Post-Mission Health Management Design Requirements

7.2.7.3 Routine Health Monitoring Design Requirements

7.2.7.3.1 Routine Crew Health Monitoring Design Requirements

7.2.7.3.2 Water Supply Monitoring Design Requirements

7.2.7.3.2.1 Water Quality Monitoring Schedule Design Requirements

Water quality shall be monitored according to the schedule shown in Figure 7.2.7.3.2.1-1.

7.2.7.3.2.2 Toxicological Monitoring Design Requirements

7.2.7.3.2.3 Microbiological Monitoring & Treatment Design Requirements

The following requirements apply to monitoring and treatment of microbiological qualities of water:

a. Determination of Potability

b. Sampling Technique

c. Iodine

d. Alternative Biocide

MSIS-339

Parameter	Process control monitoring (on-line)	Batch control monitoring (prior to use)	Periodic[1] monitoring
Conductivity	X	X	—
ph	X	X	—
Turbidity	—	X	—
Color	—	X	—
Temperature	X	—	—
Physical properties	—	↑	↑
Ammonia	X	X	—
Iodine	X	X	—
Selected specific ions	—	X	—
Inorganic constituents	—	↑	↑
TOC	X	X	↑
Selected organic constituents	—	X	↑
Total bacteria	—	X	—
Yeast and molds	—	—	X
Bacterial ID	—	—	X
Virus	—	—	—
Radionuclides	—	X	↑
Dissolved gas	—	X	—
Free gas	X	X	—

Notes:
↑ Monitoring requirements and schedule are dependent on water use and recycling process.
X Monitoring is required.
— Monitoring is not required.

Figure 7.2.7.3.2.1-1 Required Water Quality Monitoring Schedule for All Water Which Comes Into Contact With Personnel

e. Administration of Iodine

f. Monitoring

g. Treatment Bed Control

7.2.7.3.2.4 Physical Monitoring Design Requirements

7.2.7.3.3 Environmental Monitoring Design Requirements

Environmental monitoring necessary to maintain crew health shall be provided as follows:

a. Particulate Monitoring

b. Microbial Contaminants Monitoring

c. Chemical Contaminants Monitoring

d. Radiation Monitoring

e. Atmospheric Monitoring

f. Radiological Monitoring

7.3 MEDICAL CARE

7.3.3 Medical Care Design Requirements

7.3.3.1 General Design Requirements

7.3.3.2 Prevention Design Requirements

7.3.3.3 Diagnosis Design Requirements

7.3.3.4 Treatment (Therapeutics) Design Requirements

NOTES

NOTES

8.2 OVERALL ARCHITECTURAL CONSIDERATIONS AND REQUIREMENTS

8.2.3 Overall Architectural Design Requirements

8.2.3.1 Crew Station Arrangement and Grouping Design Requirements

8.2.3.2 Dedicated vs. Multipurpose Space Utilization Design Requirement

8.2.3.3 Crew Station Location

8.2.3.4 Microgravity

8.2.3.5 Reconfiguration

8.2.3.6 Decor and Lighting

8.3.3 Crew Station Adjacencies Design Requirements

8.3.3.1 Adjacent Crew Station Design Requirements

8.3.3.2 Non-Adjacent Crew Stations - Design Requirements

8.4.3 Orientation Design Requirements

The following are design requirements for establishing an orientation within a space module:

a. Consistent Orientation - Each crew station shall have a consistent orientation within a given visual field (see Figure 8.4.3-1 for illustration).

b. Visual Orientation Cue - A visual cue shall be provided to allow the crewmember to quickly adjust to the orientation of the activity center or workstation.

c. Separation - When adjacent workstations or activity centers have vertical orientations differing by 90 degrees or more, then clearly definable demarcations shall separate the two areas.

8.5.3 Location Coding Design Requirements

8.5.3.1 Alphanumeric Coding Design Requirements

An alphanumeric coding system shall be established for the space module. The system shall have the following characteristics:

a. Ease of Use - The coding system shall be simple to use, communicate, and memorize.

b. Module Consistency - The coding system shall be consistent throughout the space module and attached components. The system shall be consistent for both interior and exterior locations.

c. User Consistency - The coding system shall be consistent for all personnel who use and maintain the module. The system shall be compatible with (if not identical to) design engineering location systems.

d. Flexibility - The coding system shall be flexible to allow adaptation to space module design changes and reconfiguration.

8.5.3.2 Directional Designation Design Requirements

Whenever possible, a consistent directional orientation shall be established *for the entire space module. The following directional designation terms shall* apply to space modules:

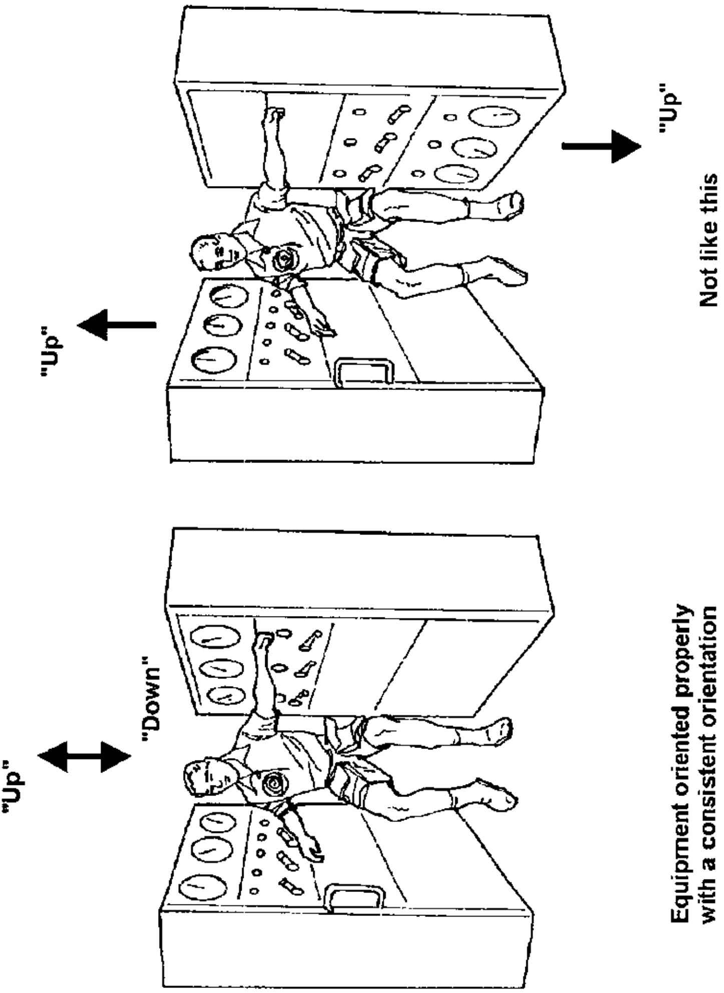


Figure 8.4.3-1 Equipment Shall Have A Consistent Orientation Within A Workstation or Activity Center

MSIS 87

a. Forward/Aft - Forward shall be defined by the plus velocity vector of the space module. *If there is no designated velocity vector, then "forward" shall be* arbitrarily defined.

b. Port/Starboard - When facing in the "forward" direction, "port" shall be defined as the direction to the left and "starboard" shall be defined as the direction to the right .

c. Up/Down - An Up/Down directional designation shall be established perpendicular to the Forward/Aft and Port/Starboard plane. If the space module has a stable orientation relative to a planetary body, then be defined as the direction toward the planetary body. Otherwise, "down" shall be arbitrarily defined.

8.5.3.3 *Location & Orientation By Color Coding Design Requirements*

The following requirements apply to the use of color for location and orientation coding:

a. Colors - The colors selected for coding shall be consistent with the requirements in Paragraph 9.5.3.2.i, Color Coding.

b. Consistency - If color is used for location coding purposes, the colors shall have the same operational significance throughout the space module and shall be consistent in application.

c. Space Module Lighting - Exterior lighting for orientation coding of space *module shall be in accordance with the following practices:*

   1. Color code - The colors shall follow the code in Figure 8.5.3.3-1

   2. Lamp intensity - Minimum lamp intensity is cited in Figure 8.5.3.3-1. These intensities assume color recognition at 600 meters (2000 feet). If greater recognition distances are required, then luminous intensities shall be increased accordingly. The intensities are to be measured 30 degrees off the centerline of the cone of radiation.

   3. Chromaticity - The chromaticity of space module lights shall be as defined in Figure 8.5.3.3-1 and MIL-C-25050.

8.5.3.4 Location Coding With Placards Design Requirements

A space module shall have markings to provide the crew with equipment and compartment identification, and directional and spatial orientation information. The specific requirements for location coding placards are as follows:

a. Map - A map of location codes shall be provided at the entrances to areas where the coding scheme is not obvious to the crewmember or for areas in which there is a significant amount of preparation activity such as stowage, adjustment, or maintenance of items.

b. Placards on Movable Items - Movable items and their stowage locations shall be labeled as necessary to ensure the item is returned to the proper location after use.

c. Control Room Placards - Control rooms shall have placards which identify the room and the control station within the room.

d. Directional Designation - A visual cue shall be provided to allow the crewmember to quickly adjust to the orientation of the crew station.

(Refer to Paragraph 8.4.3 Orientation Design Requirements, for additional information concerning orientation requirements.)

e. Markings - Label and placard format and markings shall meet the requirements in Paragraph 9.5, *Labeling and Coding.*

Color	Vehicle location	Luminous intensity * candella (candlepower)	Chromaticity (CIE chromaticity diagram coordinates)
Aviation red	Port (left) side	2.5 (0.2)	Y = not greater than 0.330 X = not less than 0.650
Aviation green	Starboard (right) side	6.3 (0.5)	Y = not less than 0.390 X = not greater than 0.270
Aviation yellow	Bottom	2.5 (0.2)	Y = not less than 0.380 X = not greater than 0.530
Aviation white	Aft (preferred)	2.5 (0.2)	Y = 0.300 to 0.400 X = 0.300 to 0.400
Aviation blue	Aft (not preferred)	6.3 (0.5)	Y = not greater than 0.200 X = not greater than 0.245
Dual aviation white/ aviation yellow	Forward	See above	See above

*** Assumes color recognition up to 600 meters (2000 feet)**

Figure 8.5.3.3-1 Spacecraft Orientation Coding Lights

MSIS 88

8.6.3 Envelope Geometry Design Requirements

Figure 8.6.2.3-1 has been included to illustrate accommodation of the body motion envelope of the 95th percentile american male

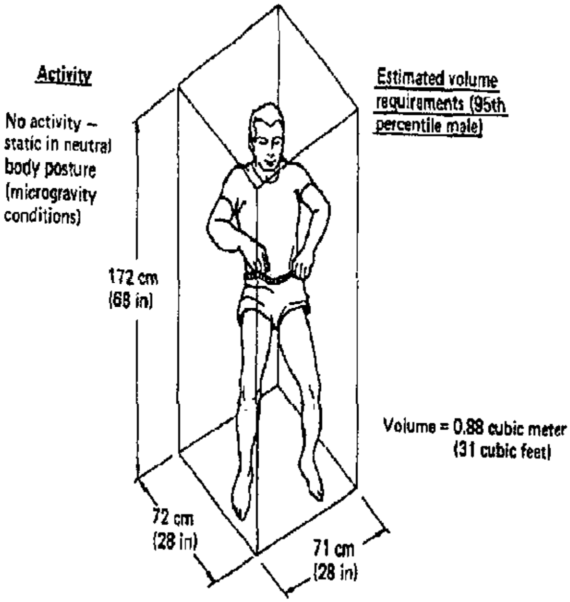
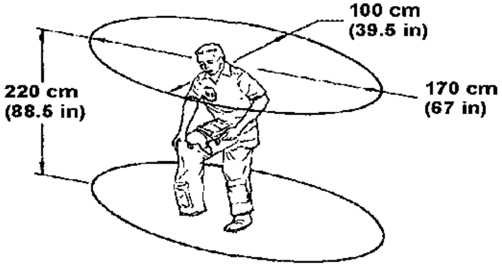


Figure 8.6.2.3-1 Approximate Dimension Required to Accomodate the Body Motion Envelope of the 95th Percentile American Male

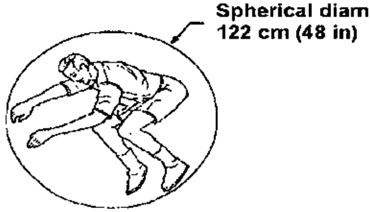
MSIS 92
1 of 2

Maximum 1-g unrestrained clothing don/doff envelope



Volume= 2.95 cubic meters (104 cubic feet)

Controlled tumbling in all planes (microgravity)



(Very approximate)

Volume= 1 cubic meter (35 cubic feet)

Figure 8.6.2.3-1 Approximate Dimension Required to Accomodate the Body Motion Envelope of the 95th Percentile American Male (Continued)

MSIS 92
2 of 2

8.6.3.1 Crew Station Body Envelopes Design Requirements

The following are requirements for crew station body envelope geometry:

a. Adequate Volume

b. Accessibility

c. Full Size Range Accommodation

8.6.3.2 Total Module Habitable Volume Design Requirements

8.7.3 Traffic Flow Design Requirements

8.7.3.1 Overall Traffic Flow Design Requirements

8.7.3.2 Congestion Avoidance Design Requirements

Traffic congestion shall be avoided. The following methods shall be taken to avoid congestion:

a. Reduce the Need for Traffic

b. Alternate Paths

c. Proper Scheduling

d. Reduce Congestion Due to Large Volume Transfer

e. Reduce Cross Traffic

f. Translation Path Size

8.7.3.3 Noninterference with Other Activities Design Requirements

8.7.3.4 Emergency and Escape Route Design Requirements

The design for traffic flow shall take into account the possibility of a space module or subsystem failure or damage that could require evacuation. Specifically, the following requirements apply:

a. Escape Routes and Isolation Areas

b. Dual Escape Routes

c. Protection of Entry/Exit Path

d. Escape From Crew Stations

e. Emergency Rescue and Return Route

f. Dead End Corridors

g. Emergency Regulation and Routes

8.8.3 Translation Path Design Requirements

8.8.3.1 Minimum Translation Path Dimensions Design Requirements

Minimum cross sectional dimensions of microgravity translation paths for one crewmember in light clothing are shown in Figure 8.8.3.1-1. Translation paths that must accommodate more than one crewmember shall be enlarged by multiples of the single person dimensions.

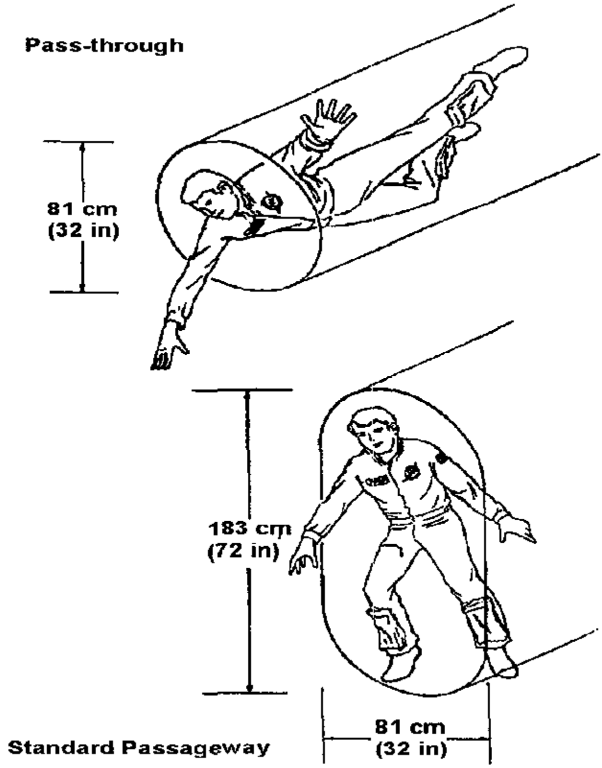


Figure 8.8.3.1-1 Minimum Translation Path Dimensions for Microgravity, One Crew Member In Light Clothing

MSIS 213

8.8.3.2 Clearances Design Requirements

In addition to the minimum dimensions given in Paragraph 8.8.3.1, translation paths shall be designed to provide the following clearances:

a. Equipment or Package Clearances

b. Orientation and Directional Change Clearances

8.8.3.3 Translation Path Obstructions and Hazards Design Requirements

The following translation path obstructions and hazards shall be minimized:

a. Injury or Damage From Translation Path Surface

b. Damage to Nearby Equipment

c. Collisions at Intersections

d. Obstructions and Entanglements

8.8.3.4 Marking of Translation Paths - Design Requirements

Emergency translation paths shall be marked in accordance with MIL-A-25165B.

8.9.3 Mobility Aids and Restraints Design Requirements

8.9.3.1 IVA Mobility Aid Integration Design Requirements

The following are requirements for integration of fixed IVA mobility aids into the space module architecture:

a. Translation Path Locations

b. Orientation Requirements

c. Noninterference

d. Contingency Space Suited Operations

8.9.3.2 IVA Restraint Integration Design Requirements

The following are requirements for integration of fixed IVA restraints into the space module architecture:

a. Crew Stations

b. Areas Where High Force Application is Required

c. Space Medical Facility

d. Undesirable Areas

e. Noninterference

8.10.3 Hatch and Door Design Requirements

8.10.3.1 Location Design Requirements

Hatches and doors shall meet the following location requirements:

a. Internal Door Placement

b. Away From Hazards

c. Emergency Passage

8.10.3.2 Pressure Hatch Indicator/Visual Display Design Requirements

Pressure hatch covers shall have the following visual displays and indicators:

a. Visual Inspection of Hatch Security - A means shall be provided on both sides of the pressure hatch for visual safety check to ensure that it has been secured properly.

b. Remote Status Display

c. Pressure Difference Indicators - Pressure hatches shall have pressure difference indicators visible on both sides of the hatch.

d. Windows - All airlock hatches shall have windows for visual observation of all decompression operations with a minimum of blind spots inside the airlock.

(Refer to Paragraph 11.11.3, Window Design Requirements, for detailed window design specifications.)

e. Operating Instructions - All pressure hatches shall display operating procedures on both sides of the hatch.

(Refer to Paragraph 9.5.3.1.8, Operating Instruction Design Requirements.)

8.10.3.3 Opening and Closing Mechanisms Design Requirements

The hatch and door opening and closing mechanisms shall meet the following design requirements:

a. Emergency Operation - Latching mechanisms shall provide for emergency operation in case of a latching system failure.

b. EVA Operation - All opening/closing mechanisms shall be operable by a pressure-suited crewmember.

c. Operation From Both Sides - Hatches shall be capable of being operated, locked, and unlocked from either side.

d. Interlock - Pressure hatches shall be prevented from unlatching prior to pressure equalization.

e. Single Crewmember Operation - Hatches shall be capable of being operated by one crewmember.

f. Parts Tethering - All safety pins or other detachable parts required for the opening/closing shall be tethered and able to be stowed.

g. Emergency Closing - Hatches and doors shall allow crewmembers to close covers with or against pressure differentials, for the worst case pressure differential anticipated.

h. Rapid Closing - Hatches used to isolate interior areas of the space module shall be designed to allow rapid closing.

8.10.3.4 Operating Forces Design Requirements

Hatch and door cover operating forces shall meet the following requirements:

a. Emergency Operation - Forces for emergency manual backup operation or breakaway of jammed internal hatches and doors shall not exceed 445 Newtons (100 lbs).

b. Latch Operations - The force required to operate door and hatch latches shall not exceed the strength of the weakest of the defined crewmember population strength range.

(Refer to Paragraph 4.9.3, Strength - Design Requirements, for strength data.)

c. Open/Close Force - Normal opening and closing forces for internal doors shall not exceed 22 Newtons (5 lbs).

d. Restraints - Restraints shall be provided as necessary to counteract body movement when opening or closing the hatch.

8.10.3.5 Minimum Size Design Requirements

Personnel hatch and door opening size shall be as large as practical. The hatch or door opening shall be free of protrusions which might injure personnel or damage equipment. The minimum size of these openings shall accommodate passage of the largest replaceable module or crewmember (whichever is larger) intended to pass through the opening.

8.10.3.6 Door and Hatch Shape Design Requirements

Doors and pressure-sealing hatches shall be shaped such that they can pass through the opening into which they are designed to fit/seal to allow for removal, **maintenance, repair, relocation, etc.**

8.11.3 Window Integration Design Requirements

The following are requirements for the architectural integration and design of windows:

a. Required Windows - Properly located and sized windows shall be provided for the following functions:

   1. Off duty recreational viewing by the crewmembers.

   2. As necessary for interface with EVA activities.

   3. To support proximity operations.

   4. To support external inspection of adjacent modules, structures, and/or other spacecraft.

   5. As necessary for scientific celestial or Earth observations.

   6. For observation of decompression through airlock and pressure hatch covers. Windows shall be located and configured with minimum blind areas inside the decompression area. Windows shall allow a 90° field of view for an eye reference point located along a normal to the window opening. This normal passes through the geometric center of the opening. This reference point shall be located half the window opening dimension from the inner pane.

b. Adequate Space Around Windows - The arrangement of equipment near the windows shall allow adequate space for the performance of designated operational, maintenance, and recreational tasks by the largest of the defined crewmember population size range.

c. Restraints - Restraints shall be provided in microgravity conditions when necessary for window task performance.

d. Compatibility With Adjacent Area - Crew stations and activities around the window location shall be compatible with the use of the window. This compatibility shall include the following:

   1. Lighting - Provisions shall be made to preclude degradation of the performance of the window viewer or surrounding crew activities by the lighting environment.

   2. Traffic - Traffic at the window area shall not degrade the performance of the window viewer or activities at adjacent crew stations.

8.12.3 Interior Design and Decor Design Requirements

8.12.3.1 Aesthetic and Psychological Requirements

8.12.3.2 Decor Flexibility

8.12.3.3 Color Selection

8.12.3.4 Decor Cleaning and Maintenance

8.12.3.5 Decor Durability

8.12.3.6 Safety

8.13 LIGHTING

8.13.3 Lighting Design Requirements

8.13.3.1 Illumination Level Design Requirements

8.13.3.1.1 General Interior Illumination Levels Design Requirements

The general illumination of Space Station Freedom shall be a minimum of 108 lux (10 foot-candles) of white light.

(Refer to Paragraph 9.2.2.2.1, Workstation Illumination Design Requirements, for specific workstation task lighting requirements.)

(Refer to Paragraph 14.4.3.3, EVA Workstation Lighting Design Requirements, for EVA lighting requirements.)

8.13.3.1.2 Illumination For Specific Tasks Design Requirements

The lighting level shall be measured on the primary work surfaces visual interface or 30 inches above the floor where appropriate. Measurement shall be taken at 80% of maximum power.

Specific IVA task lighting requirements are defined in Figure 8.13.3.1.2-1 which also defines illumination levels for workstations. EVA lighting requirements are in Paragraph 14.4.3.3, EVA Workstation Lighting Design Requirements.

8.13.3.1.3 Illumination Levels of Sleeping Areas Design Requirements

The following requirements apply to the illumination of sleeping areas:

a. The lighting level shall be adjustable from "off" to the maximum for sleeping areas.

b. Minimum lighting of 30 Lux (3 ft. cd), or other means of visual orientation shall be provided to permit emergency egress from sleeping areas.

8.13.3.1.4 Illumination Levels for Dark Adaptation Design Requirements

If maximum dark adaptation is required, red light or low level white lighting [CIE color coordinates for x and y equals 0.330 +/- 0.030 (1932)] is acceptable. All trans-illuminated displays and controls shall be visible when all other lighting is turned off.

When dark adaptation is required for performance of tasks, the following measures shall be taken:

a. Low Level Lighting - Low level lighting shall be provided for task performance which minimizes loss of dark adaptation.

Area or Task	LUX	(Ft. C.)
GENERAL	108	(10)
PASSAGEWAYS	54	(5)
Hatches	108	(10)
Handles	108	(10)
Ladders	108	(10)
STOWAGE AREAS	108	(10)
WARDROOM	215	(20)
Reading	538	(50)
Recreation	323	(30)
GALLEY	215	(20)
Dining	269	(25)
Food Preparation	323	(30)
PERSONAL HYGIENE	108	(10)
Grooming	269	(25)
Waste Management	164	(15)
Shower	269	(25)
CREW QUARTERS	108	(10)
Reading	323	(30)
Sleep	54	(5)
HEALTH MAINTENANCE	215	(20)
First Aid	269	(25)
Surgical	1076	(100)
I.V. Treatment	807	(75)
Exercise	538	(50)
Hyperbaric clinical lab	538	(50)
Imaging televideo	538	(50)
WORKSTATION	323	(30)
Maintenance	269	(25)
Controls	215	(20)
Assembly	323	(30)
Transcribing	538	(50)
Tabulating	538	(50)
Repair	323	(30)
Panels (Positive)	215	(20)
Panels (Negative)	54	(5)
Reading	538	(50)
NIGHT LIGHTING	21	(2)
EMERGENCY LIGHTING	32	(3)

Note:
Levels are measured at the task or 760 mm (30 in) above floor.
All levels are minimums.

Figure 8.13.3.1.2-1 Space Vehicle Illumination Levels

MSIS 291

b. Protection From Stray Light - Areas requiring low level illumination shall be protected from external light sources.

   1. All external windows shall be provided with protective light shields (shades, curtains, etc.)

   2. All doorways shall be lightproof when closed.

8.13.3.2 Light Distribution Design Requirements

8.13.3.2.1 Glare From Light Sources Design Requirements

The following measures shall be taken where possible to avoid glare from artificial light sources.

a. Light Sources in Front or to the Side of Operators - Locate light sources so that they do not shine directly at the operator. This includes the range within 60° to any side of the center of the visual field.

b. Source Brightness and Quantity - Use more relatively dim light sources, rather than a few very bright ones.

c. Glare Protection - Use polarized light, shields, hoods, lens, diffusers, and/or visors to reduce the glare.

d. Indirect Lighting - Use indirect lighting wherever possible.

e. Luminance Ratio - The luminance ratio for the luminaries shall not exceed 5:1 maximum to the average over the viewing area (average luminance is six readings on the luminance area).

8.13.3.2.2 Reflected Glare Design Requirements

a. Luminance of specular reflectance from the task background shall not be greater than 3 times the average luminance of the immediate background.

b. Luminance of specular reflectance from a remote task shall not be greater than 10 times the average luminance from the remote background.

c. Surface Reflection - Work surface reflection shall be diffused and shall not exceed 20 percent specularity.

d. Angle of Incidence - Arrange direct light sources so their angle of incidence to the visual work area is not the same as the operator's viewing angle.

e. Polished Surfaces - Avoid placement of smooth, highly polished surfaces within 60° of normal to the operator's visual field.

f. Light Source Behind Operator - Do not place bright light sources behind operators so that eyeglasses or display faces can reflect glare into the operator's eyes.

8.13.3.2.3 Brightness Ratio Design Requirements

a. Wall surface average luminance shall be within 50-80% of ceiling surface average luminance.

b. The maximum and minimum luminance ratio for any individual surface shall not exceed 10:1.

c. The brightness ratios between the lightest and darkest areas and/or between task area and surroundings shall be no greater than specified in Figure 8.13.3.2.3-1.

Comparison	Environmental classification[a]		
	A	B	C
Between lighter surfaces and darker surfaces within the task	5 to 1	5 to 1	5 to 1
Between tasks and adjacent darker surroundings	3 to 1	3 to 1	5 to 1
Between tasks and adjacent lighter surroundings	1 to 3	1 to 3	1 to 5
Between tasks and more remote darker surfaces	10 to 1	20 to 1	b
Between tasks and more remote lighter surfaces	1 to 10	1 to 20	b
Between luminaires and adjacent surfaces	20 to 1	b	b
Between the immediate work area and the rest of the environment	40 to 1	b	b

Notes:

[a] A- Interior areas where reflectance of entire space can be controlled for optimum visual conditions.
B- Areas where reflectance of immediate work area can be controlled, but there is only limited control over remote suroundings.
C- Areas (indoor and outdoor) where it is completely impractical to control reflectances and difficult to alter environmental conditions.

[b] Brightness ratio control not practical.

Figure 8.13.3.2.3-1 Required Brightness Ratios

MSIS 224

Chap 8

8.13.3.3 Light Color Design Requirements

Artificial light shall meet the following color requirements:

a. White Light - Work areas of Space Station Freedom shall be illuminated with white light. Color temperature shall be 5000°K or greater for fluorescent lighting and greater than 3800°K for incandescent lighting.

b. Color Temperature Variation - Light sources shall have a correlated color temperature within the visual field of 300°K when operated at maximum power.

c. Color Rendition - Unless otherwise specified the minimum CIE general color rendering index (R_a) of any light source shall be 90 or better, with no special index (R_i) of any one test color sample less than 70.

See Paragraph 9.5.3.2 j for color coding information relative to illuminated displays.

8.13.3.4 Lighting Fixtures and Controls Design Requirements

The following design requirements apply to lighting fixtures and their controls:

a. Emergency Lights

b. Controls

c. Flicker

d. Fixture Protection

e. Portable Lights

8.13.3.5 Medical Lighting Requirements

a. Habitation Module and Hyperbaric Chamber Ambient Light Requirements:

1. The light intensity shall be as specified in Figure 8.13.3.1.2-1.

2. The minimum (contingency) illuminate needed for patient treatment is 500 lux (46 ft. cd.).

3. The light source shall have a color Temperature of 5000°K. If filament lamps are used for light sources, color temperature shall be 4200° Kelvin or greater.

4. Color temperature match and uniformity shall be in accordance with paragraphs 8.13.3.3 b and 8.13.3.3 c .

b. Surgical Lighting:

1. The surgical light will double as a dental light.

2. Requirements of 8.13.3.5 a.3 and 8.13.3.5 a.4 also apply for surgical light.

3. The maximum illuminate to support surgical procedures shall be 4000 lux maximum (872 ft. cd.) to the center of a surface area of 500 square centimeters (77.5 in^2) located 147 cm (5 ft.) from the work area.

4. The illuminate may taper from the center of the pattern to the edge no more than 20% of the maximum illuminate.

5. The luminaries must be directable through a complete hemisphere.

6. The luminaries must be focusable from a pattern diameter of 45 cm (18.5 in) down to 5 cm (2 in).

7. Shadows in the surgical field shall be minimized by luminaries design.

8. Radiant energy in the spectral region of 800 to 1000 nm shall be minimized.

c. Clinical Laboratory Workstation Lighting - The minimum illuminate at the workstation surface shall be as specified in Figure 8.13.3.1.2-1.

d. Imaging Lighting:

1. Requirements 8.13.3.5 a.3 and 8.13.3.5 a.4 also apply to imaging lighting.

2. The minimum illuminate to provide adequate lighting for televideo systems is given in Figure 8.13.3.1.2-1.

8.13.3.6 Workstation Illumination Design Requirements

a. Illumination - Workstation illumination shall be determined by the tasks to be accomplished. Illumination requirements are given in Figure 8.13.3.1.2-1.

b. Adjustable Illumination - Workstation illumination shall be fully adjustable down at OFF.

c. Supplementary Lighting - Portable lighting shall be available for use when additional lighting is required at a workstation.

d. Light Distribution - Illumination shall uniformly cover the entire work/display area. The minimum ratio for differences in illumination within a work area shall meet the following specifications.

1. Primary viewing areas (30 to 60 degree visual angle about primary lines of sight) - Maintain a 3:1 ratio.

2. Adjacent viewing areas (30 to 60 degree band surrounding primary viewing areas) - Maintain a 5:1 ratio.

3. Workstation area outside "adjacent viewing areas" - Maintain a 10:1 ratio.

e. Shadows - Placement for lighting sources shall be such that shadows are not created on working surfaces or information displays by normal positioning of crewmembers or equipment.

f. Reflections - Lighting sources shall be designed and located to avoid creating reflections or glare from working and display surfaces, as viewed from any working position that might interfere with task performance.

NOTES

NOTES

9.2.2.2.1 Workstation Illumination Design Requirements

Requirements pertaining to workstation illumination in 8.13.3.6.

9.2.2.2.2 Congestion and Interference Design Requirements

9.2.2.2.3 Orientation Design Requirements

9.2.2.2.4 Workstation Color Design Requirements

(Refer to Paragraph 9.5.3.2 i, Color Coding, for related information.)

a. Color Selection - Neutral colors shall be used in workstations.

b. Reflections - Workstation surface colors shall be lusterless.

c. Controls:

   1. Controls shall be black or grey unless special functions dictate otherwise (e.g., emergency evacuation controls are striped black and yellow).

   2. Toggle switch handles shall have a satin metallic finish.

   3. Control colors shall provide good contrast between controls and background.

d. Panel Color Finish - The panel color shall provide good contrast between the labels and background. Label/background colors shall be consistent within a functional area.

e. Consoles and Pedestals - The color of structural members of control consoles and pedestals and overhead mountings for control units shall be consistent with surrounding areas.

f. Meter Bezels - The meter bezels shall be the same color specified for the particular panel on which the meter will be used.

9.2.3.2.1 Control Spacing Design Requirements

a. Normal Spacing - Minimum and preferred spacing for different types of controls are shown in Figure 9.2.3.2.1-1 for the ungloved condition.

b. Gloved Operation - All space modules shall have those controls necessary for maintenance and recovery following a depressurization operable by a space-suited crewmember.

(Refer to Paragraph 14.4.3, EVA Control and Display Design Requirements, for specific requirements.)

9.2.3.2.2 Display Readability Design Requirements

a. Accessibility - Displays shall be visually accessible.

b. Parallax Error - Displays shall be located so that they can be read from the design eye point with no discernible parallax.

c. Orientation - Display faces shall be perpendicular to the operator's line-of-sight whenever feasible. The angle between the line-of-sight and the normal to the display shall always be less than 30 degrees.

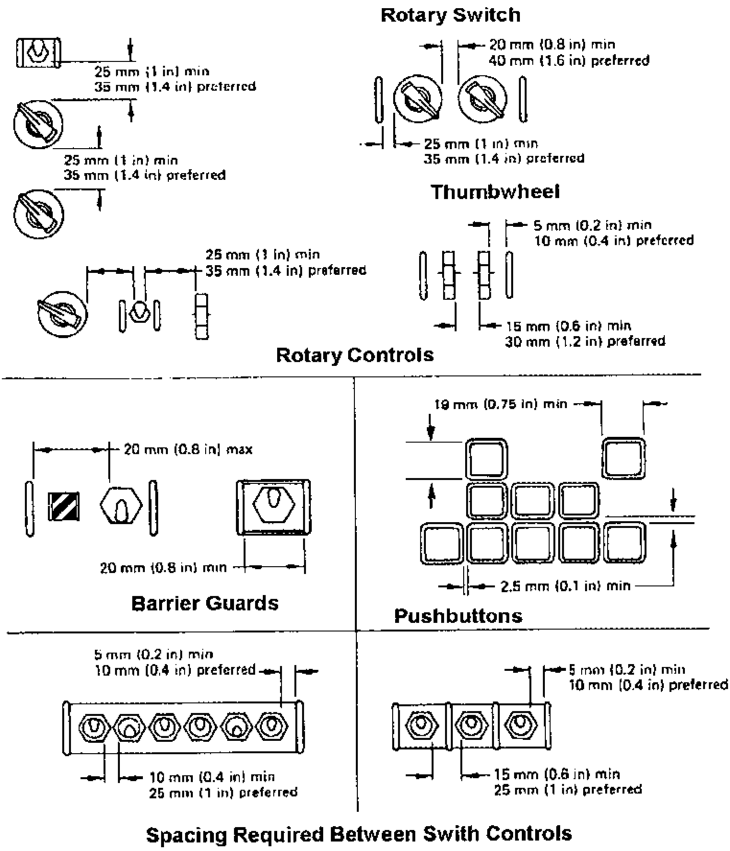


Figure 9.2.3.2.1-1 Control Spacing Requirements for Ungloved Operation

MSIS 256

d. Simultaneous Use - A visual display that must be monitored concurrently with manipulation of a related control shall be located so that it can be read to within required accuracy while adjusting the control.

e. Display Functionality - Displays shall provide positive and unambiguous indication of system state (e.g., a light indicating "power on", a blinking cursor indicating "ready"). These positive indications shall be used consistently throughout the space module.

9.2.3.2.3 Control/Display Grouping Design Requirements

a. Functional Grouping - Displays and/or controls that are functionally related shall be located in proximity to one another - arranged in functional groups (e.g., power, status, test).

b. Sequential Grouping - When a unique sequence of control actions exists, the controls and/or displays shall be arranged in relation to one another according to their sequence of use. Within a functional group, the sequence shall be from left to right or top to bottom whenever feasible.

c. Logical Flow Grouping - When there is not a unique sequence or functional grouping of control actions, controls and displays shall be arranged in a manner consistent with their logical flow.

If controls are not to be utilized in any specific sequence, then consider arranging them by importance with the most important or frequently used control in the most accessible position.

d. Functional Group Markings - If several functional groupings of displays and controls are placed in close proximity on a control panel, an effective means of discriminating between them shall be provided (e.g., color coding or outlining).

e. Left-to-Right Arrangement - If controls must be arranged in fewer rows than displays, controls affecting the top row of displays shall be positioned at the far left; controls affecting the second row of displays shall be placed immediately to right of the these, etc.

f. Vertical and Horizontal Arrays - If a horizontal row of displays must be associated with a vertical column of controls or vice versa, the farthest left item in the horizontal array shall correspond to the top item in the vertical array, etc. However, this type of arrangement shall be avoided whenever possible.

g. Multiple Displays - When the manipulation of one control requires the reading of several displays, the control shall be placed as near as possible to the related displays, but not so as to obscure displays when manipulating the control.

h. Separate Panels - When functionally related controls and displays must be located on separate panels and both panels are mounted at approximately the same angle relative to the operator, the control positions on one panel shall correspond to the associated display positions on the other panel. The two panels shall not be mounted facing each other. Controls and displays on separate panels are discouraged.

9.2.3.2.4 Preferred Control/Display Location Design Requirements

a. Display Location - The most important and frequently used displays shall be located in a privileged position in the optimum visual zone, providing that the integrity of grouping by function and sequence is not compromised. See Figure 9.2.4.2.2-2 for a definition of this zone.

b. Control Location - The most important and frequently used controls shall have the most favorable position with respect to ease of reaching and grasping (particularly rotary controls and those requiring fine settings), providing that the integrity of grouping by function and sequence is not compromised.

c. Multi-G Control Placement - Special attention shall be paid to the placement of controls which must be used while the crewmember is subject to either prolonged or transitory acceleration forces above 2-G.

1. In general, these controls shall be located so that the operator's limb is always in contact with the control (i.e., no reaching is required).

2. The requirements for movement from one control to another shall be minimized (e.g., use combined controls with several functions mounted on a single shaft).

3. Rotary controls shall be selected in preference to linear controls whenever possible.

4. When linear controls are necessary, they shall be mounted so that the direction of operation is perpendicular to the direction of G-forces.

5. Hand controls shall be placed so that when the shoulder, elbow, forearm, and wrist are supported, the following minimum movements can be made: MOVEMENT ACCELERATION - Arm Up to 4-G, Forearm Up to 5-G, (9-G if arm is counterbalanced), Hand Up to 8-G, and Finger Up to 10-G.

d. Control/Display Relationships:

1. The relationships of a control to its associated display and the display to the control shall be immediately apparent and unambiguous to the operator.

2. Controls shall be located adjacent to their associated displays and positioned so that neither the control nor the hand normally used for setting the control will obscure the display.

9.2.3.2.5 Consistent Control/Display Placement Design Requirements

a. Similarity - The arrangement of functionally similar or identical displays and controls shall be consistent from panel to panel throughout and between systems, equipment, units, and vehicles.

b. Mirror Images - Mirror image arrangements shall not be used.

9.2.3.2.6 Maintenance Controls/Displays Design Requirements

Controls and displays used solely for maintenance and adjustments shall be covered or non-visible during normal equipment operation, but shall be readily accessible when required.

(Refer to Section 12.0, Design for Maintainability, and Paragraph 9.2.3.2.1b, Gloved Operation, for additional information.)

9.2.3.2.7 Emergency Control/Display Placement Design Requirements

(Refer to Paragraph 9.4.4.3, Caution and Warning System Design Requirements, for related information.)

a. Emergency Control/Display Placement - Emergency displays and controls shall be located where they can be seen and reached with minimum delay.

b. Computer-Generated Emergency Displays - Emergency information depicted on existing computer-controlled displays shall be sufficiently conspicuous to attract the user's attention consistently.

9.2.3.2.8 Control/Display Movement Compatibility Design Requirements

a. Consistency of Movement - Controls shall be selected so that the direction of movements of the control will be consistent with the related movement of an associated display, equipment component, or vehicle (except as noted in "b" below). It must be borne in mind that in some situations, as in the case of a video camera being mounted on the wrist of a remote manipulator arm, logical movement will dictate that movement of the display not be in the same direction as movement of the control. This dictates that any control/display system which is likely to be used in conjunction with

another system needing such a "reverse" motion capability be designed to accommodate same in any direction in which the display can indicate movement.

b. Complex Movement Control - When the vehicle, equipment, or components are capable of motion in more than two dimensions, exception to 9.2.3.2.8 a shall be made to:

1. Maintain consistency with other systems.

2. Maintain a natural association between control and system movements. For example, forward motion of a directional control causes some vehicles to dive or otherwise descend rather than to-simply move forward.

c. Conflict Avoidance - When several controls are combined in one control activity, caution shall be exercised to avoid a situation in which similar movement of different controls results in different systems responses (e.g., control motion to the right is compatible with clockwise roll, right turn, and direct movement to the right).

d. Remote Controls - Where controls are operated at a position remote from the equipment or controlled vehicle, they shall be arranged to facilitate consistency of movement.

e. Movement Direction - When a rotary control and linear display are in the same plane, the part of the control adjacent to the display shall move in the same direction as the moving part of the display.

f. Labeling - When control/display relationships specified herein cannot be adhered to, controls shall be clearly labeled to indicate the direction of control movement required.

g. Time Lag - The time lag between the response of a system to a control input and the display presentation of the response shall be minimized, consistent with safe and efficient system operation. Where such time delay exceeds acceptable limits, the action of the control shall be appropriately modified (by force feedback or other means) to avoid overcontrol. Immediate feedback for operator entries shall have not more than a .2 sec delay. Simple requests for data shall be carried out more rapidly than .5 to 1.0 sec, while changes of entire data pages may be executed in up to 10 sec, depending on the user's expectations and the criticality of the information. If processing requirements result in longer delays, then the system shall acknowledge a control input immediately and provide periodic updates showing the progress of the processing.

(Refer to Paragraph 9.6.2.9.2.d and 9.6.2.9.2.e, Response Time, for recommended system response times for interactive computer-generated displays.)

9.2.3.2.9 Control/Display Movement Ratio Design Requirements

a. Adjustment Time - Control/display ratios for continuous adjustment controls shall minimize the total time required to make the desired control movement (*i.e., slewing time plus fine adjusting time*) consistent with display size, tolerance requirements, viewing distance, and time delays.

b. Range of Display Movement:

1. When a wide range of display element movement is required, small movement of the control shall yield a large movement of the display element.

2. When a small range of display movement is required, a large movement of the control shall result in a small movement of the display, consistent with accuracy requirements.

c. Coarse/Fine Knob Setting - A rotary knob used for coarse control shall move an associated display element (linear scale) 3-6 times the distance of a fine control knob per revolution of the knob.

d. Bracketing - When bracketing is used to locate a maximum or minimum value (e.g., as in tuning a transmitter), the control knob shall swing through an arc of not less than 10 degrees nor more than 30 degrees either side of the target value in order to make the peak or dip associated with that value clearly noticeable.

e. Counter - When counters are provided, the control/display ratio shall be such that one revolution of the knob produces approximately 50 counts.

9.2.3.2.10 Control/Display Complexity and Precision Design Requirements

9.2.4.2 Human/Workstation Configuration Design Requirements

9.2.4.2.1 Workstation Anthropometric Design Requirements

9.2.4.2.2 Visual Space Design Requirements

a. Viewing Distance:

1. Minimum - The effective viewing distance to displays, with the exception of visual display terminal (VDT) displays and collimated displays, shall not be less than 330 mm (13 in) and preferably not less than 510 mm (20 in.).

   When using a VDT, a minimum viewing distance of 410 mm (16 in.) shall be provided. The recommended distance depends on the detail and resolution of the display, but would generally be greater than 410 mm (16 in.). When periods of scope observation will be short, or when dim signals must be detected, the viewing distance may be reduced to 250 mm (10 in.).

2. Maximum - The maximum viewing distance to displays located close to their associated controls is limited by reach distance and shall not exceed 710 mm (28 in.). For other displays, there is no maximum limit, other than that imposed by space limitations and visual requirements, provided the display is properly designed.

b. Line of Sight - A crewmember's line of sight depends on body position and varies as a function of gravity level as shown in Figure 9.2.4.2.2-1.

c. Field of View - The field of view for a particular observer position is determined by eye and head movements.

1. The eye movement component for microgravity and 1-G is shown in Figure 9.2.4.2.2-2. (Note that the field of view is measured with respect to the shown in Figure 9.2.4.2.2-1.)

2. The head movement component for 1-G is shown in Figure 9.2.4.2.2-2. Microgravity head_movement data are not yet available and probably differs from 1-G.

d. Visual Distractions - Workstations shall be designed so that stimuli distracting to the operator are minimized.

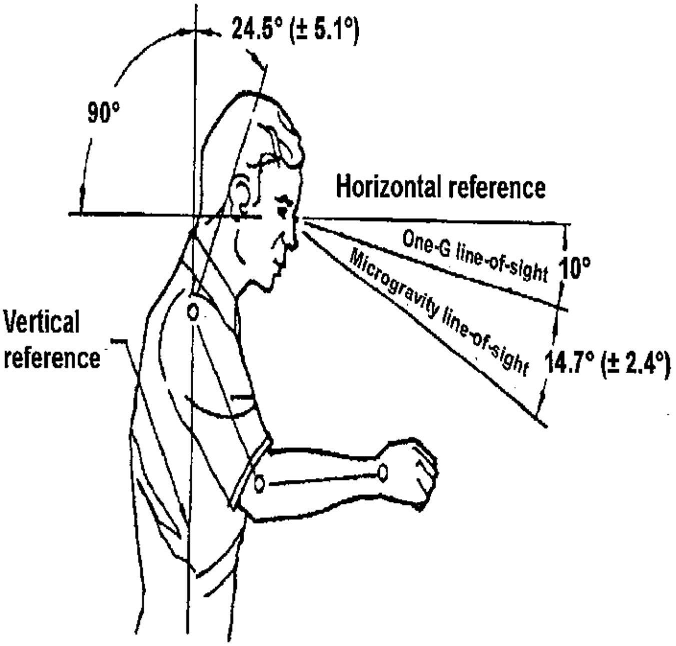


Figure 9.2.4.2.2-1 Line-of-Sight for One-G and Microgravity

MSIS 227

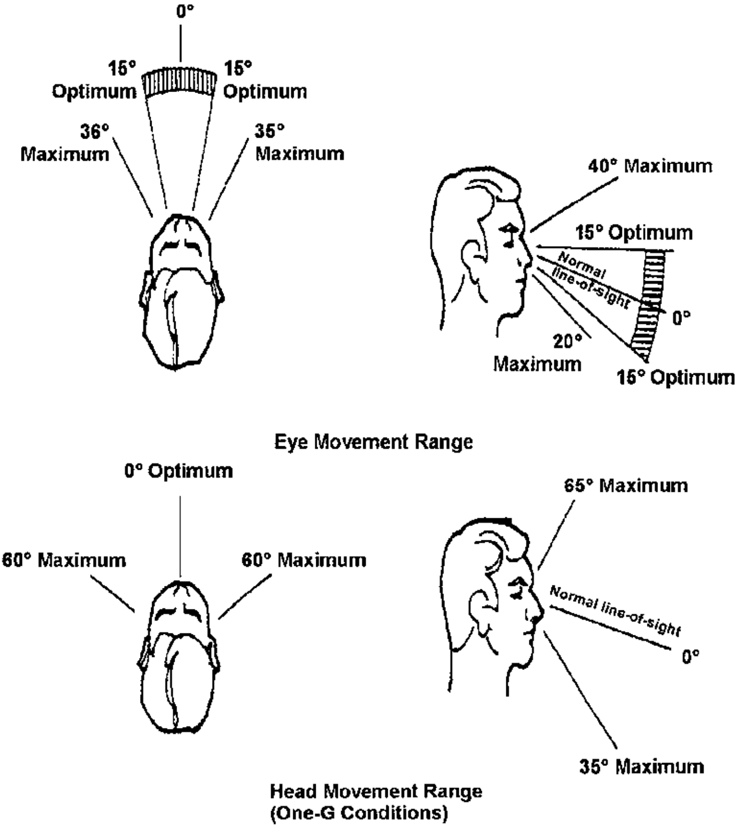


Figure 9.2.4.2.2-2 Eye and Head Movement Ranges (Line-of-Sight Depends on G-Level)

MSIS 228

9.2.4.2.3 Workstation Restraints and Mobility Aid Design Requirements

(Refer to Paragraph 11.7.2.3, Personnel Restraints Design Requirements, for specific design requirements relating to different types of restraints.)

a. Neutral Body Posture - The neutral body posture (see Figure 3.3.4.3-1) shall be used in the design of microgravity restraints. For short periods of time, significant variation from neutral body posture are acceptable but not desirable.

b. Freedom of Movement - A workstation restraint shall allow the users within the defined anthropometric range to reach all required controls and view all required displays without having to assume uncomfortable or awkward postures.

   1. Eye Position and Reach - Restraints shall be adjustable so as to achieve the best compromise between eye position (relative to displays)and reach (relative to controls) for crewmembers of differing heights.

   2. Adjustment of position shall be rapid and convenient, preferably without crewmembers having to exit restraint.

c. Required Restraint Placement - Foot, waist, or other restraint systems shall be located at all IVA workstations that require a crewmember to perform the following types of tasks.

   1. Long-term visual monitoring.

   2. Extensive manipulations requiring the use of both hands.

   3. Any task that requires the body position to be controlled.

d. Stability - As required, workstation restraints shall provide stability sufficient for:

   1. Viewing fine detail.

   2. Making fine manual adjustments.

   3. Exerting necessary force on controls without causing excessive body displacement.

   4. Executing continuous control movement when required.

e. Handholds and Handrails - Workstation handholds and handrails shall meet the following requirements:

   Refer to Paragraph 11.8.2.2, Handhold and Handrail Design Requirements, for additional requirements.)

   1. They shall aid in the translation and stability of crewmembers already in foot or other restraints.

   2. They shall allow unrestrained crewmembers access to workstation operations to the extent feasible.

   3. The physical dimensions and layout of the workstation handholds and handrails shall conform to the characteristics of the specific population of users for whom the system is to be designed.

   4. They shall not obstruct visual or physical access to workstations.

   5. They shall accommodate multiple personnel as required.

f. Equipment Restraints - Equipment restraints shall be provided to anchor every item of use that is not permanently attached to the workstation.

(Refer to Paragraph 11.7.3, Equipment Restraints.)

9.2.5.1.2 Window Workstation Design Requirements

(Refer to Paragraph 11.11, Windows, for requirements on the optical properties of windows as they apply to both humans and optical instruments, protection of humans from harmful window-related radiation, and the protection and maintenance of windows.)

a. Field of View:

   1. Design Eye Volume - The required field of view for a window workstation shall be attainable with the observer's eye position located anywhere within a specified design eye volume.

b. Window Shape - Rectangular rather than round viewing areas shall be used on windows whenever feasible. The purpose is to provide orientation cues for crewmember body position and/or extravehicular objects relative to the space module.

c. Multi-Observer Windows - When feasible, windows shall accommodate more than one observer. Window shape and work area layout shall be designed to this end.

d. Shielding:

   1. Luminance control - The capability to reduce window transmissivity through the addition of neutral filtering shall be provided. This shall allow crewmembers to work comfortably with extravehicular luminance conditions.

   2. Complete closure - The capability to completely block light transmittal through a window shall be provided.

   3. Sun Shades - When necessary, sun shades shall be provided. These shades shall be adjustable unless otherwise specified.

e. Color Discrimination - Windows used for making color discriminations shall possess neutral spectral transmission so that perceived target object hues are not altered.

f. Cleaning - Inside window surface shall be easily cleaned without damaging window.

(Refer to Paragraph 11.11.3.4, Window Maintenance Design Requirements, for additional information on window maintenance.)

g. Reflections - Workstation and work area design and lighting shall minimize reflections from the window to the lowest feasible level.

(Refer to Paragraph 11.11.3.2, Visual Protection Design Requirements, for information on antireflection techniques.)

h. Dark Adaptation - When dark adaptation is required at a window workstation, the workstation area shall allow dimming of lights to the required level without unduly interfering with other space module activities.

i. Display Shielding - Displays shall be shielded from sunlight entering the window or be designed to be legible in sunlight.

j. Control Placement - Control placement and design shall allow crewmembers to assume a position relative to the window that optimizes viewing conditions through the window.

k. Restraints - The design and placement of window workstation restraints shall allow up to four continuous hours of comfortable use.

9.2.5.2.2 Maintenance Workstation Design Requirements

a. Layout/Construction Requirements:

1. Location - The maintenance workstation shall be located in an easily accessible area.

2. Equipment size capability - The maintenance workstation shall be sized to accommodate the maximum-sized replacement unit/system that may require repair or maintenance.

3. Transparent Surfaces - All transparent surfaces (e.g., displays, windows, etc.) shall be scratch/mar resistant, antifog and anti-icing where possible, and shatter resistant.

4. Capabilities - The maintenance workstation shall be configured to support operational electrical, mechanical, vacuum, and fluid system corrective and preventive maintenance.

a) The maintenance workstation shall have general purpose diagnostic equipment and shall accommodate special purpose diagnostic equipment.

b) The maintenance workstation shall be equipped with a set of hand tools and with general purpose test and ancillary equipment and shall have ample stowage space for such tools, equipment, and supplies.

c) The maintenance workstation shall be developed with consideration being given toward providing capabilities for performing minor contingency fabrication tasks, including but not limited to turning, bending, forming, drilling, and bonding

5. The maintenance workstation shall be located in such a position that it will be convenient to accommodate extra-vehicular ORU's which must be maintained or serviced inside the pressurized volume.

b. Contamination:

(Refer to Paragraph 13.2.3, Housekeeping Design Requirements, for additional information on contamination control.)

1. Cleaning:

a) Exposed surfaces shall be designed to provide for easy cleaning. Crevices and narrow openings which can collect liquid or particulate matter and cannot be readily cleaned without special tools shall be avoided.

b) Any type of grid or uneven surface shall be configured to permit cleaning of all areas.

c) The maintenance workstation shall have a vacuum or evacuation system for purging and cleaning replacement units/systems. The vacuum effluence shall be contained to preclude external environment contamination.

d) Means shall be provided to control odors and/or to remove particulates from a system. All filters shall be easily accessible for cleaning and/or replacement. Means shall be provided to prevent leakage of any entrapped material from a filter unit during removal.

e) Maintenance workstations shall have the capability for the collection and disposal of debris, odors, particulate matter, and liquid from the workstation atmosphere as well as from exposed interior surfaces of the workstation.

f) Contamination Control:

1) The maintenance workstation shall provide for contamination control in the transport of devices to and from the maintenance workstation.

2) The maintenance workstation shall be provided with means to measure and monitor the contamination level within the work area, including the capability to measure surface contamination level.

3) The maintenance workstation shall have provisions for contamination control which assure prevention of mutual contamination between the ambient environment and the work area.

4) The maintenance workstation shall provide a contamination control method for IVA maintenance operations actions which will be performed remote from the maintenance workstation.

2. Hazardous operations - The capability to seal hazardous maintenance operations from other areas shall be provided for the duration of the operation.

3. Particulate matter retention - The maintenance workstation shall be capable of particulate matter/ odor retention and effluent scrubbing/capture.

c. Restraints:

(Refer to Paragraph 11.7.2, Personnel Restraints, Paragraph 11.7.3, Equipment Restraints, Paragraph 8.9, Mobility Aids and Restraints Architectural Integration, and Paragraph 11.3, Drawers and Racks, for additional information.)

d. Replacement Unit Interface - The maintenance workstation shall be able to interface with the failure detection, fault isolation, and built-in test capability of replacement units (e.g., ORUs) as required.

e. Maintenance Aids Package - The maintenance workstation shall be provided with a common maintenance aids package which will include but not be limited to: audio, video, and data communication links; a data management system interface; and utilities.

f. Power - The maintenance workstation shall have the capability to provide conditioned and converted power to support replacement unit design-specified requirements for servicing and repair activities.

g. Illumination - Workstation illumination shall be adequate for all anticipated tasks. Workstation illumination shall conform to paragraph 5.8.2 and Table XXI of MIL-STD-1472C.

(Refer to Paragraph 9.2.2.2.1, Workstation Illumination Design Requirements, for specific values.)

9.3 CONTROLS

9.3.3 Control Design Requirements

9.3.3.1 General Requirements

a. Standardization - Controls shall be standardized to the maximum extent practical.

b. Multi-g Controls - Controls to be used under prolonged or transitory acceleration forces above 2 g's shall be designed to accommodate the crewmember's altered physical abilities.

(Refer to Paragraph 9.2.3.2.4c, Multi-g Control Placement, for additional information.)

c. Microgravity Controls - Crew restraints shall be provided for use at all microgravity workstations.

d. Detent Controls - Detent controls shall be selected over continuous controls whenever the operational mode requires control operation in discrete steps.

e. Stops - Stops shall be provided at the beginning and end of the range of control positions if the control is not required to be operated beyond the indicated end positions or specified limits.

f. Load Limit - Controls shall withstand the crew-imposed limit loads given in Figure 9.3.3.1-1 as a minimum.

g. Blind Operation - Where "blind" operation (i.e., actuation without visual observation) is necessary, the controls shall be shape coded or separated from adjacent controls by at least 13 cm (5 in.).

(Refer to Section 9.2.3.2, Control/Display Placement and Integration - Design Requirements, for additional information.)

h. High-Force Controls - In general, controls requiring operator forces exceeding the strength limits of the lowest segment of the expected user population shall not be used. High-force controls shall only be used when the operator's nominal working position and/or restraint system provides proper support.

Item	Type of Load	Design limit load	Direction of load
Levers, handles, operating wheels	Push or pull concentrated on most extreme tip or edge	220 N (49.46 lbf)	Any direction
Small knobs	Torsion	15 Nm (11 ft-lb)	Either direction

Figure 9.3.3.1-1 Maximum Crew-Induced Design Limit Loads (Controls)

MSIS 233

i. Miniature Controls:

1. Miniature controls (e.g., DIP switches) shall be used only when severe space limitation exists and use by a suited crewmember is not required.

2. Miniature controls shall be avoided when frequent access to controls is required.

3. The movements of miniature controls shall be similar to those of standard controls.

   (Refer to Paragraph 9.2.3.2.8, Control/Display Movement Compatibility - Design Requirements, and Paragraph 9.2.3.2.9, Control/Display Movement Ratio - Design Requirements, for information on standard controls.)

4. The actuation of miniature controls shall be made as easy as possible without subjecting them to accidental actuation.

9.3.3.2 Accidental Actuation Design Requirements

a. Design and Location - Controls shall be designed and located so as to minimize susceptibility to being moved accidentally. Particular attention shall be given to critical controls whose inadvertent operation might cause damage to equipment, injury to personnel, or degradation of system functions.

b. Protective Methods - Adequate protection shall be provided for controls that are susceptible to accidental actuation.

c. Noninterference - Protection devices shall not interfere with the normal operation of controls or the reading of associated displays.

d. High-Traffic Areas - Critical controls shall not be located in high-traffic paths or translation paths. If controls must be placed in these locations, means shall be used to prevent inadvertent actuation (i.e., pull to unlatch toggle switches).

e. Dead-Man Controls - Where appropriate, controls, which result in system shutdown to a noncritical operating state when force is removed, shall be utilized where operator incapacity can produce a critical system condition.

f. Barrier Guards:

1. Barrier guard spacing requirements for use with toggle switches, rotary switches, and thumbwheels is shown in Figure 9.2.3.2.1-1.

   (For gloved operation, refer to Paragraph 14.4.3.2, EVA Control and Display Design Requirements.)

2. Accidental actuation of controls can result when crewmembers use barrier guards as handholds. Barrier guards shall be designed and located so as to minimize this problem.

g. Rotary Switch Protection - Rotary switches that control critical experiment or vehicle functions shall be recessed or have barrier guards. Dimensions are shown in Figure 9.3.3.2-1.

h. Detachment - Covers and guards shall be designed to prevent accidental detachment during operational periods.

i. Position Indication - When protective covers are used, control position shall be evident without requiring cover removal.

j. Hidden Controls - When hidden controls (i.e., controls that cannot be directly viewed) are required they shall be guarded to prevent inadvertent actuation.

k. Hand Controllers - Hand controllers shall have a separate on/off control to prevent inadvertent actuation when the controller is not in use.

l. Circuit Breaker Protection - When circuit breakers are ganged in a common array, a cover shall be used as an additional security measure to prevent inadvertent actuation or damage.

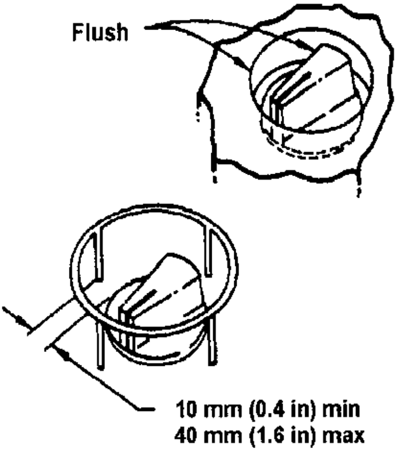


Figure 9.3.3.2-1 Rotary Switch Guard

MSIS 234

9.3.3.3 Control Types Design Requirements

9.3.3.3.1 Knob Design Requirements

a. Discrete Rotary Selection Switches:

1. General:

a) Rotary selector switches shall be used when four or more detented positions are required for discrete functions.

b) Rotary selector switches shall not be used for a two-position function unless ready visual identification of control position is of primary importance, and speed of control operation is not critical, or unless the use of other types of switches is not feasible.

2. Displacement - Up to 12 switch positions may be provided. Standard distance between positions shall be 30 degrees.

3. Knob dimensions - Pointer knobs of the type illustrated in Figure 9.3.3.2-1 are preferred for general use. Dimensions and alternate designs are, in order of preference, described within MIL-K-25049 and MIL-H-8810 (most preferred), MIL-STD-1472, AFSC DH 2-2 and MIL-STD-1348.

4. Separation and arrangement:

a) Rotary selector switches shall be designed with a moving pointer and a fixed scale.

b) The pointer knob shall be mounted sufficiently close to its scale to minimize parallax error between the pointer and the scale markings. When viewed from the normal operator's position, the parallax error shall not exceed 25% of the distance between scale markings.

c) Switch design and scale placement shall be such that there is no reasonable possibility of confusing the pointer-end and nonpointer-end of a knob.

5. Resistance - Switch resistance shall be elastic, building up, then decreasing as each position is approached, so that the control snaps into position without stopping between adjacent positions. The torque required to turn the switch from one detent position to another shall be no less than 9 N-cm (12 in. oz) at breakout and no more than 70 N-cm (100 in. oz) just prior to dropping into the next detent position.

6. Direction of movement - The order of positions shall be such that clockwise movement indicates "on" ascending order, increased performance, etc.

(Refer to Paragraph 9.2.3.2.8, Control/Display Movement Compatibility - Design Requirements, for additional information of control movement.)

b. Continuous Rotary Control Knobs:

1. General:

a) Continuous rotary control knobs (e.g., rheostats, potentiometers) shall be used for precise adjustment of system parameters.

b) Continuous controls may be either single-turn or multiturn.

2. Displacement - Single-turn controls shall have a preferred standard deflection of 240 degrees, between limits located at the 8 o'clock and 4 o'clock positions.

3. Resistance - The torque required to reposition the knob shaft shall be 6 to 25 N-cm (8 to 36 in. oz).

c. Ganged Control Knobs:

1. Use - Use of ganged control knobs shall be limited to two-knob assemblies where possible. Three-knob assemblies shall be avoided.

2. Limitations - Ganged knob configuration shall not be used under the following conditions.

a) Extremely accurate or rapid operations are required.

b) Frequent changes are necessary.

c) Heavy gloves may be worn by the operator.

3. Dimensions, torque and separation - Dimensions, torque and separation of ganged control knobs shall conform to Figure 9.3.3.3.1-1.

4. Serration of ganged control knobs:

a) Knobs shall be serrated.

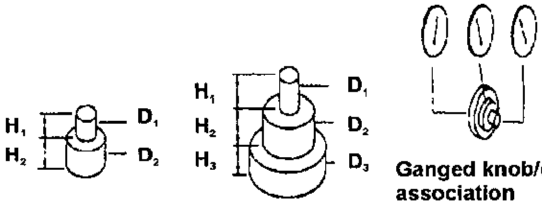
b) Fine serrations shall be used on precise adjustment knobs.

c) Coarse serrations shall be used on gross adjustment knobs.

5. Marking of ganged control knobs:

a) An indexing mark or pointer shall be provided on each knob.

b) Marks or pointers shall differ sufficiently to make it apparent which knob indexing mark is being observed.



Ganged knob/display association

	Dimensions									
	Two knob assembly				Three knob assembly					
	H_1	H_2	D_1	D_2	H_1	H_2	H_3	D_1	D_2	D_3
Minimum	16 mm (5/8 in)	13 mm (½ in)	13 mm (½ in)	22 mm (7/8 in)	19 mm (¾ in)	19 mm (¾ in)	6 mm (1/4 in)	13 mm (½ in)	44 mm (1¾ in)	75 mm (3 in)
Maximum				100 mm (4 in)						100 mm (4 in)

	Torque		Separation	
	To and including 25 mm (1 in) diameter knobs	Greater than 25 mm (1 in) diameter knobs	One hand individually Bare	Two hands simultaneously Bare
Minimum			25 mm (1 in)	50 mm (2 in)
Optimum			50 mm (2 in)	75 mm (3 in)
Maximum	32 mN-m (4½ in-oz)	42 mN-m (6 in-oz)		

Figure 9.3.3.3.1-1 Ganged Control Knobs

MSIS 235

6. Knob/display relationship - When each knob of a ganged assembly must be related to an array of visual displays, the knob closest to the panel shall relate to the left most display in a horizontal array, or the uppermost display in a vertical array (see Figure 9.3.3.3.1-1).

7. Inadvertent operation - When it is critical to prevent inadvertent actuation of one knob as the other is being adjusted, a secondary knob control movement shall be required (e.g., pressing the top knob before it can be engaged with its control shaft).

9.3.3.3.2 Thumbwheel Control Design Requirements

a. Discrete Position Thumbwheels :

1. Discrete position thumbwheels shall have 10 or fewer detent positions.

2. The standard distance between positions shall be 36°.

3. Maximum deflection shall be 360° or less if 10 or fewer positions are required.

4. Each position around the circumference of a discrete thumbwheel shall have a slightly concave surface or shall be separated by a high-friction (e.g., knurled) area that is raised from the periphery of the thumbwheel.

5. Resistance shall be elastic, building up and then decreasing as each detent is approached so that the control snaps into position without stopping between adjacent detents. The resistance of discrete thumbwheel controls to movement shall be between 11 and 34 N-cm (16 to 48 in. oz).

6. Movement of the thumbwheel forward, up, or to the right shall produce an increase in the setting value.

b. Continuous Types Thumbwheels:

1. Continuous type thumbwheels shall have a standard deflection of 300°.

2. Hard stops shall be provided to limit the maximum travel of continuous thumbwheels.

3. Continuous thumbwheels shall employ high-friction raised areas to facilitate movement.

4. The resistance of continuous thumbwheel controls to movement shall be between 1 and 4 N-cm (2 and 6 in. oz.).

5. Movement of the thumbwheel forward, up, or to the right shall produce an increase in the setting value.

c. Coding:

1. Thumbwheel controls shall be coded by location, labeling, or color (e.g., reversing the colors of the least significant digit wheel as on typical odometers).

2. Where used as input devices, thumbwheel switch OFF or NORMAL positions shall be color coded to permit a visual check that the digits have been reset to these positions (if applicable).

9.3.3.3.3 Valve Control Design Requirements

a. Low-Torque Valves - Valves requiring 1 N-m (10 in-lb) or less for operation are classified as "low torque" valves and shall be provided with a handle, 5.5 cm (2.25 in.) or less in diameter, (see "d" below).

b. Intermediate-Torque Valves - Valves requiring between 1 and 2 N-m (10 and 20 in-lb) for operation are classified as "intermediate torque" valves and shall be provided with a "central pivot" type handle 5.5 cm (2.25in.) or greater in diameter, or a "level (end pivot) type) handle, 7.5 cm (3 in.) or greater in length (the exact size shall be determined by the particular application).

c. High-Torque Valves - Valves requiring 2 N-m (20 in-lb) or more for operation are classified as "high torque" valves and shall be provided with handles greater than 7.5 cm (3 in.) in length.

d. Handle Dimensions:

   1. Valve handles shall approximate the configuration illustrated in Figures 9.3.3.3.3-1 and 9.3.3.3.3-2.

   2. Handles shall be contoured and finished so as to permit ease of operation.

   3. Circular handles, when used, shall have crowns or shall employ concave areas or convex projections along the periphery of the handle.

e. Direction of Operation - Rotary valve controls shall open the valve with a counterclockwise motion.

9.3.3.3.4 Crank Design Requirements

a. Dynamics:

   1. Where cranks are used for tuning or other processes involving numerical selection, each rotation shall correspond to a multiple of 1, 10, 100, etc.

   2. The gear ratio and dynamic characteristics of such cranks shall allow precise placement of the follower (e.g., crosshairs) without overshooting or undershooting and successive corrective movements.

b. Grip Handle - The crank grip handle shall be designed so that it turns freely around its shaft.

c. Dimensions, Resistance, and Separation - Dimensions, resistance, and separation between adjacent swept circular areas of cranks shall conform to the criteria of Figure 9.3.3.3.4-1.

d. Folding Handle - If a crank handle could become a hazard to persons passing by, or it is critical that the handle not be inadvertently displaced by being accidentally bumped, a folding handle type control shall be used. Such a control shall be designed so that the handle is firmly held in the extended position when in use and folded when not in use.

9.3.3.3.5 Handwheel Design Requirements

a. Restraints - When designed for use in microgravity, adequate restraints shall be provided for the operator.

b. Turning Aids - Knurling, indentation, high-friction covering, or a combination of these shall be built into the handwheel to facilitate operator grasp for applying maximum torque and to reduce the possibility of the wheel being jerked from the operator's hands.

c. Spinner Handles - For applications where the wheel may be rotated rapidly through several revolutions, a spinner handle may be added. Such handles shall not be used, however, if the projecting handle is vulnerable to inadvertent displacement of a critical wheel setting or if it creates a safety hazard.

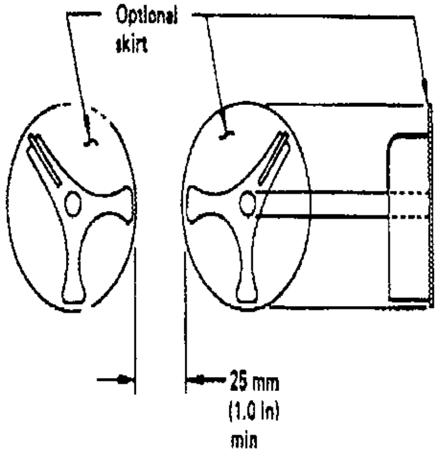


Figure 9.3.3.3.3-1 Valve Handle- Central Pivot Type

MSIS 236

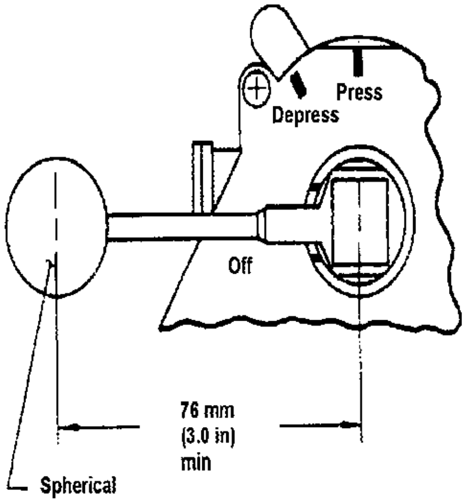
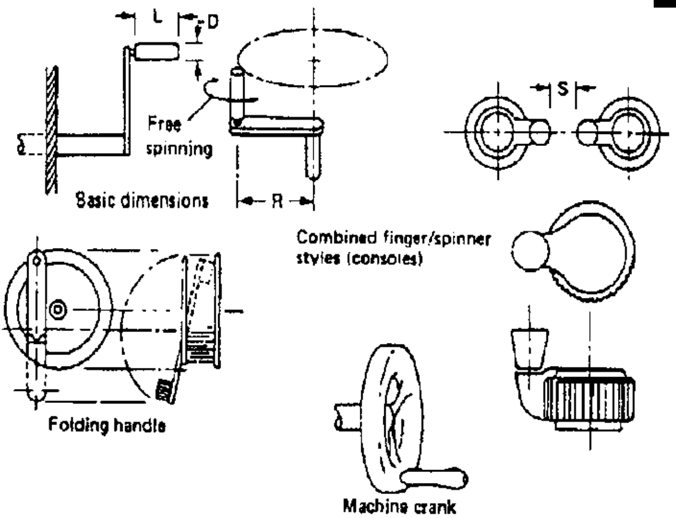


Figure 9.3.3.3.3-2 Valve Handle- Lever Type

MSIS 237



Load	Specification	Handle				R, Turning radius			
		L, Length		D, Diameter		Rate below 100 RPM		Rate above 100 RPM	
		mm	in	mm	in	mm	in	mm	in
Light loads Less than 22 N (5 lb) (wrist and finger movement)	Minimum	25	1	10	3/8	38	1-1/2	13	1/2
	Preferred	38	1-1/2	13	1/2	75	3	65	2-1/2
	Maximum	75	3	16	5/8	125	5	115	4-1/2
Heavy loads More than 22 N (5 lb) (arm movement)	Minimum	75	3	25	1	190	7-1/2	125	5
	Preferred	95	3-3/4	25	1	--	--	--	--
	Maximum	--	--	38	1 1/2	510	20	230	9

S=Separation between adjacent controls: 75 mm (3 in) minimum

MSIS 238 **Figure 9.3.3.3.4-1 Cranks**

9.3.3.3.6 Lever Design Requirements

Requirements for the design of levers are provided below.

a. Coding - When several levers are grouped in proximity to each other, the lever handles shall be coded.

   (Refer to Paragraph 9.5.3.2, Coding Design Requirements, for additional information.)

b. Length - The length of levers shall be determined by the mechanical advantage needed.

9.3.3.3.7 Toggle Switch Design Requirements

a. Dimensions - Dimensions for a standard toggle switch shall conform to the values presented in Figure 9.3.3.3.7-1.

b. Indication of Actuation:

   1. An indication of control actuation shall be provided (e.g., snap feel, audible click, associated or integral light).

   2. Switch design shall preclude stoppage between positions.

   3. Visual verification of switch position shall be obtainable at a glance from any viewing angle.

c. Operating Force:

   1. Operating force shall be in the range of 3 to 30 N (0.63 to 6.25 lbf).

   2. The selected force value shall be dependent upon the specific application (e.g., high-force switches are especially suited for applications where positive-feel is important).

   3. For lever-lock (pull-to-unlock) toggle switches, resistance of lift-to-unlock mechanisms shall not exceed 13 N (3 lbf).

d. Orientation - The preferred direction of toggle switch operation shall be vertical. Horizontal actuation of toggle switches shall be employed only for compatibility with the controlled function or equipment location.

e. Position Designation - Switch actuation shall control the system or subsystem functions as indicated in Figure 9.3.3.3.7-2.

f. Off Position - Where a third position is added for off, the off mode shall be located in the center position, except where this would compromise equipment performance. In this case, off shall be in the bottom position.

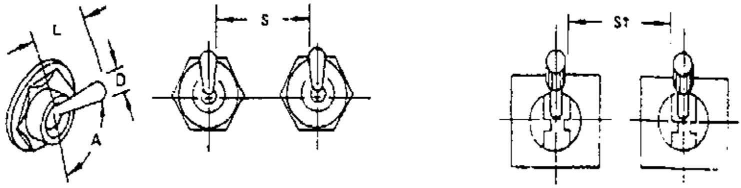
9.3.3.3.8 Pushbutton Design Requirements

(Refer to Paragraph 9.3.3.3.15, Legend Switch Design Requirements, and 9.3.3.4, Computer Input Devices, for additional information on pushbutton devices.)

a. Activation:

   1. Latching Pushbutton (push-on, lock-on). Activation shall be indicated by a sudden drop in resistance and, if possible, an audible click.

   2. Momentary Pushbutton (push-on, release-off) - Activation shall be indicated by positive feedback.



	Dimensions		Resistance	
	L Arm length	D Control tip	Small switch	Large switch
Minimum	13 mm (1/2 in)	3mm (1/8 in)	2.8 N (10 oz)	2.8 N (10 oz)
Maximum	50 mm (2 in)	25 mm (1 in)	4.5 N (16 oz)	11 N (40 oz)

	Displacement between positions A	
	2 Position	3 Position
Minimum	30°	17°
Maximum	80°	40°
Desired		25°

	Separation S			
	Single finger operation	†	Single finger sequential operation	Simultaneous operation by different fingers
Minimum	19 mm (3/4 in)	25 mm (1 in)	13 mm (1/2 in)	16 mm (5/8 in)
Optimum	50 mm (2 in)	50 mm (2 in)	25 mm (1 in)	19 mm (3/4 in)

† Using a lever lock toggle switch

Figure 9.3.3.3.7-1 Toggle Switches

MSIS 239

up / down:

on — off	open — close	activate — deactivate
increse — decrease	primary — backup	
deployed — stowed	auto — manual	

Figure 9.3.3.3.7-2 Toggle Switch Position Designation

MSIS 240

3. Alternate Action Pushbutton (push-on, push-off) - Activation shall be indicated by a sudden drop in resistance, an auditory click, and an associated display action.

4. Touch Sensitive (nonmechanical) - Activation shall be indicated by positive feedback.

b. Resistance - The resistance of pushbuttons to movement shall be 2.78 to 23.63 N (10 to 85 oz). The nominal force-resistance value shall be determined by the particular application and the environment in which it is operated.

c. Dimension:

1. The standard shape of pushbuttons shall be rectangular.

2. Round pushbuttons shall be used when dictated by special functional or hardware considerations.

3. When a pushbutton surface is not concave, the surface shall provide a high degree of frictional resistance to prevent slipping.

4. The height and width (or diameter, as applicable) of pushbuttons shall be 2 cm (0.75 in.) minimum and 4 cm (1.50 in.) maximum.

5. The illuminated area of pushbutton signal lights shall not be less than 3 cm^2 (0.40 $in.^2$) and not greater than *10* cm^2 *(1.5* $in.^2$*).*

d. Displacement:

1. Momentary pushbuttons shall have a total displacement of 0.32 to 1.84 cm (0.125 to 0.725 in.).

2. Latching pushbuttons shall have a total displacement of 0.64 to 1.84 cm (0.250 to 0.725 in.).

3. Alternate action pushbuttons shall have a displacement of 0.32 to 1.84 cm (0.125 to 0.725 in.).

4. Pre-travel shall be 0.32 to 1.52 cm (0.125 to 0.6 in.).

5. Over-travel shall be 0.32 cm (0.125 in.) maximum.

9.3.3.3.9 Foot-Operated Switch Design Requirements

a. Use:

1. Foot-operated switches shall be used only where the crewmember is likely to have both hands occupied when switch activation may be required, or when load sharing among limbs is desirable.

2. Because foot-operated switches are susceptible to accidental activation, their uses shall be limited to noncritical or infrequent operations such as press-to-talk communication.

3. Foot-operated switches shall be compatible with the restraint system being employed.

b. Operation:

1. Foot-operated switches shall be positioned for operation by the toe and the ball of the foot rather than by the heel.

2. Foot-operated switches shall not be located so near an obstruction that the crewmember cannot center the ball of the foot on the switch button.

3. A pedal may be used over the button to aid in location and operation of the switch.

4. Foot-operated switches shall be compatible with crewmember footwear.

c. Feedback - A positive indication of control activation shall be provided (e.g., snap feel, audible click, associated visual display).

9.3.3.3.10 Pedal Design Requirements

a. Control Return:

1. Except for controls that generate a continuous output (e.g., rudder controls), pedals shall return to the original null position without requiring assistance from the crewmember (e.g., brake pedal).

2. For pedals in which the operator may normally rest the foot on the control between operations, sufficient resistance shall be provided to prevent inadvertent activation of the control (e.g., accelerator pedal).

b. Pedal Travel Path - The travel path shall be compatible with the natural articulation path of the operator's limbs (i.e., thigh, knee, ankle) for the gravity condition under which the control will be used.

c. Nonslip Pedal Surface - Pedals shall be provided with a nonslip surface.

9.3.3.3.11 Rocker Switch Design Requirements

a. Positive Indication - An indication of control activation shall be provided (e.g., snap feel, audible click, associated or integral light).

b. Dimensions, Resistance, Displacement, and Separation - Dimensions, resistance, displacement, and separation between centers of rocker switches shall conform to the criteria in Figure 9.3.3.3.11-1. Resistance shall gradually increase, then drop when the switch snaps into position. The switch shall not be capable of being stopped between positions.

c. Orientation:

1. Where practicable, rocker switches shall be vertically oriented.

2. Activation of the upper wing of a rocker switch shall turn the equipment or component on, cause the quantity to increase, or cause the equipment or component to move forward, clockwise, to the right, or up.

3. Horizontal orientation of rocker switches shall be employed only for compatibility with the controlled function or equipment location.

9.3.3.3.12 Push-Pull Control Design Requirements

a. Handle Dimensions, Displacement, and Clearances - Handle dimensions, displacement, and clearances for push-pull control handles shall conform to criteria in Figure 9.3.3.3.12-1.

b. Rotation:

1. Except for combination push-pull/rotate switch configurations, push-pull control handles shall be keyed to a nonrotating shaft.

2. When the control system provides a combination push-pull/rotate functional operation using a round style knob, the rim of the knob shall be serrated to denote (visually and tactually) that the knob can be rotated, and to facilitate a slip-free finger grip.

c. Detents - Mechanical detents shall be incorporated into push-pull controls to provide tactile indication of positions.

d. Action of push-pull controls shall be:

1. Pull towards the operator for ON or activation; push away for OFF or deactivation.

2. Clockwise for activation or increasing function of combination pull/rotary switches.

Resistance - Force for pulling a panel control with fingers shall be not more than 18 N (4 lb), for pulling a T-bar with four fingers shall be not more than 45 N (10 lb).

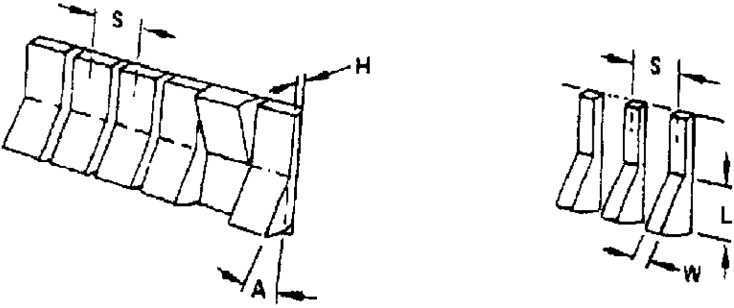
9.3.3.3.13 Circuit Breaker Design Requirements

a. General:

1. Circuit breakers shall be used for functions that require automatic protection against excessive electrical currents.

2. Circuit breakers shall be resettable.

3. Except for special cases, circuit breakers shall be of the plunger type (pull-to-release, push-to-reset).



	Dimensions		Resistance
	W, Width	L, Length	
Minimum	6 mm (1/4 in)	13 mm (1/2 in)	2.8 N (10 oz)
Maximum			11 N (40 oz)

	Displacement		Separation (center-to-center)
	H, Ht, Depressed	A, Angle	S (bare hand)
Minimum	3 mm (1/8 in)	30^{0}	19 mm (3/4in)

Figure 9.3.3.3.11-1 Rocker Switches

MSIS 241

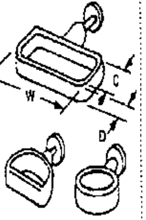
Configuration Example	Application Criteria	Design Criteria			Design Criteria	Separation
		Dimensions			Displacement	
	Push-pull control, low resistance, for two position mechanical and/or electrical systems. Alternate three position plus rotary function acceptable for applications such as vehicle headlights plus parking lights, panel and dome lights provide serrated rim.	D, min dia 19 mm (3/4 in)	C, min clearance 25 mm (1 in) Add 13 mm (1/2 in) for gloved hand		25 ± 13 mm (1 ± 1/2 in) min between pull positions 13 mm (1/2 in)	S, min space between 38 mm (1 1/2 in) Add 13 mm (1/2 in) for gloved hand
	Alternate handle; miniature electrical panel switch only. Avoid glove use application.	D, min dia 6 mm (1/4 in)	N/A	L min length 19 mm (3/4 in)	Minimum 13 mm (1/2 in)	S, min space between 25 mm (1 in)
	High-force push-pull, for two-position mechanical system only.	W, min width 100 mm (4 in)	D, depth 16-38 mm (5/8-1 1/2 in)	C, min clearance 38 mm (1 1/2 in) Add 6 mm (1/4 in) for gloved hand	Minimum 25 mm (1 in) Preferred 50 mm (2 in)	S, min space between 13 mm (1/2 in)
	Same as above. Preferred where possible garment or cable-snag possibility exists. Note: 1 and 2 finger pulls also acceptable for less than 18 N (4 lb) applications.	W, min width 100 mm (4 in) Add 25 mm (1 in) for gloves	D, depth 16-38 mm (6/8-1 1/2 in)	C, min clearance 32 mm (1 1/2 in)	Minimum 25 mm (1 in) Preferred 50 mm (2 in)	

Figure 9.3.3.12-1 Push-Pull Controls

MSIS 242

4. All tripped conditions shall be visually indicated.

Dimensions - Preferred dimensions for handles of plunger and switch type circuit breakers are illustrated in Figure 9.3.3.3.13-1.

c. Separation and Arrangement - An edge-to-edge distance of 2.5 cm (1.0 in.) nominal, 1 cm (0.5 in.) minimum, shall exist between circuit breakers grouped in horizontal rows, which is the preferred arrangement. The distance between rows shall be a minimum of 2.5 cm (1.0 in.).

d. Displacement:

1. The tripped condition of the plunger-type circuit breaker shall be indicated by a white or silver band. When the circuit breaker is closed the band shall not be visible (see Figure 9.3.3.3.13-1).

2. The "off" or tripped condition of the switch type circuit breaker shall be indicated when the handle is in the "down" position (see Figure 9.3.3.3.13-1).

Resistance - The force required to reset a plunger-type circuit breaker shall not exceed 53 N (12 lb). The force required to manually trip a plunger type circuit breaker shall not exceed 35 N (8 lb).

9.3.3.3.14 Slide Switch Control Design Requirements

a. Dimensions, Resistance, and Separation:

1. Dimensions, resistance, and separation of slide switch handles shall conform to criteria in Figure 9.3.3.3.14-1.

2. Detents shall be provided for discrete control settings. Resistance shall gradually increase, then drop when the switch snaps into position.

3. The discrete control slide switch shall not be capable of stopping between positions.

b. Orientation - Where practical, slide switches shall be vertically oriented. Horizontal orientation or actuation of slide switches shall be employed only when necessary for compatibility with a controlled function or equipment location.

c. Positive Indication - Slide-switch controls that are analog or involve more than two discrete positions shall be designed to provide positive indication of control setting, preferably a pointer located on the left side of the slide handle.

d. Switch Action - Moving the slide up or away from the operator shall result in turning the equipment or component on, causing a quantity to increase, or causing the equipment or component to move forward, clockwise, to the right, or up.

9.3.3.3.15 Legend Switch Design Requirements

(Refer to Paragraph 9.3.3.3.8, Pushbutton Design Requirements, for related information.)

a. Dimensions, Resistance, Displacement, and Separation - Dimensions, resistance, displacement, and separation between adjacent edges of legend switches shall conform to the criteria in Figure 9.3.3.3.15-1.

b. Barrier Height - Barrier height from panel surface shall conform to the criteria in Figure 9.3.3.3.15-1. Unless otherwise specified, barriers are required on critical switches and on switches likely to be inadvertently actuated. Barriers, when used, shall not obscure visual access to controls, labels or *displays*.

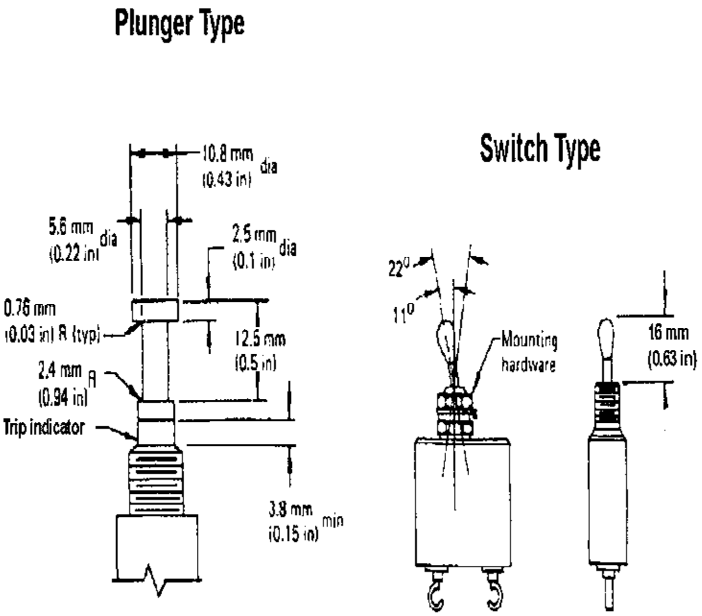
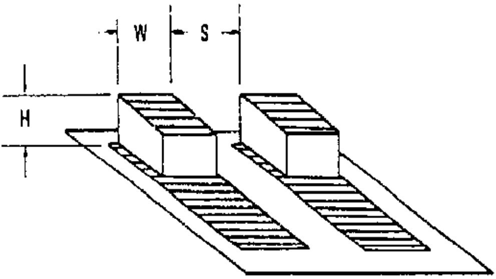


Figure 9.3.3.3.13-1 Circuit Breakers

MSIS 243

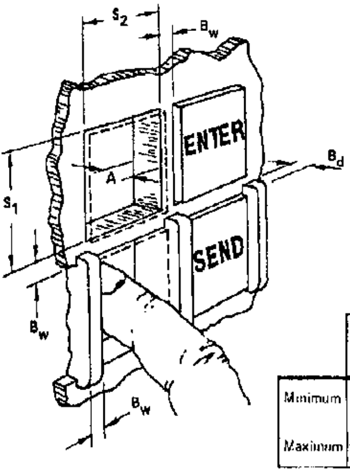


	Dimensions		Resistance	
	H Actuator height	W Actuator width	Small switch	Large switch
Minimum	6 mm (1/4 in)	6 mm (1/8 in)	2.8 N (10 oz)	2.8 N (10 oz)
Maximum	–	25 mm (1 in)	4.5 N (16 Oz)	11 N (40 oz)

	Separation, S		
	Single finger operation	Single finger sequential operation	Simultaneous operation by different fingers
Minimum	19 mm (3/4 in)	13 mm (1/2 in)	16 mm (5/8 in)
Optimum	50 mm (2 in)	25 mm (1 in)	19 mm (3/4 in)

Figure 9.3.3.3.14-1 Slide Switches

MSIS 244



	S_1, S_2 Size	A Displacement	Barriers		Resistance
			B_w	B_d	
Minimum	19 mm* (3/4 in)	3 mm** (1/8 in)	3 mm (1/8 in)	5 mm (3/16 in)	2.8 N*** (10 oz)
Maximum	38 mm (1-1/2 in)	6 mm (1/4 in)	6 mm (1/4 in)	6 mm (1/4 in)	16.7N (60 oz)

Notes:
* 15 mm (5/8 in) where switch is not depressed below the panel
** 5 mm (3/16 in) for positive position switches
*** 5.6 N (20 oz) for use in moving vehicles

Figure 9.3.3.3.15-1 Legend Switches

MSIS 245

c. Other Requirements:

1. For positive indication of switch activation, the legend switch shall be provided with a detent or click. When touch sensitive switches are used, a positive indication of activation shall be provided, (e.g., an integral light within or above the switch being activated).

2. The legend shall be legible with or without internal illumination.

3. A lamp test or dual lamp/filament reliability shall be provided for switches if the mean time between failure (MTBF) is less than 100,000 hours.

4. Lamps within the legend switch shall be replaceable from the front of the panel by hand and the legends or covers shall be keyed to prevent the possibility of interchanging the legend covers. The pushbuttons shall not be susceptible to inadvertent activation during this lamp removal or replacement process.

5. There shall be a maximum of three lines of lettering on the legend plate.

9.3.3.3.16 Printed Circuit (DIP) Switches Design Requirements

a. Use - The use of DIP switches shall be limited to nonroutine maintenance or troubleshooting applications.

b. Dimensions, Resistance, Displacement and Separation - Dimensions, resistance, displacement, and separation between adjacent DIP switch actuators shall conform to the following:

1. Dimensions of actuator shall be sufficiently high to permit error-free manipulation by the operator when using some commonly available stylus (e.g., pencil or pen). The design of the actuators shall not require the use of a special tool for manipulation.

2. Actuator resistance shall be sufficiently high to avoid inadvertent activation under expected use conditions. Resistance shall gradually increase, then drop when the actuator snaps into position. The actuator shall not be capable of stopping between positions.

3. When actuators are slide type, they have sufficient travel (displacement) to permit easy recognition of switch settings. At a minimum, the travel shall be twice the length of the actuator. When actuators are rocker type, the actuated wing shall be flush with the surface of the panel.

4. Actuators shall have sufficient separation to permit error-free manipulation by the operator (i.e., the stylus cannot inadvertently contact adjacent actuators).

c. Shape - The surface of the actuator shall be indented to accept the point of the stylus. The indentation shall be sufficiently deep to avoid slippage of the stylus during manipulation.

9.3.3.3.17 Key-Operated Switch Design Requirements

Key operated controls should be used when system requirements dictate that the function being controlled should be secured against activation by unauthorized personnel. If key operated controls cannot be justified in terms of security, they are probably not necessary and should not be used. Key operated switches should not be used solely as a means of shape coding.

9.3.3.4 Computer Input Devices

9.3.3.4.1 Keyboard Design Requirements

9.3.3.4.1.1 Layout

9.3.3.4.1.2 General

a. Keyboards design commonality - There shall be a single design for a keyboard, particularly in relation to the location of keys, and it shall be used throughout the space module.

b. Control switches - All commonly used controls associated with keyboard functioning (e.g., on/off) shall be readily accessible to the user. Both the control and its labeling shall be visible to the user.

c. Key markings - The key labels shall be placed on the keys in such a way as to be resistant to wear and abrasion. If the label cannot be placed on the key, it shall be placed above it.

d. Finger placement aids - The standard keyboards and the shall be distinguishable to the touch to facilitate the correct placement of the fingers for touch typists.

e. Microgravity placement - For microgravity operating conditions, the keyboard placement shall be compatible with the neutral body posture and the restraint system being employed.

f. Operating force - The preferred operating force of a terminal keyboard shall be 0.5 N (1.75 oz).

g. Key displacement - The recommended key displacement for activation is approximately 2.0 mm (0.08 in.) with bottoming-out occurring at about 4.0 mm (0.16 in.).

h. Feedback:

   1) The screen shall provide visual feedback each time a key is activated.

   2) Auditory feedback indicating key activation shall be provided. User shall have the option of deactivating this feedback.

   3) Kinesthetic feedback in the form of a distinct when keys are maximally depressed.

i. Keyboard interlock - A keyboard interlock shall exist to prevent the outputs from two or more simultaneously depressed keys from either jamming the print mechanism or outputting an invalid keycode.

j. Size and shape of keys - The shape of keys shall:

   1) Aid the accurate location of the user's fingers.

   2) Minimize reflections.

   3) Provide a suitable surface for the key legends.

   4) Be neither sharp nor uncomfortable to press.

   5) Have a dished profile curvature for improved keyboarding accuracy.

k. Key legend - The key legends shall be explicit and easy to understand. Alphanumeric legends shall not be smaller than 3.0 mm (0.12 in.).

l. Color and reflection of keys :

   1) The surface of keys shall have a matte finish to reduce glare.

   2) For standard keys, the primary color shall be neutral, e.g., beige or gray, rather than a color that has a high reflectance like white.

m. Function key labels - Function keys shall be labeled with standard function symbols, the function title, function title abbreviations, or function codes, in that order of preference.

n. Key Repeat - The capability of repeating characters or symbols continuously shall be provided. Keys shall be provided that automatically repeat when continually depressed for more than 0.5 seconds.

o. Key spacing - The spacing of keys shall be as indicated in Figure 9.3.3.4.1.2-1.

p. Noise Level - The "click" feedback of a keystroke shall be able to be turned off by the user on all keyboards, and preferably, also be adjustable to different volumes.

9.3.3.4.2 Joysticks Design Requirements

a. Isotonic Joystick:

1. Movement shall be smooth in all directions, and rapid positioning of a follower on a display shall be attainable without noticeable backlash, cross-coupling, or the need for multiple corrective movements.

2. Control ratios, frictions, and inertia shall meet the dual requirements of rapid gross positioning and precise fine positioning.

3. When used to create free-drawn graphics, the refresh rate for the follower on the VDT shall be sufficiently high to ensure the appearance of a continuous track.

4. The delay between control movement and the confirming display response shall not exceed 0.1 second.

5. Dimensions, resistance, and clearance shall conform to criteria in Figure 9.3.3.4.2-1.

6. The joystick shall be placed so as not to interfere with other controls.

7. Joystick placement shall allow effective operation when the operator is using the restraint system provided and maintaining an optimum viewing position with respect to the VDT.

b. Isometric Joystick

1. The output shall be proportional to the magnitude of the applied force as perceived by the operator.

2. The isometric joystick shall deflect minimally in response to applied force, but may deflect perceptibly against a stop at full applied force.

3. Isometric joysticks shall be used only when the primary feedback is not kinesthetic, but of some other form (e.g., visual).

9.3.3.4.3 Light Pen Design Requirements

a. Activating Device:

1. Light pens shall be equipped with an activating device. If the activating device is a pushbutton switch located at the tip, the force required shall be from 0.6 N to 1.4 N (2 to 5 oz).

2. Feedback shall be provided when the activating device is operated.

b. Position Indication - The computer software for light pens shall display a cursor under the light pen position. The cursor shall be large enough to be seen under the point of the light pen and shall move with the light pen.

c. Feedback - Light pens shall provide some indication that input has been received by the system.

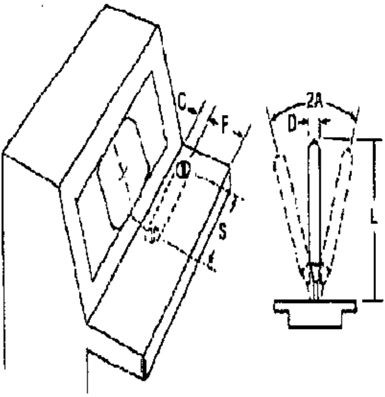
d. Dimensions - Light pens shall be between 11.9 and 18.0 cm (4.7 and 7.1 in.) long and 0.8 and 2.0 cm (0.3 and 0.8 in.) in diameter.

	Dimensions	Resistance		
	Key width Bare-handed	Numeric	Alpha-numeric	Dual function
Minimum Maximum Preferred	10 mm (0.385 in.) 19 mm (0.75 in.) 13 mm (0.5 in.)	1 N (3.5 oz) 4 N (14.0 oz)	250 mN (0.9 oz) 1.5 N (5.3 oz)	250 mN (0.9 oz) 1.5 N (5.3 oz)

	Displacement			Seperation
	Numeric	Alpha-numeric	Dual function	(between adjacent key tops)
Minimum Maximum Preferred	0.8 mm (0.03 in.) 4.8 mm (0.19 in.)	1.3 mm (0.05 in.) 6.3 mm (0.25 in.)	0.8 mm (0.03 in.) 4.8 mm (0.19 in.)	6.4 mm (0.25 in.) 6.4 mm (0.25 in.)

Figure 9.3.3.4.1.2-1 Keyboard Dimensions

MSIS 250



	Dimensions		Resistance	Displacement	Clearance		
	Dia, D	Length, L		A	Display C_L to stick C_LS	Around stick, C	Stick to shelf front, F
Minimum	6.5 mm (0.25 in)	75 mm (3 in)	3.3N (12 oz)		0		120 mm (4.75 in)
Maximum	16 mm (0.62 in)	150 mm (6 in)	8.9 N (32 oz)	45 deg	400 mm (15.75 in)	*	250 mm (9.88 in)

*** Maximum stick excursion plus 100 mm (4 in)**

Figure 9.3.3.4.2-1 Isotonic Joystick

MSIS 251

e. Storage - Light pen storage shall be passive on the part of the user: once released, the cable shall retract automatically to its storage position. During use of the light pen, the tension on the cable shall produce the equivalent of a 1g weight (+/- 20%) of the light pen.

f. Follower Movement - Light pens shall provide a smooth movement of the follower when used as a two-axis controller. The refresh rate for the follower shall be high enough to ensure the appearance of a continuous track whenever it is used to create graphics input.

9.3.3.4.4 Mouse Design Requirements

Design requirements for a mouse control device are provided below.

a. Use - A mouse is best used to select screen position rapidly through movement of the follower and shall be used for zero-order control only (i.e., generation of x and y-outputs by the controller results in proportional displacement of the follower) or rate control (i.e., cursor movement is proportional to rate of mouse movement), selectable by the user.

b. Operator Accuracy - The mouse shall be designed and placed on the maneuvering surface to allow the operator to orient it consistently to within +/- 10° of the correct orientation without visual observation. For example, when the operator grasps the mouse in what seems to be the correct orientation and moves it in a straight line along what is assumed to be the y-axis, then the direction of movement of the follower on the VDT shall be between 350° and 10°.

c. Mouse Accuracy - The mouse shall be easily movable in any direction without a change of grip and shall result in smooth movement of the follower in the same direction (+/- 10°).

d. Handedness - The mouse shall be operable with either hand.

e. Lost Cursor Control - The controller shall not drive the follower off the edge of the display.

f. Dimensions and Shape - The mouse shall have no sharp edges with limiting dimensions as indicated in Figure 9.3.3.4.4-1.

	Minimum	Maximum
Width (spanned by thumb to finger grasp)	40 mm (1.6 in)	70 mm (2.8 in)
Length	70 mm (2.8 in)	120 mm (4.7 in)
Thickness	25 mm (1.0 in)	40 mm (1.6 in)

Figure 9.3.3.4.4-1 Mouse Dimensions

MSIS 252

g. Discrete Activation - Where activation switches are required on the mouse they shall be limited to no more than three and the buttons shall be operable with normal grip.

h. Activation Surface - A surface which has a texture suited to mouse use and that is conveniently located shall be provided when a mouse is to be used.

i. Stowage - The mouse shall be removable and/or stowable.

j. Mouse/Keyboard Integration - The system shall be designed so that the user does not have to alternate frequently between the mouse and the keyboard.

9.3.3.4.5 Track Ball (Rolling Ball) Design Requirements

a. Zero-Order Control - A track ball shall be used for zero order control (i.e., a given movement of the ball produces a proportional movement of the follower on the display) or rate control (i.e., cursor movement is proportional to rate of ball movement), selectable by the user.

b. Follower Recapture - The controller shall not drive the follower off the edge of the display.

c. Location - Track ball placement shall allow efficient use of the device by crewmembers using workstation restraints and maintaining optimum view of associated VDT. The track ball shall be operable with either hand.

d. Dimensions, Resistance, and Clearance - Track ball dimensions, resistance, and clearance shall conform to the criteria in Figure 9.3.3.4.5-1.

e. Ball Diameter - The smaller diameter ball controls (Figure 9.3.3.4.5-1) shall be used only where space availability is very limited and when there is no need for precision.

f. Track Ball/Keyboard Integration - The system shall be designed so that the user does not have to alternate frequently between the track ball and the keyboard.

9.3.3.4.6 Stylus and Grid DesignRequirements

a. Input - Movement of the stylus on the grid surface shall result in a smooth movement of the follower in the same direction.

b. Stylus/Grid Correspondence - Discrete placement of the stylus at any point on the grid shall cause the follower to appear at the corresponding coordinates and to remain steady in position provided the stylus is not moved.

c. Refresh Rate - The refresh rate for the follower shall be sufficiently high to ensure the appearance of a continuous track whenever the stylus is used for generation of free-drawn graphics.

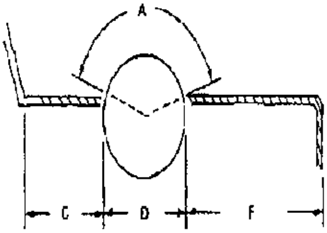
d. Remote Grid Size - Remote grids shall approximate the display size whenever possible.

e. Remote Grid Placement - Remote grids shall be at an orientation that maximally preserves the directional relationships between them and the display without violating any anthropometric considerations (e.g., a vertical plane passing through the north/south axis on the grid shall be parallel to the north/south axis on the display).

f. The stylus shall be storable in a retracted position. Retraction shall be activated automatically when the user releases the stylus. During use, tension on the cable shall be equivalent to the 1g weight (+/- 20%) of the stylus.

9.3.3.4.7 Touch-Sensitive Display Design Requirements

a. Touch Area Indication - The touch-sensitive areas of a display shall be indicated..



	Dimensions		Resistance		Clearance		
	Diameter, D	Surface Exposure, A	Precision Required	Vibration or Accel Conditions	*	Around Ball, C	Ball to Shelf Front, F
Minimum	50 mm (2 in)	100 deg			0	50 mm (2 in)	120 mm (4.75 in)
Maximum	150 mm (6 in)	140 deg	1.0 N (3.8 oz)	1.7 N (6 oz)	320 mm (12.62 in)		250 mm (9.75 in)
Preferred	100 mm (4 in)	120 deg	0.3 N (1.1 oz)				

*** Lateral distance from display centerline to ball centerline**

Figure 9.3.3.4.5-1 Trackball Design

MSIS 253

b. Touch Area Size - The touch area shall be large enough so that adjacent touch areas are not accidentally activated.

c. Touch-Sensitive-Display/Keyboard Integration - The system shall be designed so that the user does not have to alternate frequently between the touch display and other computer input devices.

d. Feedback - Positive feedback indicating that a touch has been registered shall be provided.

e. Inadvertent Activation - Inadvertent activation of the touch-sensitive device shall be precluded.

9.3.3.4.8 Bar Code Reader Design Requirement

a. Use - Bar code readers (or other computer access devices) shall be used as an interface between (Refer to Section 9.4.3.3 Audio Displays - Design Requirements, for further information.)equipment and associated data base information whenever appropriate (e.g., inventory control, maintenance procedures, etc.).

b. Ease of Use - Bar code readers shall be easy and fast to operate.

c. Orientation Flexibility - Bar code readers shall allow flexibility in the orientation match between the reader and the label to be read that is necessary for successful recognition.

d. Success Rate - Bar code readers shall successfully read the intended labels on a high percentage of passes.

9.3.3.5 Speech Transmission Equipment Design Requirements

a. Frequency - Microphones and associated system-input devices shall be designed to respond optimally to that part of the speech spectrum most essential to intelligibility (i.e., 200 to 6,100 Hz). Where system engineering necessitates speech-transmission bandwidths narrower than 200 to 6,100 Hz, the minimum acceptable frequency range shall be 250 to 4,000 Hz.

b. Dynamic Range - The dynamic range of a microphone used with a selected amplifier shall be great enough to admit variations in signal input of at least 50 dB.

c. Noise-Cancelling Microphones - In very loud, low-frequency noise environments (100 dB overall), noise-cancelling microphones shall be used and shall be capable of effecting an improvement of not less than 10 dB peak speech to root-mean-square-noise ratio as compared with non-noise-cancelling microphones of equivalent transmission characteristics.

d. Pre-emphasis - If necessary, speech system input devices shall employ frequency pre-emphasis with a positive slope frequency characteristic no greater than 18 dB per octave from 140 to 1,500 Hz and no greater than 9 dB per octave over the frequency range 1,500 to 4,800 Hz when no clipping is used.

e. Peak-Clipping of Speech Signals - Where speech signals are to be transmitted over channels showing less than 15 dB peak speech to root-mean-square-noise ratios, peak-clipping of 12 to 20 dB may be employed at system input and may be preceded by frequency pre-emphasis as specified in "d" above.

f. Noise Shields - When the talker is in an intense noise field, the microphone shall be put in a noise shield. Noise shields shall be designed to meet the following requirements.

1. A volume of at least 250 cm^3 (15.25 in^3) to permit a pressure gradient microphone to function normally.

2. A good seal against the face with the pressure of the hand or the tension of straps.

3. A hole or combination of holes covering a total area of 65 mm^2 (0.1 in^2) in the shield to prevent pressure buildup.

4. Prevention of a standing wave pattern by shape, or by use of sound-absorbing material.

5. No impediment to voice effort, mouth or jaw movement, or breathing.

g. Speaker/Side Tone - The speaker's verbal input shall be in phase with its reproduction as heard on the headset. This side tone shall not be filtered or modified before it is received in the headset.

9.3.3.6 Operating Controls for Voice Communication Equipment Design Requirements

a. Volume Controls:

1. Accessible volume or gain controls shall be provided for each communication receiving channel (e.g., loudspeakers or headphones) with sufficient electrical power to drive sound pressure level to at least 110 dB overall when using two earphones.

2. The sound pressure level (SPL) shall be maintained within + or - 3 dB when atmospheric pressure changes are encountered within the module.

3. The minimum setting of the volume control shall be limited to an audible level, i.e., it shall not be possible to inadvertently disable the system with the volume control.

   (Refer to Paragraph 5.4.3.2.2, Voice Communications Noise Exposure Requirements, for additional information.)

4. Separation of power (on-off) and volume control adjustment functions into separate controls is preferred. However, should conditions justify their combination, a noticeable detent position shall be provided between the OFF position and the lower end of the continuous range of volume adjustment. When combined power and volume controls are used, the OFF position shall be labeled.

b. Squelch Control - Where communication channels are to be continuously monitored, each channel shall be provided with a signal-activated switching device (squelch control) to suppress channel noise during no-signal periods. A manually operated, on-off switch, to deactivate the squelch when receiving weak signals, shall be provided.

9.4.2.3 Visual Display Design Requirements

9.4.2.3.1 Display Readability Design Requirements

9.4.2.3.1.1 Illumination Design Requirements

a. Luminance Control:

1. When a display will be used under varied ambient illumination, a dimming control shall be provided. The range of the control shall permit the displays to be legible under all expected ambient illumination levels.

2. Dimming to full OFF shall require a positive indication.

b. Dark Adaptation :

1. Partial Dark Adaptation - When the degree of dark adaptation required is not maximum, low brightness white light (preferably integral), that is adjustable as appropriate, shall be used.

2. *Complete Dark Adaptation - When complete dark adaptation is required,* low luminance (0.07-0.34 cd/m^2) red light (greater than 620 nm) shall be provided for better visibility.

c. Light Distribution:

1. Where multiple displays are grouped together, lighting shall be balanced across the instrument panel such that the mean indicator luminances of any two instruments shall not differ by more than 33% across the range of full ON to full OFF.

2. Light distribution shall be sufficiently uniform within an integrally illuminated instrument such that the ratio of standard deviation of indicator element luminances to mean indicator luminance shall not be more than 0.25, using eight or more equally spaced test measurements.

d. False Indication or Obscuration - Provision shall be made to prevent direct or reflected light from making indicators appear illuminated when they are not, or to appear extinguished when they are illuminated.

9.4.2.3.1.2 Display Indicator Contrast Design Requirements

Requirements for contrast within an indicator are provided below.

(Refer to Paragraph 9.4.2.3.3.9c, Contrast, for information on VDT contrast requirements.)

a. Indicator Contrast - The luminance contrast within the indicator shall be at least 50%. However, this 50% contrast requirement does not apply to special displays specifically designed for legibility in sunlight.

b. Low Ambient Illumination - For low ambient illumination applications, contrast shall be at least 90%, with the background luminance less than the figure luminance.

9.4.2.3.1.3 Reflections Design Requirements

a. Displays shall be constructed, arranged, and mounted to prevent reduction of information transfer due to the reflection of ambient illumination from the display cover.

b. Reflections in viewing surfaces (e.g., view ports, windshields, etc.) shall be avoided.

c. Anti-reflection techniques (such as shields and filters) shall not be used if they noticeably degrade display quality.

(Refer to Paragraph 8.11, Windows Integration, for related information.)

9.4.2.3.1.4 Vibration Design Requirements

Display design shall be such that vibration of the display and/or the observer shall not degrade display readability below the level required for mission accomplishment.

(Refer to Paragraph 5.5, Vibration Design Requirements, for specific requirements.)

9.4.2.3.1.5 Display Size Design Requirements

As a minimum, displays shall be of sufficient size to provide readily usable data to the user. This requirement shall hold for all reasonably anticipated locations of the user's relative to the display.

9.4.2.3.2 Information Presentation Design Requirements

a. Content - The information displayed to an operator shall be prioritized such that the information which is necessary to perform specific actions or to make decisions is easiest to acquire.

b. Equipment Response - Signal devices, including pushbutton signal lights, shall display equipment response and not merely control position.

c. Signal Absence:

1. The absence or extinguishment of a signal or visual indication shall not be used to indicate a "ready" or "in tolerance condition, unless the status of the caution light filament and its associated circuitry can be easily tested by the operator and operator perception of such events is not time critical. Display devices shall have a positive indication of on or ready.

2. The absence or extinguishment of a signal or visual indicator shall not be used to denote a condition; however, the absence of a signal or visual indication shall be acceptable to indicate a "power off" condition for operational displays only - not for maintenance displays.

d. Range and Accuracy - Display range and readout accuracy shall be consistent with the needs of the crewmembers to manage the spacecraft or equipment, but shall not exceed the accuracy of the input signal.

e. Duration - Non-dynamic signals and display information shall remain displayed until a direct user input cancels them. Dynamic signals and display information shall have durations of sufficient length to be reliably recognized under the highest expected operator workload and all anticipated operational environments.

f. Timeliness Displays (such as CRTs, head-up displays, etc.) requiring refreshed information shall be updated in a synchronous manner, where possible, and be refreshed to the degree of timeliness required by personnel in the normal operating or servicing mode.

g. Display Failure Clarity:

1. Displays shall be designed so that failure of the display or display circuitry shall be immediately apparent to the crew.

2. Where "automatic switch-over" to redundant power or signal sources (due to failure) is implemented, the automatic switch-over shall be made immediately obvious to the crew.

9.4.2.3.3 Display Types

a. System/Equipment Status - shall be inferred by the illumination of the indicator, not by the absence of illumination.

b. Indicator Labeling - shall be provided, close to the indicator, imparting the message intended by the light's illumination.

c. Indicator Color - The color of the light shall be clearly identifiable and meets with established color standards.

9.4.2.3.3.1 Maintenance Display Design Requirements

Maintenance displays shall be located so they do not interfere with normal flight displays. When possible, they shall not be visible when not in use.

9.4.2.3.3.3 Legend Light Design Requirements

a. Use - Legend lights shall be used in preference to simple indicator lights except where design constraints demand that simple indicators be used.

b. ON/OFF Legibility - When not energized, legends shall be legible but shall not appear to be energized (e.g., due to direct sunlight).

c. Information Presentation - A maximum of three lines of information shall be presented on the display face of a legend light.

d. Light/Switch Determination - It shall be easy to distinguish between legend lights and legend switches throughout the space module.

e. Status Indication - System/equipment status shall be inferred by the illumination of the indicator, not by the absence of illumination.

9.4.2.3.3.4 Scales and Pointers Design Requirements

Requirements for the design of scales and pointers are provided below.

a. Moving Pointer Circular Scales - Clockwise movement of a rotary control or movement of a linear control forward, up, or to the right shall produce a clockwise movement of circular scale pointers and an increase in the magnitude of the setting.

b. Moving Pointer Linear Scales - Clockwise movement of a rotary control or movement of a linear control forward, up, or to the right shall produce a movement up or to the right of the pointer of vertical and horizontal scales and an increase in the magnitude of the reading.

c. Fixed Pointer Moving Scale - Displays with moving scales and fixed pointers or cursors shall be avoided. When circular fixed-pointer, moving-scale indicators are necessary, clockwise movement of a rotary control or movement of a linear control forward, up, or to the right shall normally produce a counterclockwise movement of the scale and an increase in the magnitude of the reading.

d. Fixed Pointer Linear Scale - When use of vertical or horizontal fixed pointer, moving-scale indicators is necessary, clockwise movement of an associated rotary control or movement of a linear control forward, up, or to the right shall normally produce a movement of the scale down or to the left and an increase in the magnitude of the reading.

e. Pointers:

   1. Length - The control or display pointer shall extend to, but not overlap, the shortest scale graduation marks.

   2. Tip configuration - The pointer tip shall be tapered at a 20° angle (40° included angle), terminating in a flat tip equal in width to the minor scale graduations.

   3. Mounting - The pointer shall be mounted as close as possible to the face of the dial to minimize parallax (see Figure 9.4.2.3.3.4-1).

   4. Color - Pointer color from the tip to the center of the dial shall be the same as the color of the marks. The tail of the pointer shall be the same color as the dial face unless the tail is used as an indicator itself or unless the pointer is used for horizontal alignment.

f. Pattern/Color Coding - When certain operating conditions always fall within a given range on the scale, these areas shall be made readily identifiable by means of pattern or color coding applied to the face of the instrument.

g. Orientation - Alphanumerics on stationary scales shall be oriented in the local vertical position.

h. Zero Position and Direction of Movement - When positive and negative values are displayed around a zero or a null position, the zero or null point shall be located at either the 12 or 9 o'clock position. The magnitude of positive values shall increase with clockwise movement of the pointer, and the magnitude of negative values shall increase with counterclockwise movement. When pointer movement is more than 360^{0}, the zero or reference point shall be located at the 12 *o'clock position.*

i. Scale Break - There shall be an obvious break of at least 10 degrees of arc between the two ends of the scale, except on multi-revolution instruments such as clocks.

j. Number of Pointers - Whenever precise readings are required, not more than two coaxial pointers shall be mounted on one indicator face.

k. Pointer Alignment - When a stable value exists for given operating conditions in a group of circular-scale indicators, the indicators shall be arranged either in rows so that all pointers line up horizontally on the 9 o'clock position under normal operating conditions or in columns so that all pointers line up vertically in the 12 o'clock position under normal operating conditions. If a matrix of indicators is needed, preference shall be given to the 9 o'clock position.

l. Relative Position of Scale Marks and Number - When reading time and accuracy are critical, circular scale markings and the location of associated numbers shall be arranged to prevent pointers from covering any portion of the scale marks or numerals. The pointer shall come to within 0.8-1.6 mm (0.03-0.06 in.) of all scale markings (See Figure 9.4.2.3.3.4-2).

m. Placement of Pointers - Pointers shall be located to the right of vertical scales and at the bottom of horizontal scales.

n. Placement of Numerals - Numerals shall be placed on the side of the graduation marks away from the pointer to avoid having numbers covered by the pointer. If space is limited (for curved or arc scales) numerals may be placed inside of graduation marks to avoid undue constriction of the scale.

o. Setting - If the display will be used for setting a value (e.g., tuning in a desired frequency), the unused portion of the dial face shall be covered, and the open window shall be large enough to permit at least one numbered graduation to appear at each side of any setting.

9.4.2.3.3.5 Clock and Timer Design Requirements

a. Digital Clocks and Timers - Time measurement indicators shall be of the digital readout type. Where applications require the display of qualitative information (e.g., relative approximate time) other types of indicators (e.g., analog clocks and/or clocks of lesser accuracies) may be used, subject to the approval of the procuring activity.

b. Format - Time measurement indicators shall indicate time or time intervals in seconds (00 to 59), minutes (00 to 59), and hours (00 to 23). Values extending beyond 24 hours shall be displayed in terms of days unless otherwise specified. Greater or lesser resolution will be provided as required.

c. Accuracy - Accuracy shall meet the requirements of the task.

d. Control Modes - Unless otherwise specified, the manual control modes listed below shall be provided for each time measurement indicator.

1. Start - Upon activation of the start control line, the indicator shall begin to count within 100 milliseconds.

2. Stop - Upon activation of the stop control line, the indicator shall stop within 100 milliseconds.

3. Reset - Upon activation of the reset control line, the indicator shall reset to zero within 500 milliseconds.

4. Slew/Set:

a) Individual digit slew control shall be provided.

b) A manually set indicator shall slew in an upward direction (from the lowest reading to the highest reading) at the rate of 2 digits per second. A downward slewing mode is not required.

c) For applications where a "direct set" mode is provided in lieu of a timer shall display the commanded reading within 500 milliseconds after the activation of the "enter" or "proceed" command.

d) Upon activation of the count up command and start command, the indicator will count up and continue counting up through zero upon reaching maximum count (e.g., 59:58, 59:59, 00:00, 00:01, 00:02).

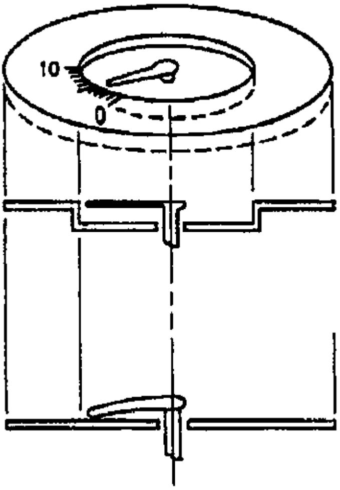


Figure 9.4.2.3.3.4-1 Scale and Dial Positioning to Minimize Parallax

MSIS 109

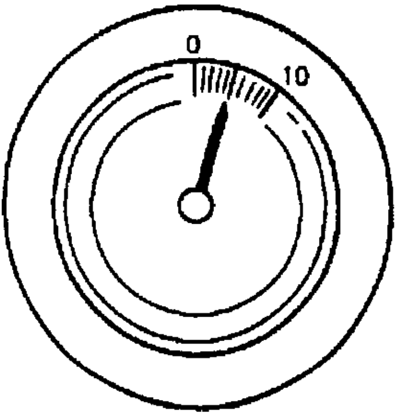


Figure 9.4.2.3.3.4-2 Relationship Between Pointer and Scale Marks to Maximize Reading Accuracy

MSIS 110

e) Upon activation of the countdown command and start command, timers shall countdown to zero and upon reaching zero shall begin to count up (e.g., 00:02, 00:01, 00:00, 00:01, 00:02). This control mode shall be implemented for event timers. The mode shall not be provided for clocks unless specifically requested.

f) There shall be no possibility of ambiguity as to whether a timer is counting toward its target time, or has passed the target time and is counting away from it, if this ambiguity could negatively affect system performance. For example, an overtime light can be used.

9.4.2.3.3.6 Flag Display Design Requirements

a. Use - Flags shall be used to display qualitative, non-emergency conditions.

b. Location and Mounting - Flag indicators shall be located above the associated control switch, within meter windows, or with associated items as applicable. Panel flags shall be mounted as close to the surface of the panel as possible without obscuring necessary information.

c. Snap Action - Flags shall operate by snap action.

d. Contrast - A minimum of 75% luminance contrast shall be provided between flags and their backgrounds under all expected lighting conditions.

e. Malfunction Indication - When flags are used to indicate the malfunction of a visual display, the malfunction position of the flag shall obscure part of the operator's view of the malfunctioning display and shall be readily apparent to the operator under all expected levels of illumination.

f. Positions - Flag indicators shall be restricted to three positions, with preference being given to the two-position type.

g. Information Content - Each flag indicator shall indicate a single, immediately identifiable event (e.g., the completed opening of a valve).

h. Legend - Alphanumeric legends shall be used in lieu of, or in addition to, color coding whenever possible. When a legend is provided on the flag, the lettering shall appear upright when the flag assumes the active or no-go position.

i. Gray Flag - A gray colored (blank position) mechanical "talk back" flag shall mean that a particular system element is in an operational mode or is not inhibited from operation.

j. Barber Pole Flags - A barber pole (striped) flag shall mean that a particular system element is indeterminant, inactive, or inhibited from operation.

k. Red Flag - a red flag shall mean that a particular system element has failed.

l. Test Provision - A convenient means shall be provided for testing the operation of flags.

9.4.2.3.3.7 Digital Display Design Requirements

a. Mounting - Counters shall be mounted as close as possible to the panel surface so as to minimize parallax and shadows and maximize the viewing angle.

b. Spacing Between Numerals - The horizontal separation between numerals shall be between one quarter and one half the numeral width. Numbers having more than five digits shall have groups of three digits separated by either blank space equivalent to one-half the width of one character or by commas. Grouping shall start from the right.

c. Movement:

1. Snap action - Numbers shall change by snap action in preference to continuous movement.

2. Update rate - The update rate shall not be faster than two per second.

3. Reset - The rotation of a counter reset knob shall be clockwise to increase the counter indication or to reset the counter.

4. Slew rate - Manual slewing modes, when provided, shall be capable of slewing individual digits at a normal rate of two characters per second. A separate control shall be provided for each individual digit (e.g., "units" digit, "tens" digit, etc.), unless otherwise specified.

d. Illumination - Digital displays shall be self-illuminated when used in areas in which ambient illumination will provide display luminance below 3.5 cd/m^2 (1 ft-L).

e. Individual characters shall normally be limited to the numbers 0 through 9, the capital letters of the English alphabet (A through Z), the plus (+) and minus (-) signs, and the decimal point.

f. Accuracy - Digital indicators shall possess an internal accuracy equal to or better than the least significant digit displayed by the indicator.

g. Analog Inputs - When analog-to-digital conversion is required to display an analog signal in digital form, the displayed digit(s) shall reflect the analog signal rounded off to the nearest whole number of the least significant digit displayed (Note: 0.5 shall be rounded up).

9.4.2.3.3.8 Light Emitting Diode (LED) Design Requirements

a. In general, the standards for LEDs will be the same as the requirement for transilluminated displays, paragraph 9.4.2.3.3.11 of this standard.

b. Intensity Control - LEDs shall be capable of being dimmed.

c. Color Coding - Use of LED color coding shall conform to Paragraph 9.5.3.2i, herein.

d. Lamp Testing - LED indicator lights with less than 100,000 hours mean time between failure (MTBF) shall require a lamp testing capability.

9.4.2.3.3.9 Visual Display Terminal (VDT) Design Requirements

a. Resolution - All displays shall have a minimum resolution of 67 lines per inch.

b. Luminance - The minimum level of luminance recommended for characters on a VDT, regardless of wavelength, shall be 70 cd/m^2 (20 fL) with a level of 170 cd/m^2 (50 fL) preferred.

c. Contrast:

1. Controls - VDTs shall be equipped with controls that permit the crew to optimize VDT discriminability under all anticipated environmental and systems operating conditions. Adjustment of brightness, contrast, and other electronic parameters shall permit the detection of the weakest target that is simulated.

2. Tolerance - Operating tolerance for contrast shall be 2 %.

3. Manual control - Under normal operating conditions, a manual VDT brightness control shall be provided allowing selection of contrast between *the lowest intensity symbology and its background of from 1:1 to at least* 16:1.

4. High ambient - As the highest ambient light level is reached, the contrast ratio between the lowest intensity symbology and the background shall degrade to not less than 2:1 (unless a lower contrast has been manually selected).

5. Automatic control - Where critical images (those necessary for crew safety and mission success) are exposed to rapid or frequent changes in ambient light levels, the contrast ratio shall be automatically maintained at a level selected by the operator.

6. Recommended contrast - The maximum contrast shall be 90%, the minimum shall be 88%. This narrow range applies specifically to alphanumeric displays with contrast defined as: %C = (Lc+Lr)-(Ld+Lr) x 100, C = contrast, Lc = character luminance, Ld = background luminance, Lr = reflected luminance.

d. Glare - Glare from a VDT screen shall be controlled for viewing from any angle within 30° of the axis normal to the screen.

(Refer to Paragraph 9.4.2.2c, VDT Enhancement, for recommendations on glare control.)

e. Surround:

1. The luminance range of surfaces immediately adjacent to the display shall be between 10% and 100% of screen background luminance.

2. Surfaces adjacent to the display shall have a dull matte finish.

f. Flicker - the refresh rate for VDTs shall not be less than 55 Hz. For alphanumerics presented in negative contrast (dark characters on light background) the refresh rate shall be at least 100 Hz.

g. Viewing Distance and Angle:

1. A nominal viewing distance of 510 mm (20 in.) for VDT use shall be provided.

(Refer to Paragraph 9.4.2.2c, VDT Enhancement, for additional information on recommended viewing distances for VDT displays.)

2. Viewing Angle - All areas of the display surface shall be legible from within at least 30 degrees of the axis centered on, and normal to, the screen.

h. Installation - The face of VDT displays shall be flush with the surface of the panel in which it is installed.

i. VDT Alphanumerics:

(Refer to Paragraph 9.5.3.1.14, Alphanumeric Design, for Labeling and Coding Requirements.)

1. Character definition - The smallest definition for a dot matrix shall be 5 by 7 dots, with 7 by 9 preferred. If system requirements call for symbol rotation, a minimum of 8 by 11 is required, with 15 by 21 preferred.

2. Character font:

a) Unless precluded by other requirements, a standard font shall be used across an entire system.

b) The font shall include lower case characters and allow for descenders.

c) Superscripts and subscripts shall be provided.

3. Character size:

a) Character height:

1) For extended text, character height shall subtend a minimum of 15 minutes of arc for low definition characters (5x7). The maximum height shall be 22 minutes of arc unless a task analysis indicates need for a greater height in any specific application.

2) Flight display characters (not extended text) shall not subtend less than 24 minutes of visual angle to ensure adequate legibility under launch/entry conditions.

b) Character width - Character width shall be approximately 75% of character height.

c) Stroke width - Stroke width shall be 1/6 to 1/8 of character height.

4. Alphanumeric spacing:

a) Vertical spacing (line spacing) - Vertical spacing between lines shall be great enough so that immediately adjacent ascenders and descenders are separated by at least one blank pixel.

b) Horizontal spacing:

1) Between words - In printed text, normal spacing between words on a line shall be one character width.

2) Between characters - Minimum spacing between successive characters on a line shall be one pixel or 20% of character width (whichever is greater).

c. Descender Length - Descenders shall descend below the line by a distance of 10% to 15% of the upper case letter size.

5. Case - Extended text shall be in uppercase and lowercase letters. Words consisting of uppercase letters shall be used only to attract the operator's attention (e.g., for a label or title).

j. Target Size - When rapid identification is required (e.g., a target of complex shape is to be distinguished from a non-target shape that is also complex), the target signal shall subtend no less than 20 minutes of visual angle at the intended viewing distance. (The term "target" is used to mean any object, symbol, pattern, or marking that an operator must see.)

k. Display Face Facsimiles - Images of scale indicators, digital indicators, signal devices, and other display faces synthesized on VDT screens shall conform to the general requirements previously listed for specific types of displays.

l. Color - When color VDTs are used, they shall possess the capability to display at least four colors (in addition to black and white) for alphanumeric and two-dimensional displays. For three-dimensional graphics displays the VDT shall possess the capability to display at least nine colors.

m. Display Overlays - The VDT shall provide the capability to display video with text and graphic overlays.

n. Highlighting - VDT, as a minimum, shall provide the following highlighting techniques: bold (high intensity) characters, reverse polarity, blinking.

o. Windowing - The VDT shall provide windowing capability. The user shall have the capability to create windows, delete windows, overlay windows, activate windows, move windows, and size windows. Images within windows shall be scrollable, if they are larger than the window itself.

9.4.2.3.3.10 Hardcopy Display Design Requirements

a. Printers:

1. The printer shall print copy at a rate of at least 400 words per minute if the user is interacting with the computer through the printer.

2. Printer delay shall be no more than 1 to 2 seconds to acknowledge a command if the user is interfacing with the computer through the printer.

3. Printer noise level shall not exceed the NC 50 contour. If it does, the printer shall be in an enclosed area away from other personnel.

   (Refer to Paragraph 5.4.3.2.3.1, Wide-Band, Long-Term Annoyance Noise Exposure Requirements, for specific requirements.)

4. Paper advance control or print head advance shall be provided to permit the operator to read the most recently printed line.

5. A provision shall be made for taking up paper.

6. The capability to remove printed material rapidly and neatly shall be provided.

7. There shall be an indicator of the remaining paper supply.

8. Reloading paper or replacing ribbon shall be accomplished without disassembly or using special tools.

9. Paper retainers shall be provided to reduce paper vibration.

10. Guides shall be provided to facilitate accurate positioning of the paper.

11. Where applicable, printers shall be designed to accept a variety of paper sizes.

12. The printer shall have graphics capability unless otherwise specified.

13. Where applicable, printers shall have draft mode (high speed) and high print quality mode (lower speed).

14. A print malfunction alarm shall be provided to alert the user when requested printing is not being done due to some malfunction.

15. Matte finish paper shall be used to avoid smudged copy and glare.

16. Hard copy print shall be black characters on a white background unless otherwise specified.

b. Plotters and Recorders:

1. Use - Plotters and recorders shall be used when a visual record of continuous graphic data is necessary or desirable.

2. Visibility - Critical graphics (those points, curves, and grids that must be observed when the recording is being made) shall not be obscured by pen assembly, arm, or other hardware elements.

3. Contrast - A minimum of 50% luminance contrast shall be provided between the plotted function and the background on which it is drawn.

4. Take-up device - A take-up device for extruded plotting materials shall be provided.

5. Job aids - Graphic overlays shall be provided where these may be critical to proper interpretation of graphic data as it is being generated. Such aids shall not obscure or distort the data.

6. Smudging/smearing - The plot shall be resistant to smudging or smearing under operational use.

9.4.2.3.4 Display Maintenance Design Requirements

a. Lamp Redundancy - Incandescent display lighting shall incorporate filament redundancy or dual lamps. When one filament or bulb fails, the intensity of the light shall decrease sufficiently to indicate the need for lamp replacement, but not so much as to degrade operator performance.

b. Lamp Testing - When indicator lights using incandescent bulbs are installed on a control panel, it shall be possible to test all control panel lights at one time. When applicable, design shall allow testing of all control panels at one time. Panels containing three or fewer lights may be designed for individual press-to-test bulb testing.

c. Lamp Replacement - Where possible, lamps shall be removable and replaceable from the front of the display panel. The procedure for lamp removal and replacement shall not require the use of tools and shall be easily and rapidly accomplished.

d. Lamp Removal Safety - Display circuit design shall permit lamp removal and replacement while power is applied without causing failure of indicator circuit components or imposing personnel safety hazards.

9.4.3.3 Audio Displays Design Requirements

9.4.3.3.1 General Design Requirements

General requirements for the design of audio displays are provided below.

a. False Alarms - The design of audio display devices and circuits shall preclude false alarms.

b. Failure - The audio display devices and circuits shall be designed to preclude warning signal failure related to system or equipment failure and vice versa. Positive and attention demanding indication shall be provided if failure occurs.

c. Circuit Test - All audio displays shall be equipped with circuit test devices or other means of operability testing.

d. Disable - An interlocked, manual disable shall be provided if there is any failure mode which can result in a sustained activation of an audio display.

9.4.3.3.2 Audio Input/Output Equipment Design Requirements

a. Frequency Response - Microphones/input devices, loudspeakers/output devices, and associated audio system devices shall be designed to respond optimally to that part of the speech/audio spectrum most essential to intelligibility (i.e. 200 to 6,100 Hz). Where system engineering necessitates speech transmission bandwidths narrower than 200 to 6,100 Hz, the minimum acceptable frequency range shall be 250 to 4,000 Hz. Amplitude variation across the frequency response bandwidth (flatness) shall be not vary more than +/- 3dB.

b. Microphones/input devices:

1. Dynamic Range - The dynamic range of a microphone/input devices shall be great enough to admit variations in signal input of at least 50 dB.

2. Noise Canceling - Noise canceling microphone/input devices are required for high noise environments (85 dB (A) or above) and are preferred in all areas.

c. Loudspeaker/output devices :

1. Sidetone - The speaker's verbal input shall be in phase (not have a perceivable delay) with its reproduction as heard on the output device.

2. Audio equipment used to feed multiple channels into output devices shall maintain the frequency response uniformly (+/- 5dB) over the bandwidth.

3. Headsets - If listeners will be working in high ambient noise (85 dB(A) or above), binaural rather than monaural headsets shall be provided. Unless operational requirements dictate otherwise, binaural headsets shall be wired so that the sound reaches the two ears in opposing phases. Their attenuation qualities shall be capable of reducing the ambient noise level to less than 85 dB(A). Provisions shall be incorporated to furnish the same protection to those who wear glasses.

d. Use of Deemphasis - When transmission equipment employs pre-emphasis and peak-clipping is not used, reception equipment shall employ frequency Deemphasis of characteristics complementary to those of pre-emphasis only if it improves intelligibility (i.e., Deemphasis shall be a negative-slope frequency response not greater than 9 dB per octave over the frequency range 140 to 4,800 Hz).

e. Feed Back Noise - Positive feedback noise shall be controlled to the extent that normal voice communication is not adversely affected.

f. Earphone/Speaker To Microphone Feedback Isolation:

1. Sufficient electrical, mechanical, and acoustical isolation shall be provided to preclude feedback oscillations (squeal problems) or echo effects (no discernable unwanted voice echo to speaker).

2. Earphone/Speaker to microphone system loop gain shall be limited to less than 1.

9.4.3.3.3 Operator Comfort and Convenience Design Requirements

a. Comfort - Communication equipment to be worn by a crewmember (e.g., headphones) shall be designed to preclude operator discomfort. Metal parts of the headset shall not come in contact with the user's skin.

b. Hands-Free Operation - Operator microphones and headphones shall be designed to permit hands-free operation under normal working conditions.

9.4.4.3 Caution and Warning System Design Requirements

9.4.4.3.1 Alarm Classification Design Requirements

9.4.4.3.1.1 Emergency Display Design Requirements

a. Definition of Class 1 Alarm - A life threatening condition requiring immediate attention. Predefined crew responses may be required prior to taking corrective action. Safe haven concept activation may be necessary. Examples: cabin pressure decrease, fire/smoke, toxic atmosphere, impending collision.

b. Annunciation Requirements:

1. Each condition shall trigger a unique aural tone, (e.g., fire-siren, cabin pressure-klaxon).

2. Tones and visual annunciation shall be heard and seen in any habitable area.

3. Tones shall wake sleeping crewmembers.

4. Illuminated visual annunciation shall indicate presence of specific emergency condition.

5. Tone shall be resettable at all major control consoles/areas.

6. Corrective action information shall be available.

9.4.4.3.1.2 Warning Signal Design Requirements

a. Definition of Class 2 Alarm - Conditions that require immediate correction to avoid loss of major impact to mission or potential loss of crew. Examples: electrical bus loss, cooling loop failure, rapid loss of consumables.

b. Annunciation Requirements:

1. A warning signal shall trigger an identifiable warning tone and master warning light at all major control consoles/areas.

2. Tone and light shall be reset only by crew action.

3. Tone shall be adjustable in sleeping quarters to wake or not to wake sleeping crewmembers as desired (but, see "4" below).

4. At least one crewmember shall always be available to receive a warning signal.

5. Message or light shall be provided to specify condition.

6. Method shall be provided to determine if condition returns within limits.

7. Corrective action information shall be available upon crew request.

9.4.4.3.1.3 Caution Display Design Requirements

Requirements for the design of caution displays are provided below.

a. Definition of Class 3 Alarm:

1. Conditions of a less time critical nature, but with the potential for further degradation if crew attention is not given. Example: heavier than normal consumable usage.

2. Messages that flag loss of redundant equipment such that a subsequent failure could result in a warning condition. Action is not necessarily required except that the effect of the loss in future activity planning must be considered. Example: loss of backup communication equipment.

b. Annunciation Requirements:

1. Caution displays shall trigger a general tone and light (different than class 2 tone/light) for a set time duration. This duration may be set differently for each caution condition .

2. Tone and light shall be extinguishable by crew action.

3. Data system message shall specify condition and corrective action at the discretion of the crew.

4. Tone shall be adjustable in sleeping quarters to wake or not to wake sleeping crewmembers as desired (but, see "4" below.)

5. At least one crewmember shall always be available to receive a caution signal.

6. A method shall be provided to determine if condition returns within limits.

7. A method shall be provided to identify momentary out of limits condition.

9.4.4.3.2 General Caution and Warning System Design Requirements

General requirements for caution and warning systems (CWS) are provided below.

a. CWS Recovery - The CWS shall be rapidly recoverable from a software system crash.

b. CWS Test Limits - Permanent limit or test conditions shall be stored redundantly in such a way that they are protected from system crashes and single operator errors involved with temporary limit changes.

c. System Failure - The system shall remain operable during and after major system failures (power, data, etc.).

d. Safe Haven CWS - The CWS shall be able to supply life support and rescue systems status to crewmembers using a "safe haven".

e. Flexibility - The CWS design shall provide for any anticipated expansion or reconfiguration of the space module or the addition of new modules, payloads, or experiments.

f. Sensor Changeout - Critical CWS sensors shall be accessible for changeout when feasible.

g. System Status During Alarm - After an alarm is triggered, it shall be quickly determinable if the out-of-limit condition still exists and/or if a new out-of-limit condition occurs.

h. CWS Suppression - The CWS shall allow alarms, due to predefined activities or conditions, to be screened or suppressed.

i. Alarm Source - The source of an alarm due to any limit violation shall be easily determined (even if alarm condition is no longer present).

j. Time History - The history of all alarms shall be maintained and shall be easily retrievable, with the time of occurrence noted.

k. Alarm Classification - The approximate level of classification of an alarm shall be instantly apparent.

l. CWS Status - After real-time modifications are made to CWS software, exact status shall be easily determined.

m. CWS Baseline Limits - A return to the baseline (default) configuration of the CWS shall be easily enabled after a temporary modification or software "crash".

n. Multiple Alarms - A single failure condition shall not cause a "waterfall" of related alarms. However, all out-of-limit conditions shall be retrievable by crewmembers.

o. *Existing Signals - Established and recognized audio alarm signals shall be* used, provided they are compatible with the acoustic environment and the requirements specified herein. Standard signals shall not be used to convey new meanings.

p. Priority - The CWS shall recognize the highest category of unacknowledged signal.

q. Disruptive Alarms:

1. All Class 1 through 3 alarms that would disrupt crew performance shall be capable of being easily downgraded to a redundant but non-disruptive alarm after its initial alerting function has been acknowledged. For example, an audio alarm might be downgraded to a non-disruptive visual signal that would be presented continuously until the alert condition no longer existed.

2. A disruptive alarm that requires manual shut-off shall not be used if the act of shutting it off would interfere with the corrective action required.

r. Alerting Function - CWS alarm signals shall have positive alerting characteristics under all operating conditions.

9.4.4.3.3 Visual Caution and Warning Display Design Requirements

a. Master Alarm Light:

1. A master alarm light shall be provided in cases where caution, warning, or emergency lights have been located outside of the operator's 30 degree cone of vision.

2. Illumination of the master alarm light shall indicate that at least one or more caution, warning, or emergency lights have been energized.

3. The master alarm light and any applicable caution, warning, or emergency light(s) shall be energized simultaneously.

4. Master alarm status lights shall be visible from any location in a space module.

b. Advisory and Alerting - Displays such as multifunction displays, cathode ray tube displays, head-up displays, collimated displays and other visual display devices displaying simultaneous and integrated information shall advise or alert operating personnel to information that becomes critical within the display.

c. Extinguishing Signal Lights - Signal lights shall be extinguished by one or more of the following methods:

1. Restoration of a within-tolerance condition without remedial action or as a result of automatic switch-over.

2. Correction of the situation as a result of remedial action by the crew.

3. Performance of some action by the crew which is directly related to the controls of the affected system or component. This action indicates one or more of the following:

a) An acknowledgement of the occurrence of the malfunction.

b) The completion of indirect remedial action.

c) The shutting down of the malfunctioning system or component.

d. Unambiguous Signals - CWS information shall be presented unambiguously, identifying the actual problem.

e. Color - The color of CWS indicator lights shall conform to the designation given in JSL-002.

f. Brightness - Indicator lights shall be at least three times brighter than the other indicators on the same panel.

9.4.4.3.4 Audio Caution and Warning System Display Design Requirements

9.4.4.3.4.1 Audio Alarm Characteristics Design Requirements

a. Frequency:

1. Range - The frequency range shall be between 200 and 5,000 Hz and, if possible, between 500 and 3,000 Hz. Frequencies below 500 Hz shall be used when signals must bend around obstacles or pass through partitions. The selected frequency band shall differ from the most intense background frequencies.

2. Spurious signals - The frequency of an alarm tone shall be different from that of the electric power employed in the system to preclude the possibility that a minor equipment failure may generate a spurious signal.

b. Intensity

1. Compatibility with acoustical environment - The intensity, duration, and source location of audio alarms and signals shall be compatible with the acoustical environment of the intended receiver as well as the requirements of other personnel in the signal areas.

2. Compatibility with clothing and equipment - As applicable, audio signals shall be loud enough to be heard and understood through equipment or garments.

3. Discomfort - Audio alarm signals shall not be of such intensity as to cause discomfort. The limits established in paragraph 5.4.3 Acoustics Design Requirements shall not be exceeded.

4. Audibility - A signal-to-noise ratio of at least 20 dB shall be provided in at least one octave band between 200 and 5,000 Hz at the operating position of the intended receiver.

5. Pressure operated gain control switches to compensate for volume attenuation in underpressurized areas shall be provided.

c. Alerting Capability:

1. Attention - Signals with high alerting capacity shall be provided when the system or equipment imposes a requirement on the operator for concentration of attention. Such signals shall not, however, be so startling as to preclude appropriate responses or interfere with other functions by holding attention away from other critical signals.

2. Onset and sound pressure level - The onset of critical alerting signals shall be sudden, and at a sound pressure level as specified in b.4. above.

3. Headset - When the operator is wearing earphones covering both ears during normal equipment operation, the audio alarm signal shall be directed to the operator's headset as well as to the work area.

d. Discriminability:

1. Use of different characteristics - When several different audio signals are to be used to alert an operator to different types of conditions, discriminable difference in intensity, pitch, or use of BEATS and HARMONICS shall be provided. If absolute discrimination is required, the number of signals to be identified shall not exceed four.

2. Action segment - The identifying or action segment of an audio emergency signal shall specify the precise emergency or condition requiring action.

3. Critical signals - The first 0.5 second of an audio signal requiring fast reaction shall be discriminable from the first 0.5 second of any other signal that may occur.

4. Differentiation from routine signals - Audio alarms intended to bring the operator's attention to a malfunction or failure shall be differentiated from routine signals, such as normal operation noises.

5. Prohibited types of signals - The following types of signals shall not be used as alarms where possible confusion might exist because of the operational environment:

a) Modulated or interrupted tones that resemble navigation signals or coded radio transmissions.

b) Steady signals that resemble hisses, static, or sporadic radio signals.

c) Trains of impulses that resemble electrical interference whether regularly or irregularly spaced in time.

d) Simple warbles that may be confused with the type made by two carriers when one is being shifted in frequency (beat-fequency-oscillator effect).

e) Scrambled speech effects that may be confused with cross modulation signals from adjacent channels.

f) Signals that resemble random noise, periodic pulses, steady or frequency modulated simple tones, or any other signals generated by standard countermeasure devices (e.g., "bagpipes").

g) Masking Other Critical Channels - Audio alarm signals shall not interfere with any other critical functions or mask other critical audio signals.

9.4.4.3.4.2 Audio Alarm Control Design Requirements

a. Automatic or Manual Shut-Off - When an audio signal is designed to persist as long as it contributes useful information, a shut-off switch controllable by the operator, the sensing mechanism, or both, shall be provided, depending on the operational situation and personnel safety factors.

b. Automatic Reset - Whether audio alarm signals are designed to be terminated automatically, by manual control, or both, an automatic reset function shall be provided. The automatic reset function shall be controlled by the sensing mechanism which shall recycle the signal system to a specified condition as a function of time or the state of the signaling system.

c. Volume Control:

1. Automatic or manual - The volume (loudness) of an audio alarm signal shall be designed to be controlled by the operator, the sensing mechanism, or both, depending on the operational situation and personnel safety factors. Control movements shall be restricted to prevent reducing the volume to an inaudible level.

2. Ganging to mode switches - Volume controls may be ganged to mode switches to provide maximum output during mission phases in which intense noise may occur and to provide reduced volume at other times. Ganging shall not be accomplished if there is a possibility that intense noise may occur in an emergency situation during a mission phase in which the volume would be decreased below an audible level.

9.4.4.3.4.3 Verbal Alarm Signal Design Requirements

a. Nature of Signals - Verbal alarm signals shall consist of:

1. An initial alerting signal (non-speech) to attract attention and to designate the general problem.

2. A brief standardized speech signal (verbal message) which identifies the specific condition and optionally suggests appropriate action.

b. Intensity - Verbal alarms for critical functions shall be at least 20 dB above the speech interference level at the operating position of the intended receiver.

c. Vocal Criteria:

1. Type of Voice - The voice used in recording verbal alarm signals shall be distinctive and mature.

2. Delivery style - Verbal alarm signals shall be presented in a formal, impersonal manner.

d. Speech Processing - Verbal alarm signals shall be processed only when necessary to increase or preserve intelligibility, such as by increasing the strength of consonant sounds relative to vowel strength. Where a signal must be relatively intense because of high ambient noise, peak-clipping may be used to protect the listener against auditory overload.

e. Message Content - In selecting words to be used in audio alarm signals, priority shall be given to intelligibility, ability to convey desired message, and conciseness in that order.

f. Critical Verbal Alarms - Critical verbal alarm signals shall be repeated with not more than a 3 second pause between messages until the condition is corrected or overridden by the crew.

9.4.5 Advisory and Tutorial Displays

9.4.5.1 Advisory and Tutorial Design Requirements

9.4.5.1.1 Advisory Display and Annunciation Requirements

a. Definition of an Advisory Display - System initiated messages advising of a processs status or other discrete event. Examples: Rendezvous solution complete, mass memory search for format in progress. Crew programmed reminder alerts keyed to time, orbit phase, bi-level state, parameter limit.

b. Annunciation Requirements:

1. No tones or lights shall be provided.

2. Message shall accompany all alerts.

3. A history of all messages shall be main- tained and available for crew recall.

4. If advisory display is crew programmed the option shall be provided to direct it to all workstations or to a single designated workstation.

5. If advisory display is not crew programmed it shall be limited by the specific workstation.

6. If advisory displays are crew programmed aural annunciation, the options shall be provided to direct them to one or more work locations.

9.4.5.1.2 Tutorial Display and Annunciation Requirements

a. Definition of a Tutorial Display - Messages denoting illegal keyboard syntax, or for assisting in proper completion of required inputs. These are limited to software configuration requirements.

b. Annunciation Requirements:

1. No tones/lights shall be used.

2. Messages shall be limited to the workstation in use.

9.5.3 Labeling and Coding Design Requirements

9.5.3.1 Labeling Design Requirements

9.5.3.1.1 Labeling Standardization Design Requirements

a. Standardization - To the extent practical, labeling shall be standardized between and within systems.

b. Categories - Different labeling categories shall be distinct from one another (e.g., it shall be obvious with a quick glance that a label with operating instructions is not an emergency procedure or a stowage label).

9.5.3.1.2 Readability Design Requirements

a. Vibration, Motion, and Illumination - Labels and markings shall allow easy and accurate reading in the operational environment, which includes vibration, motion, and illumination considerations.

b. Concise and Unambiguous - Labels shall be as concise and unambiguous as possible while still conveying the intended information.

c. Language - Labels shall be written in the English language.

d. Redundancy - Redundancy shall be minimized.

e. Accuracy - Labels and markings shall provide the required accuracy of identification.

f. Size - The size of labels and markings shall be appropriate for all distances from which they must be read.

(Refer to Paragraph 9.5.3.1.14.6, Character Height Design Requirements, for additional requirements.)

g. Illumination - Labels and markings shall be designed to be read at all expected illumination levels and color characteristics of the illuminant.

h. Critical Function - The design of labels and markings shall take into account the criticality of the function to be labeled.

i. Specular Reflection - The design of labels and markings shall minimize the effects of specular reflection on their readability. A matte or lusterless finish shall be used.

j. Sharpness, Contrast, and Wear - Labels and markings shall be sharp, have high contrast, and not lose readability as a result of wear.

k. Clutter - Labeling and markings shall be designed and placed so as to minimize visual clutter that could result in information overload.

l. Iconic/Symbolic Labels - Iconic or symbolic labels shall be permitted.

9.5.3.1.3 Display Label Placement Design Requirements

a. Orientation - All markings and labels shall be oriented horizontally to the common plane so that they may read quickly and easily from left to right (vertical orientation shall be avoided whenever possible).

b. Display Labels - Labels identifying display functions shall be placed on the panel above the display.

c. Curved Surfaces - Placement of labels on curved surfaces shall be avoided when possible.

d. Visibility - Markings shall be located so that they are visible to crewmembers in the normal position of access or operation.

e. Overhead Panels - On overhead panels, markings and labeling shall be oriented such that they appear upright when observed from the operational viewing angle.

f. Clutter - Markings shall be spaced to avoid a cluttered appearance.

g. Association Errors - The arrangement of markings on panels shall be such that errors of association of one marking or set of markings with adjacent ones shall not be possible.

9.5.3.1.4 Scale Marking Design Requirements

a. Accuracy:

1. Display range and readout accuracy shall not exceed the needs of the crew to manage the equipment for which the displays are provided.

2. Scale markings shall not permit readout accuracies that are more precise than the accuracy of the input signal.

3. In general, scales that are to be read quantitatively to the nearest graduation mark shall be designed so that interpolation between graduation marks is not necessary. Interpolation, if required, shall be limited to one half the distance between minor graduation marks.

b. Interval Values:

1. The graduation intervals shall progress by 1, 5, or 2 units or decimal multiples thereof, in that order of preference.

2. The number of graduation marks between numbered graduation marks shall not exceed 9.

c. Scale Markings (High Luminance - above 1 ft-L):

1. The minimum width of major, intermediate, and minor marks shall be 0.32 mm (0.0125 in.).

2. The length of major, intermediate, and minor graduation marks shall be at least 5.6 mm, 4.1 mm, and 2.5 mm (0.22, 0.16, and 0.09 in.), respectively.

3. The minimum distance between major graduation marks shall be 13 mm (0.5 in.).

4. Minor graduation marks may be spaced as close as 0.89 mm (0.035 in.), but the distance shall be at least twice the stroke width for white marks on black dial faces and at least one stroke width for black marks on white dial faces.

d. Scale Markings (Low Luminance - below 1 ft-L):

1. The minimum width of a major graduation shall be 0.89 mm (0.035 in.); the minimum width of an intermediate graduation shall be 0.76 mm (0.030 in.); and the minimum width of a minor graduation shall be 0.64 mm (0.025 in.).

2. The length of major, intermediate, and minor graduation marks shall be at least 5.6 mm, 4.1 mm, and 2.5 mm (0.22, 0.16, and 0.10 in.), respectively.

3. The minimum distance between major graduation marks shall be 16.5 mm (0.65 in.).

4. Graduation marks shall be spaced a minimum of 1.5 mm (0.06 in.) between centerlines.

9.5.3.1.5 Alignment Marks/Interface Identification Design Requirements

a. Hardware Connectors

(Refer to Paragraph 11.10.3.5, Connector Identification/Alignment Design Requirements, for additional information.)

(Refer to Paragraph 11.5.3.2, Alignment Devices Design Requirements, for specific requirements.)

b. Orientation - When a piece of hardware requires a specific orientation that cannot be identified by alignment marks, arrows and/or labels shall be used to indicate the proper orientation.

c. Color - Unless color coding is to be employed, alignment marks shall be lusterless white on dark colored hardware and lusterless black on light colored hardware.

d. Identification - Interface identification shall be used to indicate the relationship between unattached items that are used together, except when this relationship is obvious.

e. Tethered Equipment - Interface identification shall not be used for movable items tethered to a mating part (e.g., dust cap for an electrical connector, hinged lid for a stowage container, etc.)

9.5.3.1.6 Equipment Identification Design Requirements

a. Equipment Marking - Equipment that must be located, identified, observed, or operated by a crewmember shall be marked with nomenclature that describes the function of the item and its pertinent interfaces. However, items whose use is obvious to the crew (e.g., food table, windows, etc.) are exempt from this requirement.

b. Numbered Items - Multi-quantity items that require individual distinction but are not serialized shall be individually numbered.

c. Serial Numbers - Multi-quantity items that are serialized shall display the serial number as part of the identification.

d. Name Plates - Name plates depicting manufacturer's name, serial numbers, etc., shall not be mounted on the control or display surface area of any equipment.

9.5.3.1.7 Location and Orientation Coding Design Requirements

a. Location and Orientation Designation - A system of location and orientation coding shall be established for the purpose of designating and locating crew interface items. The system shall be so designed as to permit a unilateral logical assignment of codes to items added or relocated.

b. Location Maps - A map of location codes shall be provided at the entrances to a room or sub-volume where the coding scheme is not obvious to the crewmember.

c. Location Code:

 1. All fixed crew interface items (e.g., equipment, control/display stations, stowage containers, connector panels, etc.) shall display a location code adjacent to the identification marking.

 2. Movable items that require a crew interface but are not stowed in a containment shall display a location code on a fixed surface adjacent to the item.

d. Orientation Designation - When the orientation of the vehicle axes is significant to crew operations and is not obvious, axis designators shall be displayed on appropriate surfaces.

9.5.3.1.8 Operating Instruction Design Requirements

a. Location - Operating instructions shall be located on or near equipment whose operation is not obvious to a crewmember.

b. Completeness - Operating instructions shall be complete enough to allow accurate task performance.

c. Equipment Name - The instructions shall have the title of the equipment to be operated centered above the text (see Figure 9.5.3.1.8-1).

d. Grouping - Instructions shall be grouped and titled by category (e.g., installation, removal, activation, calibration, etc.) if appropriate. (See example in Figure 9.5.3.1.8-1).

e. Case - Instructional text shall use upper and lower case letters (See Figure 9.5.3.1.8-1).

f. Title Selection - The titles of equipment, controls, displays, switch positions, and connectors shall be listed in upper case letters only. Care shall be taken to ensure that all title nomenclature is consistent with procedural handbooks and checklists.

g. Required Tools - Instructions for removal of stowage items shall list the tools required, if any, prior to the instructional text. Markings shall be used to locate the fasteners to be removed if clarification is required.

9.5.3.1.9 Stowage Container Labeling Design Requirements

a. Purpose - Stowage containers shall be labeled so that items are easy to find and return to place.

b. Transparent - Where practical, containers shall be transparent, thus allowing identification of contents at a glance.

c. Contents List - Each stowage container shall display a list of contents on its front surface visible to the crewmember. Items shall be listed one per line and launch quantities noted if greater than one.

d. Label Revision - Provisions shall be made to permit in-flight revisions to, or replacement of stowage labels on all stowable containers.

e. Individual Crew Items - Items allocated to a specific crewmember shall be identified on the listing with the user's title, name, or other coding technique.

SMMD

OPERATION

1. Obtain note pad
2. Place specimen on tray
3. MASS/ON/TEMP — MASS
4. RESET — press
5. Control lever — RELEASE (hold until counter stops)
6. Control lever — LOCK
7. Log reading on note pad
8. Repeat measurement for total of 3
9. MASS/OFF/TEMP — OFF
10. Control lever — LOCK (verify)
11. Remove specimen and log SMMD readouts on tag
12. Process specimen
13. If necessary clean tray and tie-down

CALIBRATION

1. Obtain SPI food log
2. Measure tray temp (M487 Digital Thermometer)
3. Log reading
4. MASS/OFF/TEMP — MASS
5. RESET — press
6. Control lever — RELEASE (hold until counter stops)
7. Control lever — LOCK
8. Log reading in Food Log
9. Repeat for a total of 5
10. Calib. points 0,50,100,150,250,350,500,750,900,0
11. MASS/OFF/TEMP — OFF
12. Voice record data at any convenient time

Figure 9.5.3.1.8-1 Operating Instructions

MSIS 104

f. Subdivided Containers:

1. If a storage container is subdivided internally into smaller closed containers, the sub-containers shall carry a list of contents.

2. If a sub-container is open to view and its contents are obvious, it is exempt from this requirement.

3. If the available marking space on a sub-container is insufficient to display the complete content titles, a contents list shall be displayed elsewhere and clearly identified as belonging to the sub-container.

4. The specific contents of each sub-container and its code shall be listed on the front surface of its container or near it.

g. Similar Item Labeling - Containers with designated locations for placement of several similar items (e.g., socket wrenches in a tool kit) shall have each location identified with the title of the item stowed.

9.5.3.1.10 Failed/Expendable Item Design Requirements

a. Failed Items - A method shall be provided for visually marking failed and expended items (e.g., equipment controls, displays, connectors, etc.) to indicate their unusable status. Color-coded labels with appropriate nomenclature (e.g., DO NOT USE) are preferred.

b. Discardable Items - Items to be discarded after use shall display a unique marking on the item. Color-coded labels with appropriate nomenclature (e.g., DISCARD) are preferred, and the method of disposal shall be included when applicable.

9.5.3.1.11 Contingency Labels and Marking Devices Design Requirements

a. Blank Labels - Blank labels shall be provided to allow contingency labeling.

b. Marking Devices - Marking devices shall be supplied for marking blank labels and revising quantities noted on stowage labels.

9.5.3.1.12 Grouped Controls and Displays Design Requirements

a. Group Identification - Functional groups of controls shall be clearly identified (e.g., by common color, by boundary lines.)

b. Labels of Functional Groups - Labels shall be used to identify functionally grouped controls and displays. Labels shall be located above the functional groups they identify.

c. Boundary Lines - When a line is used to enclose a functional group and define its boundaries, the labels shall be centered at the top of the group, in a break in the line. The width of the line shall not be greater than the stroke width of the letters.

d. Related Controls - When controls and displays must be used together in certain adjustments or activation tasks, appropriate labels shall indicate their functional relationships.

9.5.3.1.13 Caution and Warning Labels Design Requirements

(Refer to 9.5.3.2i, Color Coding, and 9.4.4, Caution and Warning Displays, for related information.)

a. Identification - Caution and warning labels shall identify the type of hazard and the action that would prevent its occurrence.

b. Location - The caution markings shall be located in a position that permits sufficient opportunity for the crew to avoid the hazard.

c. Immediate Action Controls - All controls, buttons, and small handles or levers requiring immediate access shall have their panel background colored in accordance with the applicable sub-section of Section 9.5.3.2; large handles or levers shall be similarly colored on the handle or lever itself.

d. Emergency-Use Items:

1. Emergency-use items (e.g., repair kits, emergency lighting, fire extinguisher, etc.) shall display a unique marking (EMERGENCY USE) surrounded by diagonal yellow and black stripes (see either on the item or adjacent to it.

2. For items located within a storage container, the diagonal striping shall be applied to the door of the container and the titles of the emergency items shall be included on the marking instead of the words EMERGENCY USE.

e. Warning Stripe Specification:

1. Warning stripes shall be alternate yellow 33538 and black 37038 per FED-STD-595a. The black stripes shall have a width not less than 1.6 mm (0.065 in.) and the yellow stripes shall be at least two times the width of the black stripes.

2. The striping shall be applied at a 45 degree angle rotated clockwise from the vertical.

3. The striping shall begin and end with a yellow strip.

4. The striping around a switch or button shall not be wider than 25 mm (1 in) or less than 3 mm (0.125 in).

5. If one side of a switch or button has less than 3 mm (0.125 in) space, no striping shall be applied to that side.

f. Label Specifications - Hazard identification labels shall use a letter size and spacing large enough to convey the warning (see Figure 9.5.3.1.13-1).

9.5.3.1.14 Alphanumeric Design Requirements

9.5.3.1.14.1 Font Style Design Requirements

a. Dark-Color Characters - Futura font shall be preferred. Commercial font styles for dark-color opaque alphanumerics on light-color opaque or transilluminated backgrounds and for hardware labels are indicated below in descending order of preference.

1. Fonts for engraved lettering: a) Futura Demibold, b) Gorton Normal,.and c) Gorton Condensed.

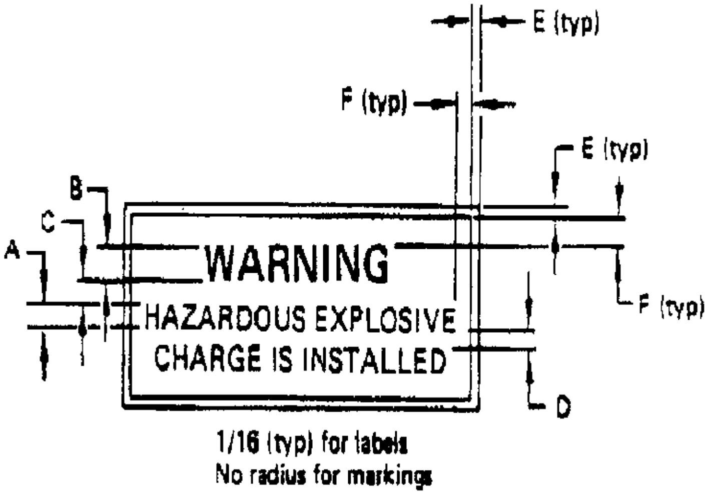
2. Fonts for engraved numerals: a) Futura Demibold, b) Gorton Modern.and c) Gorton Normal.

3. Fonts for printed lettering and numerals: a) Futura Demibold, b) Futura Medium.and c) Alternate Gothic No. 3.

b. Light-Color Characters - Futura Medium type shall be used for transilluminated or light-color opaque markings on dark opaque backgrounds.

c. Fit Problems - The use of condensed type (Future Condensed) or abbreviations shall be the preferred method for solving line length reduction in type size.

d. Stenciled Characters - Stencil-type characters shall not be used on display/control panels or other equipment.



A – Text or minor lines of lettering	= A
B – Heading or major line of lettering	= 1.25A to 2A
C – Spacing between heading and text	= 0.65A to A
D – Spacing between lines of text	= 0.50A
E – Border width	= 0.60A
F – Background border	= A

Figure 9.5.3.1.13-1 Letter Size and Spacing for Caution and Warning Labels

MSIS 105

9.5.3.1.14.2 Punctuation Design Requirements

a. Use - The use of punctuation marks shall be kept to a minimum.

b. Periods - Periods shall be omitted except when needed to preclude misinterpretation.

c. Hyphens - Hyphens shall be avoided whenever possible.

d. Parentheses and Ampersands - Parentheses and ampersands shall not be used on the display and control panel or other crew equipment.

e. Slashes - The slash (/) shall be used in place of the words to indicate multiple functions.

9.5.3.1.14.3 Upper/Lower Case Design Requirements

a. Abbreviations - Lower case letters shall be used in abbreviations or symbols in which their use is the commonly accepted practice (e.g., He, pH, Hg, etc.).

b. Operating Instructions - Equipment operating instructions shall use lower case for text and upper case for the first letter of a sentence, headings, titles of equipment, and references to control/display panel markings.

9.5.3.1.14.4 Titles Design Requirements

(Refer to Paragraph 9.6.2.8k, Abbreviations and Acronyms, for additional requirements on the use of abbreviations.)

9.5.3.1.14.5 Special Character Design Requirements

a. Subscript and Superscript Size - Subscripts and superscripts shall be 0.6 to 0.7 times the height of associated characters.

b. Subscripts - Numeric subscripts and upper case letter subscripts shall be centered on the baseline of associated characters.

c. Lower Case Letter Subscripts - The base of lower case letters and the ovals of g, p, q, etc., shall be at the same level as the base of adjacent capital letters.

d. Degree Symbol - The degree symbol shall be centered on an imaginary line extended from the top of the F or C symbols.

e. Pound or Number Symbol (#) - The pound or number symbol shall be centered on an imaginary line extended from the top of the associated numerals and placed approximately two stroke widths away from them.

9.5.3.1.14.6 Character Height Design Requirements

a. Character Height - Character height depends on viewing distance and luminance level. At a viewing distance of 710 mm (28 in) the height of letters and numerals shall be within the range of values given in Figure 9.5.3.1.14.6-1.

b. Variable Distance - For a distance (D) other than 710 mm (28 in), multiply the values in Figure 9.5.3.1.14.6-1 by D/710 mm (D/28 in.) to obtain the appropriate character height.

c. Size Categories - Where feasible and appropriate, characters used in labeling shall be graduated in size. To determine character height, all nomenclature on a label may be divided into three categories: titles, subtitles, and text. The nominal heights at a viewing distance of 710 mm (28 in) for each category shall be:

1. Titles, 5 mm (0.19 in).
2. Subtitles, 4 mm (0.16 in).
3. Text, 3 mm (0.12 in).

In general, when moving to the next larger character size, the character height shall in-crease by approximately 25 percent.

d. Space Limitations - The use of the same size letters and numerals for all categories on a label is acceptable for solving space limitation and clarity problems. In this case, the height of lettering and numerals shall be not less than 3 mm (0.12 in).

Markings	Character Height	
	3.5 cd/m^2 (1 ft-L)	Above 3.5 cd/m^2 (1 ft-L)
For critical markings, with position variable (e.g., numerals on counters and settable or moving scales):	5-8 mm (0.20-0.31 in)	3-5 mm (0.12-0.20 in)
For critical markings, with position fixed (e.g., numerals on fixed scales, controls, and switch markings, or emergency instructions):	4-8 mm (0.16-0.31 in)	2.5-5 mm (0.10-0.20 in)
For noncritical markings (e.g., identification labels, routine instructions, or markings required only for familiarization):	1.3-5 mm (0.05-0.20 in)	1.3-5 mm (0.05-0.20 in)

Figure 9.5.3.1.14.6-1 Character Height- 710 mm (28 in) Viewing Distance

MSIS 106

9.5.3.1.14.7 Character Width Design Requirements

a. Letters - The width of letters shall preferably be 0.6 of the height, except the letter "I" which shall be one stroke in width, the letters "J" and "L" which shall be 0.5 of the height, the letter "M", which shall be 0.7 of the height, and the letter "W", which shall be 0.8 of the height.

b. Numerals - The width of numerals shall preferably be 0.6 of the height, except for the numeral "4", which shall be one stroke width wider and the numeral "1", which shall be one stroke in width.

c. Wide Characters - Where conditions indicate the use of wider characters, as on a curved surface, the basic height-to-width ratio may be increased to 1:1.

9.5.3.1.14.8 Stroke Width Design Requirements

a. Height-to-Stroke Ratio - Marking letters and numerals shall have a height-to-stroke ratio of 5:1 to 8:1, depending on the application.

b. Transilluminated Background - Opaque markings on a transilluminated lighted background shall have a height-to-stroke ratio of 5:1 to 6:1.

c. Transilluminated Markings - Transilluminated markings on a dark background or markings used on integrally lighted instruments shall have a height-to-stroke ratio of 7:1 to 8:1.

d. General Purpose Illumination - Characters used on display panels and equipment when viewed under general purpose flood lighting or normal daylight conditions shall have a height-to-stroke ratio of 6:1 to 7:1.

9.5.3.1.14.9 Character Measurement Design Requirements

a. Measurement - All letters and numeral measurement shall be made from the outside edges of the stroke lines for other than machine engraving on opaque surfaces.

b. Engravings - For all mechanical engraving on opaque surfaces, the dimension controlling the size of letters and numerals shall be measured from centerline to centerline of the stroke.

9.5.3.1.14.10 Spacing Design Requirements

a. Character Spacing - The spacing between letters within words and between digits in a multi-digit number shall be the approximate visual equivalent of one stroke width between two straight-sided letters such as H and I. (This requirement is intended to accommodate the normal commercial typographical practice of spacing letters to achieve a consistent visual continuity. This permits close spacing of open letters such as C and T to avoid large apparent gaps).

b. Word Spacing - The spacing between words shall be the approximate visual equivalent of the letter W between two straight-sided letters such as N and F.

c. Line Spacing:

1. The spacing between lines of related text shall be 0.5 of upper case letter height.

2. Spacing between headings and text shall be 0.6 to 1.0 of upper case letter height.

9.5.3.2 Coding Design Requirements

a. General Coding Requirements:

1. Standardization - The application of coding techniques shall be consistent within and between systems.

2. Clutter - Coding shall only be used where useful, as excessive coding can have the negative effect of adding to visual clutter.

3. Decrements - Coding shall not reduce legibility or increase transmission time.

4. Common Usage - Codes shall conform to conventional population stereotypes and general user expectations when these exist.

5. When feasible, meaningful codes shall be used rather than arbitrary codes. For example, use M for male and F for female rather than 1 for male and 2 for female.

b. Brightness Coding:

1. Brightness coding shall be employed to differentiate between an item of information and adjacent information.

2. No more than three levels of brightness shall be used. Each level shall be separated from the nearest by at least a 2:1 ratio.

c. Size Coding:

1. Symbols - Where size difference between symbols is employed, the major dimensions of the larger shall be at least 150% of the major dimensions of the smaller with a maximum of three size levels permitted.

2. Controls - No more than three different sizes of controls shall be used in coding controls for discrimination by absolute size. Controls used for performing the same function on different items or equipment shall be the same size.

d. Pattern Coding - Pattern coding shall be used to differentiate areas of interest to the observer (e.g., the normal, warning, and danger operating zones of a scale), and reduce operator search time.

e. Location Coding - Controls associated with similar functions shall be in the same relative location from panel to panel.

f. Shape Coding - Shape coding of controls shall be used to improve their identifiability through both the visual and tactile senses. Requirements are listed below.

1. Ease of operation - The coded feature shall not interfere with ease of control manipulation.

2. Position and orientation independence - Shapes shall be identifiable and differentiable by the hand regardless of the position and orientation of the control knob or handle.

3. Gloved operation - Shapes shall be tactilely identifiable when IVA gloves are worn, where applicable.

4. Mounting - Shape coded knobs and handles shall be positively and non-reversibly attached to their shafts to preclude incorrect attachment when replacement is required.

g. Underlining, Bold Face, Italics - Coding techniques shall be used when it *is necessary to direct a reader's attention to a particular element of alpha-*numeric text. These techniques shall include, but not be limited to, underline, bold face type, and italics.

h. Flash Coding:

1. Use - The use of flashing lights shall be minimized, and used only where immediate attention is required.

2. Flash rate:

a) No more than 2 flash rates shall be used.

b) Where one rate is used, the rate shall be between 3 and 5 flashes per second.

c) Where two rates are used, the second rate shall be less than 2 per second.

3. Duty cycle - Flashing lights shall have approximately equal amounts of ON and OFF time.

4. Simultaneous signals - Flashing lights which could be simultaneously active shall have synchronized flashes.

5. Failure indication - If the indicator is energized and the flasher device fails, the light shall illuminate and burn steadily.

i. Color Coding - Color identification numbers used below are per FED-STD-595.

1. Color difference - Only one hue within a color category (e.g., reds, greens) shall be used in a given coding scheme, and that color shall always be associated with a single meaning.

2. Number of colors - No more than 9 colors, including white and black, shall be used in a coding system.

3. Ambient light:

a) Color coding shall be compatible with anticipated ambient lighting throughout the mission.

b) Color-coding shall not be used as a primary identification medium if the spectral characteristics of ambient light during the mission, or the operator's adaptation to that light, varies as the result of such factors as solar glare, filtration of light, and variation from natural to artificial light.

4. Familiar color meaning - Colors which are consistent with common usage and existing standards with respect to application are listed below. All color coordinates for transilluminated lighting are per CIE (Commission International del' Eclarirage Coordinates Chart Chromaticity Diagram 1931).

a) Red #21105 - Emergency, warning, and master alarm lights; safety controls; critical controls requiring rapid identification; emergency shutdown; control panel outline of a functionally critical emergency nature. Transilluminated devices shall have coordinates of x=.633 (+/-.03) y=.255 (+/-.03).

(Note: Under ambient red lighting, use orange-yellow and black striping.)

b) Yellow #33538 - Caution; emergency exits; safety controls associated with emergencies of a less critical nature. Transilluminated devices shall have coordinates of x=.455 (+/-.03) y=.550 (+/.03).

c) Yellow #33538 with black #37038 stripe - Immediate access; exit releases.

d) Orange #32246 - Hazardous moving parts; machinery; start switches, etc.

e) Green #14187 - Important and frequently operated controls having no urgent or emergency implications. Transilluminated devices shall have coordinates of x=.155 (+/-.05) y=.750 (+/-.05). Alternatively, for transilluminated devices, a wave length of 520nm is acceptable.

f) Green (Sage) #14260 - First aid and survival.

g) Blue #25102 - Advisory (not recommended for general use).

h) Purple #37142 (magenta) - Radiation Hazard.

i) White - Advisory (for transilluminated devices only) - Transilluminated devices shall have coordinates of x=.360 (+/-.03 y=.360 (+/-.03).

5. Color deficiency - To avoid confusion by color-deficient observers, do not use the color green if the color scheme uses more than six colors. If six or fewer colors including green #14260 and yellow are used, yellow #23655 shall be substituted for #33538. Red #11302 and blue #15177 may also be used; however, do not use red and green within the same complement.

6. Placards - The preferred markings and background color for placards are listed below.

Markings	Backgound
White	Black
Black	Yellow
Black	White
Yellow	Blue
White	Red
Blue	Yellow

7. Zone markings - On indicators where zone markings are used to indicate various operating conditions, the following requirements shall apply.

a) Primary colors shall be limited to red, yellow, orange, and green consistent with color selection criteria given above.

b) Zone markings shall be applied and located in a manner that facilitates easy removal.

c) Zone markings shall not interfere with the reading of quantitative markings.

d) When color is used to zone mark, the color shall be applied so that its meaning is consistent across applications.

8. Color Contrast - An important factor to consider when selecting colors is the contrast between various colors. This is necessary to ensure that each color is easily discriminated from the others. Although contrast is an important consideration, it should not be used without regard to other important factors such as convention or standard, inherent meaning, and consistency across displays.

a) The following color list shall be used to select colors that contrast maximally with the color just preceding it and satisfactorily with the earlier colors in the list. Colors (1) through (9) yield satisfactory contrast for red-green deficient as well as color-normal crewmembers. The remaining 13 are useful only for color-normal crewmembers.

(1) White.

(2) Black.

(3) Yellow.

(4) Purple.

(5) Orange.

(6) Light blue.

(7) Red.

(8) Buff.

(9) Gray.

(10) Green.

(11) Purplish pink.

(12) Blue.

(13) Yellowish pink.

(14) Violet.

(15) Orange-yellow.

(16) Purplish red.

(17) Greenish yellow.

(18) Reddish brown.

(19) Yellow-green.

(20) Yellowish brown.

(21) Reddish orange.

(22) Olive green.

b) Color contrast shall be selected in conjunction with color conventions and standards, inherent meaning, and consistency across displays.

9.6.2.2 Design Requirements for Data Display

a. Stand Alone - In general, data displays shall convey enough information to allow the user to interpret the data without referring to additional sources.

b. Shared Displays - If a single display monitor is used to display different categories of information alternately, none of the categories shall require continuous or concurrent monitoring.

9.6.2.3.2 Design Requirements for Text

a. Upper &Lower Case - Text shall be presented using upper and lower case letters.

b. Justification - The default condition shall be to left justify all lines of text; however, options for right justification and fill-justification shall be available.

c. User Control - Users shall have control over various features of text display: justification, line length, space between lines, margins, font style and size.

9.6.2.4.2 Design Requirements for Tables

a. Titles - All tables shall have a concise, descriptive title. Titles shall have a consistent location on tables.

b. Labels - Each group of data in a table shall have a concise, descriptive, label that is separated from other characters and can easily be identified as the label.

c. Consistent Widths of Characters - The fonts and widths of numeric characters shall be consistent within a table. Highlighting of numeric characters by means of italics or bolding shall not change the width of numeric characters. Differences in fonts and/or widths of alphabetic characters within a table shall not affect column or row size or spacing.

d. Grouping - All displayed data necessary to support a user activity or sequence of activities shall be grouped together.

9.6.2.4.3.2 Design Requirements for Matrix Tables

a. Use - Matrix tables shall be used to present row-column data.

b. Arrangement - Data in matrix tables shall be displayed in a left-to-right, top-to-bottom array. Alphanumeric data shall be left justified; numeric data shall be arranged with decimal points aligned vertically. (If a number does not have a visible decimal point, the decimal point shall be assumed.)

c. Column Order - Material most relevant to the user or most frequently used shall be in the left column and shall progress to the least relevant in the far right column.

d. Labels - Labels for the row variables shall be located in the left-most column; labels for the column variables shall be located in the top row. When a column extends over more than one "page" vertically (i.e., the user has to scroll or page to continue reading the column), the same column labels shall be displayed from "page" to "page". Similarly, when a row extends over more than one "page" horizontally (i.e., the user has to scroll or page to continue reading the row), the same row labels shall be displayed from "page" to "page".

e. Readability - In tables with many rows or columns, a blank line, dots, or other distinctive feature shall be inserted after every fifth row or column as appropriate to help maintain one's place across columns or across rows.

f. Organization of Rows and Columns - When possible, rows and/or columns in a table shall be arranged in a systematic order (e.g., chronologically, alphabetically, sequentially, by magnitude, by importance, or according to function).

g. Discriminable rows and columns - Each column shall be discriminable from every other column by means of a physical cue, such as sufficient blank space or a line. Similarly, all rows shall be discriminable from one another by means of physical cues.

9.6.2.4.4.2 Design Requirements for Functional Area Tables

a. Use - A functional area table shall be used to display related data that has a less regular structure than a matrix. The data are organized into functional groups, similar to a completed data form.

b. Group size - Related data shall be displayed in groups which subtend five degrees of visual angle or less. The groups shall be visually distinct from one another.

c. Density - The ratio of filled display character spaces to the total number of character spaces shall not exceed 30% under nominal operating conditions.

9.6.2.5.2 Design Requirements for Graphics

a. Use - Types of graphical displays include icons, schematics, data graphs, maps, flow charts, and pictures. Graphical displays shall be used when they will convey information to the user more clearly, effectively, or quickly than other formats. For example, graphics may be used as follows:

1. A statistical data graph is appropriate when users need to monitor changing data, to scan a data set or sets quickly, to compare multiple sets of data, or to see trends in data.

2. A flowchart is appropriate when users need to follow a sequence of events that involves logical branching or to observe the temporal order of events.

3. A schematic is appropriate when users need to identify both the elements of a system and the spatial/temporal organization of those elements.

4. A map is appropriate when users need to determine spatial relations between objects.

b. User control - The user shall have the ability to change various physical features of a graphic to enhance his or her viewing capability, including enlarging and reducing the graphic or a subsection thereof, increasing the amount of detail (if additional detail is available, e.g., in a system schematic), and selecting different orientations or reference points (especially for maps and schematics).

c. Simplicity - Graphical displays shall maintain the visually simplest display consistent with their function.

d. Directing the User to the Important Data - A graphical display shall direct the user's attention to the critical data. For example, users will notice heavier lines before lighter ones; brighter colors are detected before dim ones; larger bars are detected before slender ones. Use of these rules of thumb, as well as the use of coding techniques, will make for graphic displays that direct the user's attention to the desired location.

e. Identification of Graphic Displays - All graphic displays shall have unique, meaningful titles by which users can identify and access the display.

f. Identification of Elements in Graphics - All elements in graphic displays (including objects in a schematic, geographical locations in a map, and axes in a data graph) shall be identifiable and discriminable by the user. The two most prominent techniques for providing cues for identification are labeling and symbols.

1. Labels shall be in close proximity to the object that they identify, but shall not obscure the element.

2. In addition to or in place of labels, symbolic coding (e.g., texture, color, or shape) shall be used when appropriate to aid users in identifying elements of graphical displays . Symbolic codes shall be accompanied by legends that provide the symbol and its referent.

9.6.2.6.2 Design Requirements for Coding

a. Highlighting - Highlighting (display coding which serves only to call the user's attention to a feature of a display) shall be used only for important information (e.g., out-of-limit conditions). When conditions change and an item that was highlighted is no longer important (e.g., after an out-of-limits condition has been corrected), that item shall no longer be highlighted. The specific highlighting technique used (e.g., reverse video, brightness contrast, boldness contrast, underlining, or blinking) shall not have a detrimental impact on the user's perception of the display.

b. Grouping - Coding shall be used to group functionally similar information and to indicate membership in a common group. Grouping allows users to perceive a large screen as consisting of smaller identifiable pieces. Spatial distance and shape coding are particularly powerful grouping techniques.

   1. Grouping of information shall be accomplished by spatial distance, shape coding, lines, color coding or other means consistent with the application.

   2. Displays with high information density shall have an intermediate number of groups. The preferred range for number of groups is 19-40.

c. Symbols - Coding by means of graphic symbols, shapes, or color shall be a key method used to communicate the specific meaning of an element of a display to a user. The choice of a symbol shall not contradict highly overlearned associations (e.g., the use of red as a symbol for stop or danger and the use of an octagonal shape for stop).

   1. As a symbolic code, color shall be redundant with at least one other coding technique.

   2. Users shall have access to the referent for every symbol.

9.6.2.7.2 Design Requirements for Windows

a. Perceptual Characteristics of Windows - Windows are subdivisions of displays in which one functionally-related set of information is displayed. Windows shall be perceptually distinct from the rest of the display.

b. Types of Windows - Users shall be able to distinguish among different types of windows based on the perceptual characteristics of the window. Window types can be organized in a hierarchy based on their function: Open vs. Closed windows, where the user has perceptual and functional access only to the open window; Open windows can be Active or Inactive, where the active window contains an on-going activity, either user-maintained (e.g., a command language dialogue) or system-maintained (e.g., control of a Space Station Freedom subsystem by an expert system); Active windows can be an Interactive window (also known as the "listener") or a Noninteractive window, where the Interactive window is the one in which user actions have their effect.

c. Window Titles - A brief, unique, and descriptive title shall be positioned in a consistent and highly visible location for each window. The user shall be able to use that title in accessing the window.

d. Multiple Windows - When multiple windows are open simultaneously, with the exception of caution & warning information, the system shall not overwrite the active window(s).

9.6.2.8 Design Requirements for Format

a. Consistency - Display formats shall be consistent within a system.

   1. When appropriate for users, the same format shall be used for input and output.

   2. Data entry formats shall match the source document formats when feasible and efficient for user performance.

   3. Recurring data fields within a system shall have consistent names and shall have consistent relative positions within displays.

b. Standardization - The content of displays within a system shall be presented in a consistent, standardized manner.

c. Information Density:

1. Information density shall be held to a minimum in displays used for critical tasks.

2. A minimum of one character space shall be left blank vertically above and below critical information, with a minimum of two character spaces left blank horizontally before and after.

d. Selectable data display - Only data essential to the user's needs shall be displayed. The system shall permit the user to access any data at any time.

e. Readily Usable Form - Data presented to the user shall be in a readily usable and readable form such that the user does not have to transpose, compute, interpolate, or mentally translate into other units, number bases, or languages.

f. Order and Sequences - When data fields have a naturally-occurring order (e.g., chronological), such order shall be reflected in the format organization of the fields.

g. Extended Alphanumerics - When five or more alphanumeric characters without natural organization are displayed, the characters shall be grouped in blocks of three to five characters, separated by a minimum of one blank space or other separating character, such as a hyphen or slash.

h. Comparative Data Fields - Data fields to be compared on a character-by-character basis shall be adjacent. Relative position shall maximize ease of comparison.

i. Labels and Title:

1. Each individual data group, message, or window shall contain a descriptive title, phrase, word, or similar identifier to designate the content of the group or message.

2. Labels and titles shall be located in a consistent fashion adjacent to their referent; the relation between the label or title and referent shall be clearly visible.

3. Labels and titles shall be emphasized to facilitate user scanning and recognition. The technique used for emphasis (e.g., highlighting, see Section 9.6.3.1.4.a) shall be easily distinguishable from that used to highlight or code emergency or critical messages. Labels and titles shall not be confusable with data.

4. The physical features and wording of labels and titles shall be designed to avoid confusion as to whether the label is for a data entry field, a control option, a guidance message, or other displayed materials.

5. Labels and titles shall be unique to avoid confusions between labels.

6. When presenting a list of user options, the label shall be descriptive of the contents of the list and relevant to the task being performed by the user.

j. Identifying Location in Sequence of Displays - Cues shall be provided to the user to identify the currently displayed page and the total number of pages of a multiple page display (e.g., in a text file, the second page of a five page file might be labeled Page 2 of 5).

k. Abbreviations and Acronyms:

1. Information shall be displayed in plain concise text wherever possible.

2. Abbreviations and acronyms shall be standardized.

3. Abbreviations shall be distinctive to avoid confusion.

4. A single word shall have no more than one abbreviation.

5. No punctuation shall be used in abbreviations.

6. Where practical, definitions of all abbreviations, mnemonics, and codes shall be provided on-line at the user's request. If on-line capability is not provided, definitions shall be provided in hardcopy.

l. Number System - When numeric data are displayed or required, such data shall be in the decimal number system by default. Users shall have the ability to change the number system according to their task demands.

9.6.2.9.2 Design Requirements for Information Display Rate

a. Information Display Rate - The information display rate shall not exceed human perception, comprehension, or response capabilities.

b. Update Rate:

1. The rate of update of information within a display shall be a function of both task requirements and user capabilities.

2. The rate of update of information shall not exceed the user's ability to perceive changes in values of parameters.

3. For slowly changing data, the system shall aid the user in attending closely to the display and in eliminating the need for extended fixation of the display.

4. Items requiring dynamic visual acuity on a graphic display shall not move faster than 60 degrees of visual angle per second, with 20 degrees per second preferred.

c. Display Freeze:

1. A display freeze mode shall be provided to allow close scrutiny of any selected display that is updated or advanced automatically by the system.

2. An option shall be provided to allow the user to either resume the update of information from the point at which the display was frozen or at the current real-time point.

3. An appropriate label or iconic symbol shall be provided to indicate to the user that the display is in the freeze mode.

d. System Response Time - Whenever possible, the time for the system to respond to a user command or request shall not exceed 2 seconds.

e. Keystroke Echo Response Time - Whenever possible, keystroke echo response time shall not exceed 0.1 second.

9.6.3.1.2 Design Requirements for User-Computer Dialogues

a. Dialogue Type - The choice of the type of dialogue between the user and computer (e.g., command language, menus, data forms, direct manipulation) shall be compatible with user characteristics and task requirements. The human-computer dialogue for any task shall allow users to execute commands in terms of the functions to be performed without concern for internal computer data processing, storage, or retrieval mechanisms.

b. Multiple dialogues - To the greatest degree possible, users shall be able to input commands to the system using any of the available dialogue types and shall be able to switch between dialogue types within a task sequence.

c. User Viewpoint - User-computer dialogue techniques shall reflect the user's point of view such that the commands are logically-related to the user's conception of what is being done.

d. Feedback from commands:

   1. When the completion of a command results in a consequence that is perceptible to the user, the completion of the commanded action shall be the only necessary feedback.

   2. Rather than simply rejecting the entry, the system shall permit users to correct errors in commands, where feasible.

   3. When the completion of a command results in a consequence that is not visible to the user, the system shall provide explicit feedback to the user that the command was completed. The feedback shall be in the form of a message that describes the actions that resulted from the command in simple, direct, positive language.

e. Arm-Fire Sequence for Critical Commands - Users shall have to confirm that they want to perform a critical, potentially hazardous, or potentially destructive command (including commands that would destroy stored data) before the system will execute it. The confirmation request from the system to the user shall be positive, simple, and direct.

9.6.3.1.3.2 Design Requirements for Command Language

a. Use - All users shall always have access to the command language. Additionally, the command language is especially well suited for

   1. Tasks with an elaborate interaction between the user and system.

   2. Highly trained, frequent system users.

b. Standardization - The functionality, design, and operation of the command language shall be standard. The standardization of the language shall include the lexicon, semantics, and syntax.

c. Command Language Terms - To the greatest degree possible, the meaning of terms in the command language shall correspond to English and be conveyed in a form such that additional resources are not required to interpret the message. The terms in the command language shall describe actions, objects, prepositions, and the attributes of actions or objects.

d. Command Language Syntax - The structure of the command language shall resemble the structure of English as closely as possible.

e. Distinctiveness - Command language terms shall be perceptually and semantically distinct from one another.

f. Punctuation - The command language shall contain a minimum of punctuation or other special characters.

g. Truncation - The user shall be able to enter the full command name or the system-specific truncated form. Truncated forms may consist of unique partial command terms, function keys, and command keystrokes.

h. Command Area - Commands shall be entered and displayed in a standard command area in a consistent location on all displays.

i. Command Prompts - The user shall be able to request prompts, as necessary, to determine required parameters in a command entry.

j. Command Editing - Editing of commands shall follow the same rules as text editing.

k. Alternative Constructions - If users input alternative syntax or synonymous command language terms, the system shall aid the user in completing the command correctly.

9.6.3.1.4 Design Requirements for Command Keystrokes

a. Uses - Command keystrokes (i.e., the use of a limited number of keystrokes combined with pressing a Command Key to access a command language term) shall be used primarily in cases where speed of command inputs is important. Other dialogue techniques shall be available, as appropriate.

b. Consistency across applications - The structure and meaning of keyboard commands shall be consistent across applications.

9.6.3.1.5 Design Requirements for Function Keys

a. Uses - Function keys shall command an action with a singular keypress and shall not require any other preceding or simultaneous keystroke (e.g., pressing a Command Key). Function keys shall be used for tasks with unique control entries or as an adjunct to other dialogue types for functions that occur frequently, that must be made quickly, and that must be made with minimal syntax errors.

b. Consistency across applications - The consequence of pressing a fixed function key shall be consistent across applications.

9.6.3.1.6.2 Design Requirements for Menus

a. Menu Item Selection:

1. The user shall be able to select a menu item with minimal activity.

2. When selection is to be accomplished by cursor placement on the to-be-selected item, the system shall aid the user in cursor placement. For example, for a permanent menu, the cursor would be placed on the most likely option, usually the first position.

3. Where design constraints do not permit cursor placement, a standard input area shall be provided for the user to key the selected option code.

b. Presentation of Menu Items - Menu items shall be presented in a list format. Each menu item, along with any associated information (e.g., selection codes and descriptors), shall be displayed on a single line.

c. Organization of Menu Items - Menu items shall be organized in a logical order (e.g., similarity of function, expected frequency of use, temporal ordering of the task). If no logical basis exists for ordering items, an alphabetical order shall be used.

d. Coding of Menu Items:

1. When users have the capability to select a menu item by means of a coded entry, the code associated with the menu item shall be indicated on the display in close spatial proximity to the menu item.

2. Codes used to select menu items shall be related to the menu item so that users do not have to learn arbitrary codes.

3. If menu items are selectable by means of function keys, the arrangement of the function keys and menu shall be compatible.

e. Selectable Items Discriminable From Nonselectable Items - Menu items that are available to be selected by the user shall be visually different from menu items that are not available in a given application or step in a task.

f. Format Consistency - Menu formats shall be consistent throughout the system.

g. Menu Availability - Menus shall be readily available to the user at all times.

h. Movement Through Menu Hierarchies:

1. The user shall have the capability to traverse menu hierarchies forward and backward.

2. If several levels of menu hierarchy are presented, the user shall be able to move from one level to any other level without having to step through multiple menu level.

3. The system shall provide visual cues that indicate the path that the user has travelled through a hierarchy of menus.

i. Feedback:

1. When a menu item is selected, an immediate indication that the intended item was selected shall be given. This indication shall not be confusable with other kinds of display coding.

2. When selection of a menu item results in a continuing condition (e.g. turning on a pump which stays on until commanded to be shut off), a visual indication, clearly associated with the specific menu item, shall be provided to the user during the time that the condition continues.

j. Types of Menus - Menus shall be available either as permanent menus or as user-requested menus ("user-requested menus" are menus which are present only when the user specifically asks for them, e.g., pop-up or pull-down menus). The type of menu shall be a function of the task requirements.

9.6.3.1.6.3.2 Design Requirements for Permanent Menus

Permanent menus shall be used when:

a. The user needs to see the menu items throughout a task.

b. The user needs to examine every option in detail.

c. The user does not have the ability to request that a menu be displayed (e.g., in the absence of a pointing device).

d. The use of a user-requested menu would obscure information needed for a task.

9.6.3.1.6.4.2 Design Requirements for User-Requested Menus

a. Use - User-requested menus shall be used when:

1. Display space is limited.

2. Users need to see the menu items only when selecting them.

3. Information required by the user would not be obscured by the menu.

b. Menu design:

1. The height of a menu bar (used to permit the user to request a menu) shall be sufficient to contain standard text characters which serve as the menu labels.

2. Menu labels on the menu bar shall be brief, descriptive of the contents of the menu, physically separated from other menu labels, and semantically distinctive from other menu labels.

3. Menu bars shall be placed in a consistent location in all displays.

4. The organization of categories across the menu bar shall be logical (e.g., according to function or frequency of use).

c. Activation - User-requested menus shall be displayed only after a single, specific action by the user. After the menu option has been selected, the menu shall revert to its hidden state.

9.6.3.1.7.2 Design Requirements for Direct Manipulation

a. Philosophy of Direct Manipulation - In the direct manipulation interface, the user shall be able to manipulate data structures or objects directly by physically interacting with their graphical representation

b. Features of Direct Manipulation - The direct manipulation interface shall have the following characteristics:

1. The objects of interest have continuous graphical representations (e.g., as icons and windows).

2. The users accomplish functions by means of physical actions with the objects instead of by language-based commands. Two primary physical actions are selecting an object and moving an object.

3. Operations are rapid, incremental, and reversible. The impact of an operation on the object of interest is immediately visible.

c. Use - Direct manipulation shall be among the dialogue techniques used for tasks where:

1. Users have different languages.

2. The task objects and actions lend themselves to iconic representation.

3. Users are not highly practiced with the task.

9.6.3.1.7.3.2 Design Requirements for Icons

a. Icon Design :

1. The icon shall pictorially represent the object or action. (An icon is a pictorial, pictographic, or other symbolic representation of a software object or an action by the system. A user's direct manipulation of the icon is equivalent to manipulating the software object or executing the system action.)

2. Icons shall be identifiable and discriminable.

3. Icons that the user can select shall be sufficiently large enough to minimize selection time and errors.

4. Icons shall be simple, closed figures.

5. Icons shall be accompanied by text labels which correspond to the term from the command language that describes the same object or action. The text label shall be clearly associated with the icon without obscuring the visual representation.

b. Consistency - Visual features, meanings, and specific uses of icons shall be consistent within and among applications.

c. Feedback - Selecting an icon shall be acknowledged by highlighting the icon in such a way that the icon is not visually obscured. The icon shall remain highlighted during the time that it is selected.

9.6.3.1.7.4 Design Requirements for Actions in the Direct Manipulation Interface

a. Movement and Selection - Users shall be able to move the pointing cursor to and select icons by the use of any available cursor control device (e.g., X-Y controllers and arrow keys).

b. Opening - A user shall be able to "open" a selected icon by a single unique action.

c. Initiating a Process - Users shall be able to initiate the process related to an icon (e.g., opening a file or launching an application) in multiple ways: Opening the selected icon; connecting an object icon to an action icon; or selecting an icon and entering a command, e.g., via the command language, command keystrokes, or menu.

9.6.3.1.7.5.2 Design Requirements for Interactions with Windows

a. Control Over Window Dimensions- Users shall be able to change the horizontal and vertical dimension of windows independently by direct physical action on the window.

b. Control Over Window Location - Users shall be able to move windows to different locations on a display by direct physical action on the window. However, users shall not be able to move a window where it interferes with the user's ability to interact with the system or with caution and warning information.

c. Opening and Closing a Window - Users shall be able to open or close a window by direct physical action on the window.

d. "Popping" Windows - In a layered windowing environment, users shall be able to move a window in a stack to the prominent position in the stack so that its contents are visible (known as "popping" the window to the front).

9.6.3.1.8.2 Design Requirements for Data Forms/Form Filling

a. Use - The primary uses of data forms shall be for data entry and computer command tasks in which information needed by the user is displayed and the user has to complete a form.

b. Grouping - Displayed forms shall be arranged such that related items are grouped together.

c. Format and Content Consistency - If paper forms and computer-displayed forms are used in concert in a data entry task, the format and content of the two types of forms shall be compatible, within the constraints of the task and the differences in information format.

d. Distinctiveness of Fields - Fields or groups of fields shall be separated by lines or other delineation cues. Required fields shall be distinguished from optional fields.

e. Field Labels - Field labels shall be distinctively presented such that they can be distinguished from both data entry fields and data entered by the user. Labels for data entry fields shall incorporate additional cueing of data format where the entry is made up of multiple inputs [e.g., TIME (HH/MM/SS):(__/__/__)].

f. Cursor Placement - When the form is displayed, a displayed cursor shall be positioned by the system at the first data entry field to which the user has to provide input. The system shall advance the cursor to the next data field when the user has completed entry of the current field. The user shall also have the ability to move the cursor to the next field, to the previous field, or, independently, to any field on the form.

g. Actions for Movement and Completion - Distinctly different actions shall be used for:

1. Movement of the cursor forward to the next field.

2. Movement backward to a previous field.

3. Placing the cursor in a noncontiguous field.

4. Indicating that the input to the form is completed.

h. Entry Length Indication - The maximum acceptable length for variable length fields shall be indicated on that field. However, when the item length is variable, the user shall not have to remove unused underscores.

i. Overwriting - When data entry by overwriting a set of characters in a field is used, clear designation of overwritten characters (e.g., by reverse video) shall be provided.

j. Dimensional Units - When a consistent dimensional unit is used in a given entry field, the dimensional unit shall be provided and displayed by the system.

k. User Omissions - When required data entries have not been input, the omission shall be indicated to the user, and either immediate or delayed input of the missing items shall be allowed. For delayed entry, the user shall be required to indicate to the system (e.g., by entering a special symbol in the field) that the missing item is delayed, not overlooked.

l. Non-Entry Areas - Non-entry (protected) areas of the display shall be designated. In the absence of authorization of the user, those areas shall be made inaccessible.

m. Prevent Entry of Inappropriate Characters - An attempt to enter an inappropriate character into a field (e.g., entering an alphabetic character into a field reserved for entry of numeric characters) shall result in feedback from the system (e.g., an auditory signal and/or an error message).

9.6.3.1.8.3 Design Requirements for Default Values for Data Forms

a. Default Values - Default values shall be used to reduce user workload. Currently defined default values shall be displayed automatically in their appropriate data fields with the display of a form.

b. Default Modification - The user shall have the capability of changing default values and having those modifications retained by the system beyond that user interaction or session (i.e., until changed by another specific user action).

c. Default Substitution - The user shall be able to replace any default value during a given transaction without changing the default definition.

d. User Confirmation - If required, user acceptance of stored data or defaults shall be possible by a single confirming keystroke.

9.6.3.1.9.2 Design Requirements for Question and Answer

a. Use - The uses for question and answer dialogues shall include:

1. Highly constrained tasks in which each step of the task sequence has few choices available.

2. Routine data or command entry tasks in which the user needs explicit prompting.

b. Structure:

1. The system shall provide the user with a specific request for information. A question mark shall be the delimiter of the question from the system.

2. The system shall provide the user with contextual information (e.g., units of measurement used in the answer) required for answering the question.

3. The area in which the user can enter the answer shall be provided following the question as closely as possible.

4. The system shall accept as much information as is provided by the user. If the input by the user is to be severely limited, a data form shall be used.

5. The system shall display related questions (and their associated answers) simultaneously. Unrelated questions (and their associated answers) shall be displayed separately.

9.6.3.1.10.2 Design Requirements for User-definable Macros

a. The system shall allow the user to group related or sequential control or command entries into one operation known as a user-definable macro.

b. The system shall not allow users to define system-level macros (i.e., macros that can be used across two or more applications). System level macros shall be defined only by software developers.

c. The system shall provide to the user a macro-defining option which would impose a common syntax on all command strings within macros.

d. The system shall prohibit a user from modifying a macro that was defined by a different originating user.

e. When a user creates a macro, the system shall not allow a user to duplicate macro names.

f. The system shall provide users with access to an index of macros and each macro's command listing.

9.6.3.2 Design Requirements for Movement Within User Interfaces

a. Users shall be able to move the locus of their input or attention within a display by means of a pointing cursor. A placeholding cursor shall be available for location of placement in a display used for input of alphanumeric characters.

b. Users shall be able to move displayed information from the same data file by scrolling (i.e., the continuous vertical or horizontal movement of displayed information) and paging (the discrete movement from one "page" to another in an information display).

c. Users shall be able to locate and move to specific information in a data file.

9.6.3.2.1 Design Requirements for Position Designation (Cursor)

a. Control - Systems employing cursors shall provide cursor control capability consistent with user speed and accuracy requirements.

b. Locating - All cursors shall be distinctive against all backgrounds and shall be easy to locate at any position on a display.

c. Tracking - The cursor shall be easy for the user to track as it is moved through the display.

d. Distraction - The cursor shall not distract or impair the user during the search of the display for information unrelated to the cursor.

e. Data Entry - An "enter" action for data items shall result in the entry of all appropriate items (e.g., all data input to a data form or all text written in a text file) regardless of the placement of the cursor. The user shall not be required to move the cursor to any arbitrary position on the display (e.g., the top left or bottom right of the display).

f. Home Position - The home position for the cursor shall be consistent across similar types of displays.

g. Unique Shape - The shapes used for cursors shall be unique with respect to all other display structures. Cursors of different shapes shall be used for different purposes; the relation between a cursor shape and function shall be consistent across applications.

h. Types of Cursors - Users shall have access to two functionally different types of cursors -- a pointing cursor and a placeholding cursor.

9.6.3.2.1.1 Design Requirements for Pointing Cursor

a. Display Priority - The pointing cursor shall be available to the user at all times. The pointing cursor shall obscure other characters unless this would interfere with user performance.

b. Visual Characteristics:

   1. The pointing cursor shall not blink.

   2. The pointing cursor shall maintain its size and image quality across all screen and display locations.

   3. To the greatest degree possible, the pointing cursor shall be completely graphic and shall not contain a label.

c. Gross Movement:

   1. The movement of the pointing cursor shall be systematically related to the movement of the cursor control device (e.g., a trackball, a joystick, a mouse, or cursor control keys).

   2. The pointing cursor shall not move in the absence of input from the user.

   3. The movement of the pointing cursor shall appear to be smooth and continuous with smooth and continuous movement of the cursor control device.

d. Fine Positioning - When fine positioning accuracy is required, the displayed cursor shall include an appropriate point designation feature (e.g., crosshairs).

9.6.3.2.1.2 Design Requirements for Placeholding Cursor

a. Non-Interference - The placeholding cursor shall not interfere with the reading of the character that it marks.

b. Number of Placeholding Cursors - There shall be one and only one placeholding cursor in each window in which a user is entering alphanumeric characters.

c. Visual Characteristics:

   1. The placeholding cursor shall assume the height or width of the alphanumeric characters adjacent to it.

   2. If the placeholder cursor blinks, the default blink rate shall be 3 Hz. A user-selectable blink rate shall be within the range of 3 to 5 Hz.

9.6.3.2.2 Design Requirements for Scrolling

a. Method of Scrolling - Users shall be able to scroll by only one method within an application - either by "moving text" (i.e., the information in the display appears to move over a fixed display window) or by "panning" (i.e., a window appears to move over a fixed display of information. Panning shall be the preferred method.

b. Scroll Rate - The scroll rate shall allow the user to scroll in an increment of a line and shall provide the appearance of a smooth flow of text.

c. Direction of Scrolling - The direction that a user may scrolling shall be evident before the user begins the scroll action (e.g., arrows might point in the direction that corresponds to the direction that scrolling will occur).

d. Numbering - Items continued on the next page (scrolled to) shall be numbered relative to the last item on the previous page.

9.6.3.2.3 Design Requirements for Paging

a. User Control - Users shall have control over paging by use of any of several methods (e.g., dedicated paging function keys and a display-based paging icon).

b. Paging Increments - Users shall be able to move in increments of one or multiple pages.

c. Page Numbering - Each page of a multiple page display shall be numbered to identify the currently displayed page and the total number of pages.

d. Direction of Paging - The direction that a user may page shall be evident before the user begins to page (e.g., separate, labeled function keys might be used for paging forward and paging backward).

9.6.3.2.4 Design Requirements for Searching

a. Objects of Search - Users shall be able to search for and move to :

   1. A specific line number.

   2. A literal string of alphanumeric characters.

b. Multiple Occurrences - Users shall be able to find multiple occurrences of a literal string.

9.6.3.2.5.2 Design Requirements for Hypertext

a. Restricted Access to Authoring - Users shall only have access to authoring tools (i.e., tools that allow users to create modify, or delete the representation of information or links between information) if they need to have the power of those tools. Users that only need to browse (i.e., search through a database to obtain information contained in the nodes by following links between nodes), shall not have access to authoring tools.

b. Browsing Tools - Browsing tools shall generally use a question and answer dialogue.

9.6.3.3 Design Requirements for Manipulating Data

Data Manipulation - The user shall be able to manipulate data without concern for internal storage and retrieval mechanisms of the system.

9.6.3.3.1.2 Design Requirements for Editing

a. Use - Users shall be able to edit only selected data files (e.g., files that they create and files specifically designated as read/write). Certain files shall be uneditable by the user. Editable files shall be clearly distinguishable from noneditable files.

b. Methods - For all editable files, the user shall be able to edit text, tables, graphics, and any other data by means of any of several methods (e.g., command language commands, command keystrokes, and menus).

c. Consistency of Procedures - All editing procedures shall be consistent in dialogue structure, independent of the type of information being edited.

d. Modifying Physical Features:

1. The user shall have the ability to change the physical characteristics of text (e.g., the font type and size, italics, underlining, boldness, and capitalization).

2. The user shall have the ability to set and modify the tab position for user-modifiable text files.

3. The user shall be able to set and modify the margins for user-modifiable text files.

e. Insert Mode vs. Overstrike Mode - By default, the text editor shall operate in insert mode. Text shall be inserted moving to the right. However, the user shall be able to select text to be overstriken.

f. Selecting Data:

1. Users shall be able to select any editable data in any type of displayed data file (including text, tabular, or graphical) for specific editing functions (e.g., cutting, deletion, copying) with no more than two actions.

2. The selected data shall be visually distinct from non-selected data.

3. Users shall be able to remove selected data from the selected state with a single action.

g. Cutting Data:

1. Users shall be able to remove any editable data from a displayed data file by means of a "Cut" capability.

2. After the data are removed, the text or tabular display shall be reconstituted without a gap where the data were cut. Graphical displays shall be reconstituted with a gap where the graphical data were removed.

3. Users shall be able to place data that was most recently cut at any unrestricted location in any data file. Certain locations may be restricted from insertion of cut (or copied) data (e.g., menus or the system-originated parts of data forms).

h. Copying Data - Users shall be able to copy any editable data and replicate it at any unrestricted location in any data file.

i. Deleting Data - Users shall be able to delete previously-selected data by simple actions different from other editing functions (e.g., a dedicated "delete" command or function key).

1. Deletion of data shall be reversible for a limited period.

2. Deletion of critical data shall be protected by use of an "arm-fire" sequence, in which the user has to acknowledge that the system should delete the data.

9.6.3.3.1.3 Design Requirements for Graphics Editing

a. Editing Objects - Selection of a graphical object for editing shall be a function of the type of object: Icons shall be selected as a whole object; partial *selection shall not be permitted for icons. For editable schematics, maps,* flowcharts, data graphs and pictures, users shall be able to select for editing any object within the graphical display.

b. Moving - Users shall be able to move a previously selected object from one position on a display to another. An indication of the path of movement shall be provided to the user during the move.

c. User shall have the ability to increase and decrease the size of graphical objects that have previously been selected.

d. Users shall be able to rotate objects that have previously been selected. Users shall be able to rotate objects clockwise or counterclockwise. An indication of the path of rotation shall be provided to the user.

9.6.3.3.2 Saving

9.6.3.3.2.2 Design Requirements for Saving

a. Saving Data - The user shall have the ability to save data entered into an editable data file:

   1. While continuing to interact with that file .

   2. While simultaneously exiting from that file. Two different simple actions shall be used for these two different types of saving data.

b. Exiting a File - The user shall be able to exit a data file at any time without saving the changes to the file.

9.6.3.4.1 Design Requirements for Consistent Terminology

Consistent Terminology - On-line documentation, off-line documentation, and help instructions shall use consistent terminology.

9.6.3.4.2.2 Design Requirements for User Feedback

a. Use - Clear and concise feedback shall be provided to users as necessary to provide status information throughout the interaction.

b. Function Status - Feedback shall indicate actual function status.

c. Standby - If a system process (or processes) is time-consuming and causes the screen and input devices to be locked out, a progress message shall be displayed and updated, if possible, advising the user of the time remaining for the task or of the percentage of the task completed.

d. Process Outcome - When a control process or sequence is completed or aborted by the system, positive indication shall be presented to the user concerning the outcome of the process and the requirements for subsequent user action.

e. Input Confirmation - Confirmation of user input shall occur without removing the data display.

f. Highlighted Option Selection - Highlighting of data, a message, a menu item, an icon, or other display structure shall be used as feedback by the system to acknowledge that the user has selected the item.

g. User Input Rejection - If the system rejects a user's input, feedback shall be provided to indicate :

   1. The reason for rejection.

   2. The required corrective action.

   3. Where appropriate, the location of the problem.

9.6.3.4.3.2 Design Requirements for System Status Messages

a. Operational Mode - The system shall inform the user of the current operational mode when the mode might affect the user's actions.

b. System Changes - The system shall inform users about system design or system operation changes only in those aspects that may affect the user's interaction with the system.

c. Characteristics of Status Messages:

1. Status messages shall be provided to the user in a consistent location on the display.

2. The message shall contain only the information needed by the user, and conveyed to the user in a form such that additional resources are not required to interpret the message, e.g.:

a) A description of the system state.

b) Directives for user action.

c) The consequences, if any, of failing to follow the directives.

3. If the user will not be able to look at a display, the message shall be presented by means of a voice production system and shall be repeatable.

4. If the user needs to be alerted that a status message is being displayed, status messages shall be accompanied by a consistent auditory signal. The auditory signal shall be redundant with the linguistic message.

9.6.3.4.4 Design Requirements for Error Handling

a. Error Correction - The system shall provide users with a simple and easy capability to correct errors in input. Users shall be able to correct individual errors in a command string, sequence of commands, or data file by replacing only the erroneous input without having to re-enter correct input.

b. Early Detection - A capability shall be provided to facilitate detection and correction of errors before they are entered into the system. In order to avoid disrupting the user, error checking shall occur at the earliest logical break in the user's command or data input (e.g., at the end of a data field or the end of a command).

c. Timing of Feedback - If a user makes an incorrect command or data entry, the system shall detect the error and notify the user within two seconds from command or data entry.

d. Internal Software Checks - User errors shall be minimized by the use of internal software checks of user entries for the validity of the item, the sequence of entry, completeness of the entry, and the range of the value.

e. Error Message Content:

1. Error messages shall be informative, brief and conveyed to the user in a form such that additional resources are not required to interpret the message.

2. The error message shall be self-contained: The user shall not have to refer to external documents in order to interpret the error message.

3. The error message shall be constructive and neutral in tone, avoiding phrases that suggest a judgment of the user's behavior.

4. To the greatest degree possible, the error message shall reflect the user's need for information and concept of the system, not those of the person who develops the message.

5. Error messages shall be appropriate to the user's level of training and shall be as specific as possible to the user's particular application.

6. Error messages shall explicitly provide as much diagnostic information and remedial direction as can be inferred reliably from the error condition.

f. Error Recovery and Process Change - The user shall be able to stop a process at any point in a sequence as a result of an indicated error. The user shall be able to return easily to any step in a multi-step process in order to nullify an error or to effect a desired change.

g. Correction Entry and Confirmation - When the user enters correction of an error, such corrections shall be implemented only by an explicit action by the user (e.g., actuation of an "Enter" key). All error correction by the user shall be acknowledged by the system, either by indicating that a correct entry has been made or by another error message if an incorrect entry has been made.

h. Spelling Errors:

1. Spelling and other common errors shall not produce valid system commands or initiate transactions different from those intended.

2. When possible, the system shall recognize, but not execute, common misspellings of commands. Computer-corrected commands, values, and spellings shall be displayed and highlighted for user confirmation prior to execution.

i. Errors in Stacked Commands:

1. To prompt for corrections of an error in stacked commands, the system shall display the stacked sequence with the error highlighted.

2. Where possible, a procedure shall be provided to correct the error and salvage the stack.

j. Location of Error Messages - Error messages shall be placed on the display close to the point of the error and/or in a designated, consistent area of the display.

9.6.3.4.5.2 Design Requirements for Prompts

a. Use - Where appropriate, prompts and help instructions shall be used to explain commands, error messages, system capabilities, display formats, procedures, and steps in a sequence.

b. Standard Display - The location of prompts for data or commands shall be at the location of the desired input whenever possible. When the prompt cannot be placed at the location of the input, it shall be located in a standard message area.

c. Prompt Language:

1. Prompts shall be explicit, and the user shall not be required to memorize lengthy sequences or refer to secondary written procedural references.

2. Prompts shall be conveyed to the user in a form such that additional resources are not required to interpret the message. They shall not require reference to coding schemes, external documentation, or conventions which may be unfamiliar to occasional users.

9.6.3.4.6.2 Design Requirements for On-Line Instruction

Access to On-Line Documentation - For instruction, users shall have access to *on-line documentation and descriptions of procedures.*

9.6.3.4.7.2 Design Requirements for On-Line Help

a. Access to Help at Any Point in a Transaction - Users shall be able to access the Help function at any point in their interaction with the system. Access of help shall be by any of several methods, including

1. Help provided automatically by the system when users make repeated frequent errors.

2. Input of a command language request for help.

3. Actuation of a "help" function key.

4. Selection of a help option in a menu.

b. System Response to Help Request - A help request from the user shall elicit a task specific and context sensitive response from the system.

c. Levels of Help - The Help function shall provide information at a level of detail that matches the needs of the user. The user shall first receive summary information about the requested topic, then can request additional detailed information in a specific subtopic or subtopics.

d. Definitions Available - A dictionary of abbreviations, acronyms, and codes shall be available through the Help function, where feasible. Definitions of allowable options and ranges of values shall be displayed at the user's request where feasible.

e. Help about User Dialogues - At the user's request, the Help function shall provide the user with basic information about the semantics and syntax of any available user dialogue. Basic information shall include a structured listing containing each command, the associated keystroke commands and menu options, and the uses or consequences of the command.

f. Language of Help Messages:

1. Help messages shall be explicit, and the user shall not be required to memorize lengthy sequences or refer to secondary written procedural references.

2. Help messages shall be conveyed to the user in a form such that additional resources are not required to interpret the message.

3. Help messages shall not require reference to external documentation.

9.6.3.5 Design Requirements for Sequence Control

a. Hierarchical Process:

1. When hierarchical levels are used to control a process or sequence, the number of levels in depth in the hierarchy shall be minimized.

2. Display and input formats shall be similar within levels, and the system shall indicate the current positions within the sequence at all times.

3. Where it is appropriate for an experienced user to skip levels in a hierarchy, this capability shall be built in.

b. Interrupt:

1. User interrupts, processing aborts, and processing resumptions shall be allowed by the system. These actions shall not be modified by stored data.

2. The users shall be able to leave the system and store their work so that, on reentry at a later date, they can resume where they left off.

9.6.4.2 Design Requirements for User Input

a. Consistent Consequences of User Input - The consequences of any user input shall be consistent:

   1. For any individual user across time .

   2. From user to user.

b. Relation of Input to Consequence - The consequences of the user's input shall be both logically and temporally linked to the input action so that the user can learn to predict what will happen following the input action.

c. Input via a Variety of Devices - System design shall not impose on the user the use of a specific input device when other devices are available and appropriate. However, users shall not be required to switch among multiple devices to perform the same function within a task.

d. Computer Failure - In the event of computer failure, the program shall allow for orderly shutdown and establishment of a check-point so restoration can be accomplished without significant loss of computing performed to date.

9.6.4.3 Design Requirements for Data Entry Design

a. Learning - The requirement to learn mnemonics, codes, special or long sequences, or special instruction shall be minimized.

b. Abbreviations, Mnemonics, Codes, and Acronyms - When abbreviations, mnemonics, codes, or acronyms are used to shorten data entry, they shall be distinctive and have a relationship or association to normal language or specific job related terminology.

c. Length of Data Entries - The length of individual data items that are part of a required data input shall not be longer than is practicable, (e.g., difficult to remember while typing or tedious to edit).

d. Data Entry Rate - Data entry shall be paced by the user, depending on the user's application, criticality of the operation, and attention span, rather than by the system.

e. System Acknowledgment of Data Entry - The system shall provide a positive feedback to the user indicating the acceptance or rejection of a data entry and shall indicate to the user processing delays of more than 15 seconds.

f. Explicit Completion Action - Data entry shall require an explicit completion action, such as the depression of an ENTRY key after a string input.

g. Validation - Data entries shall be validated by the system for correct format, legal value, or range of values. Where data is entered in sets with the same format and range of values, the entire data set shall be validated upon its completion.

h. Input Units - Data shall be entered in units which are familiar to the user.

i. Software-Available Data - The user shall not be required to enter data already available to the software.

j. File Names - Names of files shall be distinctive and descriptive of the contents of the files to aid in locating files and deterring accidental selection or deletion of files which have similar names.

k. Originator Identification - For reference, the system shall automatically associate the originator of a data file , text file, or message with the file's name.

9.6.4.4 Design Requirements for Interactive Control

a. Simplicity - The relationship between data entry and displays shall be straightforward and explicit. Data entry actions shall be simple and direct.

b. Accidental Actuation - Provision shall be made to prevent accidental actuation of potentially destructive control actions, including the possibility of accidental erasure or memory dump.

c. Compatibility with User Skill, User Tasks - Controls for data entry shall accommodate the lowest anticipated user skill level.

d. Availability of Information - Information necessary to select or enter a specific control action shall be available to the user when selection of that control action is appropriate.

e. Minimized Keying - The amount of keying required shall be minimized by using numbered lists and abbreviations.

f. Physical Characteristics of Selectable Items - Selectable items or regions shall not be so large that they waste screen space or may not be perceived as selectable.

g. Multitasking/Multimonitor Considerations - In a multitasking environment with multiple monitors, controllers, or cursors, the location of the active cursor shall be apparent to the user. If there are two pointing cursors -- one on each of two monitors -- the active cursor shall be apparent to the user. If there is a single cursor that moves between two monitors, its path shall be continuously trackable.

h. X and Y Outputs - The controller, with the exception of arrow keys or other discrete step keys, shall be able to produce any combination of x and y output values.

i. X-Y-Z Control Outputs - Any controller shall be able to produce any combination of x, y, and z output values. Output in each of the three dimensions shall be discriminable from each other.

NOTES

NOTES

10.2.3 Personal Hygiene Design Requirements

10.2.3.1 Partial Body Cleansing Design Requirements

Partial body cleaning facility requirements are listed below:

a. Necessity for Facility - Partial body cleaning facilities shall be provided on all missions that exceed 1 day. On missions of 30 days or more, one facility shall be provided for every four crewmembers. A partial body washing facility shall be provided to accomplish washing of selected body areas.

b. Design Requirements - All partial washing equipment using water shall have the following design characteristics:

1. Method to allow application of water to the hands and face.
2. Method to remove excess water from the body and facility, and cleansing aids.
3. Means to control water temperature.
4. Means to control water flow/usage.
5. Means to prevent water from escaping into the module environment.
6. Compatibility with the use of soap, shampoo, and antiseptic solutions, and accommodation of hair and other similar substances which might commonly find their way into such an area.

   (Refer to Figure 10.3.2-1 for rate of body waste generation.)
7. Means to prevent cross contamination among crewmembers.
8. Means for final drying of body part.
9. Appropriate body and equipment (e.g., towels) restraints for reduced gravity conditions.
10. A means to personally code crew hygiene items.
11. All personal hygiene facilities shall be designed to be easily cleaned sanitized, and maintained.

c. Cleansing Agents - Refer to Paragraph 10.2.3.2.d.

10.2.3.2 Whole Body Cleansing Design Requirements

Whole body cleansing facility requirements are listed below:

a. Necessity for Facility - A whole body cleansing facility shall be provided for all long duration missions.

b. Equipment Design - Refer to 10.2.3.1.b.

c. Privacy - Privacy shall be provided for whole body cleaning.

d. Cleansing Agents

1. Soap, shampoo, and other cleansing agents shall be chosen for their compatibility with a wide range of skin types in a low humidity environment.
2. Some range of personal selection of cleaning agents, perhaps including *alternative off-the-shelf commercial brand name preparations, shall be* permitted as long as all items are judged safe for use in the space module environment and are compatible with on-board water reclamation and/or water and solid waste disposal systems.

Waste products	Mass (gm/person/day)	Volume (ml/person/day)
Hair growth	0.03 (0.3 to 0.5 mm per day)	
Desquamated epithelium	3	2
Hair — depilation loss	0.03	0.03
Hair — facial — shaving loss	0.3	0.28
Nails	0.01	0.01
Solids in sweat	3	3
Sebaceous excretion — residue	4	4.2
Solids in saliva	0.01	0.01
Mucus	0.4	0.4
Mensus (see note 1)	113.4	113.4
Flatus as gas	—	2000
Solids in feces	20	19
Water in feces	100	100
Solid in urine	70	66
Water in urine (note 2)	1630	1630

Note:
1. Approximately once every 25 to 34 days and lasts 4 to 6 days, approximately 80% released during first 3 days.
2. Based on Skylab data.

Figure 10.3.2-1 Volume and Mass of Human Body Wastes

MSIS 215

e. Dressing Area - The cleaning facility will include a means for private body drying and dressing and a dry area for clothes. The area provided for body drying and dressing shall be temperature controlled.

f. Capacity - The whole body washing system shall have sufficient capacity to allow each crewmember to wash a minimum of three times a week.

10.2.3.3 Oral Hygiene Design Requirements

a. Necessity for Facility - Oral hygiene facilities shall be provided for all missions that exceed 1 day.

b. Functional Requirement - Facilities shall allow the crew to daily maintain proper tooth, oral cavity, and gum cleaning and care.

c. Cross Contamination - The facilities shall prevent cross contamination among crewmembers.

d. Expectoration - Provide facility as necessary to allow the user to expectorate washing fluids and spittle.

10.2.3.4 Hair Cutting Design Requirements

a. Necessity for Facility - A facility shall be provided as necessary to keep facial and head hair the length dictated by mission requirements and personal grooming preferences.

(Rate of hair growth is shown in Figure 10.3.2-1.)

b. Facility Design - The facility shall be sufficiently large to allow a crewmember to assist in hair cutting and trimming. The facility shall be equipped with appropriate storage areas, restraints, and mirrors.

c. Debris Containment - The facility shall ensure that hair is contained and does not escape into the space module environment.

(Refer to Paragraph 5.1.3.3, Atmosphere Contamination, for further information on debris containment requirements.)

d. Lighting - Lighting shall be sufficient to see small details.

(Refer to Paragraph 8.13, Lighting, for specific lighting requirements.)

10.2.3.5 Grooming and Shaving Design Requirements

a. Necessity for Facilities - A shaving and grooming facilities shall be provided for all missions that exceed 2 days.

(Refer to Figure 10.3.2-1 for the rate of generation of nails and hair.)

b. Debris Containment - The capability shall be provided for collection and containment of body hair and nails.

(Refer to Paragraph 5.1.3.3, Atmospheric Particulates, for further information on debris containment requirements.)

c. Supplies - Refer to Paragraph 10.2.3.2.d Cleansing Agents

d. Facility Design - Grooming facilities shall consist of a designated space equipped with appropriate stowage areas, restraints, mirrors, and access to a water supply.

e. Lighting - Lighting shall be sufficient to see small details.

(Refer to Paragraph 8.13, Lighting, for specific lighting requirements.)

10.3.3 Body Waste Management Facilities Design Requirements

10.3.3.1 Defecation and Urination Facilities Design Requirements

The following are requirements for the design of crew defecation and urination facilities:

a. Number of Facilities - Facilities shall be provided based on crew size.

b. Fecal Collection - Fecal collection facilities shall meet the following requirements:

1. The facilities shall provide crew interfaces to accommodate the collection of fecal solids, liquids, gases, particulates, and associated consumable material (e.g., wipes).

2. The facilities shall allow simultaneous urination and defecation while seated. In addition, accommodations shall be provided for vomitus collection within reach of the seated crewmember.

3. Capacity - The fecal collection system shall have the following capacity:

a) The fecal collection devices shall accommodate fecal matter of 400 gm (14 oz) by weight and 300 ml (18 in^3) by volume per person per day.

b) The capability to accommodate a maximum of 1000 ml (61 in^3) of diarrhea discharge shall be provided.

c) The fecal collector shall accommodate a maximum BOLUS length of 330 mm (13 in).

d) Quantities in excess of these amounts shall not result in an unresolvable condition.

4. The facilities shall capture, isolate, stabilize, and store all wastes and wipes generated during defecation.

c. Urine Collection - Urine collection facilities shall meet the following requirements.

1. The urine receiver should be located so that male crewmembers may also urinate in the standing position without removing lower clothing.

2. The facilities shall provide crew interfaces to accommodate liquid capture and splash control.

3. Capacity - The urine collection system shall have the following capacity:

a) The urine collection devices shall accommodate a maximum urine output volume of 4000 ml (244 in^3) per person per day.

b) The urine collection system shall be designed to accommodate urinary discharge up to 800 ml (49 in^3) in a single micturition at a delivery rate of 50 ml/sec (3 in^3/sec).

c) Urine volumes in excess of these amounts shall not result in an unrecoverable condition.

4. The facilities shall capture, isolate, stabilize, and store all wastes and wipes generated during urination.

d. Sanitation - The defecation and urination facilities shall meet the following sanitation requirements:

1. The facilities shall be designed to allow periodic cleansing and disinfection of crew interfaces and subsystems.

2. The facilities shall prevent cross contamination among the crew members.

3. The facilities shall not contaminate other areas of the space module.

e. Noise - A means shall be provided to control noise from the facility equipment and/or crewmembers when the equipment is in operation.

f. Odors - Odors from the facility and from storage and handling facilities shall be controlled.

g. Privacy - Defecation and urination facilities shall provide both visual and auditory privacy for the user.

h. Capacity - Sufficient urination and defecation facilities and capacity shall be provided to allow use by the crew within mission time and schedule constraints.

i. Contingency System - A contingency urination and defecation facility shall be provided in the event of primary system failure.

j. Restraints - Appropriate restraints shall be provided for facility use and post use cleanup.

k. Body Cleansing - Provisions shall be provided in the urination and defecation facilities for inspecting and cleaning the body after use and the disposal of used materials.

l. Anatomical Accommodation - Urination and defecation facilities shall be provided to accommodate the physiological differences of male and female crewmembers and the anatomical size range of the crew. The crew interface hardware shall be appropriately designed to allow easy interface with other personal hygiene equipment, personal hygiene supplies, and crewmember clothing.

m. Handling of Feces and Urine - If a crewmember is required to handle urine or feces samples for transfer to another area, the following requirements apply:

1. Crewmembers shall be protected from direct contact with waste material.

2. Waste material odors shall be controlled.

3. Methods shall be provided to prevent escape of waste material into the environment.

4. Transfer containers shall be so constructed as to prevent microbial escape during transfer.

n. Inspection - The capability shall be provided for a crewmember to visually inspect his or her fecal waste products.

o. Noise (Refer to Paragraph 5.4.3.2.3, Annoyance Exposure Requirements, for applicable noise criteria.)

10.3.3.2 Facilities for Other Waste Products Design Requirements

In addition to facilities for urination and defecation, the waste management facility shall have the following capabilities:

a. Vomitus - The waste management facility shall be able to collect, contain, transport, and treat vomit. The collection facility shall be readily accessible, particularly during the first few days of the mission.

b. Menses - A means of collection, treatment, and disposal of menstrual discharge and associated absorbant material shall be provided to female crewmembers. The facility shall be private.

c. Transfer Containers - Transfer containers, if required, shall be so constructed as to prevent microbial escape during transfer.

10.4.3 Individual Crew Quarters Design Requirements

The following are design requirements for one-person individual crew quarters:

a. Communications - Two way audio/visual/data communications system shall be provided between the crew quarters and other module areas, and the ground. The system shall have the capability of alerting the crew quarters occupant in an emergency.

b. Environmental Controls - Independent lighting, ventilation and temperature control shall be provided in crew quarters and shall be adjustable from a sleep restraint.

(Refer to Paragraph 5.8.3, Thermal Design Requirements, for thermal and ventilation requirements, and Paragraph 8.13.3, Lighting Design Requirements, for lighting requirements.)

c. Noise - The noise levels in the crew quarters shall be as low as possible during sleep periods.

(Refer to Paragraph 5.4.3.2.3.1, Wide-Band Long-Term Noise Exposure Requirements, for permissible noise levels.)

d. Movement - The vibration and acceleration of the crew quarters shall be minimized to the maximum extent possible.

(Refer to Paragraph 5.5.3.3.3, Reduced Comfort Boundary, for sleep area vibration limits.)

e. Stowage - Facilities shall be provided in the crew compartment for stowing bedding, clothing, and personal items.

f. Compartment Size - For long duration space missions, dedicated, private crew quarters shall be provided for each crewmember with sufficient integral volume to meet the following functional and performance requirements:

1. 1.50 m3 (53 ft^3) for sleeping.

2. 0.63 m3 (22 ft^3) for stowage of operational and personal equipment.

3. Additional free volume, as necessary, for using a desk, computer/communication system, trash stowage, personal grooming, dressing/undressing convalescence, off-duty activities, and access to stowage or equipment without interference to or from permanently mounted or temporarily stowed hardware. The internal dimensions of the crew quarters shall be sufficient to accommodate the largest body size crewmember under consideration.

   (Refer to Figure 8.6.2.3-1 for maximum 1-g unrestrained clothing don/doft envelope.)

g. Exit and Entry - The opening shall be sufficiently large to allow contingency entry by an EVA suited crewmember.

(Refer to Paragraph 8.10.3, Hatch and Door Design Requirements, for requirements on doors.)

(Refer to Paragraph 14.5.3.5, EVA Passageway Design Requirements, for minimum opening for EVA suited crewmember.)

h. Privacy - The individual crew quarters shall provide audio and visual privacy for the occupant.

i. Restraints - Restraints shall be provided as necessary for activities such as sleeping, dressing, recreation, and cleaning.

(Refer to Paragraph 11.7.2.3, Personnel Restraints Design Requirements, for requirements on restraints.)

j. Windows - Window accommodations shall be provided in individual crew quarters on long duration missions.

10.5.3 Galley and Wardroom Design Requirements

10.5.3.1 Overall Galley and Wardroom Layout Design Requirement

The following requirements apply to the overall layout of a space module galley and wardroom:

a. Traffic Flow - The galley and wardroom shall be configured to provide clear traffic paths for the crew to efficiently perform galley activities.

b. Size of Crewmembers - Galley and wardroom hardware shall be usable by international crews and by the full size range of crewmembers.

(See Paragraph 3.3.1, Body Size, for specific dimensions.)

c. Restraints - Restraints shall be provided for crewmembers, food, utensils, cooking equipment, and other loose items as necessary at galley and wardroom locations.

d. Ambient Conditions - Comfortable eating/dining conditions over prolonged periods requires the capability to adjust light levels, light directionality and lighting type. Ambient noise levels should also be kept below 70 db (a).

(Refer to Paragraph 11.7, Personnel Restraints Design Requirements, for specific restraint design requirements.)

10.5.3.2 Food Selection, Preparation, Consumption Design Requirements

a. Inventory Update and Review - The galley shall provide a system which allows for simple and rapid update and review of the food, beverage and water inventory.

(Refer to Paragraph 13.3.3, Inventory Control Design Requirements, for additional requirements.)

b. Identification - All food items shall be identifiable in terms of contents and method of preparation.

c. Accessibility - A pantry or immediately accessible stowage area for at least one day's food supply for the entire crew shall be provided in the galley.

d. Heating - A means shall be provided in the galley for heating food and liquids to at least 66° C (150° F) in less than 30 minutes and for maintaining that temperature.

e. Chilling - A means shall be provided in the galley for cooling food and liquids to 4°+/-2° C (39°+/-3°F).

f. Rehydration - A means shall be provided in the galley for injecting necessary potable water for rehydration of food.

(Refer to Paragraph 7.2.2.3.2, Potable Water - Design Requirements, for potable water requirements.)

g. Serving and Preparation Utensils - Area shall be provided in the galley for stowage of eating utensils, servicing equipment (trays, plates, containers, etc.), and preparation tools and containers.

h. A table shall be provided for eating.

10.5.3.3 Food Packaging and Stowage Design Requirements

a. Package Portions

b. Rehydration Provisions

c. Kneading Provisions

d. Integration With Food Preparation System

e. Eating

f. Toxicity

10.5.3.4 Galley and Wardroom **Cleaning Design Requirements**

The following facilities shall be provided for galley and wardroom cleaning and sanitation:

a. Design for Cleaning - The surfaces in the galley and wardroom shall be easily accessible for cleaning and sanitation. The surface texture shall be capable of being wiped clean. Closeouts shall be provided to preclude contamination in areas that are inaccessible.

b. Cleaning Supplies and Equipment - Cleaning supplies and equipment shall be readily available to the galley and wardroom. The equipment and supplies shall be capable of the following:

   1. Sanitizing the galley and wardroom.

   2. Collection, containment, and stabilization (as necessary) of debris, spills, and odors.

   3. Washing and sanitizing of reusable utensils, serving equipment, and preparation equipment.

c. Trash Collection - A trash collection point shall be provided in the galley and wardroom for both wet and dry trash. Trash shall be kept out of sight and odors shall be controlled so that the trash collection points are not aesthetically objectionable to the crew.

   (Refer to Paragraph 13.2.3, Housekeeping Design Requirements, for specific requirements.)

10.6.3 Meeting Facility Design Requirements

10.7.3 Recreation Facility Design Requirements

10.8.3 Microgravity Countermeasure Facility Design Requirement

10.8.3.1 Microgravity Countermeasures Equipment/Supplies Design Requirements

10.8.3.1.1 Exercise Equipment

a. Strength Equipment - An isotonic strength mechanism (probably an ergometer), capable of imposing resistive forces of from 45 to 1335 N (10 to 300 lb), so that crewmembers can perform weight-lifting type exercises, shall be included.

b. Aerobic Equipment - A minimum of one piece of aerobic exercise equipment shall be provided.

10.8.3.2 Countermeasure Monitoring Design Requirements

a. Link With Medical Facility - Exercise devices shall have a real-time data link with the onboard medical facility.

b. Routine monitoring - The capability shall be provided to monitor the heart rate, duration of exercise period, and the power output from instrumented exercise device on a routine basis.

c. Periodic monitoring - The capability shall be provided to monitor electrocardiograph output, blood presssure, oxygen uptake (VO2), and muscle strength on a periodic basis.

10.8.3.3 Display Capabilities for Exercising Crewmembers Design Requirements

a. Exercise Parameters - Display of exercise parameters (heart rate, elapsed time, power input).

b. Trend Data - Trend analysis comparisons of crewmember performance over time.

c. Text and Video Entertainment (crewmember choice).

10.8.3.4 **Exercise Environment Design Requirements**

a. Cooling and Ventilation

b. Noise and Vibration Control

c. Minimize Boredom

10.8.3.5 Countermeasure Program Administration Design Requirements

Facilities shall be provided for administration of protocol, monitoring and recording, and schedule and protocol revision.

10.9.3 Space Medical Facility (SMF) Design Requirements

10.9.3.1 Medical Facility Environmental Design Requirements

The SMF shall meet the following environmental requirements:

a. Cleanliness - shall be capable of being cleaned and sanitized.

b. Lighting - shall meet requirements of Figure 8.13.3.1-1 for specific medical tasks.

c. Privacy - shall be visually separable from the remainder of the space module.

d. Noise - noise levels shall meet the requirements defined in section 5.4.3.

10.9.3.2 Equipment Requirements

10.9.3.2.1 Data Base and Communications Capability

A system shall be provided which can manage and store medical information and crew health records, inventory of medical supplies and pharmaceuticals, and two way voice and visual communications between the module and supplemental medical support facilities outside the module.

10.9.3.2.2 Environmental Monitoring Equipment

The SMF shall have the ability for real-time or near real-time monitoring for: particulate substances; microbial contamination of air, water, and surfaces; volatile contaminants of the atmosphere; potential water supply contaminants (Fig. 7.2.2.3.2.1-1); and module and biological radiation exposure.

10.9.3.2.3 Physiological Monitoring Equipment

The SMF shall have cardiovascular, pulmonary, metabolic, renal, muscular and skeletal, and body fluids physiological monitoring capabilities.

10.9.3.2.4 Medical Life Support

The SMF shall be capable of emergency life support until further medical treatment can be administered. Ventilator/respirator support and pulmonary assessment equipment shall be included with the medical life support equipment.

10.9.3.2.5 Laboratory

The SMF laboratory shall be capable of monitor and analysis of hematology, clinical chemistry, urine analysis and microbiology.

10.9.3.2.6 Diagnostic Imaging

The SMF shall provide both a radiographic and nonradiographic imaging capability.

10.9.3.2.7 Countermeasures

The SMF shall provide the equipment necessary to counteract the effects of reduced gravity on the body. The countermeasures shall include exercise equipment, physiologic monitoring equipment, pharmaceuticals, and pressure devices to counteract the effect of fluid shifts in zero gravity.

(Further details on the microgravity countermeasure facilities are in Paragraph 10.8)

10.9.3.2.8 Surgery/Anesthesia Equipment

The SMF shall provide supplies and equipment to perform minor surgery.

10.9.3.2.9 Dental Care Equipment

The SMF shall contain equipment and supplies used to treat dental anomalies of a complexity up to and including tooth removal.

10.9.3.2.10 Intravenous Fluid Injection Supplies and Equipment

The SMF shall provide equipment for preparation and measured injection of sterile water, fludis containing medications, electrolytes, or nutritional substances, and blood or blood products.

10.9.3.2.11 Hyperbaric Treatment Facilities

The SMF shall have an air lock designed for compression therapy at up to 6 Atmospheres for treatment of decompression sickness and air embolism.

10.9.3.2.12 Pharmaceuticals

The SMF shall have sufficient pharmaceuticals and facilities for their stowage.

10.9.3.2.13 Central Supply

Miscellaneous medical equipment such as bandages, burn treatments, sterile water, etc. shall be provided at a readily accessible central point.

10.9.3.2.14 Physician's Instruments

The SMF shall contain a transportable package of physician's instruments sufficient for the conduct of a routine diagnostic exam.

10.9.3.2.15 Safe Haven Medical Design Requirements

10.9.3.2.15.1 Nominal Operation Design Requirements

The safe haven shall have the following minimum operational capabilities for medical support while awaiting rescue:

a. Pharmacy.

b. Central supply.

c. Diagnostic exam.

d. Emergency airway equipment.

e. Mechanically powered intravenous production.

f. Administration capability.

g. Single deployable nonpowered exercise device (to be used only if primary exercise devices are not operational.).

10.9.3.2.15.2 Contingency Operation Design Requirements

10.9.3.2.16 Facilities For Processing and Storage of a Deceased Crew Member

10.10.3 Laundry Facility Design Requirements

10.11.3 Trash Management Facility Design Requirements

The following are the design requirements for trash management from the source to the disposal area:

a. Trash Sorting - Where it is necessary to sort trash before depositing in a receptacle, the following requirements shall be met:

   1. Receptacle labeling - Each of the receptacles shall be appropriately labeled defining acceptable and non-acceptable trash.

   2. Transfer package labeling - If trash must be transferred from one receptacle to another, there shall be a method of identifying the trash so that it is placed in the proper receptacle.

   3. Human error - The system shall be capable of recovery in the event that trash is inappropriately placed in a receptacle.

b. Trash Receptacles:

   1. Identification of receptacles - All trash receptacles shall be clearly identifiable.

   2. Receptacle location - The location of trash receptacles shall meet the following requirements:

   a. The location shall effectively reduce trash in the crew stations.

   b. The location shall minimize crew trash handling time.

   c. The location shall not interfere with crew movement.

c. Odor and Contamination Control - The following requirements apply to control of odor and contamination:

1. Trash handling equipment shall be designed to preclude module contamination during introduction of trash.

2. Trash storage areas shall preclude contamination of the living environment by harmful microorganisms or odor.

3. The trash management equipment area shall be capable of being cleaned and sanitized.

4. There shall be a safe means for disposal of any harmful chemical or radioactive wastes.

d. Operation - All trash collection, handling, and disposal equipment shall be capable of being operated by the full size and strength range of the defined crewmember population.

(Refer to Paragraph 3.3.1, Body Size, and Paragraph 4.9.3, Strength Design Requirements, for additional requirements.)

e. Receptacle Capacity - Crewmembers shall be capable of easily determining the level of trash (in relationship to capacity) in each of the trash receptacles.

10.12.3 Stowage Facility Design Requirements

The following are design requirements for space module stowage facilities:

a. Location - The following are requirements for the location of stowage areas:

1. Proximity - Items shall be stored as close as possible to their point of use.

2. Safety - Hazardous items shall be stored away from heat or ignition sources and away from crew congregation areas.

3. Interference - Stowage facilities shall not interfere with normal or emergency crew operations.

b. Accessibility :

1. Stored items shall be accessible by the defined size range of the space module crew.

(Refer to Paragraph 3.3.1, Body Size, for additional information.)

2. Removal of a stored item shall not require removal of another, unrelated item.

c. Labeling and Coding - Stowage locations and items shall be coded to allow for location, replacement, or inventory of items. The coding system shall allow modification.

(Refer to Paragraph 9.5.3, Labeling and Coding Design Requirements, for additional requirements.)

d. Environment:

(Refer to Section 5.0, Natural and Induced Environments, and Paragraph 8.13.3, Lighting Design Requirements, for habitability and lighting requirements of stowage areas that require human occupation.)

e. Hand Operation - Stowage retainers shall be designed to be operated by hand; no tools shall be required.

f. Commonality - Latching devices, containers, and container covers shall have design commonality throughout all space module stowage facilities.

g. Inventory Management - The stowage facility shall be compatible with the space module inventory management system.

(Refer to Paragraph 13.3.3, Inventory Control Design Requirements, for additional information.)

h. Retention Devices - Stowage items shall be secured within the container such that the item remains in the container/enclosure when the container is opened. Removal of retention devices shall not release other items which are not required.

NOTES

NOTES

11.2.3 Tool Design Requirements

11.2.3.1 Hand and Tool Integration Design Requirements

11.2.3.1.1 Tool Handgrip Size and Shape Design Requirements

Power and manual hand tools shall comply with the following handgrip size and shape requirements:

(Refer to Paragraph 6.5.3, Touch Temperature Design Requirements for specific touch temperature criteria.)

a. Gripping Surface - Hand gripping surfaces that minimize abrasion to the EVA glove material shall be provided on handles of tools.

b. Sleeve Type Adapters - If sleeve-type handle cover adaptors are used, they shall be adequately secured so they will not slip, rotate, or come off.

c. Orientation - Tool handles shall be oriented to allow the operator's wrist to remain in the most natural position while force or guidance inputs are applies.

d. Auxiliary Controls - If an auxiliary control on the tool must be manipulated while the operator is holding the tool, the control shall be located where:

   1. The thumb or finger of the holding hand can manipulate the control without disturbing the tool/ fastener holding position.

   2. Unintentional or inadvertent control operation is impossible.

11.2.3.1.2 Tool Handedness Design Requirements

The following requirements apply to handheld manual tools and handheld power tools:

a. Tool Operation - All general purpose hand tools shall be one-handed operable in-so-far as practical.

b. Tool Installation/Alignment - One hand only shall be required for tool installation and alignment.

c. Tool Handle Design - Tool handles shall be designed to allow the operator to use either the left or right hand.

11.2.3.1.3 Tool Actuation Forces and Direction of Action Design Requirements

All hand tools shall comply with the following:

a. Actuation Force - Hand tools shall require an actuation force of less than 89N (20 lbs) or a torque of less than 15 Nm (11 ft-lbs).

b. Throw Angles - Ratcheting tools shall be capable of providing torque with a minimum throw angle of 45 degrees.

c. Plier-Type Tools - Plier-type tools shall be spring-actuated in the open direction to permit one-handed operation.

d. Driver-Type Tools - Driver-type hand tools shall not require a push force to maintain tool engagement while providing torque.

11.2.3.2 Tool Commonality Design Requirements

To ensure that the tool complement is kept at a minimum, the following *requirements shall apply:*

a. Tool Quantity - The number of different types of tools shall be minimized.

b. Standard Attaching Hardware and Fasteners - Size and type of attaching hardware and fastener head configurations shall be standardized throughout the vehicles to limit the number and kind of tools required to perform maintenance tasks.

(Refer to Paragraph 11.9, Fastener Design Requirements, for specific fastener-to-tool interface requirements.)

c. Special Tools - The number of different and special tools required for maintenance shall be minimized.

d. For every type and size of fastener used onboard, a corresponding tool(s) shall be available for removal/replacement.

(Refer to Paragraph 11.9.3.1 l., Fastener Design Requirements for specific considerations and requirements).

11.2.3.3 Tool Tethering/Retention Design Requirements

a. Tool Restraints - A means shall be provided on all tools for restraining the tool during use.

b. Tool Transporter Devices - Tool carriers shall be provided to transport tools and to retain these tools during the maintenance activity.

c. Retention of Small Parts - Tool carriers/transfer devices shall provide a means of retaining small parts and attaching hardware. Items retainable in this manner shall be visible for retrieval.

d. Tool Restraint During Translation - Tools shall be restrained in the tool carrier/transfer device with sufficient force to prohibit detachment during translation.

e. Tool Carrier Attachment - Tool carriers and tool retention devices shall have provisions to attach the device to the crewmember or to adjacent structure or equipment.

(See Paragraph 11.7.3.3, Equipment Restraint Design Requirements, for other applicable restraint requirements.)

f. Inadvertent Tool Disassembly - A means shall be provided to prevent inadvertent tool disassembly while installing, using, removing, or transporting the tool.

11.2.3.4 Tool Stowage Design Requirements

a. General - A systematic approach shall be used in stowing tools and maintenance aids throughout the space module.

b. Stowage Provisions - Provisions for launch, entry, and temporary inflight stowage shall be provided.

c. Stowage Location:

1. Specialized tools shall be stowed in areas which correspond to their functional applications.

2. All general-purpose tools shall be grouped in one specific area.

d. Tool Stowage List - A tool summary or listing of the entire tool inventory, including stowage locations, shall be available onboard the space module.

e. Tool Arrangement in Stowage Container - A systematic approach shall be used in the arrangement of tools in the tool kit.

f. Temporary Stowage at Work Area - A systematic approach and a methodical layout of tools at the work area shall be required.

(Refer to Paragraph 10.12.3, Stowage Design Requirements, for other specific stowage requirements.)

11.2.3.5 Tool Labeling and Identification Design Requirements

(Refer to Paragraph 9.5.3, Labeling and Coding Design Requirements for detailed labeling and coding requirements.)

a. Selection of Names for General Tools - Tool names shall be identical to those names called out on the tool/ tool label and, in all cases, will be the most common definitive name recognizable by the crewmembers.

b. Selection of Names for Specialized Tools - Specialized tool nomenclature shall describe the specific task it is intended to accomplish and shall not be identified with the equipment it is servicing.

c. Identification of Specialized Tools - When special tools are absolutely necessary, they shall be coded and/or marked to indicate intended use.

d. Tool Labels - Prominent labels shall be provided adjacent to each tool in the stowage container/kit if the tool is not readily recognizable.

e. Tool Metric/English Identification - All tools shall be labeled or coded to indicate whether the tool is sized in metric or English units.

f. Tool Inventory Control Labeling - Tools shall be tracked by an automated inventory control identification system.

(Refer to Paragraph 13.3.3, Inventory Control Design Requirements, for specific requirements.)

g. EVA Tool Compatibility - IVA tools that are EVA compatible shall be so identified.

11.2.3.6 Tool Access Design Requirements

The following tool access volume and operational constraints requirements are applicable to both IVA and EVA hardware design. Refer to Figure 11.2.3.6-1 for IVA requirements.

a. Tool Head Clearance - When only tool access is required, a 2.5 cm (1 in.) clearance shall be provided around the fastener or drive stud for insertion, actuation, and removal of the drive end of the tool.

b. Tool Handle Clearance - A minimum of 7.6 cm (3 in.) shall be provided for clearance between a tool handle engaged on a fastener or drive stud and the nearest piece of hardware. The tool handle should be able to maintain this clearance through a full 180 deg. swept envelope.

c. Tool Head-to-Fastener Engagement Height - The tool socket/fastener head engagement height shall be a minimum of 0.7 cm (0.3 in.).

d. Tool Handle Offset - The maximum tool offset between the tool handle and the tool head shall be 35.5 cm (14 in.).

e. Access for Tools - Minimum tool access clearance for hand tool actuation is given in Figure 11.2.3.6-2.

11.2.3.7 Special Tool Features Design Requirements

a. Nonsparking Tools - Nonsparking materials shall be required for general purpose tools.

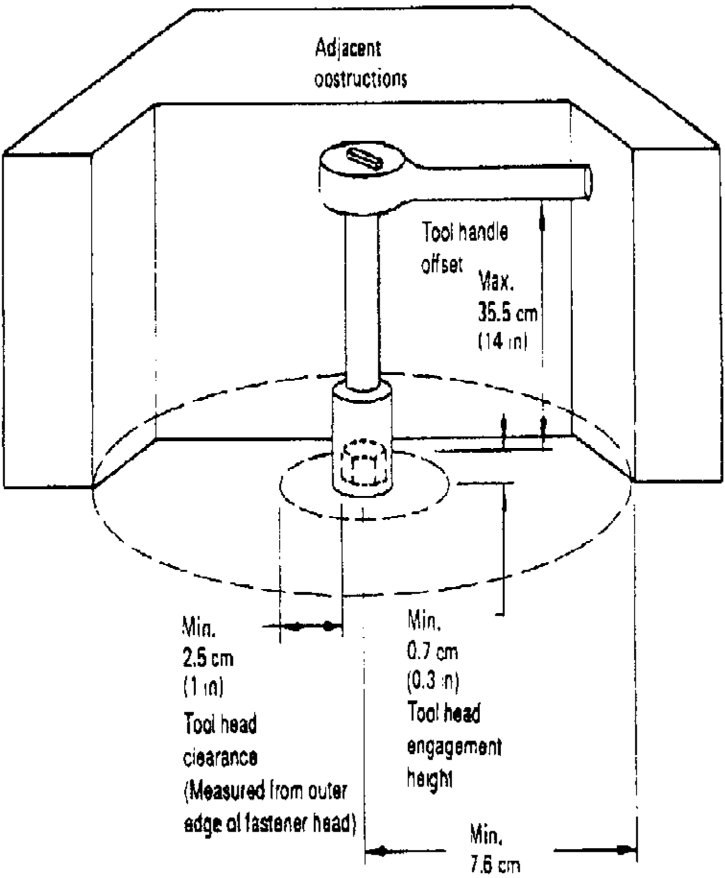


Figure 11.2.3.6-1 Tool Access Requirements (IVA)

MSIS 12

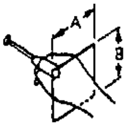
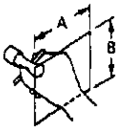
Opening Dimensions		Task
	A 117 mm (4.6 in) B 107 mm (4.2 in)	Using common screwdriver with freedom to turn hand through 180°
	A 133 mm (5.2 in) B 115 mm (4.5 in)	Using pliers and similar tools
	A 155 mm (6.1 in) B 135 mm (5.3 in)	Using T-handle wrench with freedom to turn wrench through 180°
	A 203 mm (8.0 in) B 135 mm (5.3 in)	Using open-end wrench with freedom to turn wrench through 62°
	A 122 mm (4.8 in) B 155 mm (6.1 in)	Using Allen-type wrench with freedom to turn wrench through 62°

Figure 11.2.3.6-2 Minimal Clearance for Tool-Operated Fasteners

MSIS 27

b. Nonconductive Tools :

(Refer to Paragraph 6.5.3, Touch Temperature Design Requirements, when tools are to be used in extremely hot or cold temperature areas.)

(Refer to Paragraph 6.4.3, Electrical Hazards Design Requirements, for requirements for insulation protection against electrical hazards.)

c. Finish - Tools shall be capable of being refinished in flight in order to remove burrs.

(Refer to Paragraph 6.3.3, Mechanical Hazards Design Requirements, for burrs, corners, edges, and protrusion design requirements.)

d. Battery Pack :

1. Power tools shall be designed so the battery packs can be replaced at the worksite.

2. Power tools using battery packs shall have a level-of-charge indicator or an indication as to when a battery pack is required to be replaced or recharged.

3. Hazards associated with charging and stowage of rechargeable batteries (such as toxic or flammable offgassing, leakage of corrosive electrolytes or high temperatures) shall be addressed and controlled.

11.3.3 Drawer and Rack Design Requirements

11.3.3.1 Drawer and Rack Interfacing Requirements

Stowage drawers, equipment drawers and racks shall be designed to provide the following interfacing features:

a. Size :

1. Unless prohibited by functional needs, all racks shall be designed to house single-wide drawers (and other types of equipment mounting hardware) that shall be 48.26 cm (19.00 in) wide or double-wide drawers that shall be 96.52 cm (38.00 in) wide.

   (Refer to Paragraph 2.3.2, Standardization Design Requirements, for the general standardization requirements.)

2. If equipment is intended to be launched and returned in the Shuttle stowage lockers, it shall be sized per Figure 11.3.3-1.

b. Location Related to Traffic Patterns - Racks that require frequent drawer deployment shall be located in areas that do not have high traffic.

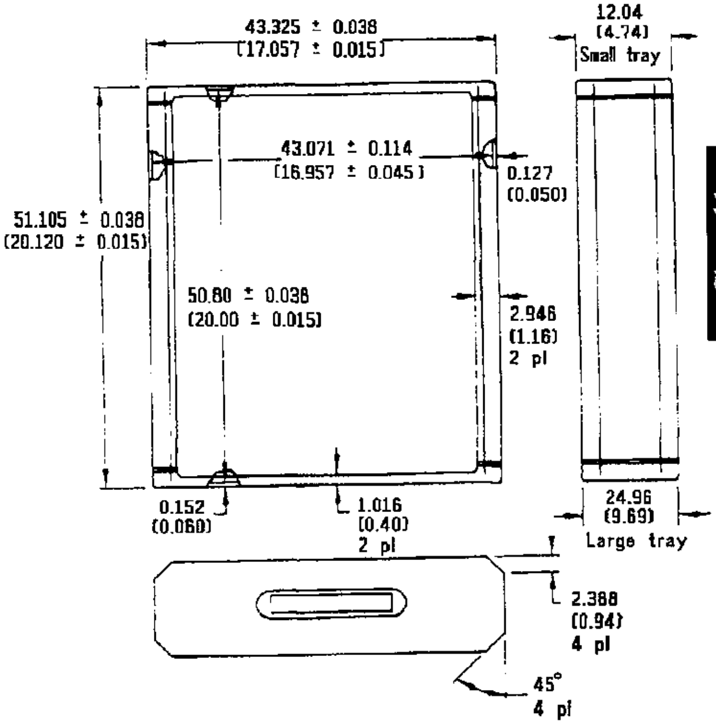
(Refer to Paragraph 8.7.3, Traffic Flow Design Requirements, for general and specific requirements related to blocking traffic patterns.)

c. Unobstructed Volume for Use - Provide adequate clearance such that the drawers can be opened, removed, and replaced without obstructions from adjacent hardware.

d. Easily Removable - Rack and drawer interfaces shall be designed such that the drawers can be removed from their rack or cabinet along a continuous straight or slightly curved path without using tools.

e. Limit Stops :

1. Provide limit stops that will prevent the drawer from being unintentionally pulled out of the rack.



Tolerances: 0.0002 (0.0001) Small tray
0.0005 (0.0002) Large tray
Dimensions are in cm (in)

Figure 11.3.3-1 Shuttle Stowage Locker Dimensions

MSIS 229

Chap 11

2. The limit stops shall be designed to hold the drawer in the full open position.

3. The limit stops shall be capable of being disengaged without using a tool to enable drawer removal.

f. Drawer Movement Forces - Drawer opening/closing or removal/installation shall not require a force greater than 156 N (35 lbs).

(Refer to Paragraph 4.9.3, Strength - Design Requirements, for crewmember strength requirements.)

g. Alignment Guides - Provide guide pins or equivalent to aid in alignment when replacing a drawer into its rack or cabinet.

(Refer to Paragraph 11.5.3.2, Alignment Devices Design Requirements, for detailed requirements.)

11.3.3.2 Design Requirements Common to Both Stowage and Equipment Drawers

In addition to the requirements given in Paragraph 11.3.3.1, all stowage and equipment drawers shall be designed to provide the following features:

a. Latches/Handles/Operating Mechanisms - All latches, handles, and operating mechanisms shall be designed to be easily latched/unlatched and opened/closed with one hand by the entire crewmember population without having to use any operating instructions.

(Refer to Paragraph 4.9.3, Strength Design Requirements, for crewmember strength capabilities.)

(Refer to Paragraph 11.6.3, Handle and Grasp Area Design Requirements, for handle and grasp area configuration requirements.)

b. Latch/Unlatch Status - The design shall be such that it is obvious when the drawer is not fastened/locked when in the closed position.

11.3.3.3 Stowage Drawer Design Requirements

In addition to the requirements given in Paragraphs 11.3.3.1 and 11.3.3.2, stowage drawers shall be designed to meet the following requirements:

a. Restraint of Contents :

1. Drawer contents shall be restrained in such a way that the items shall not float free when the drawer is opened, or jam the drawer so it cannot be opened or closed.

2. Drawer contents shall be restrained in such a way that the contents can be removed/replaced without using a tool.

   (Refer to Paragraph 11.7.3, Equipment Restraints, for specific restraint requirements.)

b. Arrangement in Housing/Cabinet - Drawers shall be arranged within their housing/cabinet such that the most frequently accessed drawers are in the most accessible locations.

c. Access to Contents - The contents of drawers shall be arranged such that the contents are visible and accessible when the drawer is in the open position.

d. Identification of Contents - In the stowed position, the contents of drawers shall be identified by labeling.

(Refer to Paragraph 9.5.3, Labeling and Coding Design Requirements, for specific requirements.

11.3.3.4 Equipment Drawer Design Requirements

In addition to the requirements given in Paragraphs 11.3.3.1 and 11.3.3.2, equipment drawers shall be designed to meet the following requirements:

a. Utility Connections :

1. The utility connections shall be designed to be easily disconnected/connected when the drawer is in the fully opened position.

   (Refer to Paragraph 11.10.3, Connector Design Requirements, for general and specific connector design requirements.)

2. If the utility connection is via a flexible umbilical, sufficient cable length shall be provided such that the drawer can be fully opened without disconnecting the cables.

   (Refer to Paragraph 11.14.3, Cable Management Design Requirements, for general and specific design requirements.)

b. Equipment Layout on Rack :

1. Components shall be mounted in an orderly array on a two-dimensional surface, rather than stacked one on another (i.e., a lower layer shall not support an upper layer).

2. Items of the same or similar form, but having different functional properties, shall be mounted with a standard orientation throughout the unit, but shall be readily identifiable and distinguishable, and shall not be physically interchangeable.

3. Delicate items shall be located or guarded so that they will not be susceptible to damage while the unit is being handled or maintained.

11.4.3 Closures and Covers Design Requirements

Equipment housings (e.g., electrical bays, cabinets, lockers, and consoles) shall be designed to provide closures and covers for inaccessible areas. The following requirements shall apply:

a. Sealing - The inaccessible areas shall be sealed to prevent small items from drifting into them.

b. Removal - Closures shall be quickly and easily removed to allow maintenance of equipment.

c. Securing - It shall be obvious when a closure is not secured, even though it may be in place.

d. Loads - Nonstructural closures should be capable of maintaining closure and of sustaining a crew-imposed minimum design load of 451 N (125 lbf) and a minimum ultimate load of 632 N (175 lbf).

e. Instructions - If the method of opening a cover is not obvious from the construction of the cover itself, instructions (including applicable tool instructions) shall be permanently displayed on the outside of the cover.

f. Clearance - Bulkheads, brackets, and other units shall not interfere with removal or opening of covers.

g. Application - An access cover shall be provided whenever frequent maintenance operations would otherwise require removing the entire case or cover, or dismantling an item of equipment.

h. Self-Supporting Covers - All access covers that are not completely removable shall be self-supporting in the open position.

   (Refer to Paragraph 12, Design for Maintainability, for other maintainability design considerations and requirements.)

i. Ventilation Screen Access - Where ventilation screens, holes, or grids are used, the ventilation surface shall be accessible for vacuuming in its installed position.

(Refer to Paragraph 13.2.3.3 Vacuum Cleaning Design Requirements, for more detailed requirements.)

11.5.3 Mounting Hardware Design Requirements

11.5.3.1 General Mounting Design Requirements

The following general requirements apply to mounting hardware:

a. Equipment Mounting - Equipment items shall be designed so that they cannot be mounted improperly.

b. Drawers and Hinged Panels - Subsystem components which are frequently pulled out of their installed position for checkout shall be mounted on equipment drawers or on hinged panels.

(Refer to Paragraph 11.3.3, Drawer and Rack Design Requirements, for specific requirements.)

c. Layout - Components shall be mounted so that a minimum amount of place-to-place hand movements will be required during operations.

d. Covers or Panels - Removal of any replaceable item shall require opening or removing a minimum number of covers or panels.

(Refer to Paragraph 11.4.3, Closures and Covers Design Requirements, for specific requirements.)

e. Installation/Removal Force - Hardware mounted into a capture-type receptacle that requires a push-pull action shall require a force less than 156N (35 lbs.) to install or remove.

(Refer to Paragraph 4.9.3, Strength Design Requirements.)

f. Rear Access - Equipment to which rear access is required shall be free to open or rotate to their full distance travel and remain in the "open" position without being supported by hand.

g. Tools - Whenever possible, items shall be replaceable with a common hand tool.

(Refer to Paragraph 11.2.3, Tool Design Requirements, for specific tool requirements.)

h. Direction of Removal - Replaceable items shall be removable along a straight or slightly curved line, rather than through an angle.

i. Visibility - All forward edges of the equipment item shall be visible to the restrained crewmember during alignment and attachment.

(Refer to Paragraph 11.5.3.2, Alignment Devices Design Requirements, for specific alignment requirements.)

j. Spacing - Mounting bolts and fasteners shall be spaced far enough from other surfaces to allow personnel to manipulate them.

(Refer to Paragraph 11.2.3.6, Tool Access Design Requirements, and Paragraph 11.9.3, Fastener Design Requirements, for specific requirements.)

k. Number of Mounting Bolts - Use the minimum number of fasteners, consistent with stress and vibration requirements, so that the crewmember's workload is minimized.

(Refer to Paragraph 11.9.3.1, General Fastener Design Requirements, for other fastener requirements.)

l. Shims, Washers - Where shims or washers are permitted in an IVA application, the following rules shall be followed:

1. Shims shall be bound together in a shim assembly.

2. Shim assemblies shall be tethered or restrained at the location or point of use and identified as to location or point of use.

3. A similar requirement shall be observed for washers and other loose items which are auxiliary connector/fastener devices.

11.5.3.2 Alignment Devices Design Requirements

The following alignment methods for replaceable hardware shall be used:

a. Alignment Marks - If proper interface orientation is not obvious by virtue of external geometry or if adequate visibility cannot be provided for hardware that will be mounted on-orbit, the hardware design shall incorporate alignment marks and/or orientation arrows.

1. Alignment marks shall be applied to both mating parts and the marks shall align when the parts are in the operational position.

2. An alignment mark shall consist of a straight line of a width and length appropriate to the size of the item.

Alignment marks shall be clearly visible to a crewmember performing hardware removal/replacement.

(Also see Paragraph 9.5.3.1.5, Alignment Marks/ Interface Identification Design Requirements.)

b. Alignment Devices - Guide pins or their equivalent shall be provided to assist in alignment of hardware during mounting, particularly on modules that have integrated connectors.

(Refer to Paragraphs 11.10.3.3, Structural Connectors Design Requirements, and 11.10.3.4, Optical Connectors Design Requirements, for connector alignment requirements.)

c. Keying - All replaceable hardware shall be designed so that it will be physically impossible to install it in the wrong orientation.

d. Replaceable Hardware Identification - Replaceable hardware shall be identified with nomenclature that aids the crewmember in identifying the hardware name, alignment of the hardware, and the correct use of attaching parts.

(Refer to Paragraph 9.5.3, Labeling and Coding Design Requirements, for specific requirements.)

11.6.3 Handle and Grasp Area Design Requirements

11.6.3.1 General Handle and Grasp Area Design Requirements

a. Provide Handles - All removable or portable units shall be provided with handles or other suitable means for grasping, tethering, handling, and carrying.

b. Exempt Items - Items less than 0.03 m*3* (1 ft^3) whose form factor (shape) permits them to be handled easily shall be exempt from the above requirement.

c. Labeling of Nonhandling Areas - Built-in features that appear to be suitable for grasping/tethering/ restraining and are not suitable must be labeled to indicate that these features are not suitable for these purposes.

(Refer to Paragraph 9.5.3, Labeling and Coding Design Requirements, for specific requirements.)

11.6.3.2 Handle and Grasp Area Location Design Requirements

The following general location requirements of handles or grasp areas shall apply:

a. Interference - Handles and grasp areas shall be located so that they do not interfere with equipment location or maintenance.

b. Clearance - Clearances shall be provided between handles and obstructions consistent with anthropometric requirements.

c. Tether Attachments - Handles and grasp areas shall be suitable as tether or bracket attachment positions.

d. Location - The location of handles or grasp areas shall be such that they do not constitute passageway hindrances or safety hazards. If they must be located in passageways they shall be recessed and designed to minimize chance of crewmember injury or inadvertent contact.

e. Location/Front Access - Handles and grasp areas shall be placed on the accessible surface of an item consistent with the removal direction.

11.6.3.3 Nonfixed Handles Design Requirements

Hinged, foldout, or attachable (i.e., nonfixed) handles shall comply with the following:

a. Locked or Use Position - Nonfixed handles shall have a stop position for holding the handle perpendicular to the surface on which it is mounted.

b. One-Handed Operation - Nonfixed handles shall be capable of being placed in the use position by one hand and shall be capable of being removed or stowed with one hand.

c. Tactile or Visual Indicators - Attachable/removable handles shall incorporate tactile and/or visual indication of locked/unlocked status.

11.6.3.4 Handle Dimensions Design Requirements

IVA handles for movable or portable units shall be designed in accordance with the minimum applicable dimensions in Figure 11.6.3.4-1.

11.7.2.3 Personnel Restraints Design Requirements

11.7.2.3.1 General Personnel Restraints Design Requirements

All EVA and IVA personnel restraints (i.e., seat belts, shoulder harnesses, body restraints, foot restraints, and sleep restraints) shall comply with the following requirements:

(Refer to Paragraph 14.4.3.4, EVA Crew Restraint Design Requirements, for EVA-unique requirements.)

a. Comfort - Restraint forces shall be reasonably distributed over the body to prevent discomfort and shall not require conscious effort to remain constrained.

b. Allowable Comfort Time - Comfort of the IVA restraint system shall allow for a four-hour uninterrupted use.

c. Muscular Tension - Restraint design shall minimize or eliminate muscular tension.

d. Anthropometric Range - All personnel restraints shall accommodate the specific population of users for whom the system is to be designed.

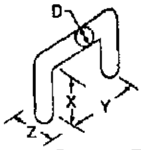
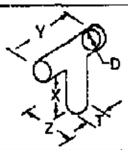
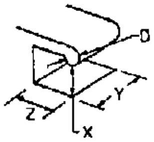
Illustration	Type of handle	Dimensions in mm (in inches) (Bare hand) X	Y	Z
	Two-finger bar One-hand bar Two-hand bar	32 (1–1/4) 48 (1–7/8) 48 (1–7/8)	65 (2–1/2) 111 (4–3/8) 215 (8–1/2)	75 (3) 75 (3) 75 (3)
	T-bar	38 (1–1/2)	100 (4)	75 (3)
	J-bar	50 (2)	100 (4)	75 (3)
	Two-finger recess One-hand recess	32 (1–1/4) 50 (2)	65 (2–1/2) 110 (4–1/4)	75 (3) 90 (3–1/2)
	Finger-tip recess One-finger recess	19 (3/4) 32 (1–1/4)	– –	13 (1/2) 50 (2)
Curvature of handle or edge (DOES NOT PRECLUDE USE OF OVAL HANDLES)	Weight of Item Up to 6.8 kg (up to 15 lbs) 6.8 to 9.0 kg (15 to 20 lbs) 9.0 to 18 kg (20 to 40 lbs) Over 18 kg (over 40 lbs) T-bar post	Minimum diameter D = 6 mm (1/4 in) D = 13 mm (1/2 in) D = 19 mm (3/4 in) D = 25 mm (1 in) T = 13 mm (1/2 in)	Gripping efficiency is best if finger can curl around handle or edge to any angle of 2/3 π rad (120°) or more	

Figure 11.6.3.4-1 Minimum IVA Handle Dimensions for IVA Applications

MSIS 18

e. Microgravity Posture - Personnel restraints to be used in microgravity applications shall be designed for microgravity posture compatibility.

(Refer to Paragraph 3.3.4.3, Neutral Body Posture Data - Design Requirements, *for specific anthropometric requirements.)*

f. Cleaning and Repair - The personnel restraint system shall be capable of being cleaned and repaired on-orbit.

11.7.2.3.2 Foot Restraint Design Requirements

11.7.2.3.2.1 General Foot Restraint Design Requirements

The following general requirements apply to all fixed and portable foot restraints:

(Refer to Paragraph 14.4.3.4, EVA Crew Restraint Design Requirements, for EVA-unique foot restraint requirements.)

a. Range of Motion - All foot restraints shall maintain foot position to allow the crewmember a complete range of motion (roll, pitch, and yaw).

b. Comfort - Foot restraints shall provide comfortable support.

c. Interchangeability - Attachment interfaces for foot restraints (portable-to-portable and fixed-to-fixed) shall be interchangeable throughout the space module.

d. Positive Retention - The foot restraint shall be positive and firmly hold the user in the desired position.

e. Load Reaction - Foot restraints shall provide the capability to react to loads applied by the crewmember.

f. Abrasion Resistance - Reinforcements shall be provided for any fabric areas exposed to high abrasion.

g. Ventilation - IVA foot restraints and covers shall allow ventilation to the feet.

h. Fixed Foot Restraints - The fixed foot restraint shall be capable of being removed for replacement/repair.

i. Portable Foot Restraints - The portable foot restraint shall be capable of being installed and removed easily and quickly without tools.

11.7.2.3.2.2 Foot Restraint Donning/Doffing Design Requirements

Foot restraints shall comply with the following donning and doffing requirements:

(Refer to Paragraph 14.4.3.4, EVA Crew Restraint Design Requirements, for EVA-unique foot restraint donning and doffing requirements.)

a. Donning - Foot restraints shall be attached or donned with minimum effort.

b. Quick Release - Rapid ingress/egress shall be inherent to all IVA foot restraints.

c. No-Hand Operation - The use of hands for placing/ removing the foot shall not be required for foot restraint ingress/egress.

d. Handholds - Handholds or structure between waist and shoulder shall be available at all foot restraint locations to aid foot restraint ingress and egress.

   (Refer to Paragraph 8.9.3.1, Required IVA Mobility Aid Integration Design Requirements, for the specific requirements.)

e. Entrapment - All foot restraints shall minimize danger of entrapment. A positive means of releasing the foot from the restraint shall be provided.

11.7.2.3.2.3 Foot Restraint Loads Design Requirements

IVA restraints must meet the following load requirements:

(Refer to Paragraph 14.4.3.4, EVA Crew Restraint Design Requirements, for EVA restraint loads.)

a. Tension Loads - Foot restraints shall be designed to withstand a tension load of 445 N (100 lbf) as a minimum (see Figure 11.7.2.3.2.3-1.)

b. Torsion Loads - The restraints shall withstand a torsion load of 200 Nm (150 ft-lb) as a minimum with the torsion vector normal to the floor. (See Figure 11.7.2.3.2.3-1.)

c. Factor of Safety - The yield factor of safety shall be 1.10 and ultimate factor of safety shall be 2.00.

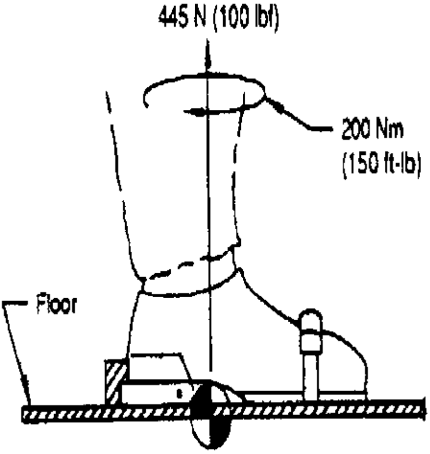


Figure 11.7.2.3.2.3-1 IVA Foot Restraint Load Limits

MSIS 19

11.7.2.3.2.4 Foot Restraint Durability and Color Design Requirements

The durability and color of IVA and EVA foot restraints shall comply with the following:

a. Durability - Finish shall be durable, smooth, and scratch resistant to prevent undue wear on footwear.

b. Color - Color for all foot restraints of a given type shall have a contrast ratio of approximately 10:1 or greater with the background.

11.7.2.3.3 Body Restraint **Design Requirements**

11.7.2.3.3.1 Body Restraint Donning/Doffing Design Requirements

The following crewmember body restraint donning and doffing requirements shall apply to all tether attachments, seat belts, and shoulder harnesses:

a. Latching Mechanisms - The latching mechanism attachment will require a positive action by the crewmember to both latch and unlatch the mechanism.

b. One-Handed Operation - The latching mechanism shall have the capability of being latched and unlatched with one hand.

11.7.2.3.3.2 Body Restraint Loads Design Requirements

The following load requirements shall apply to seat belts, shoulder harnesses, and IVA tethers:

(Refer to Paragraph 14.4.3.4, EVA Crew Restraint Design Requirements, for EVA-unique body restraint load requirements.)

a. Seat Belts and Shoulder Harnesses - IVA seat belts and shoulder harnesses installed at stations designated as occupied during launch and landing shall be designed so the occupant making proper use of the equipment will not suffer serious injury when the following ultimate inertia forces acting separately are imposed on the crewmember:

   1. Downward (Eyeballs Up): 2.0 -Gz

   2. Backward (Eyeballs Out): 9.0 -Gx

   3. Sideward : 1.5 +/- Gy

   4. Upward (Eyeballs Down): 4.5 +Gz , or any lesser force that will not be exceeded when the landing loads resulting from impact with an ultimate descent velocity of five ft/sec at design landing weight.

      (Refer to Paragraph 5.3.3.1, Linear Acceleration Design Requirements for acceleration coordinate system and requirements.)

b. Tether Attachments - IVA tether attachments shall be capable of sustaining a load of 756 N (170 lbs) along the longitudinal axis. They shall be designed so as to preclude any side loading.

c. Attach Points for Tether Attachment - IVA translation and mobility handhold tether attachment attach points shall be designed to a minimum ultimate load of 1113 N (250 lbs) in any direction.

11.7.2.3.3.3 Body Restraint Finish and Color Design Requirements

Markings, labeling, and colors shall be in accordance with Paragraph 9.5.

11.7.2.3.3.4 Body Restraint Dimensional Design Requirements

The following dimensional requirements shall apply to all seat belts, shoulder harnesses, and tethers:

(Refer to Paragraph 14.4.3.4, EVA Crew Restraint Design Requirements, for EVA-unique restraint dimensional requirements.)

a. Commonality - Seat belts, shoulder restraints, waist restraints, and tether attachments shall be uniform in size, shape, and method of operation within the limits of task performance and other design tradeoffs.

b. Size - Task requirements for which the attachment is designed shall dictate the actual size of the hooking and latch mechanism.

11.7.2.3.4 Sleep Restraints Design Requirements

Sleep restraint design shall meet the following requirements:

a. Extremity Restraint - Sleep restraints shall include provisions to prevent leg and arm float and prevent the head from moving during sleep.

b. Trapped Air - Sleep restraint design shall eliminate excessive or unevenly distributed trapped air.

c. Individual Sleep Restraints - One sleep restraint shall be provided for each crewmember.

d. Stowage, Transport, Cleanability - Sleep restraints shall be easily stowable, transportable, and cleanable on-orbit.

e. Features - A sleep restraint shall incorporate the following features:

1. Adjustable, flexible restraint straps.

2. Arm slits.

3. Adjustable, removable pillows/head-strap.

4. Adjustable thermal protection.

f. Opening/Closing - A sleeping bag opening/closing device that extends the full length of the bag shall be provided.

g. Torso Restraint - Torso restraining straps shall be provided to allow the crewmembers to restrain themselves in their choice of sleeping position.

h. Opening/Closing - The opening/closing device shall be capable of easy use, including quick opening in case of emergency.

i. Opening/Closing Device Replacement - The opening/ closing device shall be easily replaceable.

11.7.3.3 Equipment Restraint Design Requirements

All IVA and EVA equipment restraints shall be designed to the following requirements:

a. Hand Operated :

1. Equipment restraints shall be designed such that tools are not required to attach or detach the restraint.

2. Equipment restraints shall be designed such that they can be attached/detached by either the left or right hand.

b. Blind Operation - The equipment restraints shall be designed such that they can be attached/detached without having to look at them.

c. Adjustability - Provide the capability to adjust the restraint to adapt to a wide range of sizes of the items to be restrained and to provide the user with the capability to restrain the item at a preferred location relative to the restraint attachment points. This does not preclude fixed- length tethers used for specific applications.

d. Positive Restraint - The restraint shall secure the item in such a way that the item will not come loose due to inadvertent touching, air currents, vehicle dynamic motions, or due to other predictable environmental conditions.

e. Cause No Damage - The equipment restraint shall be designed such that it cannot pinch, abrade, or cut the item to be restrained or the interfacing surfaces and adjacent hardware.

f. No Adhesive Residue - Adhesive equipment restraints shall not leave an adhesive residue on the item or on the spacecraft surface when the adhesive restraint is detached.

g. Tethers :

1. Common attachment method - All equipment tethers shall use a common attachment method.

2. Tether attachment points - *All equipment items that require tethering shall* have a standardized tether hook receptacle as an integral part of the item. This standardized receptacle shall also be provided on the interfacing surface to which the item is to be secured.

3. Tether lock status indication - The tether hook shall be designed in such a way that it will be easy to recognize when the hook is locked/unlocked in both day and night lighting conditions.

h. Loads :

1. Minimum load - The minimum design load shall be based on the expected crew-imposed and environmental loads to be applied to the item in the normal operating conditions.

2. Maximum load - The maximum design load shall be based on the resultant load imposed by a crewmember attempting to dislodge a restrained item that has become entrapped in adjacent hardware. The stress of this activity should not exceed the design load of the surface to which the restraint is attached or the design load of the entrapping hardware (i.e., the restraint should break before the item, attachment surface, of entrapping hardware breaks).

   (Refer to Paragraph 4.9.3, Strength Design Requirements, for definition of maximum crew imposed loads.)

i. Color - Equipment restraints shall be of a standardized color to distinguish them from other types of loose equipment or items that will be restrained.

(Refer to Paragraph 9.5.3.2, Coding Design Requirements, for color selection criteria.)

j. Grounding :

(Refer to Paragraph 6.4.3, Electrical Hazards Design Requirements, for specific requirements.)

k. Commonality - Provide commonality of design for equipment restraints to the maximum extent possible.

l. Individual Restraints :

1. Individual restraints shall be designed to restrain one hardware item only.

2. Individual restraints shall be used when the restrained item is large in size, sensitive, or delicate or when attachments are difficult or complex in operation

m. Group Restraints :

1. Group restraints shall be used to restrain like-sized items wherever possible.

2. Group restraints shall provide a system that allows the removal of one item at a time.

n. Throw-Away Restraints - Any restraint device that is utilized during vehicle launch, and upon activation or usage removal is discarded, shall meet the following requirements:

1. Large throw-away restraints shall be designed to be torn apart or be of soft, crushable materials to accommodate the openings of onboard trash collection/disposal systems.

2. The throw-away restraints shall be color coded as a throw -away item.

   (Refer to Paragraph 9.5.3.2, Coding Design Requirements, for specific requirements.)

o. Velcro - When Velcro is used as a restraint, the item to be restrained will be equipped with hook-type Velcro and the restraining surface will be equipped with pile-type Velcro.

11.8.2.2 Handhold and Handrail Design Requirements

11.8.2.2.1 Handhold and Handrail Dimensions Design Requirements

All handholds and handrails shall adhere to the following cross-section design requirements:

a. Standardization - Cross-sectional dimensions of handholds and handrails shall be standardized throughout the space module to provide a uniform interface for mounting items such as brackets and tether hooks.

b. Cross-Section Shape - Handholds and handrails cross-section shape shall be designed such that the crewmember's hand or attached brackets will be stabilized (i.e., circular cross-section shall not be used).

c. IVA Handhold Minimum Dimensions - All IVA handholds shall have a minimum of 14 cm (5.5 in.) grip length and a minimum of 3.8 cm (1.5 in.) clearance between the lower surface of the handgrip and the surface on which it is mounted. (Reference Figure 11.8.2.2.1-1.)

(Refer to Paragraph 11.8.2.2.3, Handhold and Handrail Texture Design Requirements, for other shape requirements.)

(Refer to Paragraph 14.5.3.2, EVA Mobility Aids Design Requirements, for EVA-unique handhold/handrail dimensions.)

Chap 11

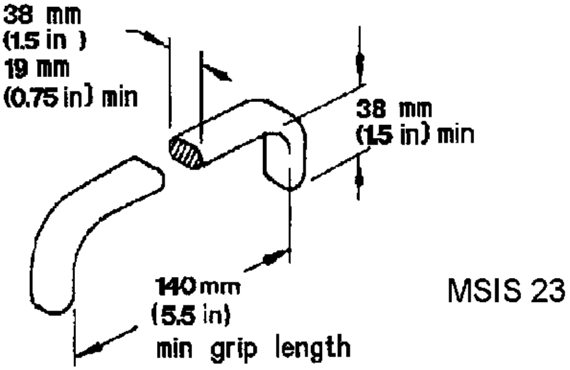


Figure 11.8.2.2.1-1 Example IVA Handhold Configuration Used In Previous U.S. Space Modules

11.8.2.2.2 Handhold and Handrail Coding Design Requirements

Handholds and handrail coding shall be such that the crew may locate them with ease:

a. Standard Color - The color of all handholds/ handrails shall be standardized within the space vehicle.

b. Contrast Ratio - The color value shall have a contrast ratio of 3:1 or greater with the background.

c. Distinguishing Color - The handhold/handrail shall be distinguishable from the surrounding area.

(Refer to Paragraph 9.5.3, Labeling and Coding Design Requirements, for other general and specific color coding requirements.)

11.8.2.2.3 Handhold and Handrail Finish Design Requirements

Handhold and handrail texture shall be such that the crew may locate them by feel and grasp them with ease:

a. Identical Finish - The finish of all handholds/ handrails shall be identical to enhance identification.

b. Safety - Handholds and handrails shall have a smooth surface with no burrs, sharp edges, or protrusions.

   (Refer to Paragraph 6.3.3, Mechanical Hazards Design Requirements, for other applicable requirements.)

c. Durability - The finish of all handholds and handrails shall be resistant to scratches, wear, flaking, and pealing.

11.8.2.2.4 Handhold and Handrail Design Loads Design Requirements

All fixed and portable IVA handholds and handrails shall be designed to a minimum ultimate load of 1113 N (250 lbs) applied in any direction without failure or damage that precludes full utilization by crewmembers.

(Refer to Paragraph 14.5.3.2, EVA Mobility Aid Design Requirements, for EVA-unique handhold/handrail design load requirements.)

11.8.2.2.5 Handhold and Handrail Temperature Design Requirements

(Refer to Paragraph 6.5.3, Surface Touch Temperature Design Requirements, for IVA handhold and handrail surface temperature design requirements.)

(Refer to Paragraph 14.5.3.2, EVA Mobility Aid Design Requirements, for EVA-unique handhold and handrail surface temperature design requirements.)

11.8.2.2.6 Handhold and Handrail Mounting Design Requirements

a. Stability - All fixed and portable handholds and handrails shall be designed so that when installed there is no instability (i.e., looseness, vibration, or slippage).

b. Portable Handhold and Handrail Lock Status Indication - Portable handhold and handrails shall provide a positive indication of when they are in the locked position.

c. Visibility and Accessibility - Handholds and handrails shall be mounted so that they are clearly visible and accessible.

   (Refer to Paragraph 8.9.3.1, IVA Mobility Aid Locations - Design Requirements, for specific requirements.)

   (Refer to Paragraph 11.8.2.2.2, Handhold and Handrail Coding Design Requirements, for color coding requirements.)

d. Handhold Removal - Fixed handholds shall be removable with common tools.

e. Safety - Handrails and associated mounting provisions shall be designed so as to preclude snagging of body, clothing, and/or loose equipment (e.g., cables).

11.8.3.2 Equipment Mobility Aid Design Requirements

(Refer to Paragraph 11.6.3, Handle and Grasp Area Design Requirements, for interface requirements.)

(Refer to Paragraph 11.7.3.3, Equipment Restraint Design Requirements, for interface requirements.)

(Refer to Paragraph 14.5.3.6, EVA Equipment Transfer Design Requirements, for EVA unique requirements.)

a. Maximum Movable Equipment Size - Equipment size shall be limited to the dimensions and configuration of the smallest hatch or opening through which the equipment must pass.

b. Access - Design shall provide adequate area around the mass for manipulation and visibility.

c. Containers for Small Items - Containers shall be provided for simultaneous transfer of small equipment items.

   1. Single items shall be individually removable

   2. The container shall be easily attached to the crewmember and space module at the worksite.

d. Bump Protection - Bump protection shall be provided. Bump protectors shall be designed so they can be used as mobility aids.

11.9.3 Fastener Design Requirements

11.9.3.1 General Fastener Design Requirements

a. Commonality - The number and diversity of fasteners shall be minimized commensurate with the structural requirements imposed by the physical environments.

b. Easily Distinguishable - Where different types of fasteners must be used, they shall be such that they are readily distinguishable from each other.

c. Hand-Actuated Fasteners Preferred - Hand-actuated fasteners shall be given preference over tool-actuated fasteners, provided that size, location, and structural constraints are met.

   (Refer to Paragraph 11.9.3.2, Hand-Actuated Fastener Design Requirements, for specific requirements.)

   (Refer to Paragraph 11.9.3.3, Tool-Actuated Fastener Design Requirements, for specific requirements.)

d. Other Devices in Lieu of Fasteners - Optimum use shall be made of mechanical devices (e.g., hinges and tongue-and-slot catches) to minimize the number of fasteners.

e. Captive Fasteners - All fastener components intended for crew interaction shall be captive. All replaceable fasteners shall be amenable to loose parts control and a means of fastener containment and/or restraint shall be incorporated in the fastener removal/replacement system.

f. Accessibility :

   (Refer to Paragraph 11.2.3.6, Tool Access Design Requirements, for specific tool clearance dimensions.)

   1. Location Near Corners - Fasteners shall be located far enough away from internal corners, wall edges, flanges, etc., that they can be manipulated with ease.

2. Separation - Fasteners shall be located far enough apart so there is adequate hand or tool clearance.

3. Location Near Adjacent Equipment - If a component is to be mounted near other pieces of equipment, fasteners shall be located away from the edges of the adjacent equipment, obstructions, or surfaces that will prevent the attachment of tools.

4. Direct Access - Locate fasteners so that they can be actuated without removing other parts or units first.

5. Access Holes - Covers or shields through which mounting fasteners must pass for attachment to the basic chassis of the unit shall have large enough holes for passage of the fastener without precise alignment (and tool/hand if tool/hand is required to replace).

g. One Handed Actuation - All fasteners shall be designed to be actuated by one hand.

h. Engagement Status Indication - Incorrect engagement of fasteners shall be apparent.

i. Multiple Fasteners :

1. Number of Fasteners - When several fasteners are required, the design shall use the minimum number of the largest size fasteners of identical type.

2. Arrangement - When several fasteners are used on one item, they shall be arranged so that the unit can be assembled in only the correct manner.

j. Safety - Fasteners shall be designed so as to preclude injury to the crewmember when the fastener is released.

k. Labeling - Appropriate markings shall be placed on fasteners that can be actuated by either hand or tool .

(Refer to Paragraph 9.5, Labeling and Coding, for specific considerations and requirements.)

l. Replacement - All fasteners shall be de- signed for on-orbit replacement.

(Refer to Paragraph 11.2.3.2 d., Fastener Tools, for specific requirements.)

11.9.3.2 Hand-Actuated Fastener Design Requirements

a. One-Handed/Either-Hand Actuation - Hand-actuated fasteners shall be designed to be actuated by one hand and by either the left or right hand.

b. Designed for Launch and On-Orbit - Fasteners shall be designed to meet the launch loads as well as on-orbit loads.

c. Fastener Knobs - Fastener knobs shall be textured.

(Refer to Paragraph 6.3.3, Mechanical Hazards Design Requirements, for specific safety design requirements.)

d. Quick-Opening Fasteners - Quick-opening captive fasteners shall:

1. Require a maximum of one complete turn to operate (quarter-turn fasteners are preferred).

2. Require only one hand to operate.

3. Be positive locking in open and closed position.

e. Locking Threaded Fasteners - Hand-actuated threaded fasteners shall have a locking feature that provides an audible, tactile, or visual feedback to the crewmember. Such locking features shall assure that threaded fasteners will not un-thread themselves without crew actuation.

f. Pin Fasteners (IVA) :

1. Designed for launch only - Pin fasteners shall be used for launch loads only.

2. Locking devices - Locking devices used in conjunction with pin fasteners shall be made accessible and easily visible.

g. Over-Center Latches :

1. Non-self-latching - Over-center latches shall include a provision to prevent undesired latch element realignment, interference, or reengagement.

2. Latch lock - Whenever possible, latch catches shall be spring loaded to lock on contact, rather than using a positive locking device. If positive locking is necessary, provide a latch loop and locking action.

3. Latch handles - If the latch has a handle, locate the latch release on, or near the handle so it can be operated with one hand.

h. Safety Wire - Safety wires shall not be used on fasteners.

11.9.3.3 Tool-Actuated Fastener Design Requirements

(Refer to Paragraph 11.9.3.4, IVA Fastener Design Requirements, for IVA-specific tool-actuated fastener requirements.)

(Refer to Paragraph 11.2.3, Tool Design Requirements, for specific requirements for the tools to be used to actuate the tool-actuated fasteners.)

a. Nonstandard Tools - Fasteners requiring nonstandard tools shall not be used.

b. High-Torque Fasteners (IVA Only) - External hex or external double-hex fastener heads are preferred and they shall be provided on all machine screws, bolts, or other fasteners requiring more than 14 Nm (10 ft-lbs) of torque. Internal wrenching fasteners shall be Allen-head-type fasteners.

c. Low-Torque Fasteners :

1. Hex-type internal grip head, hex-type external grip head, or combination-head (hex or straight-slot internal grip and hex-type external grip head) fasteners shall be used where less than 14 Nm (10 ft-lb) of torque is required.

2. Internal-grip head fasteners shall be provided only where a straight or convex smooth surface is required.

3. No straight-slot or Phillips-type internal grip fasteners shall be used.

d. Precision Torquing - When possible, design equipment so that precise torque on fasteners is not required. Where precise torque or preload is required, use fasteners that incorporate torque-indicating features or that will mate with appropriate on-board torquing tools.

e. Torque Labeling - When fastener torquing to specifications is required, an instructional label shall be provided in reasonable proximity to the fasteners.

(Refer to Paragraph 9.5, Labeling and Coding, for specific requirements.)

f. Number of Turns - When machine screws or bolts are required, the number of turns and the amount of torque shall be no more than necessary to provide the required strength.

g. Fastener Head Length (IVA Only) - Fastener heads shall be as short as possible so they will not snag personnel clothing or equipment.

h. Left-Hand Threads - Left-hand threads shall not be used unless system requirements demand them; then identify both the bolts and nuts clearly by use of markings, shape, color, etc.

i. Locking - Threaded fasteners shall incorporate features that allow them to be locked so that they will not unthread without using a tool.

j. Hand Tool Operable - All fasteners installed with power tools shall be removable with a hand-operated tool.

11.9.3.4 IVA Fastener Design Requirements

a. Fastener Lubrication - IVA fasteners that require lubrication shall use an approved lubricant or plating material.

b. Cadmium Plating - Cadmium-plated IVA fasteners shall not be used.

c. Wing-Head Fasteners - Wing-head IVA fasteners shall fold down and be retained flush with surfaces so they will not snag personnel, clothing, or equipment.

d. Cotter Keys :

1. Fit - Keys and pins shall fit snugly without requiring being driven in or out using a tool.

2. Large heads - Cotter keys shall have large heads for easy removal by hand.

3. Cotter keys shall not be used EVA.

e. Access - Minimal requirements for access and/or clearance areas for tool-actuated fasteners shall be as shown in Figures 11.2.3.6-1 and -2.

(Refer to Paragraph 11.2.3.6, Tool Access Design Requirements, for specific access requirements.)

f. Tool-Actuated Fastener Head Types - In addition to the general tool-actuated fastener design requirements given in Paragraph 11.9.3.3, the following IVA-specific tool- actuated fastener selection requirements shall apply: (NOTE: Special mission or program requirements may create the need to use other types of fastener heads than those listed below.)

1. Fastener heads directly exposed to crew impact shall meet the requirements for burrs, edges, and sharp corners, or shall be provided with protective covers or they shall be flush with surface.

   (Refer to Paragraph 6.3.3, Mechanical Hazards Design Requirements.)

2. Fastener heads not directly exposed to crew impact within habitability and stowage areas shall be internal or external hex head.

g. Due to Potential toxicity/particulate contamination hazards associated with the use of anti-sieze and positive locking compounds, designers should avoid the need for the use of such chemicals, if at all possible.

11.10.3 Connector Design Requirements

a. One-Handed Operation - All connectors, whether operated by hand or tool, shall be designed so they can be mated/demated using one hand.

b. Accessibility - It shall be possible to mate/demate or replace individual connectors without having to remove or replace other connectors. Quick Disconnects (QDs) that are designed to be operated under pressure will not require pressure/flow indicators.

11.10.3.1 Fluid Connectors Design Requirements

a. Fluid Line Connectors - All brazed or welded gas and liquid lines shall be provided with convenient-to-use, permanently installed connectors that permit on-orbit maintenance.

(Refer to Paragraph 12.3.1.4, Removal, Replacement and Modularity Design Requirements, for fluid and gas line isolation valve requirements.)

b. Indication of Pressure Flow - All liquid and gas lines shall be provided with a positive indication of the gas pressure/fluid flow to verify that the line is passive before disconnection of connectors. Quick Disconnects (QDs) that are designed to be operated under pressure will not require pressure/flow indications.

c. Fluid Loss - Liquid and gas connectors shall be designed to minimize escape or loss of fluids, particularly any toxic materials, during connect or disconnect operations.

11.10.3.2 Electrical Connectors Design Requirements

a. Ease of Disconnect - Electrical connector plugs shall require no more than one turn to disconnect or some other quick disconnect design shall be provided.

b. Self-Locking - Electrical connector plugs shall provide a self-locking safety catch.

c. Access - Electrical connectors and cable installations shall be designed with sufficient flexibility, length, and protection to permit disconnection and reconnection without damage to wiring or connectors.

(Refer to Paragraph 11.14.3, Cable Management Design Requirements, for other related requirements.)

d. Arc Containment - Electrical connector plugs shall be designed to confine/isolate the mate/demate electrical arcs or sparks.

(Refer to Paragraph 6.4.3, Electrical Hazards Design Requirements, for specific electrical safety requirements.)

e. Contact Orientation - All efforts shall be made to arrange contacts within connectors such that when the connectors are demated there will be no voltage potential on exposed male pins.

11.10.3.3 Structural Connectors Design Requirements

a. Alignment Provisions - All structural connectors shall incorporate alignment features.

(Refer to Paragraph 11.10.3.5, Connector Identification/Alignment Design Requirements, for specific requirements.)

b. Soft Latching - All structural connectors shall provide the capability to "soft-latch" prior to full firm connection or full release.

c. Lock Indication - All structural connectors will provide an indication of positive locking.

11.10.3.4 Optical Connectors Design Requirements

All fiber optic connectors shall be designed so that proper geometric alignment and abutment maintains signal fidelity.

(Refer to Paragraph 11.10.3.5, Connector Identification/Alignment Design Requirements, for specific requirements.)

11.10.3.5 Connector Identification/Alignment Design Requirements

a. Connector Shape - Use connectors that are clearly different and physically incompatible when lines differ in content (i.e., different voltages, liquids, gases).

b. Alignment Provisions:

1. Mating connectors shall be provided with aligning pins or equivalent devices to aid in alignment and to preclude inserting in other than the disired orientation.

2. If aligning pins are used on electrical connectors, they shall extend beyond the plug's electrical pins to ensure that alignment is obtained before the electrical pins engage.

c. Keying:

1. Symmetrical arrangement of aligning pins or keys shall be avoided to prevent connectors from being mismated.

(See Figure 11.10.4-2, Electrical Connector Keys and Keyways, and Figure 11.10.4-3, Arrangement of Guide Pins.)

2. The mechanical keys shall prevent incorrect connection with other accessible connectors, plugs, or receptacles.

d. Alignment Marks:

1. Alignment marks shall be applied to mating parts if the proper interface orientation is not obvious by virtue of geometry.

2. The marks shall consist of a straight line of a width and length appropriate to the size of the items and shall be located so as to be easily seen by the crewmember both before and after mating/demating operations.

e. Coding:

1. Both halves of mating connectors shall display a code or identifier unique to that connection.

2. Labels or codes on connectors and associated items shall be located so they are visible when connected or disconnected.

(Refer to Paragraph 9.5.3, Labeling and Coding Design Requirements, for specific requirements.)

f. Pin Identification - Each pin shall be clearly identified in each electrical plug and each electrical receptacle.

g. Orientation - Grouped plugs and receptacles shall be oriented so that the aligning pins or equivalent devices are in the same relative position (i.e., all keyed connectors oriented the same direction - key up).

h. Loose Hoses or Cables :

1. If the connectors on the ends of a loose electrical cable or fluid hose are not identical, each end shall be uniquely identified to prevent improper usage.

2. The loose ends of hoses and cables shall be restrained to prevent them from floating out of reach and to avoid injury to crewmembers and damage to equipment.

11.10.3.6 Connector Arrangement Design Requirements

a. Hand Access - Connectors shall be spaced far enough apart so that they can be grasped firmly for connecting and disconnecting.

b. Adjacent Connectors or Obstructions - Space between a connector and any adjacent obstruction shall be compatible with the size and shape of the plugs.

c. Single Rows - Connectors in a single row which require removal and replacement by the crew (IVA) shall be a minimum of 25 mm (1 in.) apart (edge-to-edge) for hand access during alignment and insertion. A separation of 41 mm (1.6 in.) is required for EVA and preferred for IVA. (See Figure 11.10.3.6-1.)

d. Staggered Rows - Staggered rows of connectors shall be a minimum of 64 mm (2.5 in) apart - IVA and EVA, (see Figure 11.10.3.6-2).

e. Tools - If a tool is used, the hand access clearance is still required to facilitate initial alignment by hand.

11.11.3 Window Design Requirements

This section provides the design requirements for the optical characteristics, visual protection, physical protection, and maintenance for the two types of windows to be utililized in Space Station Freedom. These requirements apply to test conditions prior to launch.

Chap 11

(Refer to Paragraph 8.11.3, Window Integration Design Requirements, for window architectural integration requirements.)

(Refer to Paragraph 9.2.5.1.2 Window Workstation Design Requirments, for additional requirements when the window will be used in conjunction with controls, displays, restraints, etc.)

11.11.3.1 General Viewing Window Requirements

11.11.3.1.1 Window Size

a. Hatch windows shall be a minimum of 20.3 cm (8 in) diameter.

b. General area windows shall be a minimum of 50.8 cm (20 in) in height and width or diameter.

11.11.3.3 Visual Protection Design Requirements

a. Sun Shields/Shades :

1. Sun shields - All viewing windows shall be provided with crew-operated, opaque sun shields capable of restricting all sunlight from entering the habitable compartments.

2. External sun shades repositioning - If external shades are designed to cast a shadow over a window, they shall be provided with a means to be remotely repositioned by the window user.

b. Radiation Protection :

1. Infrared - The maximum transmissivity of infrared shall be no more than 10% (density = 1) in the range of 800 to 1200 nm.

2. Ultraviolet - The maximum transmissivity of ultraviolet shall be no more than 0.001% (density = 10E-5) in the range of 200 to 300 nm.

3. Heat rejection - The sun shade, whether internal or external, shall be capable of rejecting radiant energy away from the window assembly.

(Refer to Paragraph 5.7.2.2, Ionizing Radiation Design Requirements, for specific ionizing radiation exposure limits).

(Refer to Paragraph 5.7.3.2, Nonionizing Radiation Design Requirements, for nonionizing radiation exposure requirements.)

4. Window design shall be coordinated with other shielding protection design to achieve less than, or equal to, the allowable radiation dosages given in these paragraphs.

c. Optical Filters - Optical filters shall be provided to meet visual protection requirement if operational functions require light transmissivity in excess of the requirements given in item b, above.

11.11.3.4 Physical Protection Design Requirements

a. External Surface Contamination Protection - Window design shall take into account all sources of external contamination and shall provide means for cleaning or replacing when degradation exceeds optical transmissivity requirements.

b. Between-Pane Contamination Protection - Window design shall take into account all sources of contamination that can occur between the transparency panes and shall provide a means for preventing or minimizing optical degradation due to these contaminants.

c. Internal Surface Contamination Protection - Window design shall take into account all sources of internal surface contamination and provide means for preventing or minimizing optical degradation due to these contaminants.

1. Antifogging - All innermost panes shall be designed for antifog protection such that breath condensation does not occur from a mouth-to-pane distance of 10 cm (4 in.).

2. Inner Pane Coatings - The innermost pane shall have no coatings except for antireflective coatings.

d. Impact Load Protection - The window assembly shall be capable of withstanding a blunt object impact load of 550 N (125 lb) from any angle of incidence.

e. Protective Covers - Removable or retractable protective covers shall be provided where the window assembly does not meet crew and equipment impact load criteria or the launch and reentry pressure profiles.

f. Retractable External Protective Covers - If external protective covers are opaque, then IVA controls shall be provided with a backup EVA capability to override the IVA system.

11.11.3.5 Window Maintenance Design Requirements

a. Window Servicing - Equipment and supplies shall be provided for efficient contingency window cleaning.

b. Protective Covers - Where surface scratching, pitting, or staining cannot be prevented by other means, provide removable window protective surfaces.

c. Window Replacement - Window assemblies shall be designed to eliminate the need for depressurizing modules in order to replace window panes or the entire window assembly.

(Refer to Paragraph 12.0, Design for Maintainability, for general and specific maintainability design considerations and requirements.)

11.12.3 Packaging Design Requirements

a. Compatible With Stowage - All packaging must conform to the stowage space available.

(Refer to Paragraph 10.12.3, Stowage Facility Design Requirements, for specific requirements.)

b. Compatible With Environments - All packaging must be able to resist physical environment exposure to which it will be exposed during ground handling, ground and air transportation and launch, on-orbit and (if returnable) entry operations.

c. Compatible With Contents - All packaging must be able to resist the physical characteristics of its contents for the maximum time duration for which the contents must be packaged.

d. Compatible With Trash Disposal System - All non-reusable packaging must be compatible with the trash collection and disposal system.

(Refer to Paragraph 10.11.3, Trash Management Facility Design Requirements, for specific requirements.)

e. Packaging Restraint - Provide means for physically attaching or restraining the package at all locations where the package may have to be temporarily placed during use.

f. Labeling - All packages shall be clearly labeled as to their contents.

(Refer to Paragraph 9.5.3.1.9, Stowage Container Labeling Design Requirements, for specific labeling requirements.)

g. Inventory Control Compatibility - All packages shall be designed to incorporate the coding features required by the inventory control system.

(Refer to Paragraph 13.3.3, Inventory Control Design Requirements, for specific requirements.)

h. Ease of Use :

1. All packaging shall be designed to be usable without extensive manipulation of the packaging materials.

2. All packaging shall be designed to provide efficient and convenient means of opening and where necessary, closing/resealing the package.

i. Sizing - All packages shall be sized to be optimally suited for ease of handling and rate of consumption.

j. Hazards :

1. Packaging that incorporates pull-tabs, lids, and other easy opening features shall be designed such that the crewmember will not be injured during normal use of the feature.

(Refer to Paragraph 6.3.3, Mechanical Design Requirements, for specific safety requirements.)

2. Packaging materials shall not introduce contaminants into the atmosphere.

(Refer to Paragraph 5.1.3, Atmosphere Design Requirements, for specific contamination requirements.)

k. Loose Packaging Materials - Loose, void-filling materials shall not be used within a package.

l. Mobility Aids - Provide interfaces on the package for the attachment of equipment mobility aids if necessary for the application.

(Refer to Paragraph 11.8.3, Equipment Mobility Aids Design Requirements, for specific requirements.)

11.13.1.3 Clothing Design Requirements

11.13.1.3.1 General Clothing Design Requirements

(NOTE: In this paragraph, the word "garments" is used to include outerwear, underwear, footwear, gloves, and headwear.)

a. Suitable for the Environment :

   1. Garments shall be provided to protect the user from the full range of anticipated working and off duty environments in the space module.

   2. Garments to be used in microgravity or partial gravity shall incorporate features that make the garment suitable for use in these environments.

b. Comfort and Freedom of Movement - Wearing comfort and freedom of movement shall be emphasized in the design and materials selection of garments.

c. Wearer Effects - The effects from the wearer's body heat generation, skin and hair flaking and loss, and perspiration shall be considered in the design of the of the garments and selection of materials.

d. Materials and Fabrics - Garment materials shall be selected taking into account the following factors: similarity to Earth garments, flammability, comfort, chemical stability, moisture absorption, water compatibility, tensile strength, abrasion resistance, flexural endurance, wrinkle/shape recovery, cleaning compatibility, electrostatic performance, crease resistance, and freedom from linting.

e. Sizing - The range of sizes available shall be sufficient to provide adequate fit and comfort for the crewmember population without resorting to personalized, custom-fitted garments.

   (NOTE: Microgravity or partial gravity anthropometric changes must be accommodated.)

f. Exclusive Use - All crewmembers shall be provided with garments for their exclusive use.

g. Unassisted Donning/Doffing - All garments shall be capable of being donned/doffed by a crewmember unassisted in normal and emergency situations and operational environments (Emergency mode donning/doffing should preferably use the normal mode closures and fasteners).

h. Off-the-Shelf Garments - Off-the-shelf, commercially available garments shall be used if possible.

i. Personal Preferences - Provide garment options that allow crewmembers to select various styles, combinations of garments, different colors and different pocket styles and cuffs.

j. Aesthetics - Garment esthetics and overall appearance shall be a very important design factor.

k. Outerwear Hazards - All outerwear garments shall be free of loops, straps, and other obstructions that can snag on equipment.

l. Inner Surface Hazards - All inner surfaces of garments shall be free of items which can impede free movement, scratch or chafe the wearer.

   (Refer to Paragraph 6.3.3, Mechanical Hazards Design Requirements, for specific requirements.)

11.13.1.3.2 Clothing Packaging and Storage Design Requirements

All IVA garments (outerwear, innerwear, footwear, gloves, and headwear) shall be designed to provide the following packaging and storage requirements:

(Refer to Paragraph 11.12, Packaging, and Paragraph 10.12, Stowage Facility, for other requirements.)

a. Identification/Removal from Stowage - Garment packaging and stowage for delivery to orbit shall be designed to make it easy to identify the type and size of garment and to remove the garment from packaging.

b. Preserve Garment Appearance - Stowage and packaging of clean garments must be designed to preserve the garment appearance.

c. Soiled Garment Storage - Temporary stowage for soiled garments shall be provided.

d. Restowage On-Orbit - Garment stowage shall be designed to provide easy restorage of garments on-orbit.

e. Overnight Stowage - A closet-type stowage area for stowing garments overnight without having to fold or package them shall be provided.

11.13.2.3 Personal Ancillary Equipment Design Requirements

Where eyeglasses or sunglasses are a crew medical necessity, they shall be made of non-shattarable material.

All eyeglasses and sunglasses shall be equipped with straps or appropriate devices to assure positive retention on the user.

11.14.3 Cable Management Design Requirements

a. Routing - Cables shall be routed so that they:

   1. Cannot be pinched by doors, lids, or slides.

   2. Will not be used as a translation device in in a microgravity environment.

   3. Will not be bent sharply when connected or disconnected.

   4. Are accessible to the crewmember.

   5. Do not infringe into the operational envelope nor constitute a safety hazard (i.e., sagging, hooking, etc.).

b. Cable Clamps - Long conductors, bundles, or cables, shall be secured by means of clamps unless they are contained in wiring ducts or cable retractors.

c. Identification - Cables shall be labeled to indicate the equipment to which they belong and the connectors with which they mate. All replaceable wires and cables shall be uniquely identified with distinct number or color codes in accordance with Paragraph 9.5.3, Labeling and Coding Design Requirements.

d. Location of Test, Experiment, or Other Cables - If it is essential that test, experiment, or other cables terminate on control or display panel junction boxes or a crewmember, the receptacles and cable routing shall be designed such that the cables will not interfere with controls, displays, or the crewmembers.

e. Coding - Cables containing individually insulated conductors with a common sheath shall be coded.

f. Protection - Guards or other protection shall be provided for easily damaged conductors such as waveguides, high-frequency cables, or insulated high-voltage cables.

g. Retention - The ends of cables which will be disconnected frequently shall have retention provisions.

NOTES

NOTES

12.3 DESIGN FOR MAINTAINABILITY DESIGN REQUIREMENTS

12.3.1 Equipment Design Requirements

12.3.1.1 General Maintainability Design Requirements

a. Growth and Update - Facilities, equipment, and software design shall allow reconfiguration and growth during the mission.

b. Independence - Systems and subsystems shall be as functionally, mechanically, electrically, and electronically independent as practical to facilitate maintenance.

c. Maintenance Support Services - Maintenance support services (e.g., electrical outlets) shall be accessible at potential problem locations or at a designated maintenance location.

d. Reliability - Equipment design shall reduce to a minimum the incidence of preventive and corrective maintenance.

e. Simplicity - Equipment design shall minimize maintenance complexity.

f. Time Requirements - Equipment design shall minimize the time requirements for maintenance.

g. Equipment - Maintenance equipment and tools shall be kept to a minimum.

h. Hazardous Conditions - System design shall preclude the introduction of hazardous conditions during maintenance procedures.

i. Critical Operations - Critical systems shall be capable of undergoing maintenance without the interruption of critical services and shall be maintained.

j. Non-Critical Operations - Non-critical systems shall be designed to operate in degraded modes while awaiting maintenance. Degraded mode operation shall not cause additional damage to the system or aggravate the original fault.

k. Redundancy Loss - Notification of loss of operational redundancy shall be provided immediately to the crew.

l. Connectors - Quick-disconnect connectors shall be used.

(Refer to Paragraph 11.10.3, Connector Design Requirements, for specific requirements.)

m. Plug-In Installation - Plug-in type hardware installation and mounting techniques shall be employed.

(Refer to Paragraph 11.5.3, Mounting Hardware Design Requirements, for specific requirements.)

n. Quick Release Fasteners - Quick release fasteners shall be used where consistent with other requirements (e.g., strength, sealing).

(Refer to Paragraph 11.9.3, Fastener Design Requirements, for specific requirements.)

o. Replacement Capabilities - Capacity of replaceable or reserviceable items (filters, screens, desiccant units, battery power supplies, etc.) shall be higher than the minimum functional requirements of the system.

p. Automation - Fault isolation, inspection, and checkout tasks shall be automated to the extent practical.

q. Restraints - Personnel and equipment mobility aids and restraints shall be provided to support maintenance.

(Refer to Paragraph 11.7.2.3, Personnel Restraints Design Requirements, and Paragraph 11.7.3.3, Equipment Restraints Design Requirements, for specific requirements.)

r. Special Skills - Maintenance requiring special skills shall be minimized.

s. EVA - Maintenance requiring EVA shall be minimized.

t. Soldering, Welding, and Brazing - Soldering, welding, brazing, and similar operations during maintenance shall be minimized.

12.3.1.2 Physical Accessibility Design Requirements

a. Relative Accessibility - Items most critical to system operation and which require rapid maintenance shall be most accessible. When relative criticality is not a factor, items requiring most frequent access shall be most accessible.

b. Access Dimensions - The minimum sizes for access openings for two hands, one hand, and fingers are shown in Figure 12.3.1.2-1.

c. Access - Access to inspect or replace an item (e.g., an *ORU*) shall not require removal of more than one access cover.

(Refer to Paragraph 11.4.3, Closures and Covers Design Requirements, for specific requirements.)

d. Mounted Components - When feasible, components shall be no more than one deep in a bay or rack.

(Refer to Paragraph 11.5.3.1, General Mounting Design Requirements, for specific requirements)

e. Environmental Control and Life Support Systems (ECLS) - Subsystem equipment supporting ECLS for safe IVA environment shall be accessible, removable, and repairable by an EVA suited crewmember.

f. Shape - Accesses shall be designed to the shape that will enable the crewmember to do his/her job and not be limited only to conventional shapes.

g. Number of Accesses - Whenever possible, one large access shall be provided rather than a number of small ones.

h. Protective Edges - Protective edges or fillets shall be provided on accesses that might injure crewmembers or their equipment.

(Refer to Paragraph 6.3.3, Mechanical Hazards, for specific requirements.)

i. Damage Inspection and Repair - Where feasible, the design of structures and equipment, including their interfaces and all portions of the pressure shell, bulkheads, and seals shall be accessible for damage inspection and repair. This shall apply to exterior as well as to interior surfaces.

(Refer to Paragraph 11.4.3, Closures and Covers Design Requirements, for specific equipment accessibility requirements.)

j. Use of Tools and Test Equipment - Check points, adjustment points, test points, cables, connectors, and labels shall be accessible and visible during maintenance.

Sufficient space shall be provided for the use of test equipment and other required tools without difficulty or hazard.

(Refer to Paragraph 11.2.3, Tool Design Requirements, for specific requirements.)

Minimal Two-Hand Access Openings Without Visual Access

Reaching with both hands to depth of 150mm (6.0 in) to 490 mm (19.25 in)

Light clothing	Width:	200 mm (8.0 in) or the depth of reach
	Height:	125 mm (5.0 in.)

Reaching full arm's length (to shoulders) with both arms (light clothing)

	Width:	500 mm (19.5 in)
	Height:	125 mm (5.0 in)

Inserting box grasped by handles on the front:

13 mm (0.5 in) clearance around box, assuming adequate clearance around handles

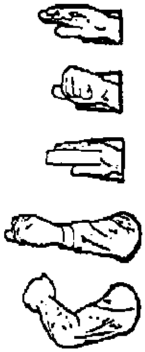
Inserting box with hands on the sides:

Light clothing:	Width:	Box plus 115 mm (4.5 in)
	‡ Height:	125 mm (5.0 in) or 13 mm (0.5 in) around box *

* Whichever is larger
‡ If hands curl around bottom, allow an extra 38 mm (1.5 in.) for light clothing

Minimal One-Hand Access Openings Without Visual Access

	Height	Width
Empty hand, to wrist:		
Bare hand, rolled	95 mm (3.75 in) sq or dia	
Bare hand, flat	55 mm (2.25 in) x 100 mm (4 in) or 100 mm (4 in) dia	
Clenched hand, to wrist:		
Bare hand:	95 mm (3.75 in) x 125 mm (5.0 in) or 125 mm (5.0 in) dia	
Arm to elbow:		
Light clothing:	100 mm (4.0 in) x 115 mm (4.5 in)	
Arm to shoulder:		
Light clothing:	125 mm (5.0 in) sq or dia	



Minimal Finger Access to First Joint

Push button access:	Bare hand:	32 mm dia (1.26 in)
	Thermal gloved hand:	38 mm dia (1.5 in)
Two finger twist access:	Bare hand:	object plus 50 mm (1.97 in)
	Thermal gloved hand:	object plus 65 mm (2.56 in)

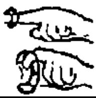


Figure 12.3.1.2-1 Minimum Sizes for Access Openings for Two Hands, One Hand, and Fingers

MSIS 297

k. Service Points for Fluid Systems - Service points for filling, draining, and purging or bleeding shall be in accessible locations.

(Refer to Paragraph 11.10.3.1, Fluid and Gas Connectors Design Requirements, for specific requirements.)

l. Plug Connectors - Full access shall be provided to plug connectors.

(Refer to Paragraph 11.10.3, Connector Design Requirements, for specific requirements.)

m. Cables :

1. Cable access - Cables shall be routed so as to be readily accessible for inspection and repair.

2. Cable trays - Wire harness and fluid lines mounted in cable trays shall be located for ready access.

3. Cable loops - Panel, console, and rack-mounted components shall have slack cable lengths or maintenance loops sufficient for removal of the connectors after the component has been extracted from its installed location, unless adequate internal access (physical and visual) is provided.

4. Cable Routing - Cables shall not be routed external to the face of the equipment rack.

   (Refer to Paragraph 11.14.3, Cable Management Design Requirements, for specific requirements.)

n. Fuses and Circuit Breakers - Fuses and circuit breakers shall be readily accessible for removal, replacement and resetting. The condition of fuses (good or blown) shall be readily discernable without having to remove the fuse.

o. Structural Members - Structural components of units or chassis shall not prevent access to or removal of equipment.

p. Fold-Out/Pull Out Drawers and Cabinets - Fold-Out/pull-out drawers and cabinets shall be used where possible to provide ease of access.

(Refer to Paragraph 11.3.3, Draw and Rack Design Requirements, for requirements for the design of sliding, rotating, and hinged equipment for maintenance related access.)

q. Slide-Out Stops - Limit stops shall be provided on racks and drawers which are required to be pulled out of their installed positions for maintenance. The limit stop design shall permit convenient overriding of stops for unit removal.

r. Hazardous Conditions - If a hazardous condition exists behind an access, a safety indicator shall be provided. The access shall be equipped with an interlock that will de-energize the hazardous condition when the barrier is opened or removed, and a manual override capability shall be provided.

(Refer to Paragraph 6.4.3, Electrical Hazards Design Requirements, for specific safety requirements.)

(Refer to Paragraph 9.4.4.3, Caution and Warning System Design Requirements, for related requirements.)

s. Covers - Where physical access is required, one of the following practices shall be followed, with the order of preference as given.

(Refer to Paragraph 11.4.3, Closures and Covers Design Requirements, for design requirements relating to maintainability.)

1. Provide a sliding or hinged cap or door where debris, moisture, or other foreign materials might otherwise create a problem.

2. Provide a quick-opening cover plate in a cap that will meet stress requirements.

t. Self-Supporting Covers - All access covers that are not completely removable shall be self-supporting in the open position.

u. Rear Access - Sliding, rotating, or hinged equipment to which rear access is required shall be free to open or rotate its full distance.

12.3.1.3 Visual Access Design Requirements

a. Visual Access - Where visual access only is required, the following practices shall be followed with the order of preference as given.

1. Provide an opening with no cover except where this might degrade system performance.

2. Provide a transparent window if dirt, moisture, or other foreign materials might create a problem.

3. Provide a quick-opening metal cover if a transparent cover will not meet stress or other requirements.

b. Visual and Manual Access - If the crewmember has to be able to see the task, design of the access shall be large enough to allow simultaneous visual as well as physical access; otherwise a separate window shall be provided for visual access to monitor task performance. (Refer to Paragraph 12.3.1.2, Physical Accessibility Design Requirements, for additional requirements.)

c. Labeling:

(Refer to Paragraph 9.5, Labeling and Coding, and Paragraph 9.4.4, Caution and Warning Displays, for related requirements.)

1. Access labeling - Each equipment access shall be labeled to indicate items visible or accessible through it.

2. Visibility - Relevant labels and mounting instructions shall be visible during all maintenance activities.

3. Identification labels - Each access shall be labeled with a number, letter, or other symbol which is directly cross-referenced to the maintenance procedures.

4. Plug configuration labels - When a plug-in device has to be inserted through a hole with limited visual access, a label adjacent to the access shall indicate how the pins on the device will align with the holes in the socket.

5. Component identification labels - Electrical cables, fluid lines, and other subsystem protective shields shall be labeled or otherwise coded to allow for positive identification.

6. Hazard labels - Accesses shall be labeled with appropriate hazard labels, advising of any hazard existing beyond the access and stating necessary precautions.

7. Hinged cover labels - If instructions applying to a covered item are lettered on a hinged door, the lettering shall be oriented to be read by the crewmember performing maintenance when the door is opened.

(Refer to Paragraph 9.5.3, Labeling and Coding Design Requirements, for additional requirements.)

d. Fluid and Gas Line Connectors - Where feasible, fluid and gas connectors shall be located and configured so they can be inspected, and so that any leakage is obvious.

(Refer to Paragraph 11.10, Connector Design Requirements, for other connector requirements.)

12.3.1.4 Removal, Replacement and Modularity Design Requirements

(Refer to Paragraph 11.5.3.2, Alignment Devices Design Requirements, and Paragraph 11.5.3.1, General Mounting Design Requirements, for additional requirements.)

a. Removal - Systems and subsystems shall be designed so that failed *Orbital Replacement Units (ORU's)* can be removed without damaging or disturbing other components.

b. Surface Removal - Replaceable units shall be designed for removal through the surface facing the crewmember as he works on the equipment.

(Refer to Paragraph 11.5.3.1, General Mounting Requirements, for other specific requirements)

c. Independence - Where feasible, it shall not be necessary to remove or disable an operable unit to obtain access to a defective replaceable unit.

d. Component Labeling - Each removable component and its position on the unit shall be labeled with corresponding numbers or other identification.

(Refer to Paragraph 9.5.3, Labeling and Coding Design Requirements, for specific requirements.)

e. Isolation Valves - Subsystems that contain liquids or high pressure gases (pressures exceeding 125 psia) and require maintenance shall be provided with isolation or disconnect valves to permit isolation and servicing and to aid in leak detection.

f. Spillage control - Replaceable units shall be designed to control spillage and the release of gases during removal or replacement.

g. Energized Units - Replaceable units and payloads which supply or receive energy shall be designed so that the power can be removed before repair, removal, or replacement is attempted. If stored energy can pose a hazard, provisions shall be made for its dissipation prior to maintenance.

(Refer to Paragraph 5.4.3, Electrical Hazards Design Requirements, for specific requirements.)

h. Fastener Coatings - Paint and/or coatings shall not adversely affect removal or installation of fasteners.

i. Short Life Components - Easy replacement shall be provided for components that fail frequently (e.g., lamps and fuses).

j. Guide Pins - For mounting and replacement of replaceable units, guides and guide pins shall be provided for alignment.

k. Replacement Specificity - All replaceable items shall be designed so that it will be physically impossible to insert the unit incorrectly.

l. Related Items - Items of the same or similar form which have different functional properties shall be readily identifiable and distinguishable, and shall not be physically interchangeable. This indication shall be readily discernable with the component in its installed position.

12.3.2 Testability Design Requirements

12.3.2.1 Fault Detection and Isolation Design Requirements

(Refer to Paragraph 9.4.4.3, Caution and Warning Display Design Requirements, Paragraph 9.4.2.3, Visual Displays Design Requirements, and Paragraph 9.3.3, Control Design Requirements, for specific requirements.)

a. General - Equipment design shall facilitate rapid and positive fault detection and isolation of defective items.

b. Checkout - On-board fault detection/isolation shall be automated and pre-programmed for mission-critical and/or life support systems. On-demand system checkout shall also be available.

c. Diagnostic Capability - Equipment shall have an integrated diagnostic capability for all functional failures identified as known or expected to occur, in mission-critical and life support systems.

d. Replacement Unit Status - When feasible, Replacement Unit design and configuration shall permit verification of operational status prior to installation without the need for disassembly.

e. Sensors - The status of sensors on replacement units shall be verifiable with respect to accuracy and proper operation.

f. Manual Override - A manual override capability for all automatic control functions shall be provided.

g. Portable Equipment - When built-in test equipment is not available, diagnostic tools and/or portable equipment shall be provided for fault isolation to the replacement unit level.

h. Critical Malfunction Alarm - If critical equipment is not regularly monitored, an alarm (auditory, visual, or both) shall be designed to ensure detection.

i. Power Failure Indication - An indication shall be provided to reveal power failures.

j. Power Interrupt - A positive indication of an open circuit shall be provided by a fuse or circuit breaker.

k. Out of Tolerance - A positive indication shall be provided when equipment has failed or is not operating within tolerance limits.

l. Trouble-shooting Sequence - A sequence of trouble-shooting checks shall be specified to maximize trouble-shooting efficiency.

m. Test Equipment Verification - All electronic test equipment shall have built-in test capability.

n. Test Equipment Accuracy - The accuracy of all test equipment shall exceed that of the equipment being tested.

o. Adjustment Controls - Appropriate feedback shall be provided for all adjustment controls and shall be readily discernible to the person making the adjustment while making the adjustment. Adjustment controls shall be reversible without dead band, slop, hysteresis, or striction as reversal.

p. Calibration Damage - Calibration or adjustment controls shall be provided with appropriate stops to prevent damage to the system. Calibration controls shall provide an indication (visual or audible) when stops are reached.

12.3.2.2 Test Point Design Requirements

(Refer to Paragraph 9.2.3.2, C/D Placement and Integration - Design Requirements, Paragraph 9.4.4.3, Caution and Warning Design Requirements, and Paragraph 9.5.3, Labeling and Coding Design Requirements, for additional requirements.)

a. Self-Checking - Appropriate test points shall be provided where a unit is not completely self-checking.

b. Proximity - Test points shall be provided at or near maintenance locations.

c. Adjustment - Test points used in adjusting a unit shall be in physical and visual proximity of the controls and displays used in the instrument.

d. Labeling - Each test point shall be clearly labeled with a description of its function, or, at a minimum, with a code number keyed to the maintenance manual.

e. Warning Labels - Test points shall be marked with appropriate warning labels when the application of conventional test probes could cause damage to internal circuits (e.g., integrated circuits) or injury to personnel.

f. Troubleshooting - Sufficient test points shall be provided so that it will not be necessary to remove sub-assemblies to accomplish troubleshooting/fault diagnosis.

g. Test Cable Termination - If it is essential that test cables terminate on control and display panels, the panel test receptacles shall be located so that the test cables will not interfere with controls and displays.

h. Layout - Primary test points shall be grouped in a line or matrix that reflects the sequence of tests to be performed.

i. Grouping - A control panel or a series of functionally autonomous panels shall be used to group test points whenever possible.

j. Testing and Servicing - Rear plug connectors shall be accessible for testing and servicing except where precluded by potting, sealing, or other requirements.

12.3.3 Maintenance Information Mgmt. Systems Design Requirements

(Refer to Paragraph 13.4.3, Information Management Design Requirements, for other specific requirements.)

a. System Capabilities - As a minimum, the on-board information systems shall provide command and status indications to/from all subsystems for the purpose of system maintenance and trouble-shooting procedures, trend data acquisition and analysis, status of consumables, fault detection/isolation, scheduled maintenance data, repair/replacement information, and replacement unit maintenance history and maintenance checklists.

b. Recording and Retrieval - The system shall provide for the recording and retrieving of maintenance information in near real-time.

c. Fail Operational Systems - All systems that incorporate an automated fail-operational capability shall be designed to provide crew notification and data management system cognizance of malfunctions until the faults have been corrected.

d. Replacement Unit Characteristics - A characteristic matrix of all replacement units shall be included in the data base containing replacement unit ID number, bite (replacement units containing built-in-test-equipment), hazardous system factors, critical system status, availability, and shelf-life limits, serial number traceable to manufacturer, batch data, date of manufacture, and storage constraints.

e. Sparing Status - Replacement unit sparing status shall be provided to ensure that procedures and on-board repair materials are adequate for each mission.

f. Spares Inventory - Th automated information management system shall contain an on-orbit spares inventory to identify the numbers and locations of replacement units stowed in the space module.

(Refer to Paragraph 13.3.3, Inventory Management Design Requirements, for specific requirements.)

NOTES

NOTES

13.2.3 Housekeeping Design Requirements

13.2.3.1 General Housekeeping Design Requirements

a. Contamination Control During Ground Handling - The greatest practicable precautions shall be taken to ensure freedom from debris and surface contamination within the space module and individual systems and components during the ground operations from manufacture to launch.

b. Surface Materials - Materials used for exposed interior surfaces shall be selected to minimize particulate and microbial contamination and be easy to clean (i.e., shall be smooth, solid, nonporous).

c. Grids and Uneven Surfaces - Grids and uneven surfaces shall either not be used or they shall be easy to remove and easy to clean.

d. Cracks and Crevices - All interior structural surfaces and equipment shall be free of narrow openings and crevices that can collect liquid or particulate matter or that require a special tool for cleaning.

e. Closures - Closures shall be provided for any area that cannot be easily cleaned.

   (Refer to Paragraph 11.4, Closures, for specific design considerations and requirements.)

f. Fluid and Debris Collection/Containment - Means shall be provided for collecting and/or containing any loose fluids or debris that may result from operational use, component replacement, maintenance, service or repair.

g. Built-in Control - Any subsystem which routinely utilizes containers of liquids or particulate matter shall have built-in equipment/methods for capture or prevention of vaporization into the atmosphere, prevention of material overflow from use, and methods of decontamination of spills.

   1. The capture elements shall be easily accessed for replacement or cleaning without risk of dispersion of the trapped materials.

   2. Grid, screen, or filter surfaces shall be directly accessible for cleaning

      (Refer to Paragraph 13.2.3.4 Air Filter Design Requirements, for filter requirements.)

h. Transfer Containers - Transfer containers, if required, shall be so constructed as to prevent contamination during transfer and disposal.

13.2.3.2 Surface Cleaning Design Requirements

a. Bacteria Sampling/Biocide Selection - Means shall be provided for taking microbial samples from all types of surfaces and for identifying an appropriate biocide.

b. Cleaning Chemicals - Cleaning chemicals shall meet the following requirements:

   1. Shall be low sudsing.

   2. Shall be safe for use in an enclosed environment.

   3. Shall be compatible with onboard water reclamation and/or waste disposal systems.

   4. Shall not stain or discolor the surface being cleaned.

   5. Shall be in an easy-to-use, controllable content container.

   6. Shall not produce a foul, unpleasant, lingering odor.

c. Illumination - Adequate illumination for visual inspection and cleaning of both internal and external housekeeping features.

(Refer to Paragraph 8.13.3, Lighting Design Requirements, for specific illumination requirements.)

d. Wipes - The following types of wipes for use in general housekeeping and personal hygiene shall be provided:

1. Dry wipes - Utility tissue used as toilet tissue and for compartment and equipment cleaning.

2. Wet wipes - Evaporative detergent-saturated tissues used for personal hygiene and eating utensil cleanup.

3. Biocide wipes - Biocide-saturated pads used for disinfecting food spills, waste management systems, etc.

4. Reusable wipes - Utility handwipes that can be impregnated or dampened with premixed evaporative detergent/biocidal solutions or with water.

e. Cleaning Implements - Provide means for dislodging and collecting dirt and debris from surfaces, cracks, and crevices.

f. One-Handed Operation - Cleaning equipment and supplies shall be designed for one-handed operation or use.

g. Housekeeping Cleansing Agents - A non-biocidal cleansing agent or agents, shall be provided for general purpose surface cleansing in which specific biological control is not required. A biocidal cleansing agent or agents shall be provided for clean-up of biological spills and biologically contaminated surfaces.

h. Biofilm Control - Means shall be provided to control the formation and growth of biofilm on the inside surfaces of all fluid lines and pipes so as not to degrade the mission.

13.2.3.3 Vacuum Cleaning Design Requirements

a. Suction - The system shall provide adequate suction capability for the collection and retention of both wet and dry particulate matter and of liquids.

b. Noise Level - The system shall have noise levels compatible with Paragraph 5.4.3.2.

c. Attachments - The system shall provide an assortment of attachments which conform to the various surfaces that need to be cleaned (e.g., flat surfaces, filters, cracks, crevices, corners, etc.)

d. Disposable Bags - The system shall provide disposable bags:

1. Suitable for containing both dry and liquid wastes.

2. Compactible for compaction in a trash compactor

3. Designed for long life, i.e., minimize frequency of replacement.

e. Lighting - The system shall provide lighting to illuminate the area to be cleaned.

f. Nonpropulsive - Propulsive characteristics and self-generated torques of the system shall be compensated for in the design.

13.2.3.4 Air Filter Design Requirements

a. Access - Air filters (grids, screens, filter surfaces) shall be readily accessible for cleaning and replacement without disturbance of collected material.

b. Configuration - Nondisposable air filters shall be configured to allow them to be cleaned by a vacuum cleaner attachment.

(Refer to Paragraph 13.2.3.1, General Housekeeping Design Requirements, item g, for other filter design requirements.)

c. Filter Condition - The design of the air filter shall incorporate the means to inform the crew of the overall condition of the filter (e.g., visual feedback, ΔP sensor).

13.3.3 Inventory Control Design Requirements

13.3.3.1 General Inventory Control Design Requirements

a. Ground Compatibility - the onboard and ground inventory data formats shall be identical.

b. Telemetry - The inventory management system shall interface with the telemetry system for realtime uplink and downlink.

c. Automatic Updating - The system shall provide the capability to automatically revise the inventory control database and other data references affected by stowage/ inventory changes.

d. Standard Procedures - The system shall provide a user/computer procedural interface that is standardized with other data management functions.

(Refer to Paragraph 9.6.3, User/Computer Interaction Design Requirements, for specific design requirements for the user/computer interface.)

e. Standard Nomenclature - The nomenclature used to refer to the items tracked by the inventory management system shall be identical to, and standardized with, that used on design drawings, training hardware, checklists, and procedures, labels, etc.

f. Cross Indexing - The information in the database shall be indexed with many cross reference categories to facilitate ease of data retrieval.

g. Minimize Inventory Control Crew Time - The inventory control system shall be designed to minimize the amount of crew time required for the inventory control functions. A design goal shall be that the inventory control function shall require no direct crew input, but rather shall automatically track items and update the database.

13.3.3.2 Inventory Control Reports Requirements

a. Item Status - Display the location(s) for an item that is selected by item number or item name. This report shall include the quantity of the item at each location.

b. Transfer Status - For an item selected by name or by number or for all items, provide a report that displays the "From Location", the "To Location", and the quantity to be transferred.

c. Location Status - Display items (by item number and item name) stowed in a specified stowage location. Quantity of each item in the specified location shall also be provided.

d. Limit Warning Report - Provide an alert message that indicates when quantities of consumables, or items, fall below a predetermined safe limit.

13.4.3 Information Management Design Requirements

13.4.3.1 General Information Management Design Requirements

a. Minimum Onboard Information - At a minimum the following information shall be accessible onboard:

   1. System Maintenance and Troubleshooting Procedures
   2. Trend data Acquisition and Analysis
   3. Consumable Status
   4. Payload Data Collection
   5. Experiment Procedures
   6. Repair and Replacement Information
   7. Medical History
   8. Inventory Control Data

   (Refer to Paragraph 13.3.3, Inventory Control Design Requirements.)

b. Information Management Facilities - Information management facilities shall be provided in the spacecraft for stowing, receiving, displaying, processing, and updating mission data.

c. Information Display Orientation - The information display provisions shall allow orientation of the data to the optimum position for use while performing the mission tasks that use the information.

d. Hands Free Use of Information - The information display provisions shall leave the crewmember's hands free once the data has been positioned.

e. Data File Organization - Means shall be provided to stow mission data in organized, segmented data files in which individual data records can be readily obtained.

f. Flight Data Hardcopy - As a minimum, hardcopy file data shall be maintained on board for all procedures for emergency operations of the spacecraft, continued crew safety, rescue, or escape.

13.4.3.2 Hardcopy Information Management Design Requirements

a. Restraints :

   1. Equipment restraints - Means shall be provided for restraining documents, loose sheets of paper, writing implements, and supplies required for documentation update (tape, scissors, etc.) at each information management workstation.

      (Refer to Paragraph 11.7.3, Equipment Restraints Design Requirements, for specific requirements.)

   2. Personnel restraints - Means shall be provided to restrain the crewmembers at the various workstations in a manner that leaves both hands free for documentation update and recording.

      (Refer to Paragraph 9.2.4.2.3, Workstation Restraints and Mobility Aids Design Requirements, for specific requirements.)

   3. Document restraints - Means shall be provided to hold documents open to specific pages.

b. Writing/Working Surface - Fixed and portable writing/working surfaces shall be provided.

c. Writing Instruments and Supplies - Writing instruments and supplies required for documentation update (e.g., scissors and tape) shall be provided.

d. Stowage of Writing Instruments, Supplies, and Documents - Consolidated stowage shall be provided for writing instruments, supplies, and documents in locations that are accessible to a restrained crewmember.

(Refer to Paragraph 10.12.3, Stowage Facility Design Requirements, for specific requirements.)

e. Illumination - Adequate illumination shall be provided for each workstation where hand documentation normally will be prepared.

(Refer to Paragraph 8.13.3, Lighting Design Requirements.)

f. Onboard Printer/Copier - Capability for onboard preparation and duplication of hardcopy documentation shall be provided.

13.4.3.3 Electronic Information Management Design Requirements

NOTES

NOTES

14.1.3 General EVA Safety Design Requirements

(Refer to Section 6.0, Crew Safety, for additional safety requirements that pertain to EVA. In the event of conflict concerning EVA safety issues, Section 14.0 shall take precedence.)

a. Temperatures - Surface temperatures of space module components requiring EVA interface shall be compatible with the touch-temperature limits of the pressure suit design being used.

b. Radiation - The EVA system design and operational procedures shall protect the EVA crewmember from radiation for the duration of the EVA exposure during the mission.

c. Micrometeoroids and Debris - EVA system design shall protect the EVA crewmember from expected particles including sand and dust.

d. Chemical Contamination - The EVA system shall protect the crewmember from hazardous chemical contamination.

e. Edges and Protrusions - All space module equipment and structures requiring an EVA interface must either be designed to preclude sharp edges or protrusions, or must be covered to protect the crewmember and the crewmember's critical support equipment.

f. Hazardous Equipment - Potentially hazardous items that could injure EVA crewmembers or damage EVA equipment by entrapment, snagging, tearing, puncturing, cutting, burning, or abrading shall be designed to ensure elimination of, or protection from, the hazard.

g. Ingress/Egress - EVA crewmembers shall always have a positive method and means to return to the pressurized module.

h. Power Sources - Special shielding and/or procedures shall be provided to preclude EVA approaches to a nuclear rector or radioisotopic generator power source located in the space module, that may result in additional radiation exposure.

i. Transmitters - Procedures shall be developed to protect crewmembers during EVA approaches that may result in harmful exposures to the non-ionizing radiation being emitted from all high-power electromagnetic EM wave transmitters (microwave, radar, laser, radio, UV/IR visible lamps) on or in the space module with exterior antennas or external apertures.

j. Tethers - EVA crewmembers shall be safety tethered to the space module at all times in microgravity, unless they are in a free-flying maneuvering unit or otherwise suitably restrained.

   (Refer to Paragraph 14.4, EVA Workstations and Restraints, and Paragraph 11.7.2, Personnel Restraints, for other restraint design considerations and requirements).

k. Ignition Sources - Electrical current limiting devices shall be provided to eliminate all potential ignition sources within any oxygen-enriched atmosphere of the life support system and pressure suit.

l. Positive Pressure - Protection shall be provided to prevent rupture by overpressurization of the crewmember's pressure envelop due to failure of the pressure supply system.

m. Electrical Voltage - The EVA crewmember shall be protected against electric voltage shocks from inadvertent grounding of electric circuits and from electrical discharge resulting from static charge build-up.

14.2.3 EVA Physiological Design Requirements

14.2.3.4 EVA Strength-Related Design Requirements

Design forces required for operation of hardware shall not exceed the capabilities of the potential population of EVA crewmembers within a given pressure suit design.

(Refer to Paragraph 4.9.3, Strength Design Requirements, for requirements that pertain to nude-body strength in one-g.)

14.2.3.5 EVA Metabolic Workload Design Requirements

The EMU shall be able to support a mean metabolic rate of 250 kcal/hr (1000 Btu/hr) for the total EVA duration x 400 kcal/hr (1600 Btu/hr) for 60 minutes, and a sustained minimum level of 65 kcal/hr (250 Btu/1 hr).

14.2.3.6 EVA Food and Drinking Water Design Requirements

a. Water Requirements - Water shall be available during EVA at a rate 240 cc/hr (8 oz/hr) for EVAs over 3 hours.

b. Food Requirements are as follows:

    1. EVAs of 4 hours or less in duration may be managed with 200 KCAL (795 Btu) of food.

    2. EVAs of greater than 4 hours in duration and at least 48 hours apart may be managed with 200 kcal (795 Btu) of food.

    3. Single or multiple EVAs of 4 to 8 hours in aggregate and repeated at intervals less than 48 hours apart may be managed with 750 kcal (2975 Btu) of food.

c. Materials used shall meet the current FDA requirements that pertain to food and drinking water.

    (Refer to Paragraph 7.2.2.3, Nutrition Design Requirements for data relative to potable water compatibility.)

14.2.3.7 EVA Body Waste Management Design Requirements

a. Body Wastes to be Accommodated - accommodation of 1000 cc (33 oz) of urine for men and women, and menses for women.

b. Contamination Protection - prevention of odor, particles, biotic contaminants, and/or toxicants.

c. Duration of Accommodation - accommodation of body wastes for maximum suited duration.

d. Oral/Nasal Breathing Environment - Space suit systems in combination with EVA procedures shall provide for an in-helmet environment that provides protection from defecation in the suit, vomiting in the suit, loose food or waste particles, and free-floating liquids.

    (Refer to Paragraph 10.3.3, Body Waste Management Facilities Design Requirements, for other information that pertains to body waste management.)

14.2.3.8 EVA Medical Monitoring Design Requirements

a. Detection Capability - the capability to detect physiological stress and/or excess during EVA.

b. Mobility - minimally interfere with personnel mobility.

c. Checkout Time - require minimum checkout time.

d. Communications, Caution, and Warning - the capability for real-time downlink, as well as in-suit caution and warning alarms, and the provision of caution and warning alarms for intravehicular crewmember support.

(Refer to Paragraph 9.4.4.3, Caution and Warning System Design Requirements, for specific requirements.)

e. Monitor Parameters - parameters that shall be monitored include O_2 consumption, heart rate and EKG signal, suit pressure, in-suit partial pressure (for active two-gas life support system designs), CO_2 partial pressure, and a physiological monitoring capability shall be provided for each EVA crewmember to measure radiation exposure in the suit either actively or passively depending on the radiation environment.

(Refer to Paragraph 5.7.2.2.3, Ionizing Radiation Monitoring and Dosimetry Design Requirements, and Paragraph 5.7.2.2.4, Ionizing Radiation Personnel Protective Equipment Design Requirements, for other applicable requirements. Refer to Paragraph 6.4.3, Electrical Hazards Design Requirements, and Paragraph 10.9.3, Health Maintenance Facilities, for information that pertains to EVA medical monitoring.)

14.2.3.9 EVA Suit Pressure Design Requirements

a. O_2 Pressure - The O_2 pressure in the space suit shall be maintained above the minimum normoxic levels shown in Figure 14.2.3.9-1.

b. O_2 Partial Pressure Exposure - Exposure to O_2 partial pressure during EVA preparation and during EVA shall be limited as a function of time due to O_2 toxicity concern as shown in Figure 14.2.3.9-2.

c. High O_2 Partial Pressure Exposure - Chronic (>6 hrs) exposure to O_2 partial pressure above 310 mmHg (6.0 psi) will require crew health assessment with pulmonary function tests and laboratory tests.

d. CO_2 Partial Pressure Exposure - The inspired CO_2 (CO_2 in the gas stream directed to the helmet plus the CO_2 rebreathed from respiration) shall not exceed 7.6 mmHg (0.15 psi) at metabolic rates up to 400 kcal/hr (1600 Btw/hr). The inspired CO_2 shall not exceed 10 mmHg (0.19 psi) for periods up to 15 minutes at metabolic rates up to 500 kcal (2000 Btu/hr), and shall not exceed 15 mmHg (0.29 psi) for periods of 5 minutes at metabolic rates up to 630 kcal/hr (2500 Btu/hr).

e. Rate of Pressure Change - The rate of pressure change experienced by the crewmember during either normal depressurization or repressurization shall not exceed 2.6 mmHg/second (0.05 psi/second).

f. Rate of Emergency Repressurization - The rate of emergency repressurization shall not exceed 52 mmHg/second (1.0 psi/second) and shall not result in a crewmember peak differential pressure across the chest in excess of 80mmHg (1.5 psi) or 40 mmHg (0.77 psi) for a period longer than 5 seconds.

14.2.3.10 EVA Radiation Dosage Design Requirements

(Refer to Paragraph 5.7.2.2, Ionizing Radiation Design Requirements, and Paragraph 5.7.3.2, Non-Ionizing Radiation Design Requirements, for other radiation dosage design requirements.)

a. Radiation Protection - Sufficient protection to keep radiation exposure below permissable EVA limits based on the maximum predicted radiation levels and the maxium expected task durations.

b. EVA Radiation Exposure Limits - based on NASA exposure limits:

1. Mission exposure limits shall be set.

Total pressure		Normoxic O_2 pressure	
Kpascal	(psi)	kPa	(psi)
25.51	3.70	25.51	3.70
27.58	4.00	24.96	3.62
34.47	5.00	23.79	3.45
41.37	6.00	23.17	3.36
48.26	7.00	22.68	3.29
55.16	8.00	22.34	3.24
62.05	9.00	22.06	3.20
68.95	10.00	21.86	3.17
101.35	14.70	21.24	3.08

Figure 14.2.3.9-1 Normoxic O_2 Pressure as a Function of Total Pressure

MSIS 299

O_2 partial pressure		Limitations
Range		Hours per period
Kpascal	(psi)	
69 - 101	(10 - 14.7)	6 hours/ 24 hour period 18 hours/120 hour period
41 - 69	(6 - 10.0)	18 hours/120 hour period
21 - 41	(3 - 6.0)	None

Figure 14.2.3.9-2 Exposure Limits to Partial Pressures During EVA Preparation

MSIS 300

2. Based on the mission exposure and the radiation dose acquired during IVA, permissible EVA radiation exposure limits shall be set.

c. Non-ionizing Radiation Standards:

1. Using terrestial exposure standards for non-ionizing radiation as a basis, exposure standards for non-ionizing radiation shall be established.

2. These standards shall be applied to protect EVA crewmembers from possible contact with high levels of non-ionizing radiation being emitted by exterior antennas or aperatures.

d. UV Eye Protection - the design of the space suit helmet and visors shall provide adequate eye protection to the EVA crewmember from the Sun's direct and reflected UV radiation for the duration of EVA exposure.

14.2.3.11 EVA Touch Temperature and Pressure Design Requirements

a. EVA Space Suit - The Space Station Extra-Vehicular Mobility Unit (SSEMU) shall maintain space suit internal surface temperatures between 10° C (50°F) and 43°C(110°F).

b. EVA Glove - The EVA glove shall provide the above protection during and subsequent to the period that the external surface of the glove is loaded to 52 mmHg (1-Opsi) for 0.5 minute by an object with a surface temperature between -120°C (-185°F) and 113°C (+235°F).

(Refer to Paragraph 6.5.3, Touch Temperature Design Requirements, for other specific requirements.)

14.3.4 EVA Anthropometry Design Requirements

(Refer to Figures 14.3.4.3-1, 14.3.4.3-2, 14.3.4.4-1, 14.3.4.4-2, for example EVA anthropometric design solutions.)

14.4.3 EVA Workstation and Restraint Design Requirements

(Refer to Paragraph 9.2.3, Control/Display Placement and Integration, for other requirements that may pertain to controls and displays).

14.4.3.1 EVA Work Envelope Design Requirements

EVA workstations shall be designed based on the reach envelopes, field-of-view, and neutral body posture of the space suited crewmember defined in Paragraph 14.3.2.2.

(Refer to Paragraph 9.2.4.2, Human/Workstation Configuration Design Requirements, and Paragraph 8.6.3, Crewstation Body Envelopes Design Requirements, for other requirements that pertain to envelope geometry.)

14.4.3.2 EVA Control and Display Design Requirements

a. Controls - EVA control type, location, and actuation forces shall conform to the EVA requirements in Paragraph 9.2, Workstation Layout, and Paragraph 9.3, Controls, with the following additions and exceptions to those requirements:

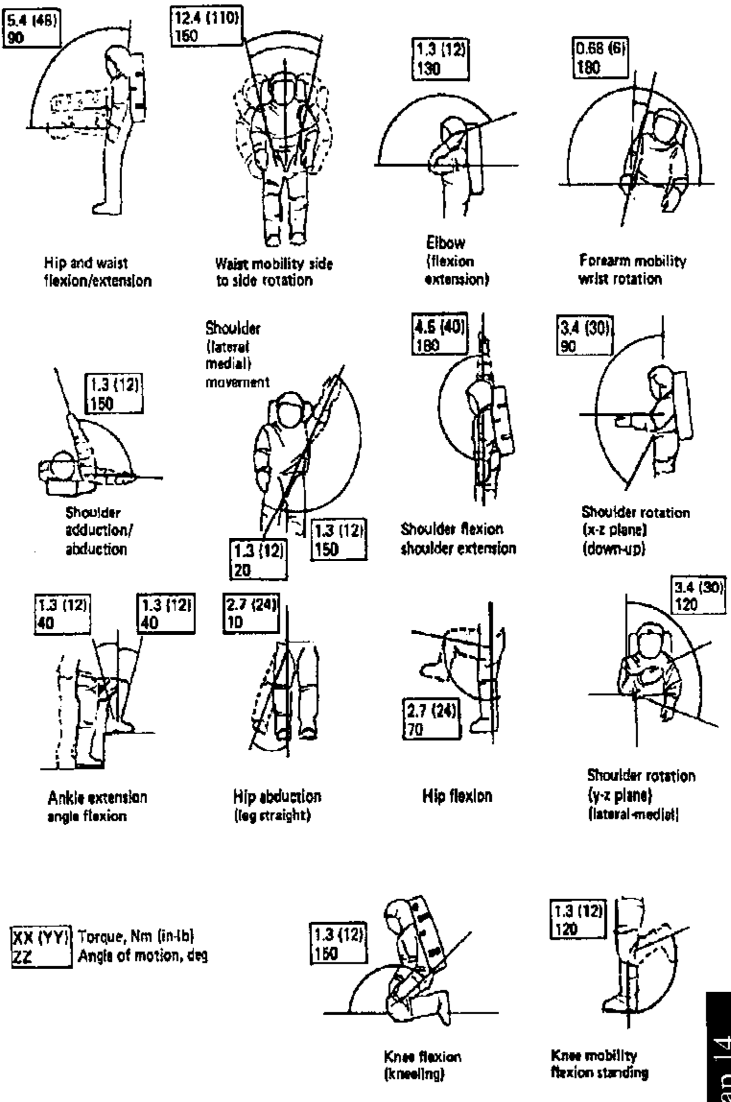
1. Glove Interface - All controls with the potential to be operated by an EVA crewmember shall be operable by a crewmember wearing a pressurized EVA space suit glove.

2. Switches - Guarded switches shall be employed where possible. Switches shall provide tactile and/or visual feedback of position.

Item	Range	Torque
Shoulder mobility		
Adduction/abduction	2.62 rad (150 deg)	13.6 Nm (12 in-lbs)
Lateral/medial	0.35/2.62 rad (20 deg/150 deg)	1.36 Nm (12 in-lbs)
Flexion/extension	3.14 rad (180 deg)	4.52 Nm (40 in-lbs)
Rotation (x-z plane)	1.57 rad (90 deg)	3.39 Nm (30 in-lbs)
Rotation (y-z plane) (lateral-medial)	2.09 rad (120 deg)	3.39 Nm (30 in-lbs)
Elbow mobility		
Flexion/extension	2.27 rad (130 deg)	1.36 Nm (12 in-lbs)
Wrist mobility		
Flexion/extension	1.57 rad (90 deg)	0.68 Nm (6 in-lbs)
Abduction/adduction	2.09 rad (120 deg)	0.68 Nm (6 in-lbs)
Waist mobility		
Flexion/extension (hip and waist)	1.57 rad (90 deg)	5.42 Nm (48 i.-lbs)
Rotation	2.62 rad (150 deg)	12.43 Nm (110 in-lbs)
Hip mobility		
Flexion	1.22 rad (70 deg)	2.71 Nm (24 in-lbs)
Abduction	0.17 rad (10 deg)	2.71 Nm (24 in-lbs)
Knee mobility		
Flexion (standing)	2.09 rad (120 deg)	1.36 Nm (12 in-lbs)
Flexion (kneeling)	2.62 rad (150 deg)	1.36 Nm (12 in-lbs)
Ankle mobility		
Flexion/extension	0.70/0.70 rad (40 deg/40 deg)	1.36 Nm (12 in-lbs)
Forearm mobility		
Wrist rotation	31.4 rad (180 deg)	0.68 Nm (6 in-lbs)
Glove mobility		
Finger flexion/extension	Grasping a one-inch diameter rod for 5 minutes	—

Figure 14.3.4.3-1 STS Space Suit Joint Mobility and Torque Specifications at 4.3 psig

MSIS 310



Note:
The angles illustrated and those listed do not always coincide

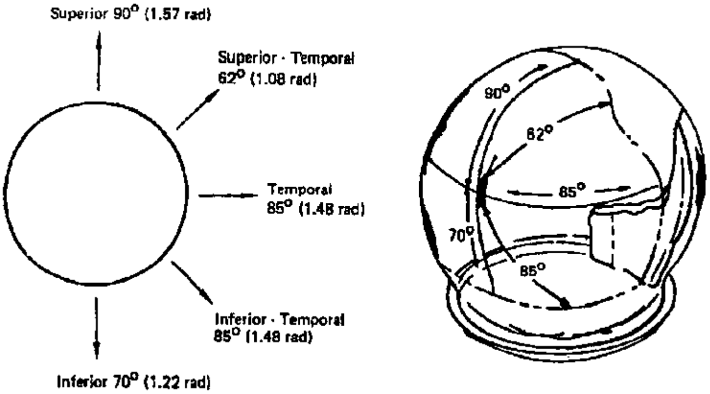
Figure 14.3.4.3-2 STS Space Suit Joint Mobility Range Specifications for 4.3 psig

MSIS 311

System provision	Parameter	Performance		
Helmet and EVVA optical visibility	Field of vision	120 deg, left and right in the horizontal plane. 105 deg. down and 90 deg. up in the vertical plane		
	Critical area of vision	Vertical Superior-temporal Superior Inferior-temporal Inferior	90 deg 1.57 rad 62 deg 1.08 rad 85 deg 1.48 rad 85 deg 1.48 rad 70 deg 1.22 rad	
Optical distortion		No visible distortion or optical defects detectable by the unaided eye. (20/20 visual acuity) at the typical "as worn" position		
		UV	Luminous	IR
Transmittance	Nanometers (nm)	200-300	400-700	700+
Thermal/coating optical characteristics				
	Characteristics	Inner protective visor	Outer sun visor	
	Transmittance			
	550 nm	70% min.	16 ± 4%	
	1100 nm	N/A	10% max.	
	Solar reflectance			
	550 nm	5% max.	40% min.	
	2400 nm	70% min.	N/A	
	700 nm	N/A	55% min.	

Figure 14.3.4.4-1 STS EVA Helmet and Extravehicular Visor Assembly Visual Range Limitations

MSIS 312



Note:
Operational field-of-vision is considerably modified by the protective extravehicular visor assembly

Figure 14.3.4.4-2 STS EMU Field-of-Vision as an Example Design Solution

MSIS 313

3. Mechanical Feedback - Mechanical control feedback shall be sufficient to override space suit glove attenuation so that the EVA crewmember receives positive indication that the control function is completed. The mechanical feedback actuation force shall be detectable but not less than 15.5 N (3.5 lb).

4. Load - EVA controls shall withstand crew-imposed loads of 1,254 Newtons in all directions or be protected from these loads.

5. Inadvertent Actuation - Protection shall be provided for all EVA controls to prevent inadvertent actuation. Toggle switches mounted on the pressure suit in sagittal or the transverse plane shall have their normal EVA operational position toward the crewmember.

6. Reach Envelope - EVA controls shall be located within the visual and reach envelope of the potential EVA crew population.

7. Spacing - Control spacing shall permit selective operation of individual controls by a space suited crewmember.

b. Displays - EVA display type and location shall conform to the IVA display requirements in Paragraph 9.4.2.3 of this document, with the following additions/exceptions:

1. Type - EVA display type shall be appropriate for the EVA task performed.

2. Loads - EVA displays shall withstand crew-imposed contact loads in all directions or be protected from these loads.

3. Field-of-View - EVA displays shall be located within the field-of-view permitted by the pressure suit and restraint system.

4. Readability - EVA displays shall be readable over the range of lighting extremes expected.

(Refer to Paragraph 9.2.3.2 Control/Display Integration and Placement Design Requirements for additional requirements onfield-of-view.)

c. Labeling - Labeling and color coding at EVA workstations shall conform to the IVA labeling and coding requirements in Paragraph 9.5 and sub-paragraphs of this document, with the following exceptions:

1. Attachment - EVA labels shall be mechanically or permanently attached to the mounting surface.

2. Color Coding - Color coding shall be used only when adequate white illumination is available at the EVA workstation.

14.4.3.3 EVA Workstation Lighting Design Requirements

(Refer to Paragraph 8.13.3., Lighting Design Requirements, and Paragraph 9.2.2.2.1, Workstation Illumination, for other requirements that pertain to lighting and illumination.)

Illumination categories and value ranges for generic EVA activities are presented in Figure 14.4.3.3-1, and minimum illumination levels for EVA tasks are given in Figure 14.4.3.3-2.

Additional illumination requirements include:

a. Lights - EVA workstations shall be illuminated by permanently mounted and/or portable lights. Illumination shall be adequate for task-specific requirements during both day and night conditions.

b. Glare - EVA lighting shall not cause excessive glare or create any other annoyance to the crew.

Type of activity	Illuminance range	
	Lux	(fc)
Translate a corridor	30 - 55	3 - 5
Lowlight work areas with occasional simple visual tasks	55 - 110	5 - 10
Visual tasks with large size or high contrast objects	215 - 325	20 - 30
Visual tasks with small size or medium contrast objects	325 - 750	30 - 70
Visual tasks with very small size or low contrast objects	540 - 1080	50 - 100
Visual tasks with objects of very small size and low contrast over a prolonged period	1080 - 2150	100 - 200

Figure 14.4.3.3-1 Illuminance Categories and Value Ranges for Generic EVAs

MSIS 315

EVA Tasks*	Minimum illuminance	
	Lux	(fc)
Astronaut movement to worksite for satellite repair mission or cargo transfer	55 - 110	5 - 10
Astronaut positions satellite in cargo bay or station worksite area	215	20
EVA satellite servicing worksite; hand tool utilization for simple, non-hazardous repair missions	325	30
EVA satellite servicing worksite; use of new and complex tools, non-hazardous	540	50
EVA satellite servicing worksite; complex tools and hazardous tasks	810	75

*** Assumes a background reflectance range of 5 - 80%**

Figure 14.4.3.3-2 Minimum Illuminance Levels for EVA Tasks

MSIS 316

c. Field-of-View - Light sources at workstations shall not be located within 1.05 radians (60 degrees) of the center of the crewmember's field-of-view.

d. Diffuse Lighting - Diffuse lighting shall be used and highly polished surfaces shall be avoided.

e. Fixtures - Light sources shall provide even illumination. Fixtures shall be designed to direct light into the desired area without causing visual discomfort to the crew. Light fixtures located close to workstations shall be designed to protect the crewmembers from thermal and physical hazards.

f. Luminance Ratio - The luminance ratio at work-stations shall conform to the following minimum specifications:

   1. 3:1 between task areas and immediate surround.

   2. 5:1 between task area and adjacent surround.

   3. 10:1 between task areas and remote surfaces.

   4. 20:1 between light sources and immediate adjacent surfaces.

g. Portable Lights - Portable lights shall be provided for unplanned maintenance, emergencies, and task performance where adequate fixed illumination is not available.

h. Exterior Light Controls - Light controls for permanently installed exterior lighting shall be located both at the exterior and interior of the space module at convenient locations.

i. Light Beam Spread - The lighting system shall have sufficient beam spread from a normal plane to provide the crewmember with good peripheral visual orientation.

14.4.3.4 EVA Crew Restraint Design Requirements

(Refer to Paragraph 8.9.3, Mobility Aids and Restraints Architectural Integration Design Requirements, and Paragraph 11.7.2.3, Personnel Restraint Requirements, for other requirements.)

a. Force Exertion - Foot restraints shall be used for actuation or operation of equipment which requires the crewmember to exert forces exceeding those given in Figure 14.4.3.4-1. EVA waist tether restraint systems may be used when actuation or operation of equipment does not require forces and durations greater than those specified in Figure 14.4.3.4-1.

Linear Forces	Duration
4.4 N (1.0 lbf)	4.5 sec
22.2 N (5.0 lbf)	2.1 sec
44.5 N (10.0 lbf)	1.4 sec

Note:
The Maximum distance through which forces may be applied is 61 cm (24 in)

Figure 14.4.3.4-1 Maximum Forces and Duration Capable of A Tethered But Free-Floating EVA Crewmember

MSIS 317

b. Foot Restraints - EVA foot restraints shall:

1. Be designed to permit easy insertion and removal of pressure suit boots by the crewmember.

2. Accommodate all boot sizes without adjustment during use.

3. Require a deliberate action for removal of a boot.

4. Provide a contingency method for removal of a jammed boot from a foot restraint.

5. Provide the capability to react to loads applied by the crewmember.

(Refer to Paragraph 11.7.2.3.2, Foot Restraint Design Requirements, for other requirements.)

c. EVA Safety Tethers and Safety Hooks - Tethers and tether hooks shall:

1. Have a handle that will fit the gloved hand of a space-suited crewmember, allow the hook to be free for utilization, and have a minimum length of 9.5 cm (3.75 in.).

2. Have design features that indicate whether the latch lock is engaged or disengaged, and to indicate direction for engaging and disengaging the lock.

3. Safety tether attachment hooks shall be removed and attachable by one-handed operation and employ a redundant lock feature such as push-to-open buttons that must be operated to disengage or release a tether.

4. Provide a contingency method for removal of a snagged tether or release of a crewmember from a tether hook.

d. Airlock- Provide handrails and tether attach points and other personnel restraints at the interior and exterior of the airlock.

e. EVA Suit Don and Doff - Provide personnel and equipment restraints at the EVA space suit facility.

14.4.3.5 EVA Equipment Tether Design Requirements

a. One-Handed Operations - All EVA equipment tethers shall be designed such that tether attachment and removal methods permit one-handed operation using a pressure suit glove.

b. Common Attachment Point - All equipment tethers shall use a common attachment method.

c. Tether Attachment Points - All equipment items shall be provided a standardized tether hook receptacle which is an integral part of each item and is compatible with NASA equipment. This standardized receptacle shall also be provided on the interfacing surface to which the item is to be secured.

d. Tether Lock Status Indicator - The tether lock shall be designed in such a way that it will be easy to recognize when the hook is locked/unlocked in body day and night lighting conditions.

14.5.3 EVA Mobility and Translation Design Requirements

14.5.3.1 EVA Translation Route Design Requirements

a. Equipment - All equipment located along EVA translation routes shall be designed to withstand repeated use as mobility aids, or the equipment shall be guarded or protected. There shall be no protrusions, corners, or sharp edges along EVA translation routes.

(Refer to Paragraph 6.3.3, Mechanical Hazards Design Requirements, for related requirements.)

b. Translation and Mobility Aids :

1. Mobility aids shall be located at terminal points and direction change points on established crew translation paths.

2. Mobility aids shall be placed in all locations where equipment is not available as a substitute.

3. For EVA translation, mobility aids shall not be separated by more than 90 cm (36 in.). The preferred spacing is 60 cm (24 in.).

c. Handholds:

1. The orientation of translation and mobility handholds shall be such that the body position normally assumed to perform a task may be attained, and that normal body movement may be accommodated.

2. They shall also be oriented such that the plane formed by the handhold longitudinal axis and the cross-section major axis is approximately parallel with the body torso frontal plane.

d. Danger Warnings:

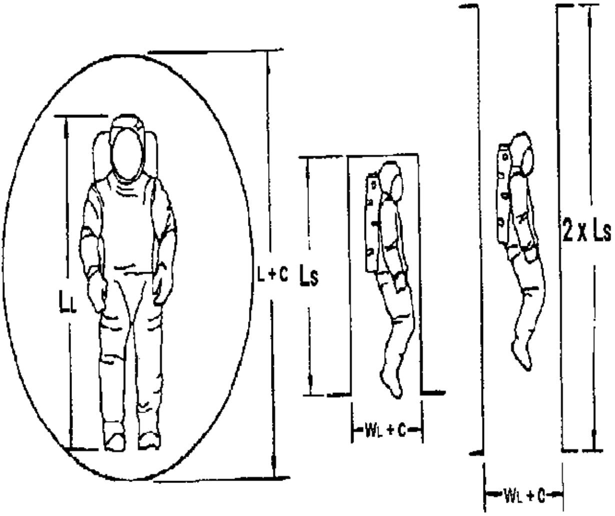
1. Translation and mobility handholds located within 30.5 cm (12 in.) of flight equipment shall be identified and color coded (regarding danger of injury to the crewmember due to equipment failure).

2. Equipment located along translation routes that could be damaged by a translating crewmember shall be identified and color coded.

e. Cross Section of the Translation Route - the dimension of the translation route (see Figure 14.5.3.1-1) shall not be smaller than the dimension required for the EVA crewmember to reverse direction (EMU height + clearance). The exceptions to this are:

1. Corridors where access is possible from either side and the length is no more than twice the length of the smallest EVA suited crewmember.

2. Corridors that have access from at least one end and are not longer than the shortest EVA suited crewmember.



W = Width at widest point; W_L = longest/largest

L = Length of EVA system; L_S = shortest/smallest; L_L = longest/largest

W = Width at widest point; W_L = longest/largest

Figure 14.5.3.1-1 Cross-Section of the EVA Translation Route

MSIS 324

f. EVA Hatches and Doors - The EVA hatches shall be operable form either side of the hatch. EVA translation aids shall be placed around the hatchway on both sides to support ingress/egress.

g. Equipment Accessibility - Translation and mobility handholds shall be positioned such that crew-operated equipment and consoles are accessible and are not obstructed visually or physically by the handholds.

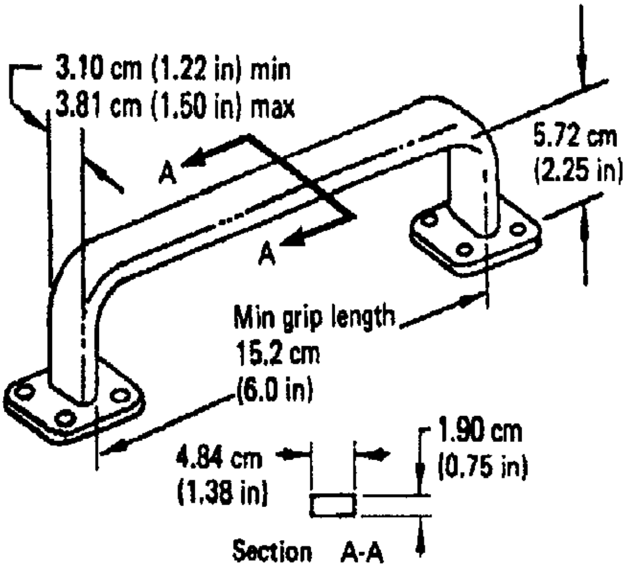
14.5.3.2 EVA Mobility Aids Design Requirements

(Refer to Paragraph 11.8.2.2.1, Handhold and Handrail Dimensional Requirements, and Paragraph 8.9.3, Mobility Aids and Restraints Design Requirements, for other handhold dimensions that may pertain to EVA mobility requirements.)

a. Dimensions - EVA handhold and handrail dimensions shall conform to Figure 14.5.3.2-1.

b. Mounting Clearance - The minimum clearance distance between the low surface of the handrail/handhold and the mounting surface is 5.7 cm (2.25 in.).

c. Spacing for Translation - For EVA translation, handholds/handrails shall not be separated more than 92 cm (36 in.). Maximum spacing of 61 cm (24 in.) is preferred.



Note: Dimensions ±0.15 cm (±0.060 in)

Figure 14.5.3.2-1 Standard EVA Handhold Dimensional Requirements

MSIS 325

d. Spacing for Worksites - Handrails/handholds shall not exceed 45.8 cm (18 in.) above or below the shoulder or 61 cm (24 in.) to the left or right of the body centerline when working in a foot-restraint position.

e. Safety Tether Attachment - EVA handrails/handholds will accommodate safety tether hooks at a spacing not to exceed 90 cm (36 in) preferred 60 cm (24 in).

f. Lighting - EVA handholds/handrails shall be illuminated in accordance with Paragraph 14.4.3.3.

g. Color - EVA handholds/handrails shall minimize specular reflection and shall be a standard color throughout the space modules, be clearly visible, and have a high visual contrast with the background.

h. Temperature - Surface temperature of EVA handholds/ handrails shall be compatible with the touch-temperature limits required by the space suit glove.

(Refer to Paragraph 14.2.3.11, EVA Touch Temperature and Pressure Design Requirements, for specified EVA glove temperature requirements).

14.5.3.3 EVA Translation Restraints Design Requirements

Except for free flying maneuvering unit operation, EVA crewmembers in microgravity environments shall always be attached or otherwise restrained to the space module. Safety tether points shall be located as follows:

a. Translation Routes - No more than 90 cm (36 in.) between EVA translation aids, 60 cm (24 in.) preferred.

b. Direction Change - At either side of a directional change in equipment transfer or a distinct hand-off point.

c. Equipment Transfer Paths - At the extreme ends of equipment transfer paths.

d. Tethers and Tether Hooks - Translation route tethers and tether hooks shall conform to the requirements in Paragraph 14.4.3.5, EVA Crew Restraint Design Requirements.

14.5.3.4 EVA Airlock Design Requirements

(Refer to Paragraph 8.10, Hatches and Doors, for additional requirements that may pertain to airlock hatches and doors requirements.)

a. Airlock Hatches - Airlock hatches shall be designed to be operated by a single EVA crewmember.

b. Any tools required for emergency contingency airlock operation shall be located near the airlock.

14.5.3.5 EVA Passageway Design Requirements

a. Minimum Cross Section - The cross section of EVA passageways shall be based on the maximum width of the largest space-suited crewmember who will use the passageway.

b. Direction Change - When abrupt changes in direction of travel are necessary, additional volume shall be provided for a change in direction normal to the corridor being traversed.

14.5.3.6 EVA Equipment Transfer Design Requirements

(Refer to Paragraph 11.8.3.2, Equipment Mobility Aid Design Requirements, for *other equipment transfer requirements.)*

All loose EVA equipment and EVA cargo shall be provided with attachment points or restraints so that it can be firmly secured or tethered at all times during transfer.

14.6.2.3 EVA Tools Design Requirements

(Refer to Paragraph 11.2.3, Tool Design Requirements, for tool requirements that may be applicable to both IVA and EVA).

a. Throw Angles - Throw angles for EVA ratcheting shall be at least 1.57 rad (90 deg.), and shall allow right- or left-handed operations.

b. Handles - A non-slip surface shall be incorporated which minimizes space suit glove abrasion.

c. Access - For EVA gloved-hand access around the tool handle, 7.6 cm (3 in.) of clearance shall be provided (see Figure 14.6.2.3-1).

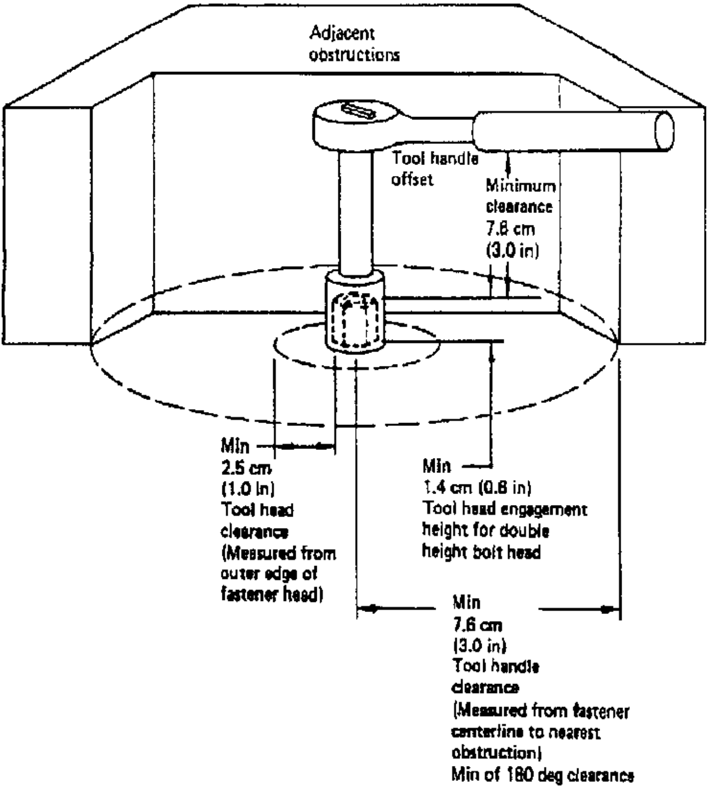


Figure 14.6.2.3-1 Visual and Hand Access for EVA Tools and Required Clearance

MSIS 326

d. Tethering - A means shall be provided on all tools for tethering the tool at all times to prevent inadvertent loss. The design shall be such that the attachment and removal methods permit one-handed operation using pressure suit glove.

e. Battery Packs - Battery powered tools shall be designed so that the battery packs can be replaced at the EVA worksite. Power tools using battery packs shall have a level of charge indicator or an indication as to when a battery pack is required to be replaced.

f. Visibility - All EVA tools shall be visible during installation, removal, and operations.

14.6.3.3 EVA Fasteners Design Requirements

a. EVA Fastener Size - The minimum size of fasteners, knobs, and head size for space-suited hand operation shall be 3.8 cm (1.5 in.) diameter and 1.9 cm (0.75 in.) high. Maximum EVA fastener size shall not exceed the grasp capabilities of the smallest EVA crewmember.

b. Captive - Captive fasteners shall be used wherever possible. Where existing hardware or other factors preclude captive fasteners, special provisions for captive devices shall be made.

c. Indication of Status - EVA actuated fasteners devices shall be verifiable visually accessible to ensure proper seating or restraint in stowed or installed locations.

d. Contingency Operation - All EVA hand-actuated rotational fasteners shall be provided with either an internal or external hexagonal feature for contingency operation with a hand tool.

e. Fastener Heads - EVA-operable bolt fasteners shall not require a push force to remain engaged with tool. EVA fasteners operated by hand or power tool shall have a double-height Hex-head bolt head.

(Refer to Paragraph 11.9.3, Fastener Design Requirements, for additional requirements.)

14.6.4.3 EVA Connectors Design Requirements

a. Clearance - Clearance shall be provided for gloved- hand operation of connectors as shown in Figure 14.6.4.3-1.

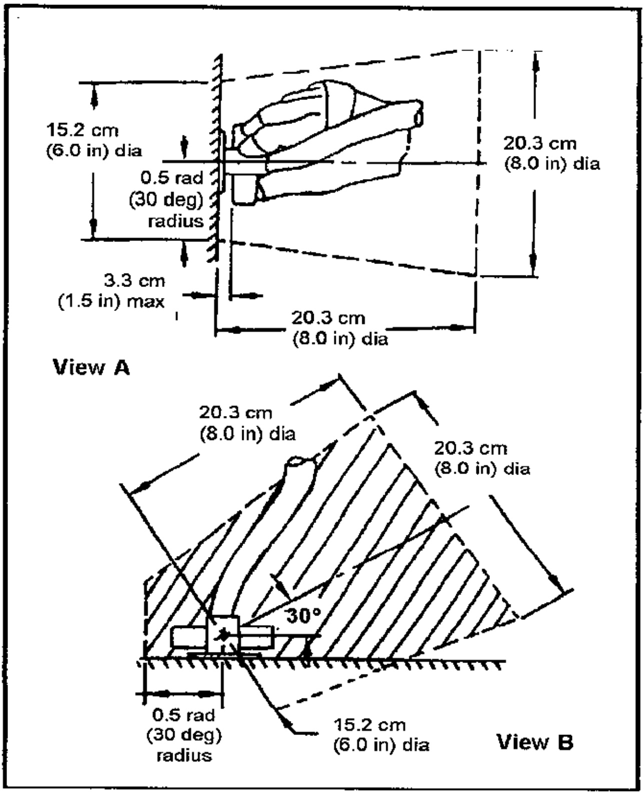


Figure 14.6.4.3-1 Typical EVA Gloved Hand Clearances Required for Wing Tab Connectors

MSIS 329

b. Wing Connectors - EVA wing connectors, similar to Figure 14.6.4.3-2, shall be used wherever appropriate. Wing length shall be proportional to the torque required.

c. Multiple Connectors - Clearance between single and staggered rows of connectors shall be at least 3.8 cm (1.5 in.) as shown in Figure 14.6.4.3-3.

d. Spacing - Spacing of connectors shall allow the gloved hand access to the connector in all directions.

e. Status - Methods such as visual indications, shall be provided to indicate connector mating status.

f. Pressure - High pressure pneumatic connectors and lines shall be tethered or otherwise captured to the main structure.

g. Protecting Caps - All connector protective caps shall be tethered in the proximity of the connector.

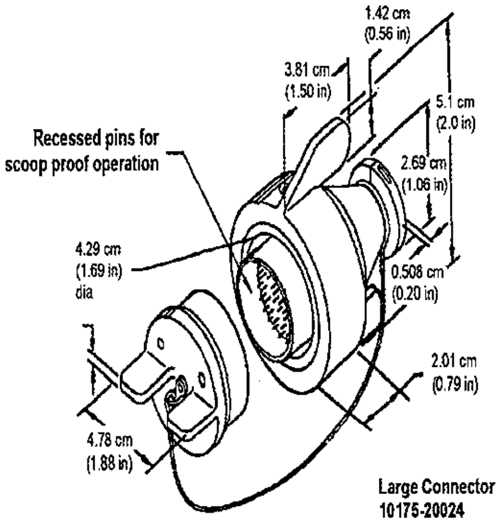


Figure 14.6.4.3-2 EVA Wing Tab Connector (Large Size)

MSIS 330

Chap 14

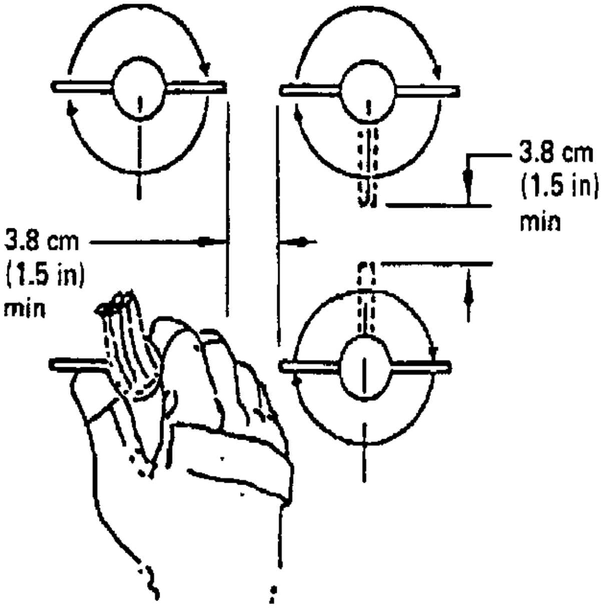


Figure 14.6.4.3-3 Minimum Clearance Between Wing Tab Connectors

MSIS 331

h. Strain Relief - Strain relief shall be provided to prevent inadvertent breakage due to induced loads.

i. Alignment - All connectors shall have provisions to ensure proper alignment during mating and demating and visible alignment markings.

j. Scoop Proof - All connectors shall be scoop proof. Scoop proof refers to the impossibility of a mating receptacle connector being inadvertently cocked into a mating plug and damaging or electrically shorting the contacts.

k. Mate/Demate - The actuation force to mate or demate an electrical or fluid connector shall not exceed 4 Nm (35 in./lb) for the preferred diameter of 5.75 cm (2.25 in.) for connectors.

l. Electrical Hazards - All electrical connectors shall have provisions for alignment and mating of connector shells prior to electrical path connections. Electrical paths shall be broken prior to connector disconnections.

(Refer to Paragraph 11.10.3, Connector Design Requirements, for additional information applicable to both EVA and IVA connectors.)

14.7.3 EVA Enhancement Systems Design Requirements

EVA Enhancement systems shall have safety tether attachments between the EVA crewmember and the enhancement system and or between the enhancement and the main space module, except for free-flying mobility units or surface rover.

NOTES

NOTES

Index

A

B

C

D

E

L

M

V

W

INDEX

PLEASE RETURN BY 1 JUN 95

Overall rating of the NASA Standard 3000 Handbook Volume III:

Very good Good Satisfactory Fair Poor

What I found most useful in the Handbook:

____

____

____

What I would delete, add, change, etc. in future editions of the Handbook:

____

____

____

Other comments:

____

____

____

Your job function (design, test, program management, etc.):

____

____

____

User Information (optional)

Name: ______________________________

Organization: ______________________________

Address: ______________________________

____

____

Phone: ______________________________

Affix Postage

Return To: John Jackson
Mail Code SP2
Johnson Space Center
Houston, TX 77058