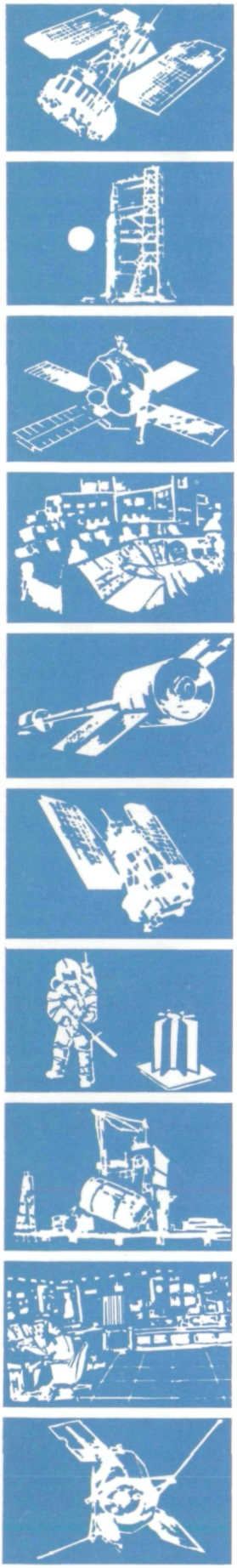
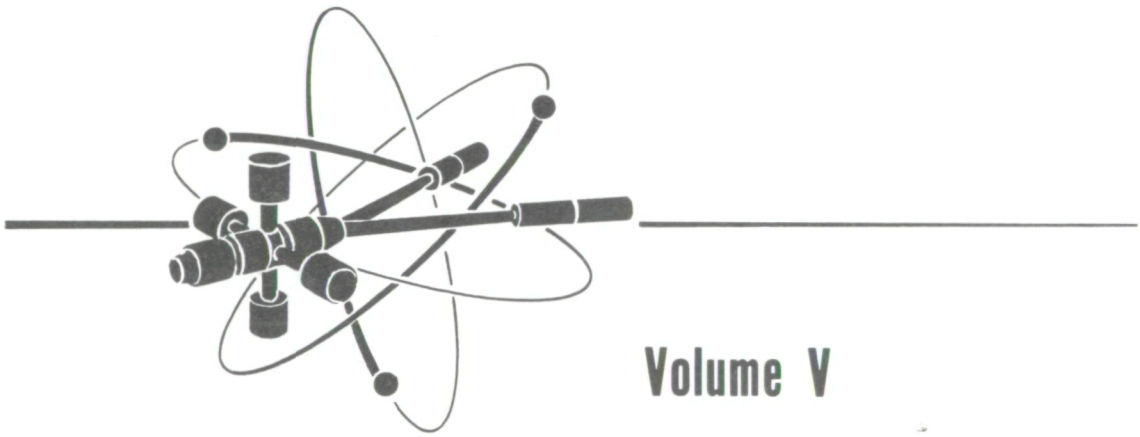
72SD4201-5-1

SPACE DIVISION



manned space flight nuclear system safety



Volume V

NUCLEAR SYSTEM SAFETY GUIDELINES

Part 1

SPACE BASE NUCLEAR SAFETY

GENERAL ELECTRIC

DOCUMENT NO. 72SD4201-5-1
JANUARY 1972

FINAL REPORT

MANNED SPACE FLIGHT NUCLEAR SYSTEM SAFETY

VOLUME V - NUCLEAR SYSTEM SAFETY GUIDELINES

PART 1 - SPACE BASE NUCLEAR SAFETY

PERFORMED UNDER

CONTRACT NO. NAS8-26283

FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

CONDUCTED BY

SPACE DIVISION
Valley Forge Space Center
P. O. Box 8555 • Philadelphia, Penna. 19101

GENERAL ELECTRIC

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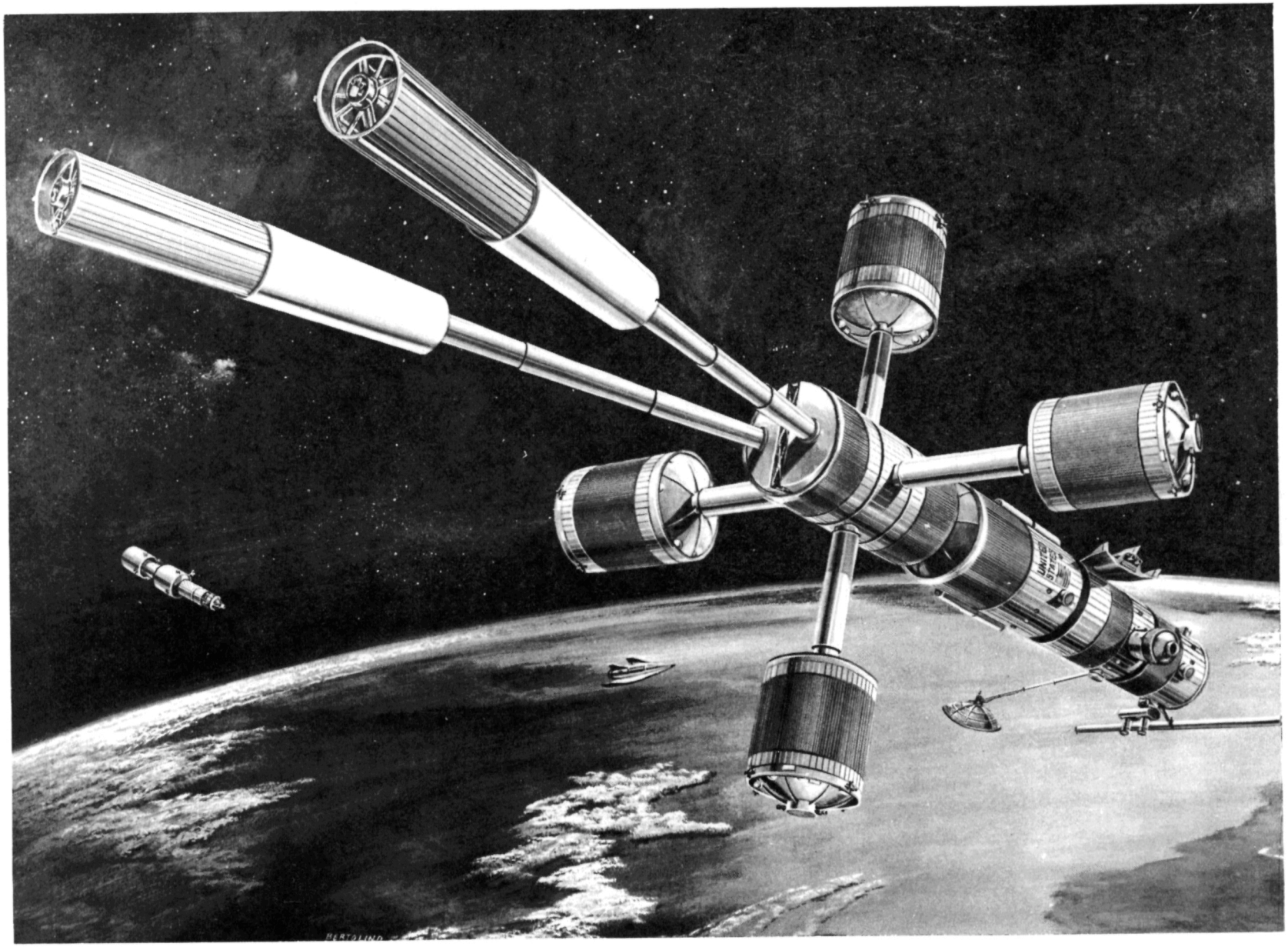
ABSTRACT

This volume of Manned Space Flight Nuclear System Safety contains the Design and Operations Guidelines and Requirements developed in the study of Space Base Nuclear System Safety. Guidelines and Requirements are presented for the Space Base Subsystems, nuclear hardware (reactor, isotope sources, dynamic generator equipment), experiments, interfacing vehicles, ground support systems, range safety and facilities. Cross indices and references are provided which relate guidelines to each other, and to substantiating data in other volumes. The guidelines are intended for the implementation of nuclear safety related design and operational considerations in future space programs.



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FOREWORD

The establishment and operation of large manned space facilities in earth orbit would constitute a significant step forward in space. Such long duration programs with orbital stay times of up to ten years would benefit the earth's populace and the scientific community by providing:

1. A flexible tool for scientific research.
2. A permanent base for earth oriented applications.
3. A foundation for the future exploration of our universe.

Specifically, the NASA objectives include earth surveys and scientific disciplines of astronomy, bioscience, chemistry, physics and biomedicine, as well as the development of technology for space and earth applications.

Operational and design requirements, of large manned space vehicles, differ from those of the Mercury, Gemini, and Apollo programs. Of particular interest are the radiation survivability and nuclear safety requirements imposed by nuclear power reactors and isotopes and the long term interaction with the natural radiation environment.

The General Electric Company under contract to NASA-MSFC (NAS8-26283) has performed a study entitled "Space Base Nuclear System Safety" for the express purposes of addressing the nuclear considerations involved in manned earth orbital missions. The study addresses both operational and general earth populace and ecological nuclear safety aspects. The primary objective is to identify and evaluate the potential and inherent radiological hazards associated with such missions and recommend approaches for hazard elimination or reduction of risk.

Work performed utilized the Phase A Space Base designs developed for NASA by North American Rockwell and McDonnell Douglas as baseline documentation.

The study was sponsored jointly by NASA's Office of Manned Space Flight, Office of Advanced Research and Technology, and Aerospace Safety Research and Data Institute. It was performed for NASA's George C. Marshall Space Flight Center under the direction of Mr. Walter H. Stafford of the Advanced Systems Analysis Office. He was assisted by a joint NASA and AEC advisory group, chaired by Mr. Herbert Schaefer of NASA's Office of Manned Space Flight.

The results of the study are presented in seven volumes, the titles of which are listed in Table A. A cross-reference matrix of the subjects covered in the various volumes is presented in Table B.

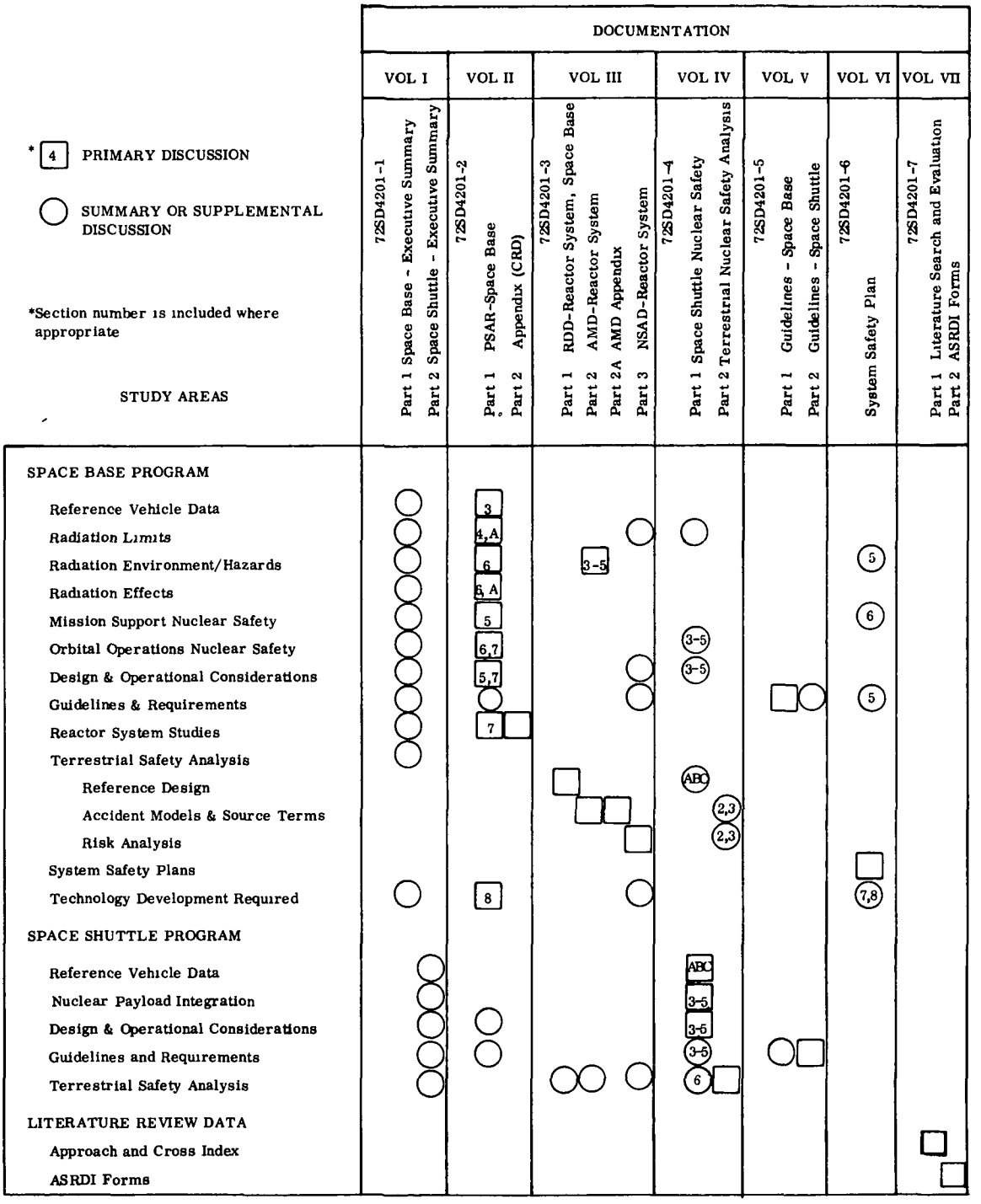
Table A. Manned Space Flight Nuclear System Safety Documentation

Volume		Document No.
I	Executive Summary	
Part 1	Space Base Nuclear Safety	72SD4201-1-1
Part 2	Space Shuttle Nuclear Safety	72SD4201-1-2
II	Space Base Preliminary Nuclear Safety Analysis	
Part 1	Nuclear Safety Analysis	72SD4201-2-1
Part 1A	Appendix-Alternate Reactor Data (CRD)	72SD4201-2-1A*
III	Reactor System Preliminary Nuclear Safety Analysis	
Part 1	Reference Design Document (RDD)	72SD4201-3-1
Part 2	Accident Model Document (AMD)	72SD4201-3-2
Part 2A	Accident Model Document - Appendix	72SD4201-3-2A
Part 3	Nuclear Safety Analysis Document (NSAD)	72SD4201-3-3
IV	Space Shuttle Nuclear System Transportation	
Part 1	Space Shuttle Nuclear Safety	72SD4201-4-1
Part 2	Terrestrial Nuclear Safety Analysis (C)	72SD4201-4-2*
V	Nuclear System Safety Guidelines	
Part 1	Space Base Nuclear Safety	72SD4201-5-1
Part 2	Space Shuttle/Nuclear Payloads Safety	72SD4201-5-2
VI	Space Base Nuclear System Safety Plan	72SD4201-6
VII	Literature Review	
Part 1	Literature Search and Evaluation	72SD4201-7-1
Part 2	ASRDI Forms	72SD4201-7-2*

*Limited distribution

This study employs the International system of units and where appropriate the equivalent English units are specified in brackets. A list of Conversion Factors and a Glossary of Terms is included in the back of each volume.

Table B. Study Area Cross Reference



ABBREVIATIONS

ADM	Add-on Disposal Modules
AEC	Atomic Energy Commission
ALS	Advanced Logistic System (Space Shuttle)
AMD	Accident Model Document
ASRDI	Aerospace Safety Research Data Institute
BOL	Beginning of Life
BPCL	Brayton Power Conversion Loop
BRU	Brayton Rotating Unit
DOD	Department of Defense
DOT	Department of Transportation
ECLS	Environmental Control and Life Support
EM	Electro Magnetic
EOD	Earth Orbital Decay
EOL	End of Life
EOM	End-of-Mission
EPS	Electrical Power System
ETR	Eastern Test Range
EVA	Extra Vehicular Activity
FC	Fuel Capsule
FPE	Functional Program Element
G&C	Guidance and Control
GSE	Ground Support Equipment
HX	Heat Exchanger
ICRP	International Committee on Radiation Protection
IDM	Integral Disposal Module
INT-21	Intermediate Saturn Stages
IR	Infrared
IRV	Isotope Re-Entry Vehicle
IU	Instrument Unit
IVA	Intra Vehicular Activity
KSC	Kennedy Space Center
LCC	Launch Control Center
LD	Lethal Dose (% Probability)
LOX	Liquid Oxygen
LV	Launch Vehicle
MCC	Mission Control Center
MDAC	McDonnell Douglas Corporation
MHW	Multi-Hundred Watt
ML	Mobile Launcher
MPC	Maximum Permissible Concentration
MSC	Manned Spacecraft Center
MSFC	Marshall Space Flight Center
MSS	Mobile Service Structure
NA	Non-Applicable
NAB	Nuclear Assembly Building
NAR	North American Rockwell
NASA	National Aeronautics and Space Administration
NC	Non-Credible
NCRP	National Committee on Radiation Protection
NSAD	Nuclear Safety Analysis Document
OPSD	Orbital Propellant Storage Depot
ORNL	Oak Ridge National Laboratory
PCS	Power Conversion System
PM	Power Module
PSAR	Preliminary Safety Analysis Report
RAD	Radiation Absorbed Dose
RCS	Reaction Control System
RDD	Reference Design Document
REM	Roentgen Equivalent Man
RMU	Remote Maneuvering Unit
RNS	Reusable Nuclear Shuttle
R/S	Reactor/Shield
RSO	Radiation Safety Officer
RTG	Radioisotope Thermoelectric Generator
SB	Space Base
SAR	Safety Analysis Report
SEHX	Separable Heat Exchanger
S-IC	First Stage of Saturn V
S-II	Second Stage of Saturn V
SNAP	Space Nuclear Auxiliary Power
SNAPTRAN	Space Nuclear Auxiliary Power Transient
TAC	Turbine Alternator Compressor
TEM	Thermoelectric Electro Magnetic Pump
TLD	Thermo Luminescent Dosimeter
USAF	United States Air Force
VAB	Vehicle Assembly Building

TABLE OF CONTENTS

SECTION 1

INTRODUCTION

KEY CONTRIBUTORS

E.E. GERRELS

SECTION 1
INTRODUCTION

The guidelines and requirements developed during the study of Space Base Nuclear System Safety are presented in this Volume. Each guideline describes a design or operational feature which, if implemented, would alleviate or minimize a particular hazard(s) and thereby increase the safety and success of the mission.

A major distinction has been made between a guideline and a requirement. A requirement is only noted as such if it has been classified as a mandatory provision under all circumstances. When any doubt exists, when alternative measures can be taken or when the provision increases the safety of the mission, but may not be required to accomplish the mission objectives, a guideline notation has been given. A majority of the considerations presented fall into the guideline category.

Guidelines prepared for the study of the transport of nuclear payloads to and from earth orbit by the Space Shuttle are presented under separate cover - Volume V, Part 2.

SECTION 2

GUIDELINES AND REQUIREMENTS DESCRIPTION

KEY CONTRIBUTORS

E.E. GERRELS

SECTION 2
GUIDELINES AND REQUIREMENTS DESCRIPTION

Figure 2-1 shows the format used in reporting all guidelines. The content and use of the format is discussed below.

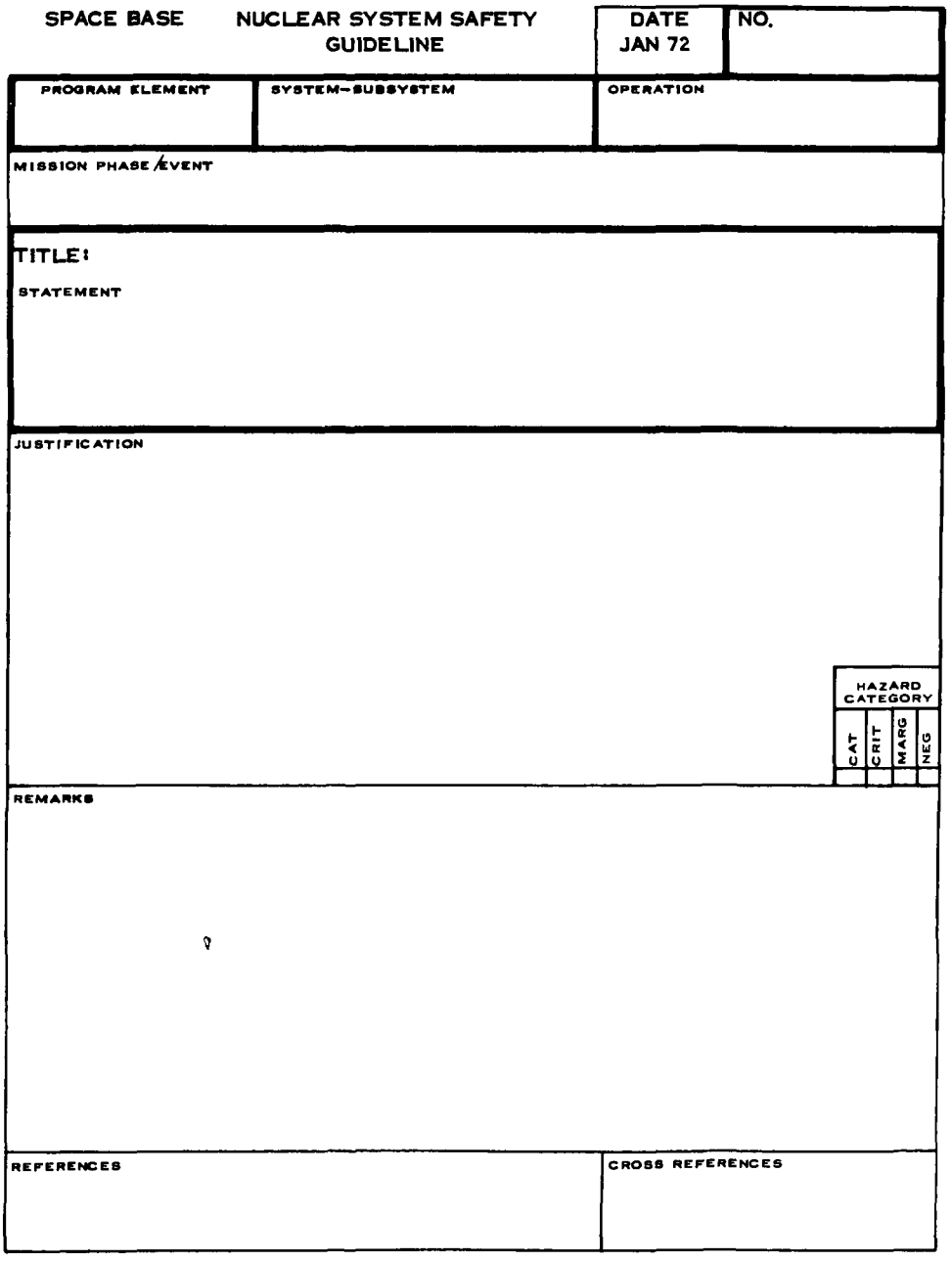
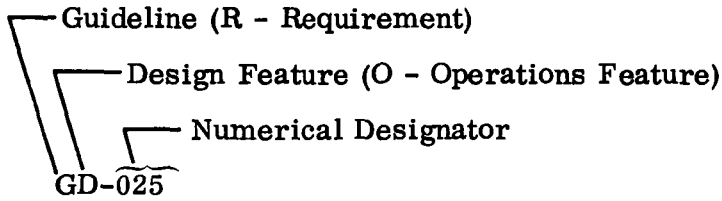


Figure 2-1. Guideline Format

2.1 NUMBER

The identifying alphanumerical designation consists of two letters followed by a three digit number.



The first alpha character denotes whether the statement is a guideline (G) or a mandatory requirement (R). The second alpha character distinguishes between design considerations (D) or operational procedures (O). Series 001 to 100 have been reserved for numerical designation of the guidelines and requirements for the Space Base Nuclear System Safety Study.

2.2 PROGRAM ELEMENT

The program element denotes the major vehicle/program for which the guideline is intended, i.e., Space Base, Space Shuttle, Space Tug, Launch Vehicle, Launch Center, etc.

2.3 SYSTEM-SUBSYSTEM GROUPING

Associated with each program element are various top level groupings of equipment designated as Systems or Subsystems. The system/subsystem groupings designated for this study include the following:

- General
- Space Base Subsystems
- Interfacing Vehicles (Shuttle, Tug, RNS, OPSD)
- Ground Support (KSC)
- Facilities
- Range Safety
- Mission Control Center (MCC)

Reactor Power Module (PM)
Isotopes
Dynamic Generator Equipment
Crew Protection
Communication & Data Management
Structures
Navigation and Control
Environmental Control & Life Support (EC/LS)
Experiments

2.4 OPERATION

The operation column is used to denote the particular operation or function to which the guideline is directed. Typical operation categories are transportation, isotope cooling, ground handling, rendezvous and docking, recovery, etc.

2.5 MISSION PHASE/EVENT

The phase or phases of the mission for which the guideline applies is listed. The various phases of a Space Base mission are shown in Figure 2-2.

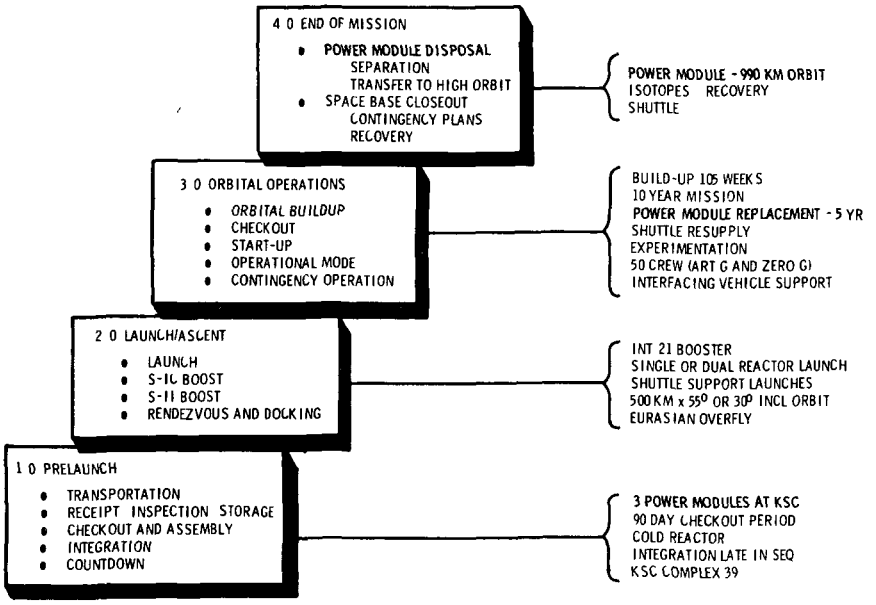


Figure 2-2. Space Base Mission Phases

2.6 TITLE

The title is provided to briefly identify the subject matter of the guideline. It is used in the cross index along with the alphanumeric designation to provide the necessary descriptive words to concisely identify the guideline and content.

2.7 STATEMENT

The statement contains the guideline, and is usually a brief statement, preferably one sentence, which describes a suggested means by which a hazard may be alleviated or eliminated. All statements for a particular Program/System form a useful checklist for a program manager or designer. Typical examples include:

- Provide a universal transporter in support of transportation and prelaunch activities of a reactor power module.
- Locate laboratories using relatively large isotope tracer concentrations in zero-g and possible isolatable and removable portions of a Space Base Vehicle.
- Provide for positive and permanent reactor shutdown prior to disposal or recovery.
- Restrict EVA during orbits intercepting the South Atlantic Anomaly.

2.8 JUSTIFICATION

The justification contains a brief substantiation for the guideline in terms of the nature of the hazards presented. A hazard category column is provided to be used in conformance with the hazard categories listed in NASA Office of Manned Space Flight Safety Program Directive No. 1 Revision A. Due to the preliminary nature of this study hazard categories were not assigned to individual guidelines. However, this potential exists and should be reserved for subsequent evaluations.

2.9 REMARKS

The remarks column is intended to provide additional information needed to further define the guideline or to indicate techniques worthy of consideration which could be applied or are used in existing systems.

2.10 REFERENCES

The key references (supporting data) in the study final reports or other related documents which are used to arrive at the guidelines are listed.

2.11 CROSS REFERENCES

The cross reference column lists the related guidelines that should be referred to by the user.

SECTION 3

GUIDELINE USAGE

KEY CONTRIBUTORS

E.E. GERRELS

SECTION 3
GUIDELINE USAGE

This particular set of guidelines is intended for use by:

1. Manned Space Flight and Space Experiment Program/Design personnel in implementing nuclear payload and nuclear safety operational and design considerations.

2. Nuclear Payload development personnel in implementing safety related design and operational features for the reactor, isotope-Brayton and small isotope systems.

3. System safety personnel in planning, establishing priorities, directing and controlling the safety program.

The guidelines can be used to establish requirements on future hardware design and development. They can also be used as a checklist against a preliminary or final design. They also form the basis of trade-off evaluations for the optimization of design when considering safety as related to performance, cost, schedules, etc.

Safety guidelines impact design details, operations and procedures and in some instances can be classified as key configuration drivers. It is important that safety guidelines be reviewed at an early date for implementation in Manned Space Flight Programs. Early consideration and implementation will result in a design capable of supporting nuclear hardware missions with minimum perturbations on spacecraft systems and Ground Support.

SECTION 4

GUIDELINES AND REQUIREMENTS CROSS INDEX

KEY CONTRIBUTORS

E. E. GERRELS

SECTION 4
GUIDELINES AND REQUIREMENTS CROSS INDEX

This section contains cross indices of all the guidelines and requirements developed.

4.1 HAZARD REDUCTION SEQUENCE INDEX

Table 4-1 contains a summary of the key guidelines in accordance with the hazard reduction sequence of the OMSF Safety Program Directive No. 1, Revision 4. This hazard reduction precedence sequence is as follows:

4.1.1 DESIGN FOR MINIMUM HAZARD

The major effort throughout the design phases shall be to insure inherent safety through the selection of appropriate design features (e.g., fail safe design, redundancy, increased ultimate safety factor).

4.1.2 SAFETY DEVICES

Known hazards which cannot be eliminated through design selection shall be reduced to the acceptable level through the use of appropriate safety devices as part of the system, subsystem, or equipment.

4.1.3 WARNING DEVICES

Where it is not possible to preclude the existence or occurrence of a known hazard, devices shall be employed for the timely detection of the condition and the generation of an adequate warning signal. Warning signals and their application shall be designed to minimize the probability of wrong signals or of improper personnel reaction to the signals.

4.1.4 SPECIAL PROCEDURES

Where it is not possible to reduce the magnitude of an existing or potential hazard through design, or the use of safety and warning devices, special procedures shall be developed to counter hazardous conditions for enhancement of ground and flight crew safety. Precautionary notations shall be standardized in accordance with the direction of the procuring activity.

Table 4-1. Hazard and Reduction Sequence Index

DESIGN FEATURES

- Provide multiple and independent radiation monitoring equipment in the Shuttle.
- Provide multiple and independent system monitoring and control equipment in the Shuttle.
- Provide a clean, smooth surface cargo bay interior.
- Consider uncooperative "tumbling" payload retrieval with Shuttle.
- Provide maximum Shuttle contingency stay times in orbit of at least 20 days.
- Provide maximum separation distance between Shuttle crew and nuclear payload.
- Provide for free, unobstructed ejection path at the launch pad.
- Consider use of a "transfer module" to improve safety in handling.
- Provide for intact reentry and impact of nuclear hardware (consider use of crush-up material in Shuttle).
- Provide for double containment of liquid metal systems (possible use of inert-gas pressure liner)
- Provide blast overpressure and fragmentation protection.
- Provide Shuttle fireball protection for nuclear payloads
- Provide tracking devices on nuclear payloads
- Consider retrieval/recovery of reactor and shield only.
- Provide isotope thermal control (cooling) capability throughout all phases of the Shuttle mission.
- Provide isotope heat source cooling to 420°K during prelaunch.

SAFETY DEVICES

- Provide compatible liquid metal fire protection and fighting capability in the Shuttle and at launch and landing sites.
- Provide capability to defuel the Shuttle in nuclear emergencies on the launch pad.
- Provide dry N_2 purging capability of the Shuttle cargo bay volume on the launch pad.
- Consider use of a back-up Shuttle to support repair of a failed Shuttle or transfer or retrieval of the payload in orbit for the continuance of the mission.
- Provide Shuttle radiation and liquid metal decontamination capability at the launch and landing sites.
- Provide tracking and location aids for rapid land and water recovery.
- Provide for positive and permanent reactor shutdown prior to Shuttle retrieval and recovery.

WARNING DEVICES

- Provide rapid response fire detection and alarm systems for liquid metal fires on the Shuttle.
- Provide capability of detecting and alerting the Shuttle crew of payload and Shuttle failures and hazardous conditions during transport.
- Provide crew/personnel dosimetry and radiation instrumentation in Shuttle cargo bay and crew.
- Provide means for warning of imminent collisions with orbiting vehicles.
- Provide proper governmental authorities with technical data for advanced warnings and preparations of impending ground impact of Shuttle with nuclear payload.

SPECIAL PROCEDURES

- Provide training and procedures in the use of radiation monitoring equipment.
- Maintain administratively controlled areas with a minimum radius of approximately 13 km and exclusion areas of 4 km radius from launch site.
- Provide installation, retrieval and maintenance procedures that do not require breaking or opening of Nak loops.
- Establish emergency procedures and decisions (contingency plans) for emergency situations.
- Prohibit launch during unsatisfactory weather conditions, particularly with winds blowing towards populated areas.
- Minimize overflight of land and continental shelf areas.
- Provide nuclear cargo transfer operations that do not involve EVA.
- Provide direct visual or TV coverage of transfer operations.
- Minimize the crew and support personnel dose rate.
- Provide rendezvous and docking/transfer operations that make maximum use of "spent" reactor shadow shielding.
- Allow at least 10 days after reactor shutdown before enacting Shuttle retrieval/replacement operations.
- Provide minimum 100 year orbital lifetime for spent reactor in high earth disposal orbit.
- Provide procedures for ejection of the payload over deep ocean or continental shelf areas.
- Install isotope heat sources at last practicable point in Shuttle launch countdown sequence.
- Consider touchdown area remote from inhabited facilities.

4.2 CROSS INDEX

The cross index of all the guidelines and requirements developed is contained in Table 4-2.

NUMBER	TITLE	APPLICABLE SYSTEMS: SPACE BASE SUBSYSTEMS: GENERAL	REACTOR PM	ISOTOPES	DYNAMIC CONVERSION EQUIPMENT	CREW PROTECTION	COMM & DATA MGT	STRUCTURES	NAVIGATION AND CONTROL	ECLS	EXPERIMENTS	INTERFACING VEH (SHUTTLE TUG, ISS & ORS)	GROUND SUPPORT (GSE)	FACILITIES	RANGE SAFETY	MISSION CONTROL CENTER (MCC)
REQUIREMENTS																
DESIGN																
RD-001	REACTOR POWER MODULE SHIPPING & STORAGE CONTAINERS		X													
RD-002	REACTOR CONTROL DRUM LOCKOUT DEVICES		X													
RD-003	SAFING REACTOR IN QUASI-STEADY STATE CONDITION		X										X		X	
RD-004	SAFE DISPOSAL/RECOVERY OF REACTOR/SHIELD		X									X				
RD-005	REACTOR REENTRY AND IMPACT PROTECTION		X													
RD-006	REDUNDANT OR ALTERNATE MEANS OF DISPOSAL		X	X								X				
RD-007	ISOTOPE HEAT SOURCE SHIPPING & STORAGE CONTAINER DESIGN			X												
RD-008	HEAT SOURCE FUEL CAPSULE CONTAINMENT			X												
RD-009	FRAGMENTATION PROTECTION			X												
RD-010	ISOTOPE HEAT SOURCE COOLING			X									X			
RD-011	PERSONNEL DOSIMETRY & RADIATION MONITORING												X	X		
OPERATIONS																
RO-001	STRICT ADHERENCE TO PROCEDURES AND REGULATIONS	X														
RO-002	PERSONNEL LIMITATIONS & REGULATIONS	X												X		
RO-003	NUCLEAR HARDWARE STORAGE AND PACKING LIMITS		X	X										X		
RO-004	REACTOR DISPOSAL/RECOVERY		X													
RO-005	RETURN TO EARTH OF EXPERIMENT ISOTOPES			X								X				
RO-006	USE OF IMPACT/RECOVERY TEAM		X	X										X		
RO-007	ADMINISTRATIVELY CONTROLLED AREAS		X	X										X		
GUIDELINES																
DESIGN																
GD-001	RADIATOR COOLANT FLUID SELECTION		X													
GD-002	REACTOR PM LIQUID METAL ENVIR PROTECTION		X										X	X		
GD-003	ENVIRONMENTAL PROTECTION AT LAUNCH SITE		X										X			
GD-004	REACTOR DESIGN TO PRECLUDE CRITICALITY ACCIDENTS		X													
GD-005	REACTOR CONTROL DRUM POSITION INDICATORS		X													
GD-006	NaK LEAK CONTAINMENT		X													
GD-007	NaK COOLANT LEAK DETECTION		X													
GD-008	REACTOR PRIM LOOP & INTERMEDIATE LOOP SEPARATION		X													
GD-009	REACTOR DISPOSAL ROCKETS & COMP DESIGN FOR SEPARATE INSTALLATION		X													
GD-010	PREVENTION OF NaK COOLANT LOOP FREEZE-UP		X													
GD-011	REACTOR TRACKING & IMPACT LOCATION DEVICES		X											X		
GD-012	INDEPENDENT REACTOR/SHIELD DECAY HEAT REMOVAL		X													X
GD-013	GROUND CONTROL BACKUP OF REACTOR PM OPERATIONS		X													
GD-014	PRIMARY LOOP NaK COMPONENT LOCATION		X													
GD-015	POWER CONVERSION SYSTEM PLACEMENT		X													
GD-016	MULTIPLE POWER CONVERSION SYSTEM OPERATION		X													
GD-017	PRESSURIZED AND TEMPERATURE CONTROLLED ENGINE ROOM		X													
GD-018	USE OF MULTIPLE REDUNDANCY IN HIGH RADIATION AREAS		X													
GD-019	"BLACK BOX" MAINTENANCE FOR REPAIRABLE EQUIPMENT		X													
GD-020	NON-REPAIRABLE, REDUNDANT NaK LOOP DESIGN PHILOSOPHY		X													
GD-021	USE OF QUICK DISCONNECTS		X	X												
GD-022	PROTECTIVE SHIELDING AROUND DYNAMIC MACHINERY		X	X												
GD-023	HIGH TEMPERATURE & ELECTRICAL HAZARD GUARDS		X	X												
GD-024	METEORITE & SPACE DEBRIS PROTECTION OF NaK LOOP		X													
GD-025	PLACEMENT OF REPAIRABLE COMPONENTS		X													
GD-026	PLACEMENT OF DISPOSAL SYSTEM ELECTRONICS		X													

NUMBER	TITLE	APPLICABLE SYSTEMS: SPACE BASE SUBSYSTEMS: GENERAL	REACTOR PM	ISOTOPES	DYNAMIC CONVERSION EQUIPMENT	CREW PROTECTION	COMM & DATA MGT	STRUCTURES	NAVIGATION AND CONTROL	ECLS	EXPERIMENTS	INTERFACING VEH (SHUTTLE TUG, ISS & ORS)	GROUND SUPPORT (GSE)	FACILITIES	RANGE SAFETY	MISSION CONTROL CENTER (MCC)
GD-027	FAULT DIAGNOSIS BY GROUND SUPPORT	X		X										X		X
GD-028	FAULT ISOLATION DIAGNOSTIC SYSTEM	X		X				X						X		X
GD-029	MODULAR REPLACEMENT OF DISPOSAL SYSTEM	X														
GD-030	DETECTION OF ABNORMAL RADIATION FROM REACTOR SHIELD	X						X								
GD-031	INSURE REACTOR NEUTRON SHIELD INTEGRITY	X														
GD-032	LiH SHIELD PUNCTURE DETECTION	X														
GD-033	REACTOR/SHIELD FRAGMENTATION PROTECTION	X														
GD-034	REACTOR SHIELD COOLING	X														
GD-035	POSITIVE & PERMANENT REACTOR SHUTDOWN MECHANISM	X														
GD-036	RAPID RESPONSE PM EJECTION	X						X								
GD-037	POSITIVE MECHANICAL SEPARATION OF REACTOR PM	X						X								
GD-038	POSITIVE REACTOR SHUTDOWN MECHANISM	X														
GD-039	AUTOMATIC REACTOR SHUTDOWN MECHANISM	X														
GD-040	REACTOR SHIELD DOSE REQUIREMENTS (OPTIMIZATION)	X														
GD-041	REACTOR PM TELEMETRY TRACKING & CONTROL	X						X								X
GD-042	USE OF DEPLETED Pu-238			X												
GD-043	ISOTOPE HEAT SOURCE SHIELDING			X												
GD-044	ISOTOPE INERT GAS BLANKET			X										X		
GD-045	ISOTOPE HANDLING TOOLS			X										X		
GD-046	FLOTATION GEAR FOR LARGE ISOTOPES			X												X
GD-047	SUBSYSTEM/COMPONENT PIECE PART SELECTION FOR RADIATION MONITORING	X	X		X		X	X	X	X	X	X	X			
GD-048	COLLISION WARNING SYSTEM						X	X								X
GD-049	USE OF NaK COMPATIBLE EVA SUIT						X									
GD-050	CREW SUITS IN PM ENGINE ROOM		X				X									
GD-051	STORM SHELTER PROVISIONS						X		X							
GD-052	LOCALIZED PROTECTION FOR THE EYES						X									
GD-053	ON-BOARD INDIVIDUAL RADIOLOGICAL MONITORING						X	X								
GD-054	CENTRAL ON-BOARD RAD WARNING SYSTEM						X	X								X
GD-055	LASER BEAM PROTECTIVE DEVICES						X		X		X	X				
GD-056	AUXILIARY CREW SHIELDING WITH INTERFACING VEHICLE						X				X	X				
GD-057	SCREENING OF DOSE RATE SENSITIVE NAVIGATION & CONTROL EQUIP								X		Y					
GD-058	RAPID ORBIT ADJUST CAPABILITY								X							
GD-059	ON-BOARD SUPPORT OF RAD SAFETY PROGRAM							X								X
GD-060	SEPARATE WASTE MGT SYSTEM FOR RAD WASTE										X					
GD-061	SEPARATE ATMOS CONTROL FOR LABS CONTAINING ISOTOPES & TRACERS			X							X					
GD-062	LOCALIZED RADIATION SHIELDING FOR ISOTOPE SOURCES			X							X					
GD-063	LOCATION OF ISOTOPE HEAT SOURCES			X					X		X					
GD-064	USE OF STRIPPABLE COATINGS								X		X					
GD-065	COMPARTMENT ISOLATION/EJECTION								X							
GD-066	USE OF NaK COMPATIBLE STRUCTURAL MATERIAL								X							
GD-067	COATING OF STRUCTURES FOR NaK COMPATIBILITY								X							
GD-068	STORAGE & CONTAINMENT OF ISOTOPES IN EXPERIMENTS			X							X					
GD-069	EXPERIMENT ELECTRONICS RADIATION HARDENING										X					
GD-070	SHIELDED STORAGE OF PHOTOGRAPHIC FILM & EMULSIONS								X		X					
GD-071	DOSIMETRY MEASUREMENT IN FILM STORAGE										X					
GD-072	DOSIMETRY FOR SENSITIVE BIOSCIENCE EXPERIMENTS										X					
GD-073	USE OF RADIATION SCREENING TECHNIQUES										X					
GD-074	DETACHED MODULES FOR γ & n SENSITIVE EXPERIMENTS							X			X					
GD-075	SENSITIVE EXPERIMENT LOCATION WITHIN REACTOR SHADOW SHIELDING										X					
GD-076	SAFETY FEATURES FOR DYNAMIC GENERATOR EQUIPMENT										X					
GD-077	EXPERIMENT LAB SAFETY FEATURES WITH ISOTOPES/TRACERS			X												

NUMBER	TITLE	APPLICABLE SYSTEMS: SPACE BASE SUBSYSTEMS: GENERAL	REACTOR PM	ISOTOPES	DYNAMIC CONVERSION EQUIPMENT	CREW PROTECTION	COMM & DATA MGT	STRUCTURES	NAVIGATION AND CONTROL	ECLS	EXPERIMENTS	INTERFACING VEH (SHUTTLE TUG, ISS & ORS)	GROUND SUPPORT (GSE)	FACILITIES	RANGE SAFETY	MISSION CONTROL CENTER (MCC)
GD-078	ISOTOPE THERMAL SHIELDING			X												
GD-079	G-LOCATION OF EXPER LABS USING ISOTOPES/TRACERS			X				X			X					
GD-080	ISOLATABLE/REMOVABLE EXPERIMENT LABS			X				X			X					
GD-081	LOCATION OF EXPER LABS USING DYNAMIC GENERATORS			X				X			X					
GD-082	SHIELDING FOR DOCKED/DETACHED EXPERIMENT MODULES			X				X			X					
GD-083	SHUTTLE/TUG GAMMA SHIELDING										X	X				
GD-084	IR SCANNER THERMAL RADIATION INTERFERENCE								X			X				
GD-085	USE OF UNIVERSAL TRANSPORTER		X										X			
GD-086	HARDWARE POSITIONING AND TIE DOWNS		X										X			
GD-087	DECONTAMINATION CAPABILITY												X	X	X	
GD-088	FACILITY DESIGN		X	X										X		
GD-089	FACILITY MODIFICATIONS		X	X										X		
GD-090	LIQUID METAL SERVICING & SAFING		X											X		
GD-091	LIQUID METAL SERVICING FACILITY LOCATION		X											X		
GD-092	LIQUID METAL/NUCLEAR HDWE FIRE PROTECTION		X	X									X	X		
GD-093	LIQUID METAL SUMPS		X											X		
GD-094	SEGREGATED NUCLEAR HARDWARE STORAGE		X	X										X		
OPERATIONS																
GO-001	USE OF NUCLEAR EXPERIENCED PERSONNEL	X											X			
GO-002	MINIMIZE NUCLEAR HDWE OPERATIONS AT LAUNCH PAD	X	X	X									X			
GO-003	AIR TRANSPORTATION OF REACTOR PM		X													
GO-004	BARGE TRANSPORTATION OF REACTOR PM		X													
GO-005	TRANSPORTATION ESCORTS & WARNINGS		X	X									X			
GO-006	TRANSPORTATION ROUTE SELECTION		X	X												
GO-007	ORDINANCE/ROCKET-FACILITY RESTRICTIONS		X											X		
GO-008	MINIMUM HANDLING OF REACTOR PM		X										X			
GO-009	LAUNCH VEHICLE INTERFACE SIMULATION		X	X												
GO-010	REACTOR CRITICALITY TEST		X													
GO-011	PRELAUNCH TESTING OF REACTOR PM		X													
GO-012	RESTRICTION OF CONTROL DRUM MOVEMENT		X													
GO-013	PRELAUNCH REACTOR PM SIMULATION		X													
GO-014	PM INSTALLATION LATE IN PRELAUNCH SEQUENCE		X													
GO-015	PERIODIC CHECKOUT		X	X												
GO-016	READINESS STATE OF STORAGE REACTOR & ISOTOPES		X	X												
GO-017	DUMMY PM ORBITAL HANDLING OPERATIONS		X													
GO-018	LOW LEVEL OPERATION DURING REACTOR REPLACEMENT		X													
GO-019	EMERGENCY REACTOR PM OPERATION		X													
GO-020	NO REPAIR OF LIQUID METAL LINES		X													
GO-021	REPAIR RESTRICTIONS IN REACTOR GALLERY AREA		X													
GO-022	REPAIR OR REPLACEMENT OF PM AFTER REACTOR SHUTDOWN		X													
GO-023	SLOW DRUM MOVEMENT FOR RESTART		X													
GO-024	AVOIDANCE OF SUBSTANCES THAT REACT WITH LIQUID METALS		X										X	X		
GO-025	IGNITABLE MATERIAL HAZARD AROUND HEAT SOURCES			X												
GO-026	INTEGRATION OF ISOTOPES WITH SPACE BASE			X												
GO-027	CREW ROTATION PROCEDURES															
GO-028	EVA RESTRICTIONS THROUGH SOUTH ATLANTIC ANOMALY															
GO-029	EVA RESTRICTIONS DUE TO REACTOR RADIATION															
GO-030	EVA RESTRICTIONS DUE TO PM THERMAL RADIATION															
GO-031	EVA COORDINATION WITH SSO															
GO-032	EVA RESTRICTIONS WITH NaK LEAKS															
GO-033	IMPLEMENTATION OF APPROACH & LOITER OPERATIONS															

NUMBER	TITLE	APPLICABLE SYSTEMS: SPACE BASE SUBSYSTEMS: GENERAL	REACTOR PM	ISOTOPES	DYNAMIC CONVERSION EQUIPMENT	CREW PROTECTION	COMM & DATA MGT	STRUCTURES	NAVIGATION AND CONTROL	ECLS	EXPERIMENTS	INTERFACING VEH (SHUTTLE TUG, ISS & ORS)	GROUND SUPPORT (GSE)	FACILITIES	RANGE SAFETY	MISSION CONTROL CENTER (MCC)
GO-034	MAINTENANCE OF NOMINAL BRAKING GATE VELOCITIES					X					X					
GO-035	LOITER TIME CONSTRAINTS					X					X					
GO-036	PROMPT CREW RESCUE					X					X					
GO-037	CREW RESCUE OPERATIONS					X					X					
GO-038	RNS APPROACH CONSIDERATIONS											X	X			
GO-039	APPROACH CORRIDORS WITH INTERFACING VEHICLES					X						X	X			
GO-040	EXPERIMENT MODULE DEPLOYMENT TRAJECTORY											X				
GO-041	EXPERIMENT SCREENING PROCEDURES											X				
GO-042	CURTAILMENT OF EXPERIMENT OPERATION											X				
GO-043	PLANNED EXPERIMENT INTERFERENCE											X	X			
GO-044	OPERATIONAL RESTRICTIONS-DYNAMIC BAD GEN											X				
GO-045	LASER BEAM OPERATION RESTRICTIONS											X		X		
GO-046	PHOTO FILM/EMULSION RESUPPLY											X				
GO-047	HIGH SPEED FILM RESUPPLY AFTER INTENSE SOLAR FLARE											X				
GO-048	MCC SUPPORT DURING MISSION	X	X										X			X
GO-049	LOITER & TRANSFER OPER RESTRICTIONS													X		
GO-050	ADVANCED WARNING OF NUCLEAR IMPACT	X	X												X	X
GO-051	SHUTTLE RECOVERY MODE	X	X												X	
GO-052	TRACKING NETWORK ADDITIONS											X				
GO-053	SAFING S-II DESTRUCT SYSTEM	X	X												X	
GO-054	COMMAND DESTRUCT DELAY	X	X												X	
GO-055	FLIGHT DETERMINATION IMPACT AREAS	X													X	
GO-056	LAUNCH AZIMUTH RESTRICTIONS	X	X												X	
GO-057	WEATHER RESTRICTIONS FOR LAUNCH	X	X												X	
GO-058	NUCLEAR PROCEDURES AT LAUNCH SITE														X	
GO-059	TRAINED FIRE FIGHTING PERSONNEL											X				
GO-060	MULTIPLE ESCAPE ROUTES											X	X			
GO-061	USE OF PROPER CLOTHING & PROTECTION EQUIPMENT											X	X			
GO-062	SMOKING & EATING REGULATIONS											X	X			
GO-063	USE OF TWO MAN "BUDDY" SYSTEM											X	X			
GO-064	GROUND SUPPORT RADIATION DOSIMETRY PROCEDURES											X	X			
GO-065	CHECKOUT AND INTEGRATION IN VAB	X	X										X			
GO-066	STORAGE AREA IN NUCLEAR ASSEMBLY BUILDING	X	X										X			
GO-067	STORAGE LIFETIMES	X	X										X			

SECTION 5
SAFETY GUIDELINES

SECTION 5
SAFETY GUIDELINES

This section contains the complete set of guidelines and requirements arranged in the following order:

Requirements

Design Requirements	*RD-001 - RD-011*
Operations Requirements	RO-001 - RO-007

Guidelines

Design Guidelines	GD-001 - GD-094
Operations Guidelines	GO-001 - GO-067

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. RD-001

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Packaging, Transportation, Storage and Handling

MISSION PHASE/EVENT

Prelaunch

TITLE: REACTOR POWER MODULE SHIPPING AND STORAGE CONTAINER

STATEMENT Provide shipping and storage containers and procedures in conformance with AEC manual Chapter 0529 and the Department of Transportation regulations in Volume 33, No. 194 of the Federal Register.

JUSTIFICATION Shipping and storage containers used for nuclear hardware must be designed to and in conformance with above regulations to allow shipping and storage within the USA.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.3	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. RD-002

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Reactor PM	Reactor Control

MISSION PHASE/EVENT

Prelaunch, Launch Ascent, End of Mission

TITLE: REACTOR CONTROL DRUM LOCKOUT DEVICES

STATEMENT Provide a positive means for locking reactor control drums in the least reactive position during all prelaunch operations and at the end of mission disposal phase

JUSTIFICATION Provides protection against ground transportation, checkout, launch pad installation, inadvertant signal and disposal criticality accidents.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Lockout devices which can be singularly or multiply released by command should be considered. Reinitiating these devices after powerplant usefulness in orbit is also advisable.

Remote operation should be considered.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.1, 5.2.3, 5.2.5, 6.3.2, 7.2.2, 7.3.4 72SD4201-3-2	GD-035

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. RD-003

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM, Ground Support, Range Safety	Reactor Safing

MISSION PHASE/EVENT

Prelaunch, Launch/Ascent, End of Mission/Recovery

TITLE: SAFING REACTOR IN QUASI-STEADY STATE CONDITION

STATEMENT Provide means of safing an aborted or impacted reactor undergoing quasi-steady state operation.

JUSTIFICATION Reduce dispersal of radioactive materials, radiation levels and contamination and provide accessibility to reactor for recovery.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Quasi-steady state conditions can result when emmersed in shallow water areas. Safing methods need to be evaluated.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5, 5.3.2	GD-004 GD-035

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. RD-004

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Reactor PM, Interfacing Vehicle-Shuttle	Disposal

MISSION PHASE/EVENT

Launch/Ascent, End of Mission

TITLE: SAFE DISPOSAL RECOVERY OF REACTOR/SHIELD

STATEMENT Provide an effective reactor/shield disposal or recovery system capable of enacting disposal at anytime after orbit has been achieved. Safe disposal is assumed to mean the planned discarding or recovery of the reactor, providing for minimum radiological risk to the general public.

JUSTIFICATION The most hazardous reactor conditions exist for several years after power-plant operations (fission product inventories are high). Random reentry cannot be tolerated during this time period.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Disposal can be achieved by a boost of the reactor/shield or entire power module into a high earth orbit providing a several hundred year decay time. Eventual reentry, even though of low radiological risk may be politically undesirable. Reboost may be necessary. The shuttle provides a prime alternative whereby safe recovery can be virtually assured.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.5, 7.3.4 72SD4201-3-2 72SD4201-3-3 Section 4	RD-005 GD-029 RD-006 GD-011

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. RD-005

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Reentry and Impact

MISSION PHASE/EVENT

Launch/Ascent, End of Mission

TITLE: REACTOR REENTRY AND IMPACT PROTECTION

STATEMENT Provide an effective reliable reentry and impact protection shield for a reactor capable of reentry and impact survival prior and after long term operation in space.

JUSTIFICATION Reentry burnup of a reactor powerplant is of low risk to the general populance, but spreads low level radiation over a large portion of the world. Political implications are undesirable even though radiological risk may be low. Prevention of reactor disassembly upon earth impact can minimize the dispersal of fission products and inhalables which reduce the subsequent radiological hazards.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS LiH is currently used as an effective neutron shield and is also contemplated for use as the reentry heat shield. Tests, although inconclusive, indicate that LiH may not be an entirely effective ablative shield due to the dissociation of H_2. Further study is necessary and the incorporation of additional heat shield material combined with impact protection should be considered. Tests should account for long term deterioration due to radiation, space vacuum, temperature, etc.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 7.2.2, 7.3.4 72SD4201-3-2 72SD4201-3-3	RD-004

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. RD-006

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Reactor PM, Isotopes, later facing Vehicles - Shuttle	Disposal

MISSION PHASE/EVENT

End of Mission/Disposal

TITLE: REDUNDANT OR ALTERNATIVE MEANS OF DISPOSAL

STATEMENT Capability shall be provided for a redundant or an alternative means of disposal or recovery of the Reactor/Shield or Isotope.

JUSTIFICATION Early reentry of a post operational reactor must not be permitted, as source terms can be high with corresponding relatively high risks to the general populace.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Consider replaceable disposal module components, a replaceable disposal module and or the use of the Space Shuttle as a means of recovery

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 7.3.4 72SD4201-3-2 72SD4201-3-3 72SD4201-4-1	RD-004

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. RD-007

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Isotopes	Packaging, Transportation, Storage and Handling

MISSION PHASE/EVENT

Prelaunch

TITLE: ISOTOPE HEAT SOURCE SHIPPING AND STORAGE CONTAINER DESIGN

STATEMENT Provide isotope shipping and storage containers and procedures in conformance with AEC Manual, Chapter 0529 and the Department of Transportation regulations in Volume 33 No. 194 of the Federal Register.

JUSTIFICATION Shipping and storage containers used with nuclear material must be designed to and in conformance with the above regulations to allow authorized shipping and storage within the U.S.A. and to minimize hazard potential.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Design must include prevention of critical masses, provide for adequate cooling and freedom from penetration.

Refer to SNAP-27, SNAP-19 and IRV shipping container designs and philosophy.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Sections 5.2.1, 5.2.3 SC-M-70-434 Isotope Brayton Safety Feasibility Study	RO-003

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. RD-008

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Isotopes	

MISSION PHASE/EVENT

Prelaunch, Launch Ascent, Orbital Operations, End of Mission

TITLE: HEAT SOURCE FUEL CAPSULE CONTAINMENT

STATEMENT Provide heat source encapsulation to prevent fuel release under all credible subjected environments

JUSTIFICATION Prevention of fuel release will significantly reduce the source terms and potential hazards to personnel by ingestion and inhalation.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.1, 5.2.3, 6.3 72SD4201-4-1 72SD4201-4-2	GD-068

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. RD-009

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Isotopes	Launch

MISSION PHASE/EVENT

Prelaunch, Launch Ascent

TITLE: FRAGMENTATION PROTECTION

STATEMENT Provide fragmentation protection for isotope fuel capsules in shipping container design and in the launch configuration to reduce fuel capsule rupture potential from penetration, and explosive accidents

JUSTIFICATION Fragmentation protection will reduce the source terms associated with the release of fuel.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Fragmentation protection can be placed around the fuel capsule or in special cases, placed near the penetrating or explosive source.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.1, 5.2.2, 5.2.5, 5.3	GD-022

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. RD-010

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Isotopes, Ground Support	Ground Operations

MISSION PHASE/EVENT

Prelaunch, Launch Ascent, End of Mission

TITLE: ISOTOPE HEAT SOURCE COOLING

STATEMENT Provide redundant external cooling for isotope heat sources during non-operational periods to lower and maintain capsule temperatures at or below 420°K in the natural open air environment.

JUSTIFICATION Isotope fuel capsule cooling to 420°K is required to prevent fuel clad oxidation and eventual rupture in an open air environment and to reduce the ignition potential. Fuel clad weakening and ruptures will increase the radiological source terms and associated hazard to personnel.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Cooling to prevent capsule damage is most important where refractory metal encapsulation is used.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.1, 5.2.3, 5.2.5	GO-025 GD-044

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. RD-011

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Ground Support, Facilities	Ground Operations

MISSION PHASE/EVENT

Prelaunch, Launch/Ascent, End of Mission/Recovery

TITLE: PERSONNEL DOSIMETRY AND RADIATION MONITORING (GROUND)

STATEMENT Personnel dosimetry and or portable and fixed radiation monitoring/alarm provisions must be available and used in all areas designated "Radiation Areas" in accordance with 10CFR-20 (yearly radiation levels which may exceed 0.5 rem per year).

JUSTIFICATION To monitor and control radiation doses received by personnel. To avoid over exposures and to take necessary remedial actions should radiation doses reach undesirable levels.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Equipment includes portable, pocket type and fixed dosimetry and alarms in addition to biological specimens (urinanalysis).

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.6, 5.3.3	GD-051 GD-052 GD-053 GD-059

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. RO-001

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	General	Ground Support, Orbital Activities

MISSION PHASE/EVENT

All Phases

TITLE: STRICT ADHERENCE TO PROCEDURES AND REGULATIONS

STATEMENT Provide and enforce training, instruction, drills, signs and written procedures for work in and around nuclear and liquid metal facilities and hardware.

JUSTIFICATION The importance of this type of enforcement cannot be over stressed in the nuclear industry due to the nature of the unseen, unheard and unfelt radiation. Abiding by regulations and rules must be inborn.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5, 5.2.6	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. RO-002

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	General, Facilities	Ground Activities

MISSION PHASE/EVENT

Prelaunch

TITLE: PERSONNEL LIMITATIONS AND REGULATIONS

STATEMENT Limit and regulate personnel in nuclear hardware designated areas.

JUSTIFICATION Prevent untrained and unauthorized personnel errors involving nuclear hardware and minimize and record radiation dose to personnel.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. RO-003

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM, Isotope, Facilities	Assembly, Transportation and Storage

MISSION PHASE/EVENT

Prelaunch

TITLE: NUCLEAR HARDWARE STORAGE AND PACKING LIMITS

STATEMENT Adhere to nuclear hardware storage and packing limits to prevent critical assemblies.

JUSTIFICATION Storage and packing limits must be determined and adhered to to prevent critical masses and subsequent severe nuclear radiation hazards.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Anti-criticality containment should be specified and designed into storage and shipping containers.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.4	RD-007

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. RO-004

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Reactor Disposal

MISSION PHASE/EVENT

End of Mission/Disposal

TITLE: REACTOR DISPOSAL RECOVERY

STATEMENT Provision should be made for a high earth orbit boost of the reactor power module or reactor/shield which permits a decay lifetime of >100 years. A prime alternative to this guideline is the use of the proposed shuttle as a means of recovery to the earth.

JUSTIFICATION The principle nuclear risks to the general populace are during the End of Mission/disposal phase due to the potential large fission product inventory of the reactor core. A highly reliable boost to an orbit of a minimum of 100 years decay time will allow fission products to decay to nearly negligible levels.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Reliability of disposal boost package is key element. Eventual re-entry of reactor/shield may not result in a radiological safety hazard, but may be undesirable politically. Retrieval or reboost should be considered.

The availability of an earth-space shuttle provides a reliable and minimum risk mode of reactor disposal/recovery.

REFERENCES	CROSS REFERENCES
72SD4201-2 Section 7.2.2, 7.3.4, Appendix E 72SD4201-3-2 72SD4201-3-3 72SD4201-4-1 72SD4201-4-2	GO-051

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. RO-005

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Experiments, Isotopes	Isotope Recovery

MISSION PHASE/EVENT

Orbital Operations, End of Mission

TITLE: RETURN TO EARTH OF EXPERIMENT ISOTOPES

STATEMENT Provide for the intact return to earth of isotopes and contaminated waste associated with the experiment program.

JUSTIFICATION Radiation contamination of the upper atmosphere should be avoided and random reentry of isotope capsules should not be planned to prevent accidental exposure of the general populace.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Retreival and reentry/recovery by the Space Shuttle should be considered.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.4, 1.3.2 72SD4201-4-1 Section 5 72SD4201-4-2 Section 3	GO-051

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. RO-006

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Range Safety, Ground Support, Reactor PM, Isotopes	Contingency, Recovery

MISSION PHASE/EVENT

Prelaunch, Launch/Ascent, End of Mission/Recovery

TITLE: USE OF IMPACT/RECOVERY TEAM

STATEMENT Provide emergency equipment and trained personnel who can quickly render safe and supervise the recovery and handling of impacted and or damaged nuclear hardware at all potential locations around the world.

JUSTIFICATION Reduce contamination and radiation hazards to the ecology and general populace.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Launch/Ascent and End of Mission phases may require the team to provide render safe and recovery support at any location along the payload trajectory.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5	GO-001

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. RO-007

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Facilities, Reactor PM, Isotopes	Prelaunch Operations and Launch

MISSION PHASE/EVENT

Prelaunch, Launch/Ascent

TITLE: ADMINISTRATIVELY CONTROLLED AREAS

STATEMENT Provide controlled areas for the prelaunch operations and an exclusion area for launch operations. Current 13 Km administratively controlled area appears adequate for perimeter control around nuclear operations. An exclusion area of $\sim$ 4 Km should be established around the launch pad at launch.

JUSTIFICATION To reduce radiation hazard potential to the general populace around the launch site and hazards to ground support personnel at launch.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Specified areas at KSC appear adequate

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.6, 5.3.2	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-001

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	General

MISSION PHASE/EVENT

Prelaunch, Launch Ascent, Orbital Operations

TITLE: RADIATOR COOLANT FLUID SELECTION

STATEMENT Where performance permits, consideration should be given to the use of non-liquid metal radiators to substantially reduce the liquid metal hazards.

JUSTIFICATION Some powerplant cycles, namely the Brayton cycle and organic rankine cycle afford the possibility of a non-liquid metal radiator. Handling, fire protection and facility requirements are simplified. Use of non-liquid metal loops minimizes the associated liquid metal hazards.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Non-liquid metal radiators provide reduced liquid metal inventory and hazards, but due to their lower operating temperature are larger in overall area. Other performance tradeoffs need to be considered

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.2, 5.2.3, 5.2.5, 5.2.6, 7.2.4 72SD4201-3-2	GD-020

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-002

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Reactor PM, Ground Support, Facilities	Prelaunch Operations

MISSION PHASE/EVENT

Prelaunch, Launch/Ascent

TITLE: REACTOR POWER MODULE LIQUID METAL ENVIRONMENTAL PROTECTION

STATEMENT Provide protection/isolation of the liquid metal components and radiators from the ambient air, O_2, water and other hydrogenous substances during prelaunch and launch ascent operations.

JUSTIFICATION Liquid metals such as NaK, react with O_2 and hydrogenous substances. Reactions can result in fires and possibly explosions which can be the cause of severe equipment damage and secondary fires.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Double wall containment can be provided to prevent leaks to the air in many situations. Some components cannot be efficiently designed with double wall containment and the best single protection may be the use of an environmental cover gas (blanket) such as Argon, Helium or Nitrogen. Such a blanket can be in place throughout most of the prelaunch and launch operations.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.2, 5.2.3, 5.2.5	GO-002 GD-003

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-003

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Reactor PM, Ground Support	Launch Site Operations

MISSION PHASE/EVENT

Prelaunch

TITLE: ENVIRONMENTAL PROTECTION AT LAUNCH SITE (REACTOR PM)

STATEMENT Consider provision of an environmental protective shroud (vapor barrier) around power module while at launch site.

JUSTIFICATION Provides an added measure of protection in the humid and salt laden air at KSC. Reduces possibility of liquid metal reactions.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Barrier could be included in thermal shroud and designed to assist purging operations.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.5	GD-002 GD-006

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-004

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	General

MISSION PHASE/EVENT

Prelaunch, Launch Ascent, End of Mission

TITLE: REACTOR DESIGN TO PRECLUDE CRITICALITY ACCIDENTS

STATEMENT Provide a reactor design which is relatively free from criticality accidents (power excursions) resulting from collisions, pad explosions or impact on the earth's surface or water.

JUSTIFICATION The risk to the general populace during the prelaunch and launch ascent phases of the mission can practically be eliminated if excursions can be prevented. A reactor excursion is a major source of radiation and this potential risk to the general populace needs to be avoided.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS The reference ZrH reactor is relatively insensitive to criticality accidents. It is relatively free from compaction accidents which can bring about an excursion. Areas of concern include possible control drum rotation, overmoderation due to water or hydrogen immersion, etc.

The use of an alternative reactor (e.g.; fast reactor) may require additional study and design effort to reduce this hazard

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.3, 7.2.1, 7.2.2, 7.2.5 72SD4201-2-1A 72SD4201-3-3	RD-003

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-005

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Reactor Control and Start-up

MISSION PHASE/EVENT

Prelaunch, Orbital Operations

TITLE: REACTOR CONTROL DRUM POSITION INDICATORS

STATEMENT Provide an independent means of sensing individual reactor control drum position.

JUSTIFICATION Control drum position indication will assist in the control drum/actuator rotation checks conducted in ground checkout and will provide positive control position during startup and reactor operations in orbit.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Present ZrH reactor utilizes a pulse counting system which is not a positive means of determining control drum position should a drive train failure or a sticking drum occur. Detents to indicate rotation past designated points could be considered.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.5, 7.2.2	GO-011 GO-012

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-006

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Leak Containment

MISSION PHASE/EVENT

Prelaunch, Launch Ascent, Orbital Operations

TITLE: NaK LEAK CONTAINMENT

STATEMENT Provide a means to minimize or contain a NaK leak within a reactor power module.

JUSTIFICATION Reduce potential hazards, radioactive NaK contamination and fire potential.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Double containment and isolation values should be considered. Use of an additional barrier such as an inert cover gas during prelaunch activities should also be considered.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.2, 5.2.5, 5.2.6, 6.2.2, 7.2.1, 7.2.2	GD-003 GD-007

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-007

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Leak Detection

MISSION PHASE/EVENT

Prelaunch, Launch Ascent, Orbital Operations

TITLE: NaK COOLANT LEAK DETECTION

STATEMENT Provide means of measuring/detecting NaK leaks within the coolant loops.

JUSTIFICATION Minimizes the NaK release hazards and will provide early determination of leaks, possible affected areas and implementation of emergency procedures. An early detection and subsequent safing on the launch pad may prevent major equipment damage due to fire and explosions. Detection during ascent would preclude docking of a damaged powerplant.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Consider use of pressure and flow measurements in the coolant loops. When combined with Guideline GD-006, provides a means of detection, isolation and switchover to redundant loop.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.2, 5.2.5, 6.2.2, 7.2.1	GD-003 GD-006

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-008

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Reactor Separation from PM

MISSION PHASE/EVENT

Prelaunch, Orbital Operations, End of Mission

TITLE: REACTOR PRIMARY LOOP AND INTERMEDIATE LOOP SEPARATION

STATEMENT Provide a means of separating the reactor/shield from the intermediate coolant loop and primary radiator.

JUSTIFICATION Provides a clean separation interface which (1) allows separate shipment of the reactor/shield apart from the rest of the power module, (2) permits reactor/shield or primary radiator replacement in orbit and (3) permits disposal or recovery of just the reactor/shield. These features minimize the transportation, handling, and disposal hazards. The boost to high earth orbit of the reactor/shield only, will increase the objects ballistic coefficient to achieve orbital decay lifetimes 9 to 10 times greater than achievable with a complete power module.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Consider the use of a separable heat exchanger concept.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.3, 7.2.2, 7.3.4	RD-004

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-009

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Disposal Module Rocket and Component Installation

MISSION PHASE/EVENT

Prelaunch, End of Mission

TITLE: REACTOR DISPOSAL ROCKETS AND COMPONENTS DESIGNED FOR SEPARATE INSTALLATION

STATEMENT
Capability shall be provided for the installation of rocket motors at the launch pad and the replacement of life limited "black box" components in-orbit prior to enacting disposal.

JUSTIFICATION Rocket motor installation at the launch pad reduces the hazards within the nuclear assembly facilities and in the Vehicle Assembly Building. In-orbit replacement of black boxes permits repair of a faulty disposal module so disposal can be enacted.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Consider possibility of engine room type replacement in-orbit to allow IVA and possible shirtsleeve environment.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.3, 5.2.5 72SD4201-3-2	GO-007 GD-029

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-010

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Reactor PM	Reactor Shutdown - Restart

MISSION PHASE/EVENT

Launch Ascent, Orbital Operations

TITLE: PREVENTION OF NaK COOLANT LOOP FREEZE-UP

STATEMENT Assure against NaK coolant freeze-up within the coolant loops of the power module.

JUSTIFICATION NaK-78 freezes at $\sim 260^{o}K$ ($12^{o}F$) and would be subject to freezing during launch ascent and in orbit when the reactor is not in operation. Severe freezing can cause coolant loop damage. Frozen loops also become difficult to thaw in order to permit circulation and cooling of the reactor. Overtemperature conditions or complete failure to operate can result.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Freeze conditions can exist at launch, ascent and in orbit. Freeze-up can also occur after a reactor shutdown and prior to restart. Consideration should be given to a radiator shroud which can be removed or repositioned on command and or electrical or nuclear heaters in the loops coupled with circulation. A barbeque mode could also be used to some advantage.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 7.2.2	GD-001

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-011

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM, Range Safety	Tracking

MISSION PHASE/EVENT

Launch, Ascent, End of Mission

TITLE: REACTOR TRACKING AND IMPACT LOCATION DEVICES

STATEMENT Provide reactor/tracking and impact location devices which can assist in orbit and reentry tracking and location of impact zones on the earth or in shallow water areas.

JUSTIFICATION Principle risks to the general populace occur during the end of mission phase upon reentry and impact of the reactor on the earths surface (Shuttle recovery will minimize the hazards). Tracking and eventual location of the reactor will provide added warnings and quick isolation of hazards should reentry and impact occur either on launch/ascent or during the end of mission.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Effective for reservoir, lake or land impact. Transponders, pingers, dye markers etc. can be considered. Reliability over the hundreds of years lifetime in a wide range of temperatures and servere radiation environment must be an important design goal.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.3.2, 5.4, 7.3.4 72SD4201-3-3	RD-004 GO-050 GO-051

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-012

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Decay Heat Removal

MISSION PHASE/EVENT

Orbital Operations, End of Mission

TITLE: INDEPENDENT REACTOR/SHIELD DECAY HEAT REMOVAL

STATEMENT Provide an independent reactor/shield decay heat removal system capable of the dissipation of reactor heat in the event of loss of coolant during operation.

JUSTIFICATION Prevents reactor meltdown and subsequent release of fission products and activated materials. Reduces nuclear hazards in orbit.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS The reference ZrH power plant has marginal self cooling capability at its normal 330 kWt operating power level. Higher power levels would require the heat removal system. Similar consideration should be given to alternative powerplant designs. Multiple operating PCS can also reduce the possibility of these situations.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.2.2, 6.3.2, 7.2.2, 7.3.4	GD-034 GO-019

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-013

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Ground Support (Mission Control)	MCC, Reactor PM	Operations and Disposal

MISSION PHASE/EVENT

Orbital Operations and End of Mission

TITLE: GROUND CONTROL BACKUP OF REACTOR POWER MODULE OPERATIONS

STATEMENT Provide real-time back-up and alternate control and monitoring of reactor power module operations via the Mission Control Center.

JUSTIFICATION Provides contingency and backup capability. Permits the additional ground support required in obtaining and evaluating reactor power module operating histories and fault diagnosis. Assists in mission planning and logistic resupply. Permits disposal control functions to be administered by the MCC if necessary.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Requires long term attended support by Mission Control Center personnel.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Sections 5.2, 5.3.4, 5.4.2, 7.2.2, 7.3.4 72SD4201-3-3	GO-048 GD-027

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-014

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Reactor PM	Power Module Operation

MISSION PHASE/EVENT

Orbital Operations End of Mission

TITLE: PRIMARY LOOP NaK COMPONENT LOCATION

STATEMENT Primary loop NaK components (e.g., accumulator, pumps, heat exchanger) should be located within a gallery which provides shielding of the crew from the activated NaK. This shielding is particularly important during maintenance operations within the power module engine room.

JUSTIFICATION Radiation doses from unshielded NaK can be a significant contributor when full 4π reactor shields are used.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Galleries can be placed between the reactor and the shield or as in the case of the reference Space Base power module - placed on the outside of the reactor shield but away from the Space Base and crew quarters.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 7.2.2, 7.3.3	GO-021

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-015

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Maintenance and Repair

MISSION PHASE/EVENT

Orbital Operations

TITLE: POWER CONVERSION SYSTEM PLACEMENT

STATEMENT The Power Conversion System components including rotating equipment should be placed toward the aft of the Power Module to permit ease of maintenance and lower radiation doses to the crew. Placement of the TAC unit in the aft section away from the reactor shield will also reduce shield fragmentation potential caused by TAC failures.

JUSTIFICATION Radiation levels drop significantly as you move away from the reactor/shield within the power module ~a factor of 10 in 5 meters.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Placement of the components within an engine room at the aft end of the Power Module (~ 8.5 meters from the reactor) can lower radiation levels to less than 40 mrem/hr thereby permitting repair stay times of several hours. A pressurized compartment can also be considered.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 7.2.6, 7.3.3 SD-60-168-2 Volume II	GD-017 GD-025 GD-033

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-016

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Reactor PM	Operation

MISSION PHASE/EVENT

Orbital Operations

TITLE: MULTIPLE POWER CONVERSION SYSTEM OPERATION

STATEMENT Consider the provision of simultaneous operation of two power conversion systems with each operating reactor.

JUSTIFICATION Provides a means of maintaining power in the event of failure of one unit and also provides for the dissipation of reactor heat while an additional unit comes on line. Minimizes temperature transients of the reactor and potential temperature excursions due to abrupt loss of cooling accidents.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Normal load can be split between two power conversion systems with each unit capable of operating at twice its normal power.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 7.2.2, 7.2.6	GD-020

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-017

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Maintenance and Repair

MISSION PHASE/EVENT
Orbital Operations

TITLE: PRESSURIZED AND TEMPERATURE CONTROLLED ENGINE ROOM

STATEMENT Provide a pressurizable and temperature controlled engine room within the reactor power module which is accessible without the need of EVA from the Space Vehicle.

JUSTIFICATION Facilitates repairs of the reactor power conversion system and electrical distribution system hardware and minimizes crew radiation exposure during maintenance duties. Allows for shirtsleeve maintenance.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG
			X

REMARKS: Engine room does not require continuous pressurization but should be capable of being environmentally controlled within a few minutes by command from the space vehicle.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 7.2.2, 7.3.3	GD-025 GD-015 GD-026 GD-050

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-018

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Reactor PM	Maintenance

MISSION PHASE/EVENT

Orbital Operations

TITLE: USE OF MULTIPLE REDUNDANCY IN HIGH RADIATION AREAS

STATEMENT Consider use of multiple redundancy components in high radiation areas of the power module and where EVA is required.

JUSTIFICATION Reduction or elimination of maintenance time in high radiation areas will reduce the radiation dose to the crew and extend the life of the PM where maintenance could not be allowed.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 7.3.3	GO-021

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-019

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Maintenance and Repair

MISSION PHASE/EVENT

Prelaunch and Orbital Operations

TITLE: "BLACK BOX" MAINTENANCE FOR REPARABLE EQUIPMENT

STATEMENT Employ the "black box" modular replacement approach in the design of equipment within the engine room and other repairable locations of the reactor power module.

JUSTIFICATION Facilitates repairs, reduces diagnosis required and piece part storage and minimizes crew radiation exposure by shortening repair time.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG
			X

REMARKS Black box maintenance can be applied to the component, subsystem and system level. It lends itself to ease of repair either in or out of a space suit and can substantially reduce dexterity required and overall stay time in potentially hazardous environments.

This approach should be considered for other systems in the space vehicle where repair times must be minimized due to hazardous environments.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 7.3.3	GD-022

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-020

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Maintenance and Repair

MISSION PHASE/EVENT

Orbital Operations

TITLE: NON-REPARABLE, REDUNDANT NaK LOOP DESIGN PHILOSOPHY

STATEMENT The philosophy used in the design of the NaK coolant loops should be one of no repair in orbit, but which provides for long life through redundancy, isolation systems, increased armor and double containment.

JUSTIFICATION The hazards, corrosiveness and handling complexities of NaK make the repair of NaK lines in a space environment unfeasible.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS It does not appear advisable nor practical to assume repair by the crew of the NaK coolant loops of a reactor power module. Replacement is advisable.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.2.2, 7.3.3	GD-001 GD-016 GO-020 GD-024

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-021

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Reactor PM, Isotopes	Maintenance and Repair

MISSION PHASE/EVENT

Orbital Operations

TITLE: USE OF QUICK DISCONNECTS

STATEMENT Provide quick disconnects wherever possible in high radiation and other hazardous areas.

JUSTIFICATION Reduce maintenance time and hence reduce radiation exposure of the crew.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 7.3.3.	GD-014

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-022

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM, Isotopes	Maintenance and Repair

MISSION PHASE/EVENT

Orbital Operations

TITLE: PROTECTIVE SHIELDING AROUND DYNAMIC MACHINERY

STATEMENT Provide protective shielding around dynamic machinery within the power module to prevent injury to personnel and damage to other hardware.

JUSTIFICATION The PCS is comprised of high speed dynamic machinery which if overspeeds or otherwise flys apart can cause extensive sharpnel damage to adjacent hardware or injury to personnel in the area. Shielding can confine the damage.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS The placement of shielding involves a trade-off of distance, size etc. for maximum effectiveness and minimum weight.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 7.3.3	RD-009 GD-033 GD-015

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-023

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM, Isotopes	Maintenance and Repair

MISSION PHASE/EVENT

Orbital Operations

TITLE: HIGH TEMPERATURE AND ELECTRICAL HAZARD GUARDS

STATEMENT Provide guards around high temperature equipment and electrical hazards within the working areas of the power module.

JUSTIFICATION Coolant lines, heat exchangers and the PCS hardware may operate at temperatures from 150°K up to 900°K or so. Electrical hazards also are present. Guards preventing contact will reduce potential damage to clothing and personnel.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 7.3.3	GD-017

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-024

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Operation, Maintenance

MISSION PHASE/EVENT

Orbital Operations

TITLE: METEORITE AND SPACE DEBRIS PROTECTION OF NaK LOOP

STATEMENT Provide impact protection of primary NaK coolant lines to minimize probability of meteorite and space debris damage and subsequent loss of coolant and release of fission products.

JUSTIFICATION Meteorite and space debris impact probabilities are such that added protection in exposed areas can reduce the possibility of releasing radioactive NaK to the space environment surrounding the space vehicle.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Increased armor and/or double wall containment in exposed areas can be considered. The gallery is exposed in the reference design of the study.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.2, 7.2.1, 7.2.2	GD-020

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-025

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Maintenance and Repair

MISSION PHASE/EVENT

Orbital Operations

TITLE: PLACEMENT OF REPARABLE COMPONENTS

STATEMENT Components with repair frequencies less than the lifetime of the power module should be placed in the engine room.

JUSTIFICATION Maintenance and repair in the engine room will eliminate need for EVA and reduce radiation dose to the crew

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 7.3.3	GD-017

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-026

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Maintenance and Repair

MISSION PHASE/EVENT

Orbital Operations, End of Mission/Disposal

TITLE: PLACEMENT OF DISPOSAL SYSTEM ELECTRONICS

STATEMENT Consider placement of disposal system electronics within the engine room to provide ease of maintenance and increased environmental protection.

JUSTIFICATION Electronics are susceptible to radiation and temperature fluctuation damage and therefore may exhibit somewhat reduced reliability in long duration missions. Repair or replacement of these components within the engine room as contrasted from external portions of the PM will eliminate EVA and reduce radiation exposure to the crew.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 7.3.3, 7.3.4	GD-017

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-027

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM, Isotopes, Ground Support, MCC	Maintenance and Repair

MISSION PHASE/EVENT

Orbital Operations

TITLE: FAULT DIAGNOSIS BY GROUND SUPPORT

STATEMENT Consider the use of ground support systems to assist in the diagnosis of power module faults and failure conditions while in orbit.

JUSTIFICATION Quick and accurate fault isolation and repair results in minimum system down time and reduces the radiation dose received by the crew during repair operations.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Fault diagnosis should include a tie in with the data management system to provide advanced warnings of degrading conditions which allow ground and orbital preparations for repair. Certain repairs could be made prior to a complete failure and subsequent hazardous condition.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 7.3.3	GD-013 GD-028 GO-048

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-028

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Reactor PM, Isotopes, Communications and Data Mgt, Grd Support	Maintenance & Repair

MISSION PHASE/EVENT

Orbital Operations

TITLE: FAULT ISOLATION DIAGNOSTIC SYSTEM

STATEMENT Provide fault/failure diagnostic capability of the power module to assist in rapid maintenance and repair.

JUSTIFICATION Quick fault isolation and repair results in minimum down time of the power system or portions thereof and reduces the time spent in maintenance and hence reduces the radiation dose received in relatively high radiation areas.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Fault diagnosis system could be tied in with the control room of the Base so that maintenance procedures can be planned prior to entrance into the PM engine room. Ground support can also provide added diagnostic data.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 7.3.3	GD-027 GD-048

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-029

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Disposal

MISSION PHASE/EVENT

Orbital Operations, End of Mission/Disposal

TITLE: MODULAR REPLACEMENT OF DISPOSAL SYSTEM

STATEMENT Consider use of a modular disposal system which is capable of being separated from and installed to the Power Module in orbit.

JUSTIFICATION End of mission risks can be reduced by successful operation of the disposal system. Long duration missions in the space and high radiation environments may cause failures in the disposal system. A replaceable module would provide higher total reliability and reduce or eliminate EVA maintenance and hence reduce the radiation dose to the crew.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS A disposal module compatible with the Shuttle should be considered.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 7.3.4 72SD4201-3-3 Section 4	RD-004 GD-009 GO-007

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-030

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM, Communications & Data Management	Normal PM Operations

MISSION PHASE/EVENT

Orbital Operations

TITLE: DETECTION OF ABNORMAL RADIATION FROM REACTOR SHIELD

STATEMENT Provide radiological instrumentation to detect increased radiation resulting from reactor shield damage.

JUSTIFICATION Early detection of shield damage will allow the crew and ground logistics to enact early repair or replacement and reduce the potential radiation hazard to the crew.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS This instrumentation could be combined with pressure transducers in the shield compartments.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.2, 7.3.3	GD-032

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-031

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Reactor PM	Shield Leak Detection

MISSION PHASE/EVENT

Orbital Operations, End of Mission

TITLE: INSURE REACTOR NEUTRON SHIELD INTEGRITY

STATEMENT Provide means to improve and insure reactor neutron shield integrity during operation.

JUSTIFICATION The H_2 of a LiH shield dissociates when exposed to space vacuum. This situation can result from a puncture of the stainless outer clad by meteorites, space debris, collision and possibly natural causes. A puncture will cause an increase in the radiation level in the vicinity of the puncture and can ultimately lead to a gradual reduction of the entire shield effectiveness.

HAZARD CATEGORY			
CAT	CRIT	MARG.	NEG

REMARKS Double containment and compartmentalized sealed sections would minimize the shielding loss due to puncture or leaks and allow additional time for repair or replacement.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.2.2, 6.3.2, 7.2.1, 7.2.2	GD-030 GD-032

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-032

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Shield Leak Detection

MISSION PHASE/EVENT

Orbital Operations, End of Mission

TITLE: LiH SHIELD PUNCTURE DETECTION

STATEMENT Provide instrumentation to detect Reactor LiH shield puncture.

JUSTIFICATION Early detection of shield puncture will allow the crew and ground logistics to affect repair or replacement, warn of possible radiation streaming and in general minimize the radiation hazard.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS: Pressure transducers in shield compartments would complement Radiological safety instrumentation.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.2, 7.3.1, 7.3.3	GD-030

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-033

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Power Module Operation

MISSION PHASE/EVENT

Orbital Operations

TITLE: REACTOR/SHIELD FRAGMENTATION PROTECTION

STATEMENT Provide reactor/shield protection against fragmentation accidents in the event of Power Conversion System (rotating machinery) overspeeds and the like, during orbital operations.

JUSTIFICATION Fragmentation damage can render shield ineffective for radiation attenuation and may reduce or eliminate the shield reentry capability. Reentry may result in burnup and dispersal of radioactive material in atmosphere.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Several design features can reduce or nearly eliminate this potential hazard. Consider the placement of the turbomachinery the maximum feasible distance away. Also fragmentation shields can be placed around or near the PCS or near the shield. Certain NaK lines may also require protection.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 7.2.1, 7.2.2	GD-015 GD-022

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-034

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Shield Cooling

MISSION PHASE/EVENT

Orbital Operations and End of Mission

TITLE: REACTOR SHIELD COOLING

STATEMENT Consider provision of a reactor shield cooling system which will provide for reduced and more evenly distributed shield temperatures during peak operations and reduce or prevent LiH dissociation and associated loss of neutron shield effectiveness.

JUSTIFICATION Local temperatures in the reference design range up to 900°K. Configuration changes such as additional reentry protection would aggravate the problem. Reactor shields utilizing lithium hydride should be maintained at sufficiently low temperatures to minimize hydrogen vapor pressure which results from dissociation. Heating of the shield results from neutron absorption and reactor core heat losses during normal operation and reactor after-heat due to power system shutdown.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Several design concepts appear feasible, one such concept involves the use of variable conductance heat pipes to control the temperature. The system could be designed to maintain the shield at the desired temperature with the variable conductance feature maintaining temperatures during periods of increased heat load.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 7.2.2, 7.3.3, 7.3.4	GD-012 GO-019

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-035

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Reactor Shutdown

MISSION PHASE/EVENT

End of Mission/Disposal/Recovery

TITLE: POSITIVE AND PERMANENT REACTOR SHUTDOWN MECHANISM

STATEMENT Provide a positive and permanent reactor shutdown mechanism which renders the reactor inoperable and incapable of obtaining criticality or of undergoing a criticality accident at the end of mission for the power module and prior to enacting disposal or recovery.

JUSTIFICATION Permanent reactor shutdown will prevent excursion accidents in the relatively high risk end of mission phase.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS: Control drum lockouts and/or core poisons are possible candidates. Permanent shutdown mechanisms can be irreversible.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.7.2, 7.3.4	RD-002
72SD4201-3-2 Section 3, 5	GD-038
72SD4201-3-3 Section 4	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-036

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Reactor PM, Structure	Contingency Operations

MISSION PHASE/EVENT

Orbital Operations, End of Mission

TITLE: RAPID RESPONSE PM EJECTION

STATEMENT Consider the capability for a rapid ejection of the PM during orbital operations after PM failures which result in potentially high radiation around the Base.

JUSTIFICATION Conditions (although remote) could occur which result in the deposition of highly radioactive materials in and around the power module. Ejection would reduce the radiation levels to the crew.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Reactor excursions or destruction by collisions etc. are severe catastrophic situations. Radiation levels would be very high and only a quick response (seconds-minutes) will prevent lethal doses from the crew.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.2	GD-037

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-037

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM, Structure	Power Module Separation

MISSION PHASE/EVENT

End of Mission/Disposal

TITLE: POSITIVE MECHANICAL SEPARATION OF REACTOR POWER MODULE

STATEMENT Provide a positive mechanical means of separating the reactor power module from the Space Vehicle or Boom assembly under all potential failure conditions including a loss of power accident.

JUSTIFICATION Permits a highly reliable means of separation from the Space Vehicle interface without EVA or disposal rocket ignition.

HAZARD CATEGORY			
CAT	CRIT	MARG.	NEG

REMARKS A separation system capable of imparting an initial velocity of approximately one meter/second is sufficient.

Provision could be made for separation of the Reactor/Shield from the radiator and/or the Reactor Power module from the Space Vehicle.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Sections 7.2.1, 7.2.2, 7.3.4 72SD4201-3-1	GD-036

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-038

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Reactor Shutdown

MISSION PHASE/EVENT

Orbital Operations, End of Mission

TITLE: POSITIVE REACTOR SHUTDOWN MECHANISM (AFTER LOSS OF ELECTRICAL POWER)

STATEMENT: Provide a positive means for shutdown of the reactor after a loss of electrical power.

JUSTIFICATION Reactor could continue to operate and continue to generate thermal power for some time after loss of power to control system and actuators. A loss of the PCS or radiators would cause loss of cooling and subsequent rupture of fuel elements and possible release of fission products.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Reactor control should be connected to a back-up power supply and control system.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.2.2, 6.3.2, 7.2.1, 7.2.2 72SD4201-3-2	RD-002 GD-039 GD-035

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-039

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Reactor Shutdown

MISSION PHASE/EVENT

Orbital Operations, End of Mission

TITLE: AUTOMATIC REACTOR SHUTDOWN MECHANISM

STATEMENT Provide an effective and automatic means of rapid reactor shutdown in specific failure mode and emergency situations.

JUSTIFICATION To minimize extent of reactor damage and potential hazards due to massive failures in the power module or control system (e.g., loss of coolant, collisions, shield damage, loss of control, etc.).

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Consider the use of a SCRAM mechanism or similar feature. System could be operable in a loss of power accident and where the power module becomes physically and or electrically separated from the Space Vehicle.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.2.2, 6.3.2, 7.2.1, 7.2.2, 7.3.4	GD-038

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-040

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Shield Optimization

MISSION PHASE/EVENT: Orbital Operations

TITLE: REACTOR SHIELD DOSE REQUIREMENTS (OPTIMIZATION)

STATEMENT The major contributor to the power system weight is the reactor shield. A careful tradeoff review of the mission, the natural radiation environment and allowable crew and equipment doses will allow the design of a minimum weight shaped shield.

JUSTIFICATION A mission permitting increased radiation levels away from the spacecraft can reduce outer shielding requirements substantially and not necessarily increased levels in the habitable quarters of the space vehicle. The natural radiation environment may well be the most significant contributor to the crew integrated dose.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Reactor shield optimization can contribute to a significant reduction in power-plant weight. Requirements on radiation levels permitted around and away from the shield should be carefully formulated.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 3.8.2.1, 6.2, 7.2.2	GO-029 GO-033 GO-035

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-041

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM, Comm & Data Mgt., MCC	Operations & Disposal

MISSION PHASE/EVENT

Orbital Operations and End of Mission

TITLE: REACTOR POWER MODULE TELEMETRY, TRACKING AND CONTROL

STATEMENT and control

Provide capability for real-time primary or back-up telemetry tracking of the power module from the Space Vehicle or the ground (Mission Control Center).

JUSTIFICATION Provides contingency capability should hardwire functions within the Space Vehicle be terminated or questioned. Provides ground support in obtaining operating histories and fault diagnosis. Provides location and tracking data and redundant control of critical disposal functions.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Requires a very reliable receiver, transmitter and command control system on the power module which is capable of hardwire or telemetry stimulus. A beacon employed on the reactor shield would enahnce tracking by ground and space radar. Reliability of such a device under the thermal, radiation and long life environment needs to be evaluated.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Sections 5.2,5.3.4,5.4.2,7.2 ,7.3.4 72SD4201-3-3	GO-048 GD-027

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-042

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Isotopes	General

MISSION PHASE/EVENT

All Phases

TITLE: USE OF DEPLETED Pu-238

STATEMENT The use of Pu 238 depleted in O^{17} and O^{18} should be considered when several kg of the material is to be used in manned missions - to reduce radiation doses to the crew and the general public.

JUSTIFICATION A large heat source may contain several hundred kg of Pu 238. The use of depleted fuel will reduce the neutron radiation dose rate from ~ 1400 mrem/hr to less than 300 mrem/hr for a representative heat source.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.1	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-043

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Isotopes	Ground Operations

MISSION PHASE/EVENT

Prelaunch

TITLE: ISOTOPE HEAT SOURCE SHIELDING

STATEMENT Consider the use of special semi portable and/or portable shielding around or near isotope capsules to reduce the integrated radiation dose received by ground personnel who are working with or in near proximity to the sources.

JUSTIFICATION Isotope sources constantly emit radiation. Isotope quantities of the size used in the IRV can emit over 510 mrem/hr at a distance of 1 meter. Shielding can reduce the dose to personnel and allow longer work times in the area.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Shielding should be provided for the assembly of the large heat source fuel capsules.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.1, 5.1.3, 5.2.5 SC-M-70-434 Isotope Brayton Safety Feasibility Study	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-044

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Isotopes, Ground Support	Ground Operations

MISSION PHASE/EVENT

Prelaunch, Launch/Ascent

TITLE: ISOTOPE INERT GAS BLANKET

STATEMENT Isotopes employing refractory metal encapsulation require the use of an inert gas environment when not in vacuum conditions to prevent oxidation of the capsule surface at elevated temperatures.

JUSTIFICATION Oxidation can weaken containment capsule and subject heat source to potential release of fuel situations.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS This is primarily a requirement for refractory metal encapsulation.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.3, 5.2.5	RD-010

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-045

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Isotopes, Ground Support	Handling

MISSION PHASE/EVENT

Preluanch, Orbital Operations, End of Mission

TITLE: ISOTOPE HANDLING TOOLS

STATEMENT. Provide long handled tools, which assure positive (no drop or release) contact with the isotope specimen.

JUSTIFICATION Long handled tools reduce the radiation levels and in particular the thermal hazards of the high temperature isotope sources. Positive contact reduces the possibility of inadvertent dropping of the sources during ground or in-space (possibly zero g and free space) handling.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Tools must not mar the surfaces of the capsule, if used in EVA or in IVA zero gravity conditions, means should be provided to eliminate possibility of release of the tool and/or capsule into free space.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.3	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-046

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Isotopes, Range Safety	Recovery

MISSION PHASE/EVENT

Launch/Ascent, End of Mission/Recovery

TITLE: FLOTATION GEAR FOR LARGE ISOTOPES

STATEMENT Consider use of flotation gear in the recovery of large isotopes.

JUSTIFICATION Reduce potential hazards to ecology and recover high worth material.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Flotation device could be equipped with a time limited device that provides submersion if not recovered within a preselected time.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.3.2	RD-005

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-047

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Subsystems - General	Orbital Activities

MISSION PHASE/EVENT

Orbital Operations

TITLE: SUBSYSTEM/COMPONENT PIECE PART SELECTION FOR RADIATION HARDENING

STATEMENT: Select components and component piece parts to minimize degradation due to radiation exposure over the mission duration.

JUSTIFICATION Solid state electronics and similar hardware is most susceptible to degradation/damage due to radiation. Careful selection of components/materials can provide adequate radiation hardening - resistance to radiation to withstand the 10 year mission environment.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Guideline pertains to bulk and ionization damage effects and is not necessarily applicable to dose rate effects causing data degradation.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.3, Appendix A	GD-069

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-048

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Crew Protection, Comm and Data Management, MCC	Collision Warning

MISSION PHASE/EVENT

Orbital Operations

TITLE: COLLISION WARNING SYSTEM

STATEMENT Provide means for monitoring and warning of imminent collisions with space debris and orbiting vehicles.

JUSTIFICATION The probabilities of collision over a 10 year mission are high enough to merit consideration of a warning system which can alert the crew of impending collision of trackable objects. Damage to the Base and or PM can occur, some giving rise to radiological hazards.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Warning system could be tied in with ground systems and be combined with a rapid response orbit adjust system.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.3	GO-028 GD-054 GD-058

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-049

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
SpaceBase	Crew Protection	EVA

MISSION PHASE/EVENT

Orbital Operations

TITLE: USE OF NaK COMPATIBLE EVA SUIT

STATEMENT Provide emergency EVA suits which are compatible with NaK.

JUSTIFICATION EVA operations may occur following accidents which have released NaK around the Base. Compatible suit material will prevent damage to the suit and possible loss of life.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.3	GO-032 GD-050

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-050

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Crew Protection, Reactor PM	Reactor PM Maintenance

MISSION PHASE/EVENT

Orbital Operations

TITLE: CREW SUITS IN PM ENGINE ROOM

STATEMENT Consider the provision of EVA and IVA crew protective clothing (suits) in the engine room to be used for emergency purposes. (Suits to be compatible with the liquid metal environment).

JUSTIFICATION Normal maintenance and repair may be done in a pressurized shirtsleeve environment. However, conditions may arise where a loss of pressure occurs or a liquid metal leak results in unsafe conditions. Donning protective clothing can reduce or eliminate injury and allow continued repair to take place.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Normal maintenance performed in a shirtsleeve environment is desired.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 7.22, 7.3.3	GD-017 GD-049

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-051

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Crew Protection, Structure	Orbital Activities

MISSION PHASE/EVENT

Orbital Operations

TITLE: STORM SHELTER PROVISIONS

STATEMENT Provide Storm Shelter facilities for refuge from solar flare events (particularly applicable for high inclination orbits $> 40^{o}$).

JUSTIFICATION For missions which require crew stay times of a year or more, the expected solar flare dose combined with the other radiation environment will exceed the allowable dose limits to the eyes. A solar flare at anytime can cause rather high doses which could limit the stay-time of the crew. The use of a shelter can substantially reduce the peak doses received and extend crew stay time.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Storm shelter provisions are not required for relatively short duration crew stay times of less than 90 days provided the frequency and intensity of solar flares remains as predicted. Solar flare provisions are discussed in Section 6.3.1.2 of Volume II.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1	RD-011

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-052

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Crew Protection	Orbital Activities

MISSION PHASE/EVENT

Orbital Operations

TITLE: LOCALIZED PROTECTION FOR THE EYES

STATEMENT Consider the use of localized protection for the eyes in relatively high radiation areas.

JUSTIFICATION The dose limit to the eyes appears to be the most limiting. Localized protection of the head and eyes can extend the allowable stay time of a particular crew member.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS The use of special helmets with extra radiation protection for the eyes should be considered. These precautions may impose additional constraints on visibility and crew dexterity and may not be required for the short duration missions.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1	RD-011

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-053

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Crew Protection, Comm. & Data Management	Orbital Activities

MISSION PHASE/EVENT

Orbital Operations

TITLE: ON-BOARD INDIVIDUAL RADIOLOGICAL MONITORING

STATEMENT Provide on-board radiological monitoring of the accumulated radiation dose for each crew member.

JUSTIFICATION Although the natural radiation dose within the Space Base modules is fairly constant, activities around isotopes, repair within the Power Module and EVA activities can provide significant variances. Dose guideline limits established should not be exceeded but maximum effectiveness of the crew is important. Individual monitoring assists in meeting these objectives.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Several special types of personnel dosemetry are necessary and recommended, both portable and fixed.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1, 7.3.1	RD-011

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-054

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Crew Protection, MCC, Comm. & Data Management	Orbital Activities

MISSION PHASE/EVENT

Orbital Operations

TITLE: CENTRAL ON-BOARD RADIOLOGICAL WARNING SYSTEM

STATEMENT Provide a central on-board warning system for the monitoring and alerting against radiological hazards.

JUSTIFICATION The normal hazards are designed for and crew rotation schedules are based on them. However, high intensity solar flares or accidental events can cause a substantial increase in radiation dose. Advanced warnings can help instigate action to prevent or minimize the occurrence by use of solar storm shelters, changing of Space Base orbits etc.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS The central warning system should be supported by ground systems ie, solar flare warnings, and fault diagnosis of nuclear hardware.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.4.1, 6.3.1, 7.3.1	GD-048

SPACE BASE NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-055

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Crew Protection, Experiments, Navigation & Control, Interfacing Vehicles	Orbital Activities, Rendezvous and Docking

MISSION PHASE/EVENT

Orbital Operations

TITLE: LASER BEAM PROTECTIVE DEVICES

STATEMENT Consider the use of crew shielding and warning devices (particularily for the eyes) during laser operations.

JUSTIFICATION Concentrated light (energy) from laser beam sources can damage eye retinas.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Current energy level restructions are set at $10 mW/cm^2$. The threshold level for damage to the retina is 0.1 $joules/cm^2$.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1	GO-045

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-056

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Crew Protection, Experiments, Interfacing Vehicles	Orbital Activities, Rendezvous and Docking

MISSION PHASE/EVENT

Orbital Operations

TITLE: AUXILIARY CREW SHIELDING WITH INTERFACING VEHICLE

STATEMENT Consider the use of supplemental shielding for the crew engaged in servicing detached experiment modules/interfacing vehicles containing nuclear sources.

JUSTIFICATION Normally unmanned detached vehicles containing nuclear sources may not be provided with personnel shielding. Additional protective shielding carried by the Tug, Shuttle or on the Base can be used to minimize the dose to the repair/servicing crew, especially where extended operations are involved.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-057

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Navigation and Control, Interfacing Vehicles	Orbital Activities

MISSION PHASE/EVENT

Orbital Operations

TITLE: SCREENING OF DOSE RATE SENSITIVE NAVIGATION & CONTROL EQUIPMENT

STATEMENT Consider the screening of dose rate sensitive navigation and control equipment to eliminate catastrophic interference from high radiation levels during normal operations or accident conditions.

JUSTIFICATION Screening/protection during approach and rendezvous operations can prevent erroneous operation of attitude sensors and possible control and guidance errors or destruction of sensitive components.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Design of navigation and control equipment should consider possible effects of gamma and neutron radiation from reactor sources.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.3, App A	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-058

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Navigation & Control	Orbit Change

MISSION PHASE/EVENT

Orbital Operations

TITLE: RAPID ORBIT ADJUST CAPABILITY

STATEMENT Consider providing sufficient orbit adjust capability to rapidly change the Space Base altitude.

JUSTIFICATION Some remote accident situations or events result in considerable fission products, gases and radioactive debris around the space. A rapid change of orbit can reduce the accumulated dose to subsystems and the crew.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Orbit adjust for worst case situation would require a change of orbit ~10Km within several minutes of the detection.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.3, 6.3.2	GD-048

SPACE BASE NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-059

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Communications & Data Management, MCC	Radiological Safety Operations

MISSION PHASE/EVENT

Orbital Operations

TITLE: ON-BOARD SUPPORT OF RADIOLOGICAL SAFETY PROGRAM

STATEMENT Provide capability and interfaces with the Communications and Data Management system to support the recording, processing and handling of radiation dose data.

JUSTIFICATION This capability is particularly important when large crews are to be supported. Individual doses will vary during the mission and it is important to record and process dose data on a periodic basis to assure that overdoses and ineffective use of the crew does not result.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Communication and data management system can be tied into the ground network.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1, 7.3.1	GO-053 RD-011 GO-048

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-060

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Environmental Control and Life Support, Isotopes	Radioactive Waste Disposal

MISSION PHASE/EVENT

Orbital Operations

TITLE: SEPARATE WASTE MANAGEMENT SYSTEM FOR RADIOACTIVE WASTE

STATEMENT Provide a separate waste management system(s) for crew and laboratory contaminated (radioactive) waste.

JUSTIFICATION Radioactive waste (tracer materials) from the crew and laboratories will be comprised of low level radiation. The radioactivity would not be eliminated from the system but in a closed cycle waste management system would be reprocessed and find its way into potable water. Separate systems would eliminate the problem.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1	GD-080

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-061

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Environmental Control and Life Support, Isotopes	Orbital Activities

MISSION PHASE/EVENT

Orbital Operations

TITLE: SEPARATE ATMOSPHERE CONTROL FOR LABS CONTAINING ISOTOPES AND TRACERS

STATEMENT: Consider the use of separate atmosphere control in laboratories/modules with high concentrations of isotope in use or in storage.

JUSTIFICATION A release of isotopes/tracers into the atmosphere must be prevented from low level contamination of the entire Base. An isolatable or entirely separate environmental control system would assist contamination control.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Labs employing isotopes/tracers could be located adjacent to one another and common atmosphere control systems could be considered in specialized cases.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1, 7.3.1, 7.3.2	GD-080

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-062

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Environmental Control and Life Support, Isotopes	Orbital Activities

MISSION PHASE/EVENT

Orbital Operations

TITLE: LOCALIZED RADIATION SHIELDING FOR ISOTOPE SOURCES

STATEMENT Provide localized radiation shielding for isotope sources located near habitation quarters or near susceptible subsystems or experiments.

JUSTIFICATION Although the dose rates associated with most of the candidate isotope systems are low, the accumulated dose to the crew and critical subsystems must be accounted for. Localized shielding can effectively reduce the hazard.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS The isotope powered waste management system is typical of the type of isotope that would be located in or near habitation quarters.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.3, 7.3.2	GD-063

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-063

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Structure, Isotopes, Environmental Control and Life Support	Orbital Operations

MISSION PHASE/EVENT

Orbital Operations

TITLE: LOCATION OF ISOTOPE HEAT SOURCES

STATEMENT Consider locating isotope heat sources in areas of low traffic which are not continuously occupied by a specific individual(s).

JUSTIFICATION Even through radiation dose rates associated with an isotope heat source may be relatively low, consideration must be given to the accumulated dose.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS An isotope powered waste management system is a typical isotope heat source which would be in or near a habitable area but should be removed from the high traffic or constant occupation areas in so far as possible.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.3, 7.3.2	GD-062

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-064

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Structure, Environmental Control and Life Support	Orbital Activities Maintenance

MISSION PHASE/EVENT

Orbital Operations

TITLE: USE OF STRIPPABLE COATINGS

STATEMENT Consider using strippable thermal control coatings on the vehicle exterior surfaces for long term maintainability and as a means of NaK or fission product decontamination.

JUSTIFICATION Several failure modes have identified the possibility of NaK or fission products being deposited on the outer surface of the Base. To avoid possible abandonment of the Base, a strippable coating could be used to bring radiation levels down to allow habitation.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS: Strippable coatings could also be considered for Interior surfaces vulnerable to contamination.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1, 7.2.2	GD-066

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-065

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Structures	Orbital Activities

MISSION PHASE/EVENT

Orbital Operations

TITLE: COMPARTMENT ISOLATION/EJECTION

STATEMENT Consider capability to isolate or eject compartments containing a high concentration of isotopes/tracers.

JUSTIFICATION Isolation or ejection of a contaminated compartment will reduce the hazard to other subsystems and the crew.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS If modules containing significant quantities of isotope were attached modules which could be jettisoned or returned to earth following use or an accident, the radiation hazards around the Base could be reduced.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.3, 7.2.2, 7.3.2	GD-080

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-066

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Structures	Orbital Activities

MISSION PHASE/EVENT

Orbital Operations

TITLE: USE OF NaK COMPATIBLE STRUCTURAL MATERIAL

STATEMENT Consider the use of outer structural materials compatible with NaK.

JUSTIFICATION Several potential accidents can cause a release of NaK and possible deposit on the Base structure. Corrosion can result if non-compatible materials are used.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.3, 7.2.2	GD-067

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-067

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Structures	Orbital Activities

MISSION PHASE/EVENT

Orbital Operations

TITLE: COATING OF STRUCTURES FOR NaK COMPATIBILITY

STATEMENT Consider the coating of structural surfaces (pressure hulls, tankage, etc.) with material compatible with NaK.

JUSTIFICATION Several potential accidents can cause a release of NaK and possible adherence to the Base structure. Corrosion can result if non compatible materials are used. The uses of special coating could prevent NaK corrosion.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.3, 7.2.2	GD-066

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-068

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Experiments, Isotopes	Isotope Storage

MISSION PHASE/EVENT

Prelaunch, Launch/Ascent, Orbital Operations

TITLE: STORAGE AND CONTAINMENT OF ISOTOPES IN EXPERIMENTS

STATEMENT Provide secure, anti-spill, and unbreakable containers for the storage and use of isotopes (tracers, capsules) both in launch and operational configurations in zero "g" and artificial "g" conditions.

JUSTIFICATION Spilllage or release of isotope material, & tracers can result in low level contamination of parts of or entire modules.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Double containment and special seals should be considered.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.4, 7.3.2	RD-008 GD-081

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-069

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Experiments	Orbital Activities

MISSION PHASE/EVENT

Orbital Operations

TITLE: EXPERIMENT ELECTRONICS RADIATION HARDENING

STATEMENT Provide piece part selection/hardening of electronics associated with experiment equipments expected to be in long term usuage.

JUSTIFICATION Solid state electronics (exclusive of film and emulsions) are most susceptible to degradation due to radiation. Careful selection of components and materials can provide potential for adequate resistance to radiation for long term - 10 year-missions.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Guideline pertains to bulk damage and ionization effects and is not applicable to dynamic interference (data degradation) of the experiment.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.4, Appendix A	GD-047

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-070

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Experiments, Comm & Data Mgt.	Orbital Activities Film Storage

MISSION PHASE/EVENT

Orbital Operations

TITLE: SHIELDED STORAGE OF PHOTOGRAPHIC FILM AND EMULSIONS

STATEMENT Provide shielded storage for photographic film and emulsions.

JUSTIFICATION Photo film and emulsions are very sensitive to radiation, the faster the film speed the more sensitive it becomes. Shielding is required of film prior to its processing to prevent fogging and reduction of resolution.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Shielding of high speed film (> ASA 400) with 20 g/cm^2 will permit its use from 25 to 50 days without severe fogging effects. However, an intense solar flare can wipe out the entire film supply. Additional shielding is of little use for the high energy particles.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.4, Appendix A	GD-071 GO-046

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-071

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Experiments	Orbital Activities, Film Radiation Monitoring

MISSION PHASE/EVENT

Orbital Operations

TITLE: DOSIMETRY MEASUREMENT IN FILM STORAGE

STATEMENT Consider placing radiation dosimeters in on-board film storage areas to allow evaluation of fog condition and film acceptability.

JUSTIFICATION Use of degraded, fogged film could render experiment useless. Use of dosimetry measurement would provide indication of acceptability and prevent use of damaged film and emulsions.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Periodic checks of film dosimeters is suggested. Additional dosimetry data in and around the Base would also provide an extimation of film acceptability provided film was stored in a representative area.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.4	GD-070

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-072

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Experiments	Experiment Radiation Monitoring

MISSION PHASE/EVENT

Orbital Operations

TITLE: DOSIMETRY FOR SENSITIVE BIOSCIENCE EXPERIMENTS

STATEMENT Provide radiation dosimetry monitors for sensitive bioscience experiment specimens.

JUSTIFICATION Those specimens particularly sensitive to radiation should be monitored by dosimetry to ascertain whether observed effects may be due to radiation.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.4	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-073

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Experiments	Orbital Activities, Radiation Screening

MISSION PHASE/EVENT

Orbital Operations

TITLE: USE OF RADIATION SCREENING TECHNIQUES

STATEMENT Consider the design and use of radiation screening of specific experiments to reduce dynamic interference when taking measurements within environmental radiation regimes.

JUSTIFICATION Experiments can experience significant data degradation when taking measurements in or near the radiation environment regime. Screening techniques can provide some degree of improvement where the obtaining of data is an absolute requirement.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Anti-coincidence techniques can be considered.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.4, Appendix A	GO-041 GO-042

SPACE BASE NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-074

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Experiments, Structure	Orbital Activities

MISSION PHASE/EVENT

Orbital Operations

TITLE: DETACHED MODULES FOR GAMMA AND NEUTRON SENSITIVE EXPERIMENTS

STATEMENT Consider use of detached modules (subsatellites) for the implementation of reactor gamma ray and neutron sensitive experiments.

JUSTIFICATION Certain experiments, particularly those associated with the astronomy discipline - are sensitive to the radiation environment generated by a reactor or isotope sources. In order to reduce dynamic interference, the experiments should be deployed on detached modules normally operating several KM from the Base.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Additional gamma ray and neutron shielding to substantially reduce or eliminate dynamic interference becomes prohibitive.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.4, Appendix A	GO-040 GO-045

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-075

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Experiments	Orbital Activities

MISSION PHASE/EVENT

Orbital Operations

TITLE: SENSITIVE EXPERIMENT LOCATION WITHIN REACTOR SHADOW SHIELDING

STATEMENT Maintain neutron and gamma ray sensitive experiments on the Space Base within the shadow shielding of the reactors.

JUSTIFICATION Neutron and gamma ray fluxes are drastically reduced by the shadow shield of the reactor, although feasible shields do not eliminate all of the high energy radiation. Considerable reduction in dynamic interference can be obtained by placement of sensitive experiments within the shadow shielding cone.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS: Typical experiments in the NASA "Blue Book" susceptible to neutron and gamma ray radiation are the astronomy discipline FPE 5.7 and 5.17.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.4, Appendix A	GO-041

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-076

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Experiments	Use of Dynamic Generators

MISSION PHASE/EVENT

Orbital Operations

TITLE: SAFETY FEATURES FOR DYNAMIC GENERATOR EQUIPMENT

STATEMENT Provide shielding and operational interlocks and restrict reorientation and relocation of dynamic generators (X-rays, ion guns, lasers and microwave sources).

JUSTIFICATION Stray and focused radiation can be injurious to crew and experiments. Safeguards must be implemented to prevent inadvertent exposure.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS: Crew members and experiments can be affected in adjacent compartments. Interlocks and alarms should be considered when equipment is to be used.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.4	GO-044

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-077

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Experiments, Isotopes	Isotope Handling and Containment

MISSION PHASE/EVENT

Orbital Operations

TITLE: EXPERIMENT LAB SAFETY FEATURES WITH ISOTOPES/TRACERS

STATEMENT Establish laboratory protection equipment consistent with the type and quantity of isotope and tracers likely to be used in a given laboratory.

JUSTIFICATION Spillage of isotopes/tracers can result in wide spread low level radiation which if unchecked may negate experiments and cause abandonment of the module or laboratory. The use of protection equipment can reduce or prevent the hazard.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Typical equipment includes filters, radiation detectors, leak detectors, glove boxes, airlocks, etc.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.4, 7.3.2	GD-078 GD-079

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-078

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Experiment, Isotopes	Orbital Activities

MISSION PHASE/EVENT

Orbital Operation

TITLE: ISOTOPE THERMAL SHIELDING

STATEMENT Provide thermal shielding to protect personnel and equipment from high temperature isotope capsules.

JUSTIFICATION. Isotope capsules can operate at temperatures of over 900°K and would present a thermal hazard to personnel and equipment in the vicinity.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS: Thermal shields, insulation and warning are required.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.4, 7.3.2	GD-077

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-079

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Experiments, Isotopes, Structure	Orbital Activities

MISSION PHASE/EVENT

Orbital Operations

TITLE: GRAVITATIONAL LOCATION OF EXPERIMENT LABS USING ISOTOPES/TRACERS

STATEMENT: Consider location of laboratories using isotope tracers, in zero "g" portions of the Base in order to preclude contamination (spills) resulting from the loss of artificial "g" capability.

JUSTIFICATION: From time to time zero "g" operation will exist in normally artificial "g" sections of the Base. Therefore design for zero "g" is necessary and constant zero "g" operations could minimize spillage.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS: Zero "g" operation is recommended for only those experiments which do not require artificial "g".

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.4, 7.3.2	GD-077 GD-078

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-080

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Experiments, Isotopes, Structure	Orbital Activities

MISSION PHASE/EVENT

Orbital Operation

TITLE: ISOLATABLE/REMOVABLE EXPERIMENT LABS

STATEMENT Consider locating laboratories with high tracer and isotope concentrations, in isolatable, removable modules to preclude general internal contamination of large permanent portions of the Base.

JUSTIFICATION Spillage or release of isotopes in experiment labs can result in wide spread low level radiation possibly rendering portions of the Base uninhabitable. Isolation of a lab could restrict the extent of contamination.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Use of an airlock, separate environmental control or complete removal of the module could be considered.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.4, 7.3.2	GD-065 GD-061 GD-060

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-081

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Experiments - Isotopes, Dynamic Generator	Orbital Activities

MISSION PHASE/EVENT

Orbital Operations

TITLE: LOCATION OF EXPERIMENT LABS EMPLOYING DYNAMIC GENERATORS AND ISOTOPES

STATEMENT: Consider locating laboratories containing dynamic generator equipment (X-rays) or isotopes in low traffic areas to minimize exposure to the crew.

JUSTIFICATION: Use of dynamic generator equipment requires special shielding or curtailment of accessibility. Even though radiation dose rates associated with an isotope heat source may be relatively low, consideration must be given to the accumulated dose.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS: Radiation labs could be attached modules not in the normal traffic pattern.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.4	GD-080 GD-063 GD-068

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-082

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Experiments, Isotopes, Structure	Maintenance and Repair

MISSION PHASE/EVENT

Orbital Operations

TITLE: SHIELDING FOR DOCKED DETACHED EXPERIMENT MODULES

STATEMENT Consider auxiliary shielding of adjacent/radiation sensitive areas of the Base when detached experiment modules employing isotopes are docked for servicing.

JUSTIFICATION Docking of detached experiment modules containing nuclear sources will increase the radiation levels in the vicinity. Consideration must be given to sensitive hardware and personnel in adjacent areas to minimize the radiation effects on hardware and dose rates to personnel.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Localized, portable shielding could be provided. These requirements are dependent on the type, location and duration of the nuclear source.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1	GD-077 GD-062

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-083

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Interfacing Vehicles - Space Shuttle/Tug	Reactor PM Maintenance

MISSION PHASE/EVENT

Launch/Ascent, Orbital Operations, End of Mission

TITLE: SHUTTLE/TUG GAMMA SHIELDING

STATEMENT Consider use of special gamma shielding for the Shuttle or Tug crew if immediate reactor servicing is required after shutdown.

JUSTIFICATION Radiation level at gallery end of reactor shield is high immediately after shutdown >200 rem/hr. Special shielding would be required to reduce dose rates to acceptable levels for at least 10 days after shutdown.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS It has been recommended that at least a 10 day waiting period be planned before Shuttle retrieval is initiated if no additional shielding within the Shuttle is a ground rule.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3 72SD4201-4-1 Section 3	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-084

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Interfacing Vehicles, Navigation and Control	Rendezvous

MISSION PHASE/EVENT

Orbital Operations

TITLE: IR SCANNER THERMAL RADIATION INTERFERENCE

STATEMENT Design for susceptibility of IR scanners on interfacing vehicles to false signals from waste heat PM radiators.

JUSTIFICATION Waste heat PM radiators can be a significant IR source. False signals could result in loss of control, and possible damage to both the interfacing vehicle and the Space Base.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Design of navigation and control equipment should consider possible IR sources and their effects on scanners.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.3	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-085

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Ground Support, Reactor PM	Transportation and Ground Handling

MISSION PHASE/EVENT

Prelaunch

TITLE: USE OF UNIVERSAL TRANSPORTER

STATEMENT Consider use of a universal transporter during transportation, inspection, checkout, assembly, integration and storage of the reactor power module.

JUSTIFICATION Provides environmental protection and minimizes the handling required of the power module during prelaunch operations. Accident potential is reduced.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Transporter should be equipped with instrumentation to monitor environmental conditions and provide protection from the entrance of hydrogeneous materials during transportation and storage operations.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2	GD-002 GD-003 GO-008

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-086

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Ground Support, Reactor, Isotopes	Transportation

MISSION PHASE/EVENT

Prelaunch, End of Mission/Recovery

TITLE: HARDWARE POSITIONING AND TIE DOWNS

STATEMENT Provide secure tie-downs and proper positioning of nuclear hardware on transportation beds to prevent the compaction of fuel into critical masses and possible separation from the carrier.

JUSTIFICATION. Reduces accident potential and radiological risks to the general populace.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS:

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.3	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-087

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Ground Support Facilities, Range Safety	Ground Operations

MISSION PHASE/EVENT

Prelaunch, Launch/Ascent, End of Mission

TITLE: DECONTAMINATION CAPABILITY

STATEMENT. Provide radioactive material decontamination capability in nuclear facilities, and at potential radiation hazard areas.

JUSTIFICATION: Minimize exposure to the ecology and personnel.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS: Apply presently used decontamination procedures used at nuclear facilities.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5	GO-058 GO-064

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-088

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Facilities, Reactor PM, Isotopes	Checkout and Storage

MISSION PHASE/EVENT

Prelaunch

TITLE: FACILITY DESIGN

STATEMENT Provide facilities designed for the safe accommodation and storage of nuclear hardware and components which contain liquid metal inventories.

JUSTIFICATION Reduce potential accidents, hardware damage and nuclear hazards.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Facilities must not contain water sprinklers. They must have clean smooth floors and have freedom from trapped water due to flooding etc. Environmental protection is required.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.7	GO-066

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-089

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Facilities, Reactor PM Isotopes	Prelaunch Operations

MISSION PHASE/EVENT

Prelaunch

TITLE: FACILITY MODIFICATIONS

STATEMENT. Provide facility modifications (VAB, ML, Launch Pad) to support nuclear hardware.

JUSTIFICATION To minimize accidents and provide the radiological control, decontamination, limited access and minimum radiation exposure to personnel during operations involving the nuclear hardware.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS: Modifications include (1) addition of environmental cover gas, (2) thermal control, (3) fire protection, (4) radiation monitors, (5) liquid metal leak detection and (6) accessibility, etc.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.5, 5.2.7	GO-065 GO-003

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-090

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Ground Support Launch Center	Facilities, Reactor PM	Liquid Metal Servicing and Safing

MISSION PHASE/EVENT

Prelaunch

TITLE: LIQUID METAL SERVICING AND SAFING

STATEMENT. Provide at minimum, a liquid metal servicing capability which can unload and render safe a leaking, ruptured or otherwise damaged power module prior to shipment back to the point of manufacturer or designated repair facility.

JUSTIFICATION Provides the proper equipment and techniques to safe the system and reduce the liquid metal hazards during shipment to the repair facility. A complete liquid metal facility capable of liquid metal charging and purification is not specified but should be a consideration if extensive nuclear activities or several programs are to be supported.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS: No facility of this nature is currently available at KSC.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.2, 5.2.7	GD-089 GD-091

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-091

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Facilities, Reactor PM	Liquid Metal Servicing

MISSION PHASE/EVENT

Prelaunch

TITLE: LIQUID METAL SERVICING FACILITY LOCATION

STATEMENT Consider locating the liquid metal servicing facility outside the nuclear assembly building but within the confines of the controlled area.

JUSTIFICATION To avoid potential liquid metal accidents and fires from causing damage to nuclear hardware and equipment located in the nuclear assembly building. Reduces nuclear accident potential.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.7	GD-090

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-092

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Facilities, Ground Support, Reactor PM, Isotopes	Fire Protection Ground Handling

MISSION PHASE/EVENT

Prelaunch

TITLE: LIQUID METAL/NUCLEAR HARDWARE FIRE PROTECTION

STATEMENT. Provide fire protection capability compatible with launch vehicle and nuclear liquid metal hardware and operations at KSC.

JUSTIFICATION Normal fire suppressents utilizing hydrogeneous substances or sources containing O_2 can not be used in fighting liquid metal fires. Large amounts of water are presently used at the launch site for launch vehicle fire prevention. New substances and techniques must be evoluated and provided when liquid metals are present.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS: A thorough evaluation should be conducted of the adequacy and potential incompatibility of the present provisions and procedures at the VAB, ML and launch site in the fighting of nuclear and liquid metal fires.

Liquid metal fire protection equipment should be marked yellow.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.6	GO-059 GD-093

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-093

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Facilities, Reactor PM	Fire Protection

MISSION PHASE/EVENT

Prelaunch

TITLE: LIQUID METAL SUMPS

STATEMENT Consider use of liquid metal sump tanks to remove remaining metal into a confined area.

JUSTIFICATION Permits accessibility for coverage of flames with fire extinguisher.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.6	GD-092 GO-059

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GD-094

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Facilities, Reactor PM, Isotopes	Storage, Checkout

MISSION PHASE/EVENT

Prelaunch

TITLE: SEGREGATED NUCLEAR HARDWARE STORAGE

STATEMENT Provide adequate isolation (segregation) for the checkout and storage of various nuclear hardware.

JUSTIFICATION. Reduce potential nuclear hardware damage. Reduce radiation dose rates to ground support personnel.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS. Separate reactor and isotope checkout and storage areas are recommended if simultaneous operations exist.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.4, 5.2.7	GO-066 RO-033

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-001

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	General, Ground Support	Ground Support

MISSION PHASE/EVENT

Prelaunch, Launch/Ascent, End of Mission

TITLE: USE OF NUCLEAR EXPERIENCED PERSONNEL

STATEMENT Provide ground support personnel trained and experienced in the handling and operations of nuclear hardware.

JUSTIFICATION Personnel trained and experienced in the support operations of radioactive material are made aware of the unique hazards of radiation, are trained in emergency operations and therefore can reduce the accident potential and doses received.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5, 6	RO-006

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-002

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	General, Reactor PM, Isotopes, Ground Support	Prelaunch Activities

MISSION PHASE/EVENT: Prelaunch

TITLE: MINIMIZE NUCLEAR HARDWARE OPERATIONS AT LAUNCH PAD

STATEMENT: Keep nuclear hardware operations at the launch pad to a minimum.

JUSTIFICATION: Minimizing the exposure of nuclear hardware to the launch pad environment will reduce the potential of damage and accidents occurring to the nuclear hardware.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS: Consideration should be given to the installation of nuclear hardware as late as practical in the prelaunch sequence.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.5	GD-002

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-003

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Transportation

MISSION PHASE/EVENT

Prelaunch

TITLE: AIR TRANSPORTATION OF REACTOR PM

STATEMENT Consider use of air transportation of reactor PM with special consideration to the separation of the reactor/shield from the main radiator to permit easier handling and better air transportation compatibility.

JUSTIFICATION Air transportation (guppy) provides good environmental protection and speediest delivery. Air routes can be selected to give minimum population overfly. Separation of radiator from Reactor/Shield can reduce handling problems and reduce the potential liquid metal hazards in the presence of the reactor.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS A separable heat exchanger permits the separation of the Reactor/Shield from the main radiator. If air transportation is not possible, barge must be considered when module diameters of 20+ feet are encountered. Consider use of the transportation trailer.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.3	GD-008 GD-085

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-004

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Transportation

MISSION PHASE/EVENT

TITLE: BARGE TRANSPORTATION OF REACTOR PM

STATEMENT Where barge transportation is required, the PM must be protected from the environment and sealed in a water tight and buoyant container equipped with purge gas, status monitoring equipment and fire protection.

JUSTIFICATION The external environment of barge transportation requires extensive protective measures to safely transport the reactor and liquid metal inventory.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Use of transportation trailer should be considered. Lockout provisions should be incorporated. Emmersion in water should be prevented.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.3	RD-002 GD-085

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-005

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM, Isotope, Ground Support	Transportation

MISSION PHASE/EVENT

Prelaunch, End of Mission/Recovery

TITLE: TRANSPORTATION ESCORTS AND WARNINGS

STATEMENT Provide escorts and warnings during transportation of nuclear hardware.

JUSTIFICATION Reduces accident potential and radiological risks to the general populace.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.3	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-006

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM, Isotope, Ground Support	Transportation

MISSION PHASE/EVENT: Prelaunch, End of Mission/Recovery

TITLE: TRANSPORTATION ROUTE SELECTION

STATEMENT: Select transportation routes to avoid heavily traveled roads and populated areas when transporting nuclear hardware.

JUSTIFICATION: Reduces accident potential and radiological risks to the general populace.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES
72SD4201-2-1 Section 5.2.3

CROSS REFERENCES

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-007

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM, Facilities	Assembly and Checkout

MISSION PHASE/EVENT

Prelaunch

TITLE: ORDNANCE/ROCKET FACILITY RESTRICTIONS

STATEMENT Do not permit ordnance and disposal rocket motors in the nuclear assembly and liquid metal servicing facilities.

JUSTIFICATION Prevent inadvertent explosions, detonations and fires which can lead to nuclear hardware damage and nuclear hazards.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.5, 5.2.7	GD-009 GD-029

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-008

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM, Ground Support	Transport Storage, Checkout Handling

MISSION PHASE/EVENT: Prelaunch

TITLE: MINIMUM HANDLING OF REACTOR POWER MODULE

STATEMENT Provide GSE and procedures which minimize the handling required of the reactor power module during prelaunch activities.

JUSTIFICATION The provision of GSE which minimize and simplified handling of the powerplant reduces the chances of damage and accident potential during prelaunch. Overall radiological risk of a "cold" powerplant is low. Equipment damage or injury from other causes may be of greatest concern during prelaunch.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS The provision of a multiple usage shipping, checkout, storage and rating transport trailer (transporter) should be considered. A cradle or transfer module supporting the powerplant within the transportor could be used for horizontal, vertical and horizontal to vertical operations and be made compatible with the booster or shuttle cargo bay.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5, 5.2.3, 5.2.5	GD-085 GO-002

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-009

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM, Isotopes	Checkout

MISSION PHASE/EVENT

Prelaunch

TITLE: LAUNCH VEHICLE INTERFACE SIMULATION

STATEMENT Consider provision of launch vehicle electrical and mechanical interface simulators for initial prelaunch tests within nuclear assembly facility.

JUSTIFICATION Reduce flight hardware damage and handling during integration.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Checks for alignment, roundness and interface compatibility. Particularly important where large diameter circular surfaces are involved.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.5	GO-065

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-010

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Reactor PM	Prelaunch Complex Tests

MISSION PHASE/EVENT

Prelaunch

TITLE: REACTOR CRITICALITY TEST

STATEMENT The important criticality checks of the reactor and control system should be performed at the contractor facility prior to shipment to the launch site. No criticality tests should be run at the launch site. Full power tests of the flight reactor should be avoided.

JUSTIFICATION The important criticality checks of the reactor are best performed in the closely controlled and instrumented environment of the contractors facility. Operating levels for these tests and any others should be held to a minimum to minimize the fission product inventories of the reactor at the launch site.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS The possibility of only conducting low power criticality and control system tests of the flight reactor should be considered where full power, and qualified tests would be performed on other powerplants. 100 watt operation for 12 days will result in a very low fission product inventory a few weeks after the test.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.1, 5.2.5 72SD4201-3-2	GO-011

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-011

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Prelaunch Testing

MISSION PHASE/EVENT

Prelaunch

TITLE: PRELAUNCH TESTING OF REACTOR POWER MODULE

STATEMENT No reactor power module criticality tests or power tests should be performed at the launch center.

JUSTIFICATION Previous tests of qual reactors and flight reactor at the contractors facility should be designed to verify operation. Launch center facility requirements and radiation hazards would be reduced.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Test program must provide assurance of reliable full power operation. Tests at the launch center should concentrate on integrity, integration and functioning of control and instrumentation systems.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.1, 5.2.5 72SD4201-3-2	GD-005 GO-010 GO-012

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-012

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Prelaunch Checkout

MISSION PHASE/EVENT

Prelaunch

TITLE: RESTRICTION OF CONTROL DRUM MOVEMENT

STATEMENT Restrict control drum movement to a single drum during prelaunch checkout where criticality tests are not performed.

JUSTIFICATION Prevents inadvertent criticality and subsequent nuclear radiation hazard.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Restriction may be incorporated into control drum lockout device.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.5	GD-005 GO-011

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-013

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Launch Vehicle Integration

MISSION PHASE/EVENT

Prelaunch

TITLE: PRELAUNCH REACTOR POWER MODULE SIMULATION

STATEMENT Consider the use of a simulated power module for initial integration tests of launch complex GSE and launch vehicle.

JUSTIFICATION Initial tests with a simulator will fulfill a majority of the initial launch complex integration verification needs without subjecting a fueled nuclear power module. Potential accidents and nuclear hazards will be reduced.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS: A simulated power module (mass, size and electrical circuits) could be used to verify compatibility of GSE (transporter, test sets etc), launch complex systems (launch vehicle interfaces, ML, cranes etc) and operations procedures.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.5	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-014

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Reactor PM	Installation

MISSION PHASE/EVENT

Prelaunch

TITLE: POWER MODULE INSTALLATION LATE IN PRELAUNCH SEQUENCE

STATEMENT Consider installation of the PM late in the prelaunch sequence, possibly at the launch pad, thus bypassing the VAB.

JUSTIFICATION Installation of the PM late in the sequence will minimize the accident potential involved with the reactor power module during prelaunch operations. The essentially "dormant" condition of the PM may permit late installation. Bypassing the VAB would eliminate the additional nuclear and liquid metal hazards within that facility.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS A minimum amount of functional tests need to be performed on the PM while on the launch vehicle. Tests prior to installation on the launch vehicle such as electrical continuity, service arm compatibility could for the most part be performed with a PM simulator.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.5	GO-065

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-015

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor, Isotopes	Checkout, Storage

MISSION PHASE/EVENT

Prelaunch, All Phases

TITLE: PERIODIC CHECKOUT

STATEMENT Provide for periodic checkout and status monitoring while in storage.

JUSTIFICATION To assure launch/logistic readiness over the mission lifetime.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Periodic checkout quarterly or semi annually.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2	GO-016 GO-067

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-016

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM, Isotopes	Storage, Checkout

MISSION PHASE/EVENT

Prelaunch, Orbital Operations

TITLE: READINESS STATE OF STORAGE REACTORS & ISOTOPES

STATEMENT The reactor power module and isotopes should be kept in a state of readiness such that a replacement can be integrated with the launch vehicle within 2 days after request from orbit. Total time from request to delivery in-orbit should be on the order of 15 days.

JUSTIFICATION Loss of power or operation on partial power in orbit-curtailing mission. To provide minimum down time of operations.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Power module could be stored in transporter, having previously and periodically undergone status checks for readiness. Launch vehicle readiness is also required.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.4	GO-015 GD085 GO-067

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-017

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Reactor PM	Docking, Replacement, Disposal

MISSION PHASE/EVENT

Launch Ascent, Orbital Operations, End of Mission

TITLE: DUMMY POWER MODULE ORBITAL HANDLING OPERATIONS

STATEMENT Consider launch and orbital rendezvous, docking, maintenance, replacement and disposal operations with dummy Reactor Power Module to minimize operational accidents and verify procedures and hardware capability.

JUSTIFICATION Validation of procedures and hardware will reduce orbital accidents resulting in crew hazards and eventual requirements for disposal or recovery of nuclear hardware.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.5, 5.3	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-018

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Reactor PM	Reactor Replacement or Maintenance

MISSION PHASE/EVENT

Orbital Operations

TITLE: LOW POWER LEVEL OPERATION DURING REACTOR REPLACEMENT

STATEMENT Consider minimizing the reactor operating power level during the non operating reactor replacement or maintenance.

JUSTIFICATION The studies of Section 7.3.3 of 72SD4201-2 indicate that radiation levels in the vicinity of a non operating reactor due to the operation of the remaining reactor are sufficiently low so as not to inhibit replacement or maintenance operations. However, where general Space Vehicle operations are not adversily affected, consideration should be given to reducing the power level and therefore the radiation level to the work crew.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 7.2.4, 7.3.3	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-019

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Reactor PM	Emergency Operation

MISSION PHASE/EVENT

Orbital Operations

TITLE: EMERGENCY REACTOR PM OPERATION

STATEMENT Operation of a reactor PM at emergency levels (600 kWt) should be restricted to an individual reactor to minimize the effects due to radiation.

JUSTIFICATION Radiation dose rates at increased reactor power levels increases. Operation of more than one reactor at emergency power levels may cause radiation dose rate design limits to be exceeded.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Emergency operation power levels are usually designed to allow one reactor to assume the entire load of the nominal two reactor Base for short periods of time.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 3.2.2, 3.8.2, 6.3 72SD4201-3-1 Section 2	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-020

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Maintenance & Repair

MISSION PHASE/EVENT

Orbital Operations

TITLE: NO REPAIR OF LIQUID METAL LINES

STATEMENT No attempt should be made to repair liquid metal (NaK) coolant loops/lines during orbital operations.

JUSTIFICATION Repair is not considered feasible due to the hazards involved in toxicity, potential fire around O_2 sources and radioactivity resulting from NaK activation.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Failure of liquid metal loop or loopswould either be tolerated by redundancy or a replacement of the power module would be required.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 3.8.2, 7.3.3	GD-020

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-021

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Maintenance and Repair

MISSION PHASE/EVENT

Orbital Operations

TITLE: REPAIR RESTRICTIONS IN REACTOR GALLERY AREA

STATEMENT Repair in the reactor gallery area and around the reactor should not be attempted.

JUSTIFICATION Repair in these areas is considered impractical and too hazardous due to the high radiation levels that exist, even after reactor shutdown.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS: Components with repair frequencies less than the lifetime of the power module should be placed in the engine room.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 3.8.2, 7.3.3	GD-014 GD-017 GD-018

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-022

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Maintenance and Repair

MISSION PHASE/EVENT

Orbital Operations, End of Mission

TITLE: REPAIR OR REPLACEMENT OF PM AFTER REACTOR SHUTDOWN

STATEMENT Consider allowing at least a 10-day wait period prior to initiating crew activities involving the Shuttle or Tug around the shutdown reactor interface.

JUSTIFICATION Radiation levels immediately after shutdown around the reactor, particularly near the gallery, are high, > 200 rem/hr. Radiation decay allows near proximity work with the Shuttle crew about 10 days after shutdown, but distances and loiter times must be restricted.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Additional crew shielding is required if repair or replacement is required prior to the 10 day waiting period

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6, 3, 7.3.3	GD-019 GO-035

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-023

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM	Reactor Restart

MISSION PHASE/EVENT

Orbital Operations

TITLE: SLOW DRUM MOVEMENT FOR RESTART

STATEMENT Consider moving reactor control drums at slow speed for a reactor restart since criticality margins will not be known as precisely as at original startup.

JUSTIFICATION To avoid possible over reactive/over temperature conditions and possible damage to the reactor power module.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 7.2.2, 7.3.4	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-024

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Reactor PM, Ground Support, Facilities	Ground Handling

MISSION PHASE/EVENT

Prelaunch, End of Mission/Recovery

TITLE: AVOIDANCE OF SUBSTANCES THAT REACT WITH LIQUID METALS

STATEMENT Avoid the use of materials, gases and liquids that are incompatible/ react with liquid metals used in nuclear hardware.

JUSTIFICATION Avoidance of reactive materials will reduce the potential for liquid metal reactions resulting from leaks.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.6	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-025

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Isotopes	Ground Handling

MISSION PHASE/EVENT

Prelaunch

TITLE: IGNITABLE MATERIAL HAZARDS AROUND HEAT SOURCES

STATEMENT Prevent low temperature ($\sim 420^{\circ}K$) ignitable materials and gases from approaching the radiating surfaces of the heat sources.

JUSTIFICATION To reduce the possibility of igniting gases and materials used around the heat source installation.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Consider use of inert cover gases, purges or other protective barriers.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.2, 5.2.3, 5.2.5	GD-078 RD-010

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-026

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Isotopes	Space Base Integration

MISSION PHASE/EVENT

Prelaunch

TITLE: INTEGRATION OF ISOTOPES WITH SPACE BASE

STATEMENT Mate/ install and integrate isotope heat sources as late in the prelaunch operations as feasible - perferrably at the launch pad.

JUSTIFICATION Prelaunch checkout activities in conjunction with a Space Base are limited. Integration late in the prelaunch sequence will reduce the restrictive operations around the source due to the thermal and radiation hazards and minimize the cooling requirements.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Consider isotope installation in the latter stages of the countdown - possibly in conjunction with ordnance installation.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.5	GO-002

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-027

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Crew Protection	Crew Rotation

MISSION PHASE/EVENT

Orbital Operations

TITLE: CREW ROTATION PROCEDURES

STATEMENT Provide/ establish crew rotation procedures in conformance with career and periodic dose guidelines.

JUSTIFICATION Adherence to procedures combined with radiological monitoring of the crew will prevent over dose to individual crew members and allow effective scheduling and use of the crew.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES 72SD4201-2-1 Section 6.3.1

CROSS REFERENCES
GD-053
GD-054

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-028

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Crew Protection	EVA

MISSION PHASE/EVENT

Orbital Operations

TITLE: EVA RESTRICTIONS THROUGH SOUTH ATLANTIC ANOMALY

STATEMENT Restrict EVA during orbits intercepting the South Atlantic anomaly.

JUSTIFICATION Normal EVA operations result in radiation dose rates a factor of 2 greater than when shielded by a 1.6 g/cm^2 spacecraft. Intersections through the intense South Atlantic anomaly regions can result in dose rates at least 2 orders of magnitude greater.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Orbits intersecting the South Atlantic anomaly vary in accordance to altitude and inclination. A nominal 55^o with 500 KM orbit intersects the South Atlantic anomaly ~ 1 out of 5 orbits. Planned EVA can thus reduce the accumulated dose to the crew members concerned.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-029

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Crew Protection, Reactor PM	EVA

MISSION PHASE/EVENT

Orbital Operations

TITLE: EVA RESTRICTIONS DUE TO REACTOR RADIATION

STATEMENT Restrict EVA in the vicinity of the Reactor Power Module due to the increased nuclear radiation environment.

JUSTIFICATION Radiation levels (depending on operation and design features) may be significantly higher near the PM and particularly near the upper portion of the shield (dose rates 2 to 3 orders of magnitude greater than the interior of the Base). Dose rates are very dependent on position and restrictions of position can minimize dose received.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS The dose rates around a reactor are highly dependent on the shield design and operating level of the reactor.

REFERENCES	CROSS REFERENCES
72SD 4201-2-1 Section 6.3.1	GD-040

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-030

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Crew Protection, Reactor PM	EVA

MISSION PHASE/EVENT

Orbital Operations

TITLE: EVA RESTRICTIONS DUE TO PM THERMAL RADIATION

STATEMENT Restrict EVA in the vicinity of the Power Module radiators due to the thermal radiation environment.

JUSTIFICATION Radiator surface temperatures can range from 350° to over 800°K and present a hazard to the crew and cause suit damage.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-031

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Crew Protection	EVA

MISSION PHASE/EVENT

Orbital Operations

TITLE: EVA COORDINATION WITH RSO

STATEMENT Coordinate EVA with the Radiological Safety Office to ensure safe EVA environment at the time of implementation.

JUSTIFICATION The RSO must be informed of impending Solar Flares, accumulated radiation doses and anticipated doses, so is in a position to determine individuals and times most appropriate for EVA operations. Considered important to maintain radiation doses within allowable limits

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1, 7.3.1	GO-048

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-032

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Crew Protection, Reactor PM	EVA

MISSION PHASE/EVENT

Orbital Operations

TITLE: EVA RESTRICTIONS WITH NaK LEAKS

STATEMENT Avoid EVA when NaK leaks are suspected.

JUSTIFICATION NaK can be corrosive to many materials and should not be subjected to an O_2 environment.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.2	GD-032

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-033

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Crew Protection, Interfacing Vehicles	Rendezvous and Docking

MISSION PHASE/EVENT

Orbital Operations

TITLE: IMPLEMENTATION OF APPROACH AND LOITER OPERATIONS

STATEMENT Advantage should be taken of the particular shielding characteristics in implementing approach and loiter operations. Restrictions should also be placed on approach distances and attitudes.

JUSTIFICATION Radiation levels around the shield vary with the square root of the distance and also vary dramatically with position around the shield due to its shape. Loiter and approaches within the low radiation zones can reduce doses received. Restrictions will prevent undue exposure of personnel and equipment.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1	GD-040 GO-035

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-034

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Crew Protection, Interfacing Vehicles	Rendezvous

MISSION PHASE/EVENT

Orbital Operations

TITLE: MAINTENANCE OF NOMINAL BRAKING GATE VELOCITIES

STATEMENT Nominal braking gate velocities of rendezvous and docking vehicles should be maintained so as to not increase the radiation doses in the vicinity of nuclear hardware.

JUSTIFICATION This guideline is specifically applicable when rendezvous corridors bring the Shuttle or Tug in the near vicinity of the operating reactor power modules. Accumulated doses are well within allowable limits if braking gate velocities are maintained.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-035

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Crew Protection, Interfacing Vehicles	Rendezvous and Docking

MISSION PHASE/EVENT

Orbital Operations

TITLE: LOITER TIME CONSTRAINTS

STATEMENT Minimize the loiter time in the vicinity of high radiation areas such as the reactor power modules.

JUSTIFICATION Although nuclear sources can be shielded such that radiation levels on all sides are very low, it is common practice to optimize the shield design to allow higher radiation levels in areas away from crew/hardware areas. Crew-and logistic-vehicle loiter time in these high radiation areas must be strictly controlled to minimize the total dose received.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1	GD-040 GO-033

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-036

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Crew Protection, Interfacing Vehicle - Shuttle	Contingency Operation

MISSION PHASE/EVENT

Orbital Operations, End of Mission

TITLE: PROMPT CREW RESCUE

STATEMENT Consider the prompt rescue of the entire Space Base crew.

JUSTIFICATION Remote but severe accidents involving a reactor excursion or collision in orbit could result in a very high radiation environment on and around the Space Base. Such a condition may necessitate early abandonment.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Rescue could involve the removal within a few hours or possibly a few days of the entire crew of 50 to 60.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.2	GO-037

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-037

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Crew Protection, Interfacing Vehicle - Shuttle	Contingency Operation - Rescue

MISSION PHASE/EVENT

Orbital Operations, End of Mission

TITLE: CREW RESCUE OPERATIONS

STATEMENT Perform crew rescue upon decision of the Radiation Safety Officer and Mission Control when radiation levels in around the Base are intolerable.

JUSTIFICATION: Remote but severe situations could result which require plans for rescue of the entire crew to minimize total radiation doses to the crew which exceed tolerable levels.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS: Large crews will require the use of an extensive rescue capability.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.2	GO-036 GO-048

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-038

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Experiments, Interfacing Vehicle (RNS)	RNS Operations

MISSION PHASE/EVENT

Orbital Operations

TITLE: RNS APPROACH CONSIDERATIONS

STATEMENT Consider the RNS approach and departure trajectories in selecting detached module deployment position.

JUSTIFICATION RNS radiation effects can result in dynamic interference of experiments. Dynamic interference can be minimized if deployment position considers effects of approaches and departures of the RNS.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.4	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-039

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Experiments, Crew Protection, Interfacing Vehicles	Approach, Rendezvous and Docking

MISSION PHASE/EVENT

Orbital Operations

TITLE: APPROACH CORRIDORS WITH INTERFACING VEHICLES

STATEMENT Establish and maintain adequate/ safe approach corridors with interfacing vehicles employing nuclear sources to minimize exposure of the crew and experiment interference.

JUSTIFICATION: Interfacing vehicles such as the Reusable Nuclear Shuttle can present a significant radiation hazard. Attitude position of shielding and operating condition are important in minimizing dose to the Space Base. Approach restrictions should account for potential failure conditions.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS: Approach corridor limits are dependent on the nuclear source, operating condition etc. In some instances (RNS) an approach limit of hundreds of Km may be required during thrusting operations.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-040

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Experiments	Experiment Module Deployment

MISSION PHASE/EVENT

Orbital Operations

TITLE: EXPERIMENT MODULE DEPLOYMENT TRAJECTORY

STATEMENT Plan experiment "free flying" module deployment trajectory to minimize approach to and loiter time around the high radiation areas around the Base reactors.

JUSTIFICATION Experiments may encounter dynamic interference and also substantial film fogging while in the high radiation areas around the reactors.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS: Trajectories should be planned to make maximum use of reactor shadow shielding and if possible rendezvous from the end of the Base apposite from the reactors.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.4, 3.8.2	GO-033 GD-074 GD-075

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-041

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Experiments	Orbital Activities, Radiation Screening

MISSION PHASE/EVENT

Orbital Operations

TITLE: EXPERIMENT SCREENING PROCEDURES

STATEMENT. Provide experiment data screening procedures for experiments sensitive to South Atlantic anomaly interference.

JUSTIFICATION: Where data is required through the South Atlantic anomaly certain screening techniques would be required.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.4	GD-073

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-042

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Experiments	Orbital Activities, Experiment Shutdown

MISSION PHASE/EVENT

Orbital Operations

TITLE: CURTAILMENT OF EXPERIMENT OPERATION

STATEMENT. Consider curtailing experiment operation through major portions of the South Atlantic anomaly and portions of the polar regions.

JUSTIFICATION. Radiation energy levels in the South Atlantic anomaly are such that significant experiment dynamic interference can result and therefore considerable data degradation is expected.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Typical of the experiments listed in the NASA "Blue Book" which could be effected by the South Atlantic anomaly are FPE's 5.1, 5.3, 5.5, 5.6, 5.7, 5.8, 5.11, 5.17, 5.21, 5.22, 5.24 and 5.26.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.4	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-043

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Experiments, Interfacing Vehicles	Experiment Operation

MISSION PHASE/EVENT

Orbital Operations

TITLE: PLANNED EXPERIMENT INTERFERENCE FROM INTERFACING VEHICLES

STATEMENT: Intermittent experiment interference must be anticipated and planned for when relatively high radiation source interfacing vehicles are in operation in the vicinity of the Base.

JUSTIFICATION

It would be uneconomical and quite unfeasible to design for the elimination of experiment interference under all operational conditions.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS:

A thrusting RNS can cause some experiment interference at distances up to 18 - 19000 Km from the Base.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-044

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Experiment, Dynamic Rad. Gen	Experiment Operations

MISSION PHASE/EVENT

Orbital Operations

TITLE: OPERATIONAL RESTRICTIONS - DYNAMIC RAD GENERATORS

STATEMENT Provide procedural restrictions in the operation of dynamic radiation generators and the location and movement of personnel in the vicinity during operation.

JUSTIFICATION: Radiation streaming can result from operation of X-ray equipment and the like. Restrictions in operation and location of personnel can eliminate inadvertant exposures.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS: Operational restrictions should be combined with design features which locate habitation quarters and sensitive equipment in suitable areas.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1, 6.3.2	GD-076

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-045

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Experiment, Navigation and Control, Interfacing Vehicle	Orbital Activities, Rendezvous and Docking

MISSION PHASE/EVENT

Orbital Operations

TITLE: LASER BEAM OPERATION RESTRICTIONS

STATEMENT Provide restrictive procedures (location, viewing, and operation) during the operation of laser equipment in and around the Space Base.

JUSTIFICATION: Concentrated light from laser beam sources can damage the eye retina.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS: Laser equipment could be located on interfacing vehicles as well as on the Base.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1	GD-055

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-046

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Experiments, Communication and Data Management	Resupply

MISSION PHASE/EVENT

Orbital Operations

TITLE: PHOTO FILM/ EMULSION RESUPPLY

STATEMENT Provide regular/periodic resupply of photographic film and emulsions.

JUSTIFICATION Noticeable film fogging occurs with high speed film ASA 400 stored in 20g/cm^2 shielding in approximately 25 to 50 days. Storage time of slower film planned for up to 200 days.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS: Data assumes threshold fogging limits. If considerable fogging can be permitted (reduction of resolution and contrast) storage times could be extended.

Note: Processed film is not governed by this guideline. However, exposed film as well as unexposed is affected by radiation.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.4	GD-070 GD-071 GO-047

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-047

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Experiments, Communication and Data Management	Resupply

MISSION PHASE/EVENT

Orbital Operations

TITLE: HIGH SPEED FILM RESUPPLY AFTER INTENSE SOLAR FLARE

STATEMENT Provide for the entire replacement of the high speed film (ASA > 400) supply after an intense solar flare.

JUSTIFICATION An intense solar flare event can wipe out the entire high speed film supply in orbit. Additional shielding above the 20g/ cm^2 provided in the storage containers has little effect.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS:

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.4, 3.8.1	GO-046 GD-070 GD-071

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-048

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	MCC, Reactor PM, Isotopes, Ground Support	Operations

MISSION PHASE/EVENT

Orbital Operations, End of Mission

TITLE: MCC SUPPORT DURING MISSION

STATEMENT Consider the continual attended support of the mission by the MCC.

JUSTIFICATION: To provide logistics requirements, failure diagnosis and rescue operations - minimizing radiation hazards to the crew and general populace.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.3.4, 5.4.3	GD-013 GD-027 GD-028 GD-041 GD-048 GD-059

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-049

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Navigation and Control	Loiter, Rendezvous, Docking

MISSION PHASE/EVENT

Launch Ascent, Orbital Operations, EOM

TITLE: LOITER AND TRAVERSE OPERATIONS RESTRICTED NEAR PM

STATEMENT Minimize the loiter and traverse operations near the reactor and PM radiators to reduce potential radiation and thermal interference with navigational equipment.

JUSTIFICATION Radiation and IR interference can cause possible loss of control or guidance errors giving rise to potential collisions.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 6.3.1.3	GD-084

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-050

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	MCC, Range Safety, Reactor PM, Isotopes	Reentry

MISSION PHASE/EVENT

Launch/Ascent, End of Mission

TITLE: ADVANCED WARNING OF NUCLEAR IMPACT

STATEMENT Provide determination of potential impact areas, technical and hazard data and advanced warnings of nuclear hardware impact to proper recovery team and governmental authorities.

JUSTIFICATION To take necessary safing actions and reduce potential hazards to personnel.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.5	GD-011

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-051

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Interfacing Vehicle - Space Shuttle, Reactor PM, Isotopes	Disposal, Recovery

MISSION PHASE/EVENT

End of Mission/Recovery

TITLE: SHUTTLE RECOVERY MODE

STATEMENT Consider use of Space Shuttle as a prime or backup mode of disposal/ retrieval/ recovery of nuclear hardware.

JUSTIFICATION Provide contingency support and reduce mission risk to personnel.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES
72SD4201-2-1 Section 5.5
72SD4201-4-1 Section 3, 4, 5
72SD4201-4-2

CROSS REFERENCES
RD-004 RO-004
RD-006 RO-005

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-052

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	MCC, Range Safety	Range Tracking

MISSION PHASE/EVENT

Launch/ Ascent, Orbital Operations, End of Mission

TITLE: TRACKING NETWORK ADDITIONS

STATEMENT. Consider additional tracking, command and telemetry network capability for missions in 55° inclination orbits.

JUSTIFICATION. To provide adequate tracking/ command and control.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.3.4	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-053

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Range Safety, Reactor PM, Isotopes	Flight Termination

MISSION PHASE/EVENT

Launch/ Ascent

TITLE: SAFING S-II DESTRUCT SYSTEM

STATEMENT Consider safing the S-II destruct system as Eurasian overfly is made with a nuclear payload.

JUSTIFICATION May reduce nuclear hardware impact potential and release of radioactive material on the Eurasian continent.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.3.2	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-054

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Range Safety, Reactor PM, Isotopes	Flight Termination

MISSION PHASE/EVENT

Launch/ Ascent

TITLE: COMMAND DESTRUCT DELAY

STATEMENT Consider a command destruct delay to allow separation of the nuclear payload prior to stage destruct.

JUSTIFICATION: Reduces potential of releasing radioactive material due to stage explosion and subsequent fragmentation.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS:

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.3.2	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-055

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Range Safety, Reactor PM	Flight Termination

MISSION PHASE/EVENT

Launch/ Ascent

TITLE: FLIGHT TERMINATION IMPACT AREAS

STATEMENT Consider flight termination impact areas of a reactor power module outside the continental shelf-preferrably in deep ocean areas.

JUSTIFICATION. Reduce possibility of quasi-steady-state operation and release of radiation which presents hazards to the ecology (fish) and general populace.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.3.2	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-056

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Range Safety, Reactor PM, Isotopes	Launch and Ascent

MISSION PHASE/EVENT

Launch/ Ascent

TITLE: LAUNCH AZMIUTH RESTRICTIONS

STATEMENT Land overflight during the launch/ ascent phase should be minimized. Semi-polar launches over central and Southern Florida and Cuba should not be allowed.

JUSTIFICATION To minimize the radiation hazards (risks) to the general populace.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS A southerly launch with dogleg should be considered to avoid overfly of the Eurasian continent.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.3.2	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-057

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Range Safety, Reactor PM, Isotopes	Launch

MISSION PHASE/EVENT

Launch/ Ascent

TITLE: WEATHER RESTRICTIONS FOR LAUNCH

STATEMENT Launches of nuclear hardware at KSC should be scheduled with prevailing winds blowing away from populated areas (preferrably out to sea).

JUSTIFICATION Reduce radiation hazard potential to the general populace around KSC.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS:

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.3.2	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-058

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Ground Support	Prelaunch Operations

MISSION PHASE/EVENT

Prelaunch

TITLE: NUCLEAR PROCEDURES AT LAUNCH SITE

STATEMENT Provide nuclear hardware launch site procedures in the KSC Ground Safety Plan (K-V-053)

JUSTIFICATION Incorporate nuclear safety procedures into overall KSC operations to reduce possibility of accidents involving nuclear hardware and assure proper operations and handling when nuclear hardware is present.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.5, 5.3	GD-087 RD-011

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-059

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Ground Support Facilities	Fire Protection

MISSION PHASE/EVENT

Prelaunch

TITLE: TRAINED FIRE FIGHTING PERSONNEL

STATEMENT Provide well trained personnel with considerable actual liquid metal fire fighting practice and under simulated conditions.

JUSTIFICATION Provide best efficiency possible to isolate and quickly contain the fire.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Configuration is important and may present a difficult fire extinguishing position. Extinguishing agents should be applied carefully to prevent splashing. Complete coverage of the liquid metal is mandatory.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.6	GD-092

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-060

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Ground Support, Facilities	Operations in Facilities

MISSION PHASE/EVENT

Prelaunch

TITLE: MULTIPLE ESCAPE ROUTES

STATEMENT Provide and designate multiple escape (exit) routes within facilities in the case of nuclear emergencies.

JUSTIFICATION Reduce dose to personnel in working areas in case of nuclear accidents which release radiation. More than one exit should be available in case of exit blockage.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS Protective measures include escape provisions, and the use of protective clothing and respiratory equipment.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.5, 5.2.6, 5.2.7	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-061

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Ground Support, Facilities	Ground Handling

MISSION PHASE/EVENT

Prelaunch, End of Mission/ Recovery

TITLE: USE OF PROPER CLOTHING AND PROTECTION EQUIPMENT

STATEMENT Provide proper protective clothing, respiratory and first aid equipment for work around nuclear and liquid metal hardware.

JUSTIFICATION Prevent contamination, thermal burns, and reactions with liquid metal components.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS:

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5	

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-062

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Ground Support, Facilities	General

MISSION PHASE/EVENT

Prelaunch, End of Mission/ Recovery

TITLE: SMOKING AND EATING REGULATIONS

STATEMENT Provide regulations, warnings and control of smoking and eating in designated nuclear areas.

JUSTIFICATION: Smoking and eating should not be permitted when nuclear material has been handled or has been dispersed into the area and surrounding atmosphere due to inhalation and ingestion potential. Under normal circumstances, smoking and eating can be allowed when and where designated.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5	RO-001

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-063

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Ground Support, Facilities	Ground Operations

MISSION PHASE/EVENT

Prelaunch, End of Mission/ Recovery

TITLE: USE OF TWO MAN "BUDDY" SYSTEM

STATEMENT Consider the use of the two man "buddy" system in operations with nuclear hardware.

JUSTIFICATION To reduce chances of nuclear accidents and over exposure of personnel. The buddy system provides a rescue capability and additional monitoring of hazardous situations.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS: Two man "buddy" system would require the use of at least two trained personnel in a facility or near operations involving nuclear hardware. One of the men could be monitoring radiation if procedures require it.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.5	GO-001

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-064

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Ground Support, Facilities	Ground Operations

MISSION PHASE/EVENT

Prelaunch, End of Mission

TITLE: GROUND SUPPORT RADIATION DOSIMETRY PROCEDURES

STATEMENT Provide procedures for the implementation of radiological monitoring and control during all ground operations involving nuclear hardware.

JUSTIFICATION: Provide tabulation of radiation doses and prevent over exposures.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.6, 5.3.3	RD-011 GD-087

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-065

PROGRAM ELEMENT	SYSTEM–SUBSYSTEM	OPERATION
Space Base	Facilities, Reactor PM, Isotopes	Prelaunch Checkout and Integration

MISSION PHASE/EVENT

Prelaunch

TITLE: CHECKOUT AND INTEGRATION IN VAB

STATEMENT Conduct a thorough evaluation of the necessity and desirability of integrating and testing of nuclear hardware within the VAB.

JUSTIFICATION: Limited checkout of nuclear hardware is required with the Launch Vehicle. Avoidance of activities in the VAB would eliminate accident potential nuclear hazards and the need of providing nuclear support requirements within that facility.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.5, 5.2.7	GO-014

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-066

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Facilities, Reactor PM, Isotopes	Storage

MISSION PHASE/EVENT

Prelaunch

TITLE: STORAGE AREA IN NUCLEAR ASSEMBLY BUILDING

STATEMENT Consider use of the nuclear assembly building as the prime nuclear hardware storage facility.

JUSTIFICATION Within controlled facility and minimize handling and transportation. Makes best use of nuclear trained personnel and nuclear facilties.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS: Storage can be separated from checkout and assembly bays.

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.4, 5.2.7	GD-094

SPACE BASE	NUCLEAR SYSTEM SAFETY GUIDELINE	DATE JAN 72	NO. GO-067

PROGRAM ELEMENT	SYSTEM-SUBSYSTEM	OPERATION
Space Base	Facilities, Reactor PM, Isotopes	*Storage*

MISSION PHASE/EVENT

Prelaunch and All Phases

TITLE: STORAGE LIFETIMES

STATEMENT Consider provisions for the storage of mission nuclear hardware from a few months to several years.

JUSTIFICATION Required for orbital replacement over a typical 10-year mission.

HAZARD CATEGORY			
CAT	CRIT	MARG	NEG

REMARKS

REFERENCES	CROSS REFERENCES
72SD4201-2-1 Section 5.2.4	GO-015 GO-016

CONVERSION FACTORS
INTERNATIONAL TO ENGLISH UNITS

Physical Quantity	International Units	English Units	Conversion Factor Multiply By
Acceleration	m/sec^2	ft/sec^2	3.281
Area	m^2	ft^2	10.764
		in^2	1550.39
Density	Kg/m^2	lb/ft^3	6.242×10^{-2}
		lb/in^3	3.610×10^{-5}
Energy	Joule	Btu	9.479×10^{-4}
Force	Newton	lbf	2.248×10^{-1}
Length	m	ft	3.281
		nm	5.399×10^{-4}
Mass	Kg	lbm	2.205
Power	watt	Btu/sec	9.488×10^{-4}
		Btu/min	5.691×10^{-2}
		Btu/hr	3.413
Pressure	$Newton/m^2$	Atmosphere	3.413
		lbf/in^2	1.451×10^{-4}
		lbf/ft^2	2.088×10^{-2}
Speed	m/sec	ft/sec (fps)	3.281
Temperature	K	F	$(9/5 - 459.67/t_K)$
Volume	m^3	in^3	6.097×10^4
		ft^3	35.335

GLOSSARY OF TERMS

Abort	Premature and abrupt termination of an event or mission because of existing or imminent degradation or failure of hardware. (In the safety analysis, no distinction is made between an accident and abort.)
Accident	An undesirable unplanned event which may or may not result from a system failure or malfunction.
Airborne Material	*Radioactive gases, vapors and particulates released to the air.*
Breached	Fuel elements, coolant loops, pressure vessel, core, or radiation shield are (a) physically torn by thermal or mechanical stresses, (b) cut open by fragmentation or (c) split open by internal pressures.
Bulk Damage (Radiation)	Radiation causing atomic displacement in semiconductor devices - sometimes commonly referred to as "crystal" damage.
Contamination	A condition where a radioactive material is mixed or adheres to a desirable substance or where radioactivity has spread to places where it may harm persons, experiments or make areas unsafe
Control Drum Motion	Rotation of the control drums or drum toward or away from the most reactive position within a reactor. (As used in safety analysis results in a reactor excursion)
Core Compaction	The act of increasing the density of the core which results in increased reactivity and possible criticality
Cover Gas	A gas blanket used to provide an inert atmospheric environment around hardware to minimize potential reactions which can give rise to accident situations.
Credible	An event having a relative or cumulative probability of occurence of $> 10^{-12}$.
Criticality	The act of obtaining and sustaining a chain reaction
Critical Mass	The mass of fissionable material necessary to obtain criticality
Cumulative Probability	Sometimes referred to as "Mission probability" is the overall probability of a sequence of events occurring (product of "relative probabilities" of the individual events along a path of an abort sequence tree)
Damaged	Same as "Breached".
Decontamination	The removal of undesired dispersed radioactive substances from material, personnel, rooms, equipment, air, etc. (e g , washing, filtering, chipping).
Destructive Excursion	An excursion (safety analysis assumes ~ 100 MW-sec) accompanied by a complete disassembly of the reactor, a prompt radiation emission and release of fission product gases, vapors and particulates.
Disassembly/Disassembled	Nuclear hardware (e g , reactor) which has been violently broken or separated into parts and not capable of forming a critical mass.
Disposal	The planned discarding or recovery of nuclear hardware
Distributed Material	The spread of nuclear fuel and radioactive debris on the earth's surface following impact or destructive excursion
Dose Guidelines	Established radiation levels used in the nuclear safety analysis for evaluating number of exposures and in determining operating limits and boundaries.
Dosimetry	Techniques used in the measurement of radiation

GLOSSARY OF TERMS (CONT)

Dynamic Interference	An experiment radiation effect where the flux rate above some threshold (a fraction of the experiment signal-to-noise ratio at maximum sensitivity, for electronic detectors) causes noticeable degradation of data quality
Early Reactor Disposal	Attempted disposal of the reactor prior to its successful completion of 5 years operational lifetime.
Electrical Power System	All components (heat source, regulation, control, power conversion and radiators) necessary for the development of electrical power. The reactor electrical power system includes all hardware associated with the Power Module with the exception of the Disposal System
End of Mission	Generally associated with the termination of the mission or flight. Is also used to define those activities involved with disposal and recovery of hardware after intended lifetime
Excursion	A rapid and usually unplanned increase in thermal power associated with the operation of a power reactor
Exposure Limit	Total accumulated or time dependent radiation exposure limits imposed on personnel by regulatory agencies or limits which preclude equipment damage.
Fission Products	The nuclides (quite often radioactive) produced by the fission of a heavy element nuclide such as U-235 or Pu-239.
Fuel	Fissionable material in a reactor or radioisotopes in a heat source used in producing energy
Fuel Element/Capsule	A shaped body of nuclear fuel prepared for use in a reactor or heat source Common usage involves some form of encapsulation
Fuel Element Ablation	Fuel element clad and/or fuel removed by reentry heating, releasing fission products to the atmosphere
Fuel Element Burial	Individual fuel elements beneath the ground surface completely covered by soil
Gallery	The compartment of the reactor shield which houses the major primary loop components
Ground Deposited Particles	Particles deposited on the ground from radioactive fallout
Hazard	An existing situation caused by an unsafe act or condition which can result in harm or damage to personnel and equipment
Hazard Source	The location and/or origin of the hazard
Immediate Reentry	Very early reentry of the reactor (e g , misaligned thrust vector which causes firing of the reactor disposal rockets toward earth resulting in 1-2 day reentry)
Impact in Deep Ocean	Reentering and/or impact of nuclear material in the ocean, beyond the Continental Shelf where contamination of the food chain is extremely remote
Impact in Reservoir	Reentering and/or impact of nuclear material in reservoir containing potable drinking water
Impact in Water Containing Edible Marine Life	Reentering and/or impact of nuclear material on the Continental Shelf or in a body of water such as a lake, river or stream where contamination of the food chain is likely.
Intact Reentry/Reactor	A nuclear system that retains its integrity upon impact and in the case of a reactor is capable of undergoing an excursion.
Integrated/Cumulative Dose	The total dose resulting from all or repeated exposures to radiation
Interfacing Vehicle	Any defined module, spacecraft, booster or logistic vehicle which may have an interaction with the Manned Space Base.

GLOSSARY OF TERMS (CONT)

Ionization Damage	Radiation causing surface damage in materials (e.g., the fogging of film)
Land Impact	Nuclear hardware which impacts land at terminal velocities following reentry and lower velocities during prelaunch or early in the launch/ascent phase.
Loss of Coolant	Loss of organic or liquid metal coolant in reactor coolant loops due to failure/accident
Mission Support	Supporting functions provided the Space Base Program by ground personnel and interfacing vehicles throughout all mission phases.
Moderator	Material used in a nuclear reactor to slow down neutrons from the high energies at which they are released to increase the probability of neutron capture. Water and hydrogen are moderators in a thermal reactor.
NaK-78	An alloy of sodium (22% by weight) and potassium (78%) used as a liquid metal heat transfer fluid.
No Discernible Hazard	Represents no hazard to the general populace
Non-credible	An event having a relative or cumulative probability of occurrence of $< 10^{-12}$. Considered not worthy of concern.
Non-destructive Excursion	A temperature excursion which may rupture the primary coolant loop and release fission products to the environment but - leaves the reactor shield essentially intact.
Normal Operations	Planned and anticipated mission activities and events
Over Moderation	Immersion of reactor in an hydrogenous medium (moderator) resulting in increased neutron reflection into the core causing a reactor excursion
Permanent Shutdown	Enacting provisions which preclude reactor criticality under all foreseeable circumstances.
Poison	A material that absorbs neutrons and reduces the reactivity of a reactor
Power Module	The complete reactor/shield, radiator, power conversion system and disposal system unit as provided on the Space Base
Premature Reentry	Any reentry of the reactor from Earth orbit with orbital lifetimes less than the planned (1167 year) orbital decay time of the 990 km disposal altitude.
Pre-poison	A poison which is added to the reactor fuel for purposes of controlling reacticity. Sometimes referred to as "burnable poison"
Prompt Radiation	The neutron and gamma radiation released coincident with the fission process as opposed to the radiation from fission product decay. Commonly associated with an excursion event.
Quasi-Steady State	A term used to describe the condition when a reactor periodically goes critical and then sub-critical due to water surging in and out of the core
Radiological Consequences	The radiation exposure effect on personnel and the ecology from a radiation release accident or event
Radiological Hazards	Hazards associated with radiation as differentiated from other sources.
Radiological Risk	The term used to define the average number of people anticipated to be affected by radiation in a given mission or phase thereof
Random Reentry	The uncontrolled non-directed reentry of a vehicle from orbit.
Reactivity	A measure of the departure of a reactor from critical such that positive values correspond to reactors super-critical and negative values to reactors which are sub-critical (Usually expressed in multiples of a dollar)

GLOSSARY OF TERMS (CONT)

Reactor Fails to Survive Reentry	Reactor/shield is completely disassembled by reentry heating, releasing individual fuel elements and structural debris to the atmosphere.
Reactor Survives Reentry	Reactor is not disassembled by reentry heating, radiation shield may be damaged
Reactor/Shield	A system containing the reactor, control drums, gallery and surrounding LiH and Tungsten shield.
Relative Probability	Probability of the occurrence of a particular event given a defined set of choices
Repair/Replacement	Consists of (a) physically repairing all faulty systems, or (b) complete replacement of the faulty system(s).
Ruptured	Same as "Breached".
Safety	Freedom from chance of injury or loss to personnel, equipment or property
Safety Catastrophic	Condition(s) such that environment, personnel error, design characteristics, procedural deficiencies, or subsystem or component malfunction will severely degrade system performance, and cause subsequent system loss, death, or multiple injuries to personnel (SPD-1A).
Safety Critical	Condition(s) such that environment, personnel error, design characteristics, procedural deficiencies, or subsystem or component malfunction will cause equipment damage or personnel injury, or will result in a hazard requiring immediate corrective action for personnel or system survival (SPD-1A).
Safety Marginal	Condition(s) such that environment, personnel error, design characteristics, procedural deficiencies, or subsystem failure or component malfunction will degrade system performance but which can be counteracted or controlled without major damage or any injury to personnel (SPD-1A).
Safety Negligible	Condition(s) such that personnel error, design characteristics, procedural deficiencies, or subsystem failure or component malfunction will not result in minor system degradation and will not produce system functional damage or personnel injury (SPD-1A).
Scram System	A separate, possibly automatic, mechanism used to rapidly shut down a reactor.
System Safety	The optimum degree of risk management within the constraints of operational effectiveness, time and cost attained through the application of management and engineering principles throughout all phases of a program.
Space Base Program	All aspects of the Space Base mission including all prime and support hardware and personnel both on the ground, at sea or in orbit, which are required throughout all mission phases.
Space Debris	Uncontrolled radioactive or non-radioactive man-made objects in space, these objects may present collision and radiation hazards to earth orbital missions.
Space Shuttle	The manned vehicle used for the transportation of cargo to and from earth orbit. A separately launched vehicle (booster) on which the Shuttle is placed provides the initial first stage thrust.
Source Terms	Characterization of a radiation hazard with regard to (a) location, (b) magnitude, and (c) exposure mode.
Tracer	Material in which isotopes of an element may be incorporated to make possible observation of the course of the element through a chemical, biological or physical process.

Space Division / Headquarters: Valley Forge, Pennsylvania ☐ Daytona Beach, Fla. ☐ Cape Kennedy, Fla. ☐ Evendale, Ohio ☐ Huntsville, Ala. ☐ Bay St. Louis, Miss. ☐ Houston, Texas ☐ Newport Beach, Calif.