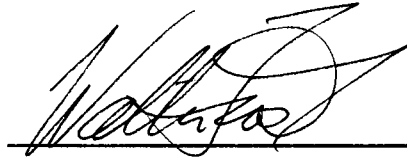


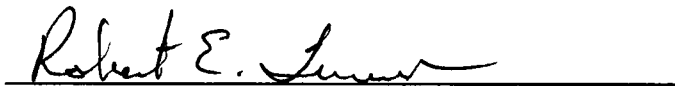
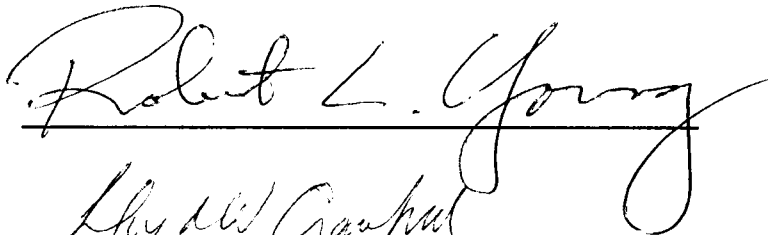
To the Graduate Council:

I am submitting herewith a dissertation written by Richard Thomas Congo entitled "Design and Development of a Space Station Hazardous Materials Information System for Assessing Chemical Compatibility". I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Engineering Science.



Walter Frost, Major Professor

We have read this dissertation
and recommend its acceptance:



Accepted for the Council:



Vice Provost and Dean
of the Graduate School

DESIGN AND DEVELOPMENT OF A SPACE STATION
HAZARDOUS MATERIALS INFORMATION SYSTEM FOR ASSESSING
CHEMICAL COMPATIBILITY

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Richard Thomas Congo
May 1990

ACKNOWLEDGEMENTS

The author wishes to express sincere appreciation to the people who have stimulated interest and contributed to this dissertation. He is indebted to those who have willingly given their time and shared expertise in the many disciplines which make this dissertation possible. Thanks go to his committee members, Dr. Robert E. Turner, Dr. Lloyd Crawford, Dr. Robert L. Young and Dr. Kenneth Kimbel, for their professional guidance, academic instructions, and personal encouragement.

In particular, the author wishes to acknowledge the help of his advisor, Dr. Walter Frost, who devoted an immeasurable amount of time and patience for useful suggestions during the authors attendance at UTSI and completion of this dissertation.

The author wishes to further extend his appreciation to his wife, Terrie, and his son, Richie, for their support during those many days and nights that I could not be with them.

ABSTRACT

This dissertation addresses the need for and development of a modeling process which will perform chemical and material compatibility analyses for the Space Station Microgravity and Material Processing Facility (MMPF). The modeling process includes development of a data base containing physical, chemical, toxicological, reactive, corrosive, and incompatibility properties for materials to be used in construction of the Space Station Freedom or in experiments to be conducted on-board. The underlying hypothesis of the modeling process is that by knowing the number of chemical incompatibilities, hazards and corrosivities for any given facility or mission, one can modify or substitute chemicals for a facility or facility manifest to reduce the number of chemical incompatibilities, hazards and corrosivities thus reducing the number of potential safety problems aboard the Space Station MMPF. The proposed process was developed into a computerized system with the aid of a relational data base and the development of application programs. An experiment was performed to validate the proposed model. This experiment consisted of utilizing the computerized system to identify the number of chemical incompatibilities, hazards and corrosivities for a given facility and a mission. The chemical requirements for the facility were modified utilizing "substitute" chemicals where appropriate, and the mission set

was modified by replacing facilities with "substitute" facilities. The model was utilized to identify any reduction in the number of chemical incompatibilities, hazards and corrosivities resulting from the substitutions. The results of the study and the experiments establish both the process and the hypothesis to be accurate.

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LIST OF ABBREVIATIONS

UTSI - University of Tennessee Space Institute
MMPF - Microgravity and Manufacturing Process Facility
SSF - Space Station Freedom
WP01 - Work Package 1
USL - United States Laboratory
HAB - Habitation Module
LOG - Logistics Module
PMMS - Process Materials Management Subsystem
ECLSS - Environmental Control and Life Support System
SSP - Space Station Program
MUA - Materials Usage Agreement
MSFC - Marshall Space Flight Center
HDBK - Handbook
SwRI - Southwest Research Institute
NACE - National Association of Corrosion Engineers
CorSur - Corrosion Survey
DMSO - Dimethyl Sulfoxide
TGS - Triglycine Sulfate
EDTA - Ethylenediamine tetraacetate
DECHEMA - Deutsche Gesellschaft für Chemisches Apparatewesen,
Chemische Technik und Biotechnologie e.V.
ChemPro - Tradename for Occupation Health Services'
Material Safety Data Sheets
CAS - Chemical Abstract Service

LIST OF ABBREVIATIONS (continued)

CEA - Chemical Engineering Abstracts
EMA - Engineered Materials Abstracts
MAPTIS - National Aeronautical and Space Administration -
Materials and Processes Technical Information
System
RAP - Resource Allocation Program
TBE - Teledyne Brown Engineering
MPY - Milliinches Per Year
SCC - Stress Corrosion Cracking
TFE - Teflon, tetrafluoroethylene
FEP - Teflon, fluorinated ethylene propylene
A-B-S - Butadiene-acrylonitrile
GaAs - Gallium Arsenide
HgCdTe - Mercury-Cadmium-Tellurium
TiC - Titanium Carbide
NCHIS - NASA Chemical Hazards Information System
MSDS - Material Safety Data Sheet
IOC - Initial On-orbit Configuration
PMC - Permanent Manned Configuration
ALF - Acoustic Levitator Facility
ASF - Alloy Solidification Facility
BIF - Bioreactor/Incubator Facility
BSF - Bridgeman, Small Facility
CFEF - Continuous Flow Electrophoresis Facility

LIST OF ABBREVIATIONS (continued)

CPPF - Critical Point Phenomena Facility
DSBF - Droplet Spray Burning Facility
EF - Electroepitaxy Facility
ELF - Electrostatic Levitator Facility
EMF - Electromagnetic Levitator Facility
FPF - Fluid Physics Facility
HTF - High Temperature Facility
IFF - Isoelectric Focusing Facility
LRF - Latex Reactor Facility
OPCGF - Organic & Polymer Crystal Growth Facility
PGCF - Premixed Gas Combustion Facility
PCGF - Protein Crystal Growth Facility
RSCF - Rotating Spherical Convection Facility
SSBF - Solid Surface Burning Facility
VCGF - Vapor Crystal Growth Facility
SMAC - Spacecraft Maximum Allowable Concentration
OSHA - Occupational Safety and Health Administration
JSC - Johnson Space Center

CHAPTER I

INTRODUCTION

1.1 Background

Space Station Freedom (SSF) represents America's premier eminence in space. For the first time, the United States will continuously house astronauts for scientific studies unimaginable during the Skylab years. SSF's mission is to support scientific and technological activities in space leading to potential commercialization. These activities involve the life sciences, astronomy, astrophysics, remote sensing, planetary exploration, environmental monitoring, satellite servicing, and materials processing.

NASA plans to perform over a hundred different missions in the coming decade. Incrementally deployed, the Space Station will evolve into modules linked to a main structure. Because the Space Station is to be "user friendly," i.e., NASA will attempt to accommodate all experimenters with electric power, laboratory storage, drains, vents, etc.. It is therefore evident that a large variety of different chemicals will be taken on-board.

Space Station Freedom is estimated to be operational in the mid to late 1990's. The SSF's design and development has been divided into various work packages and assigned to corresponding NASA centers for management. Work Package 1 (WP01), which is under the auspices of the Marshall Space

Flight Center, Huntsville, Alabama, is chartered to design, manufacture, and assemble the Resource Nodes and Airlock Systems, the United States Laboratory Element (USL), the Habitation Element (HAB), and the Logistics Element (LOG). Each element or module will be outfitted with appropriate hardware and software for operations over the 30 year life duration. As pictured in Figure 1.1, the current SSF design consists of five pressurized modules.

1. The U.S. Laboratory Module
2. The Habitation Module
3. The Logistics Module
4. The European Space Agency Columbus Module
5. The Japanese Experiment Module

The modules are linked together by pressurized nodes which can accommodate experiment hardware. The nodes also provide attachment points for additional modules, berthing ports, or additional nodes.

In order to establish a microgravity laboratory for research and technology development, NASA turned to current microgravity researchers, academia, aerospace industries, and others to define their research interests. This resulted in the Microgravity and Manufacturing Processing Facility (MMPF).

The primary functional requirement of the MMPF is to provide a laboratory environment for conducting microgravity science and materials processing technology development. The laboratory will include primary processing equipment as well

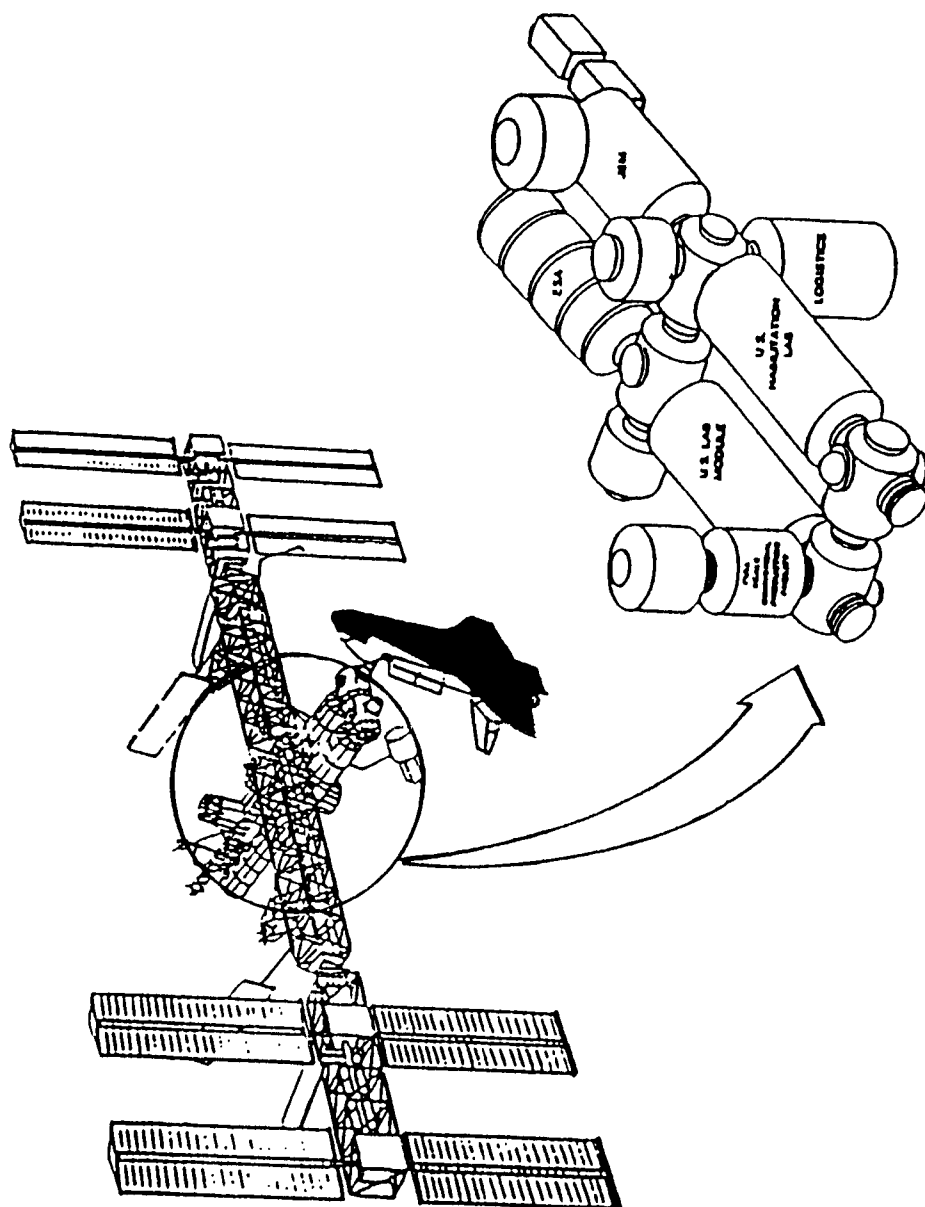


Figure 1.1 Current Space Station Configuration

as experimental facilities and/or instrumentation to be used for characterization studies. The MMPF must be designed for the 30 year life of the station and flexible enough to change payload complements at any time.

A listing of the proposed facilities and a brief description of the example experiments and operating parameters is included in Appendix A (Ref 1). Because of the limited space and diversity in disciplines, the US Laboratory module cannot accommodate all of the facilities at any one time.

1.2 Problem Statement

In performing analyses of chemical and material compatibility for Space Station applications, it became apparent that a complete set of payload operational data including physical, chemical, toxicological, reactive, corrosive, and incompatible properties of the chemicals to be used for each experiment and/or facility must be developed. This data set must be coupled with a modeling process capable of rapidly identifying the potentially toxic or hazardous combinations of specific chemicals that could occur with any proposed manifest of experiments planned for the Space Station. The chemical compatibility model with the chemical information could also be used to perform numerous design and redesign studies. From these studies acceptability of candidate construction materials to be used in storage

vessels, transport networks, valves, seals, etc., can be evaluated. Thus, the model serves a two fold purpose:

1. compatibility determination of experiment manifests and
2. materials selection for facility design.

1.3 Solution Approach

The model developed for this dissertation examines the chemicals anticipated for use within the MMPF and those for the Process Materials Management Subsystem (PMMS). The PMMS must accommodate the effluent wastes anticipated from the MMPF. The chemical reactivity between any two chemical species must be examined for safety and design considerations. While it is not possible to design the Space Station to accommodate any and all chemicals for potential flight experiments, it can be designed to provide the maximum scientific benefits to the experimenter and doing so in a safe environment. The ultimate program objective would be to couple this modeling program with a knowledge based artificial intelligence integration capability that could predict the synergistic reaction products, thermophysical property data, and incorporate decontamination methodologies.

The MMPF, located within the USL, will consist of a variety of "facilities" to accommodate the experiments. Everything from crystal growth chambers to alloy solidification furnaces will be carried on-board. Although

the generic experiments planned for the Space Station module have been established (Ref 1), the extent of the chemical hazards and the toxicity of the materials anticipated for use within these experiments have not been fully evaluated (Ref 2). Identification of the chemical reactions one might anticipate from materials associated with the experimental research, including precursors, products, and byproducts is initiated in this study.

A data base of chemicals and their compatibility is developed to evaluate potential accidents that might occur from a failure of, or leak in, the Fluid Management System of the Environmental Control and Life Support System (ECLSS) or from the Waste Management System of the PMMS. Coupled with the appropriate software this will provide a tool which will allow hazardous situations to be identified and permit safety considerations to be factored into the design during development phases of the station and is illustrated in Figure 1.2

Hazards may occur through inadvertent mixing of incompatible chemicals which yield explosive or highly corrosive mixtures. To evaluate these hazards and to assess the potential effects of materials incompatibility, a methodology to assess and assure chemical compatibility is developed. First a comprehensive data base for each experiment, listing the chemical composition of the experimental substances, as well as, that of the operational

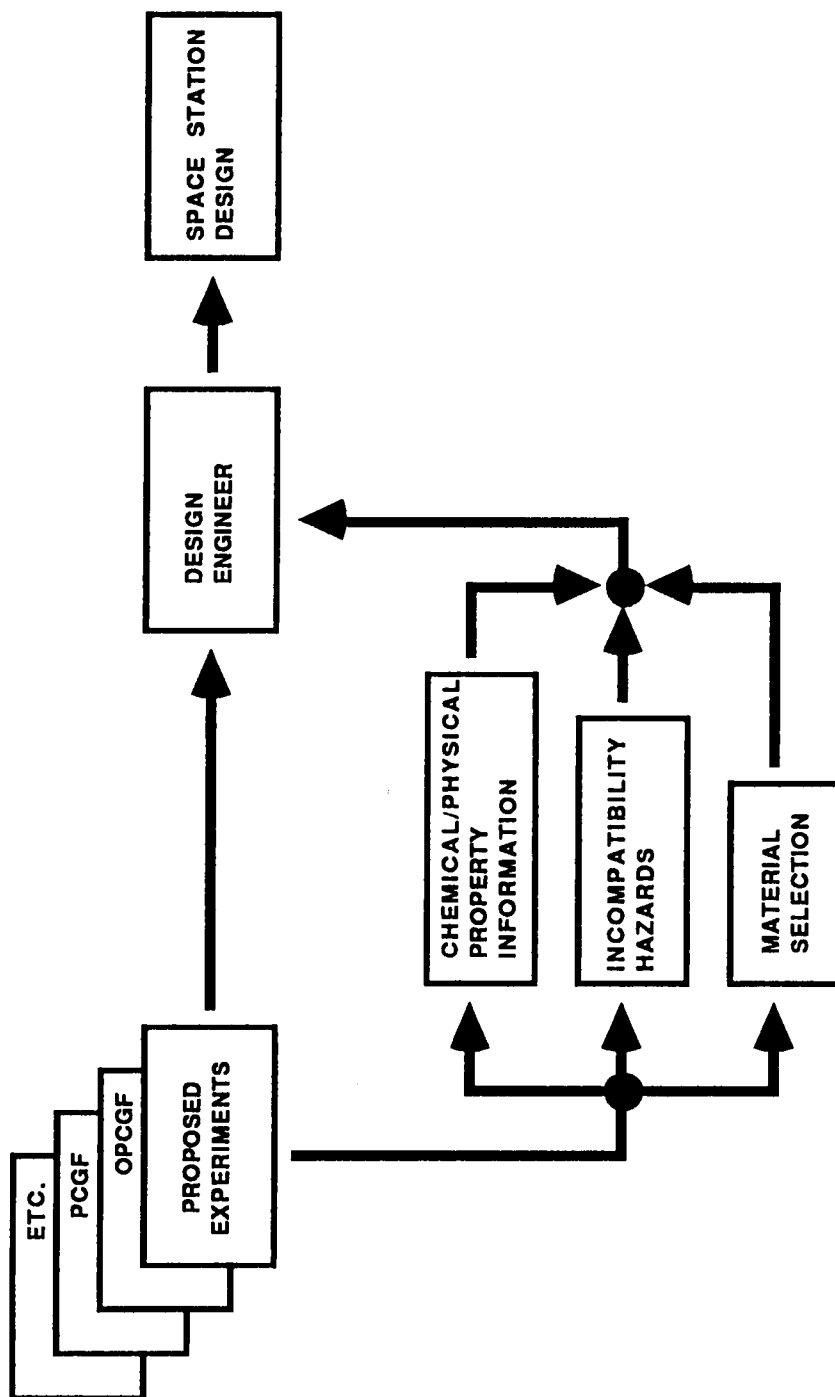


Figure 1.2 Space Station Design Logic

materials, (i.e. cleaning fluids, equipment exchange fluids, etc) is established. The data base is structured to readily allow routine updating.

Payload operational data required for the data base include:

1. Facility
2. Experiment
3. Operating parameters
4. Chemicals used per cycle
5. Characterization/Support chemicals
6. Number of cycles required during mission
7. Waste chemicals
8. Waste gases
9. Venting
10. Storage

The data base will ultimately contain detailed drawings or schematics of each experimental apparatus as this information becomes available. Potential sources from which chemical substances could be accidentally released will be clearly identified on the drawings with rapid chemical properties data retrieval routines available to superimpose hazardous conditions. The physical and chemical property of each substance is determined and cross referenced with the respective experiment and/or facility. A list of the quantity for each suspected contaminant in grams or in liters is given. The data base is programmed to contain information on the

toxicological hazards associated with each of the identified contaminants.

The hazardous materials model contains information so that future experiments can be evaluated as to potential hazardous operations. The computer program, which rapidly and qualitatively identifies and displays incompatible chemicals associated with MMPF experiments on-board the spacecraft, has been developed using the Paradox /386 Database. Paradox /386 is a registered trademark of Borland International. A detailed listing of the contents and exact composition of each facility or experiment however is currently unavailable. Actual flight hardware is still years away from final design. The purpose of this dissertation is to develop the computer system as an engineering tool to aid in the design and to simultaneously develop a model for identifying the chemical hazards and remedial procedures. For this dissertation the capability of the computer system is demonstrated with the current MMPF data base along with hypothetical Space Station manifests of facilities and experiments.

1.4 Design Requirements

The new generation Space Station is being designed to accommodate a multiplicity of experiments and experimental programs. These experiments will involve many chemicals for testing, support materials for operating the system, and a

variety of materials of construction. Compatibility of these chemicals during storage, transport, or disposal of the effluent waste, becomes an important design consideration.

Since the primary purpose of the Space Station is to offer scientists unprecedented opportunity for extended research and experimentation in low Earth orbit, questions on how the wastes from the various experiments react with one another (effluent/effluent) and how they react with the materials used in construction (effluent/system) must be answered. Moreover the questions must be addressed during the design and construction phases of the Space Station. Results obtained from this research, will provide NASA and its contractors with an engineering design tool which will assure the safe disposal of chemicals for the 30 year life span of the station. This dissertation presents an engineering tool for investigating these considerations.

NASA has developed specific documentation detailing the general requirements for materials used in the fabrication of the Space Station hardware by considering the operational requirements and the engineering design properties of the candidate materials. The document, SSP 30233, (Ref 3) provides a listing of applicable general and detailed requirements and a listing of 33 other applicable documents to form a part of the Materials and Processes (M&P) specifications and requirements.

SSP 30233 defines therein the requirements for acceptability of materials for flammability and offgassing (Ref 4), fracture control (Ref 5), materials selection list (Ref 6), welding (Ref 7), vacuum stability of materials and polymeric materials (Ref 8), external contamination control (Ref 9), and metallic materials for aerospace vehicle structure (Ref 10). The use of SSP 30233 is to aid the designers in considering material selection based on mechanical properties, fracture toughness, flammability and toxicity, etc. SSP 30233 does not address hazardous chemical/chemical interactions and offers limited information with respect to corrosion resistant materials.

To ensure that the contractor complies with the requirements as identified in SSP 30233, NASA has imposed additional constraints that the contractor must provide an M&P selection, control, and verification plan detailing compliance. This plan covers the methods of coordinating, approving, and tracking of materials and/or process usage.

When a material or process does not meet the requirements as identified in SSP 30233, then a Materials Usage Agreement (MUA) is submitted. MUAs shall be submitted for materials not rated "A" in MSFC-HDBK-527 (Ref 6) and are subject to further reviews by appropriate technical personnel prior to final design.

In the selection of candidate materials and processes, the designer must first answer the question as to what

function must the component or system accomplish. Limitations as to the size, weight, or power must be defined in the beginning, as well as, constraints detailing reliability, operating life, and potential failure modes. Anticipated performance must consider fabrication, assembly, transportation, installation and maintenance.

There is still another set of criteria that potential materials and processes must consider. As alluded to in the preceding paragraph, reliability and potential failure modes narrow the range of acceptable materials due to potentially hazardous exposure to environmental conditions. The designer must be aware of the consequences from exposure to reactive liquids and vapors, the amount of time exposed and the frequency of exposure. One must decide how to minimize the acute hazards during the consequences of a failure.

Southwest Research Institute (SwRI) has published a report entitled "Structural and Mechanical Systems Long-Life Assurance Design Guidelines" (Ref 11). This report identified areas that must be carefully considered from the viewpoint of long-life design. Among these are thermal-fatigue cycles due to extended orbital exposure, particle debris penetrations of structural members, and the atomic oxygen effects on exposed polymers and lubricants. SwRI identifies the material selections issues and provides guidelines for long-life design by grouping materials into metals, polymers, composites, and thermal control and radiation coatings. Each topic is

examined for effects due to atomic oxygen, solar radiation, plasma, aging, debris and micrometeoroid damage, mechanical and thermal loadings, fatigue and wear. However, SwRI has failed to include the effects of chemical interactions of experiment effluent waste into their long-life design considerations.

1.5 Safety Considerations

Development of a "user friendly" laboratory environment has generated an enormous amount of controversy. Driven by the desire to accommodate any and all experimenters, the Space Station endeavors to offer a laboratory facility that will allow crewmembers to be much more interactive with the experiments than allowed by either SKYLAB, SPACELAB, or shuttle mid-deck experiments. Although this direct participation in on-orbit processing, material transfer, and characterization of samples provides scientists an increased knowledge of microgravity effects on material processing, it at the same time increases, significantly, associated risks. The probability of a hazardous materials situation is dependent upon the safety guidelines and requirements imposed. Once a programmatic decision has been made as to the level of the acceptable risk, then safety requirements are imposed to prevent that risk from becoming a reality.

SSP 30309, "Safety Analysis and Safety Risk Assessment Requirements and Processes Document for the Space Station

Program" provides Safety Engineers the techniques for performing specific hazard analyses. However, because of the diversity of experiments proposed for the Space Station, developing the safety guidelines and requirements for working with hazardous materials requires new considerations of chemical interactions, material compatibility, and in deciding the mission manifest of experiments. Effluent waste from these experiments may be incompatible with each other generating either a violent reaction or potential explosion with the module waste duct. Alternately, experiment wastes from different point sources may combine to produce a third component which is incompatible with other effluent waste or system materials. The possibility of synergistic reactions therefore must be considered by the Safety Engineers.

CHAPTER II

RELATED MODELING PROCESSES

2.1 Considerations in Assessing the Design of the Process Materials Management System

In view of the fact that Space Station Freedom is to be designed to operate safely for 30 years, the types of materials used for construction must be compatible with the chemicals anticipated for use in each envisioned experiment. Manifesting these experiments will be the most difficult task in assuring maximum scientific benefit as a function of safety and materials compatibility. Moreover, in order to minimize the costs of operations, multiple experiments will be operating simultaneously. Effluent wastes associated with these experiments are ducted through a common waste line to the Process Materials Management System (PMMS) for further processing. It is essential to know the exact effluent waste from each experiment in order to assess its compatibility with the materials of construction and with other chemical effluents.

The PMMS is tasked to provide benign storage or safe destruction of either solid, liquid, or gaseous wastes for the manifested experiments from the Microgravity and Life Science Experiments area. The design features of the PMMS include:

1. No toxic or hazardous materials in the module.
2. No crew involvement except in maintenance or contingency mode.

3. Ninety day operation without shuttle resupply.
4. Handling and process components/materials compatible with wastes.
5. Use of passive, low maintenance, long life components.
6. Redundant PMMS components.
7. Generalized waste handling/treatment system.

Plans for treatment of waste include a number of viable options. Among these are processing and treatment directly at the experiment, processing through a central treatment system, or segregated storage and return. Included in all of these options is some means of transferring the material.

A set of design criteria for the PMMS to accommodate all of the chemicals from the science areas, including the experimental apparatus and support equipment, requires information on:

1. Experiment waste effluent
2. Flow rate
3. Chemical composition of wastes
4. Chemical compatibility (effluent/effluent and effluent/system)
5. Classification of compounds for simultaneous processing
6. Processing, storage, and venting plans
7. Recycle

The design logic incorporating the chemical compatibility safety evaluation is shown in Figure 2.1.

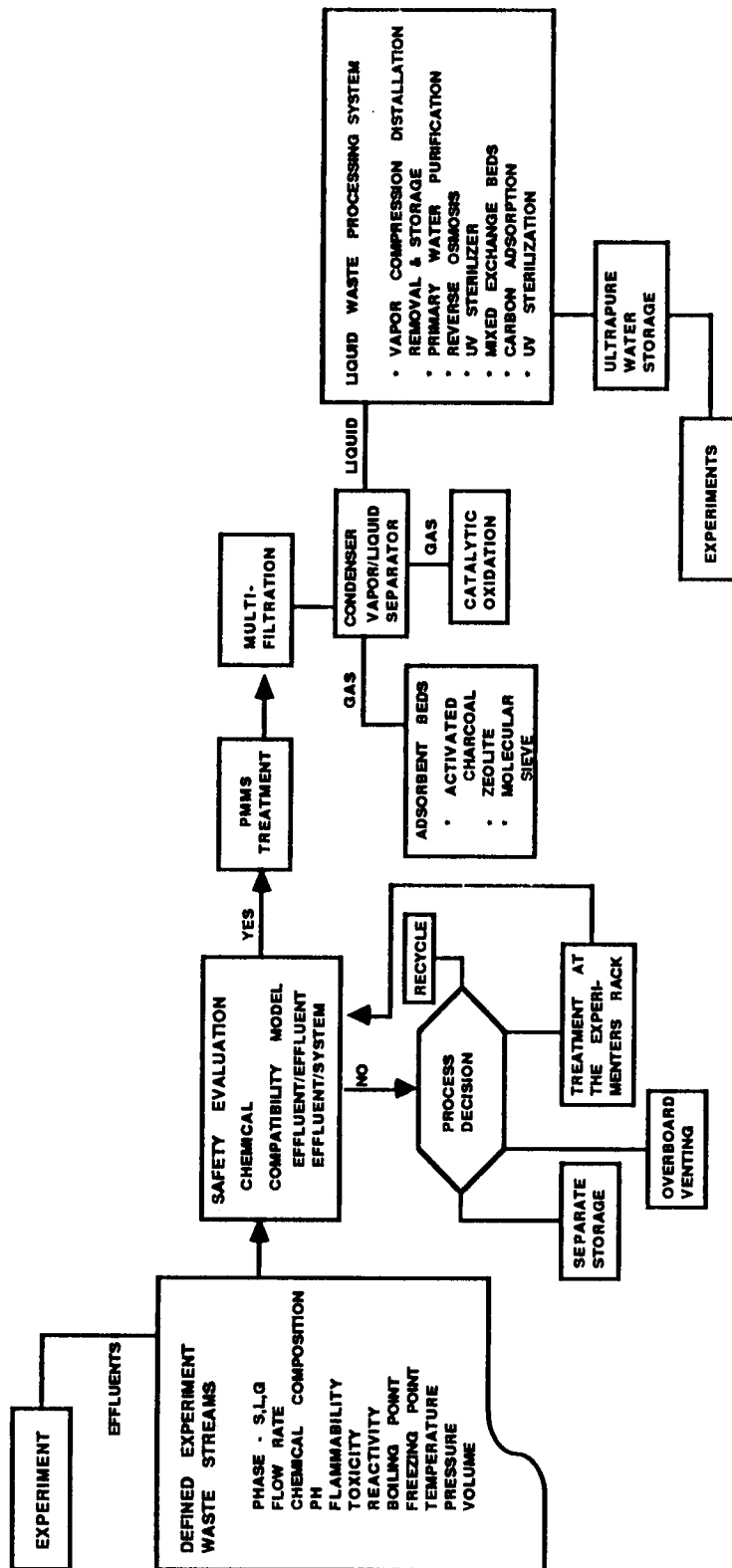


Figure 2.1 PMMS System Design Logic

The anticipated chemicals for use in the PMMS system are listed in Table 2.1. The corresponding metal corrosivity and nonmetal compatibility data for these chemicals, excluding the biomedical, were used in the model development for materials evaluation. Data from the National Association of Corrosion Engineers (NACE) Corrosion Survey (CorSur) programs are widely used by design engineers and are incorporated into the model reported herein.

2.2 Survey of Modeling Processes with Potential Application

An extensive literature search was carried-out to locate modeling processes encompassing chemical compatibility and corrosivity data extensive enough to attack the problem addressed herein. None were found. There are numerous on-line and personal computer data base services which address chemical interaction safety data. Examples of these can be found in Table 2.2.

Lockheed Missiles and Space Company has prepared various modeling scenarios (Ref 12) for preliminary design considerations of the PMMS. The effluent chemical waste steam compositions were the same as those used in the McDonnell Douglas Resource Allocation Program (RAP) study (Ref 13) for a 90 day mission. The Lockheed report identified the chemical contaminants that should not be allowed to enter the PMMS for processing. The limited results from this analysis indicated

Table 2.1 Candidate Materials for USL Experiments

CLASSIFICATION	CHEMICALS
CORROSIVES	Ammonium Bifluoride Bromine Chromic Acid Hydrochloric Acid Hydrofluoric Acid Hydrogen Peroxide Lithium Lithium Hydroxide Lithium Niobium Nitric Acid Phosphoric Acid Potassium Potassium Hydroxide Perchloric Acid Silver Nitrate Sodium Aluminate Sodium Hydroxide Sodium Hypochlorite Sulfuric Acid
FLAMMABLES	
<u>Liquids</u>	Acetone (2-propanone) Acetonitrile (Methyl Cyanide) Benzene n-Butanol Decane Dimethyl Sulfide Ethane Ethanol Furan (Furfuran) Glycerol Isopropyl Alcohol Kerosene (Fuel Oil No. 1) Latex Solution Methanol Methyl Ethyl Ketone (2-butanone) n-Propanol Toluene (Methyl Benzene) Xylene (o-,m-,p-)

Table 2.1 Candidate Materials for USL Experiments (continued)

CLASSIFICATION	CHEMICALS
<u>Gases</u>	Acetylene n-butane Ethylene Oxide Heptane Hydrogen Methane Oxygen Propane Trichloroethane
<u>Solids</u>	Lithium Potassium Potassium Ferricyanide Potassium Hypophosphite
HARMFUL VAPORS	
<u>Irritants</u>	Acetic Acid Acrolein Allyl alcohol Ammonium Hydroxide Benzene Carbon Tetrachloride Chlorine Chlorobenzene Chlorodifluoromethane (Freon 22) Copper Sulfate Pentahydrate Dichloromethane (Methylene Chloride) N,N-Dimethyl Formamide Fluorine Formaldehyde Formalin Hydrofluoric Acid Hydrogen Iodide Iodine Iron (Ferric) Chloride Isopropyl Alcohol Methanol Methyl Ethyl Ketone Oxalic Acid (Ethanedioic Acid) Phenol Orthophosphoric Acid Sodium Hypochlorite Sulfuric Acid

Table 2.1 Candidate Materials for USL Experiments (continued)

CLASSIFICATION	CHEMICALS
	Trichloroethylene Trichlorotrifluoroethane (Freon 113) Trimethylbenzene Xylene (o-,m-,p-) Zinc Chloride
ASPHYXIANTS	Argon Carbon Dioxide Carbon Monoxide Freon 113 (1,1,2-trichloro- 1,2,2-trifluoroethane) Halon Helium Nitrogen (gas & liquid) Xenon
TOXINS	Acetonitrile Acrolein (2-propenal) Allyl Alcohol (2-propenol) Ammonia Ammonium Chloride Arsenic Atropine Benzalkonium Chloride Beryllium Bromine 2-butoxyethanol (Butyl Cellusolve) n-butyl alcohol Cadmium Cadmium Iodide Cadmium Sulfide Cadmium Selenide Cadmium Telluride Carbon Monoxide Carbon Tetrachloride Copper (Cupric) Chloride Copper Nitrate Cyclohexanol Dihydroxydiethyl Ether (Diethylene Glycol) Diisobutyl Ketone 2,6-dimethyl-4-heptanone (Disobutyl Carbinol)

Table 2.1 Candidate Materials for USL Experiments (continued)

CLASSIFICATION	CHEMICALS
	Ethylene Oxide
	Fluorine
	Gallium
	Gallium Arsenide
	Gallium Phosphide
	Germanium
	Glutaraldehyde
	Hydrogen Bromide
	Hydrogen Peroxide
	Hydrogen Iodide
	Iodine
	Indene
	Indium
	Indium Phosphide
	Lead
	Magnesium Chloride
	Magnesium Oxide
	Mercury
	Mercuric Bromide
	Mercuric Chloride
	Mercuric Iodide
	Mercurous Iodide
	Mercury Cadmium Telluride
	Ozone
	Potassium Dichromate
	Potassium Ferricyanide
	Potassium Orthophosphate
	Potassium Permanganate
	Phenol
	Styrene
	Sodium Aluminate
	Sodium Azide
	Sodium Chlorate
	Sodium Nitrate
	Sodium Phenobarbitol
	Sodium Thiocyanate
	Silver Nitrate
	Sulfamic Acid
	Tellurium
	Tantalum
	Trichloroethane
	Trichloroethylene
	Trinitrophenol (Picric Acid)
	Hemimellitine (1,2,3-trimethyl benzene)

Table 2.1 Candidate Materials for USL Experiments (continued)

CLASSIFICATION	CHEMICALS
	Pseudocumene (1,2,4-trimethyl benzene)
	Mesitylene (1,3,5-trimethyl benzene)
	Zinc Chloride
	Zinc Telluride
HAZARDOUS DUSTS	Aluminum
	Beryllium
	Cadmium
	Cadmium Selenide
	Cobalt
	Copper
	Magnesium
	Magnesium Iodide
	Nickel
	Silicon
	Silicon Carbide
	Tellurium
	Tin
	Tungsten
	Zinc Telluride
	Zirconium
OTHERS	
<u>Chemicals</u>	Aluminum Oxide
	Ammonium Sulfate
	Boric Acid
	Ceric Oxide (Cerium Dioxide)
	Dimethyl Sulfoxide (DMSO)
	Iron
	Iron (Ferrous) Chloride
	Lactic Acid
	Latex Solution
	Lithium Niobium
	Magnesium Sulfate
	Niobium
	Polypeptides
	Polyphenylene Sulfide
	Potassium Chloride
	Potassium Metabisulfite
	Potassium Sulfate
	Sodium Acetate

Table 2.1 Candidate Materials for USL Experiments (continued)

CLASSIFICATION	CHEMICALS
	Sodium Citrate Sodium Chloride Sodium Sulfate Triglycine Sulfate (TGS)
<u>General Materials</u>	Activated Carbon Acepromazine Amine Acids Ampoule Fragments Atropine Boule Fragments Buffer Solution Burn Catalytic Suppressant Compounds Carbon Steel Catalyst Solution Cleaning Fluids Combustion Products (Ash, Soot, Tar) Contained Contaminants Culture Medium Cutting & Polishing Fluids Ethylenediaminetetraacetic Acid (EDTA) Electropolishing Solution
	<u>Enzymes</u>
	Acid proteinase Ademylate kinase Alcohol dehydrogenase Carbonic anhydrase C Carbonic anhydrase B Carbonic anhydrase A Carboxypeptidase A Carboxypeptidase B a-chymotrypsin b-chymotrypsin Chymotrypsinogen Elastase Glyceraldehyde-3 Hexokinase Lactate dehydrogenase Malate dehydrogenase Nuclease

Table 2.1 Candidate Materials for USL Experiments (continued)

CLASSIFICATION	CHEMICALS
	Pepsin Phosphoglycerate Protease S/G PB Ribonuclease A Ribonuclease B Subtilsin BPN Subtilsin Nov Superoxide dimutase Thermolysin Triesophosphate isomerase Trypsin Trypsin inhibitor Trypsin-trypsin inhibitor complex Trypsin-soybean trypsin inhibitor complex Tryrosine t-RNA synthetase
	Etchant Solutions Hoagland's Nutrient Solution Initiator Ketamine Hydrochloride Monomer Solution MPD Nutrients Oil Oxymorphone Hydrochloride Pentacocine Plastic Encapsulant Product Crystals/Spheres
	<u>Proteins</u>
	Raw Protein Solution: Lysozyme Ribonuclease Enzymes of Trypsin Family Phycoeyasin Pepsin Phospholipase As Rhodamase

Table 2.1 Candidate Materials for USL Experiments (continued)

CLASSIFICATION	CHEMICALS
	Globins: Hemoglobin Myoglobin Redox Systems: Cytochrome Bs Ferredoxin Cytochrome C Myogen Cytochrome C3 Proalbumin Comeamevalin A Raw Materials: Coal Paper PMMA Wood Felts Plastics Plexiglass Seed Crystals Semisolid Silicon Oils Sodium Cacodylate Staining Solutions or Fluids Tracer Elements: Tritium Chromium 51 Iron 59 Iodine 125 Zylazine

Table 2.2 Chemical Interaction and Corrosion Data Bases

ABBREVIATION	SOURCE
Hazardline	Occupational Health Services on-line service
DoD Laser Disks Service	Department of Defense
DECHEMA	Deutsche Gesellschaft fur Chemisches Apparatewesen, Chemische Technik and Biotechnologie e.v.
ChemPro	Occupational Health Services Laser Disk System
CAS	Chemical Abstracts Service
CEA	Chemical Engineering Abstracts
EMA	Engineered Materials Abstracts
MAPTIS	National Aeronautics and Space Administration Materials and Processes Technical Information System
CorSur	National Association of Corrosion Engineers Corrosion Survey
EHN	Environmental Health News

the fluid requirements, mass balances, total waste results (solids, liquids, or gases, and liquids with recycling) and the general resource requirements such as power, number of crew involvement activities per day, the number of experiments, physical size of experiment racks, as well as the number of waste chemical effluent event cycles. The Lockheed report did not address the hazards associated with the

chemical interactions nor the potential damaging effects due to improper material compatibility selection.

Using logistic programming models such as RAP and Spacelog (Ref 14), Teledyne Brown Engineering (TBE), who have responsibility for the PMMS design, has drafted an updated proposed experiment manifest list for a 10 year facility timeline. The data (Ref 15), (an example of which is shown in Figures 2.2 and 2.3 for Bridgman, Small experiment) represent only a draft version of a proposed facility manifest. It was developed to assess PMMS design constraints. This data represents updates from the 1986/1987 MMPF list of consumables for use in the PMMS Process Fluids Distribution and Storage System (Ref 1). An examination of these data indicates that specific chemical interactions must be understood and evaluated before PMMS processing or storage can safely occur. This dissertation develops a chemical compatibility model that identifies not only the chemical interactions, but the corrosive interactions as well. By incorporating the data provided by TBE and those which were originally established by SS-SPEC-0002 (Ref 16) for PMMS accommodation, safety evaluation requirements and materials and processes requirements can be assessed. The confidence level from this analysis may lead to additional evaluations, modifications to hardware, or modifications to the manifest timeline.

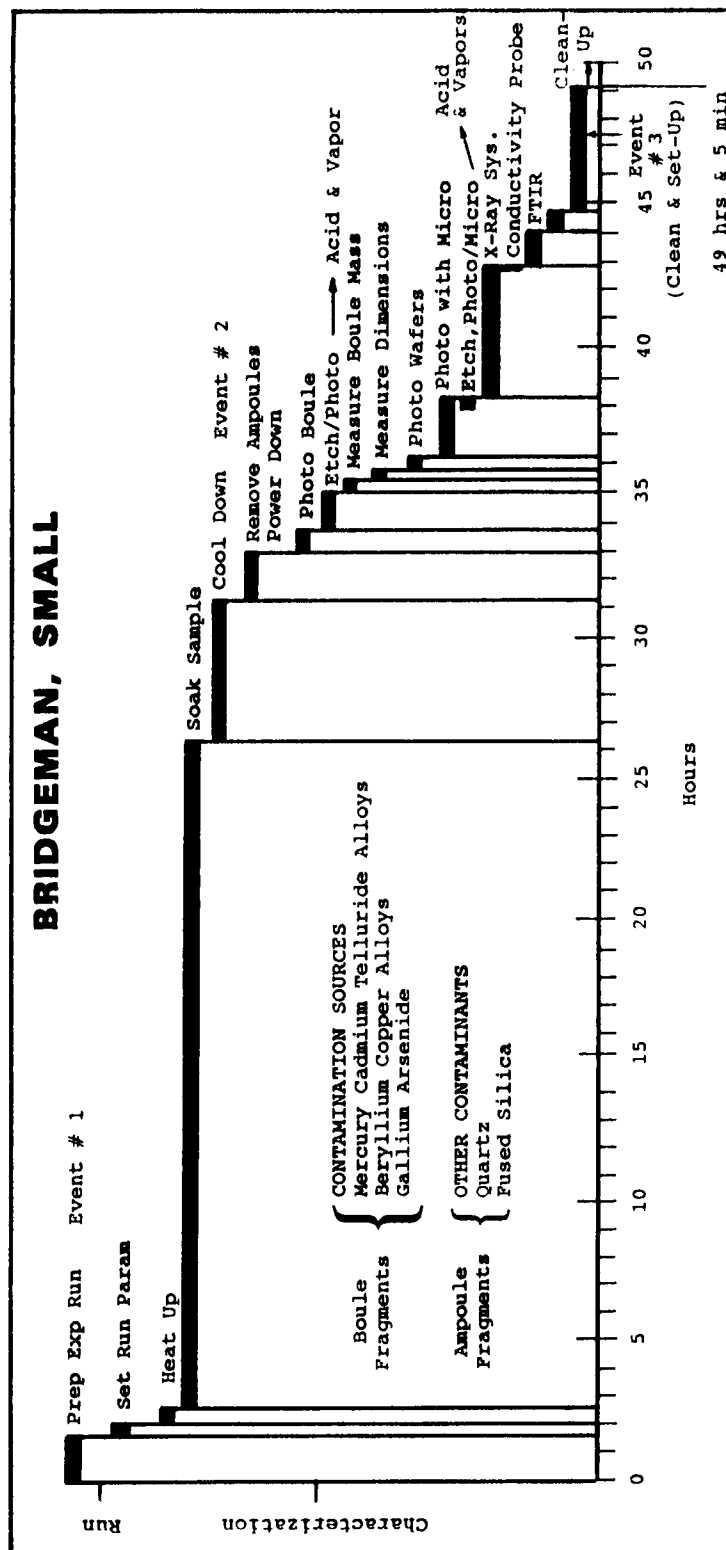


Figure 2.2 Bridgeman, Small -- Facility Timeline

EVENT WASTE (L)	1	2	3	TOTAL
ARGON	10	165		175
CABIN AIR	175	10		185
DISTILLED WATER			2+.002	2+.002
CLEANING FLUIDS			5+.005	5+.005
TIME (MIN)	25	25	15	65

Figure 2.3 Bridgeman, Small -- Effluent Wastes

2.3 Fundamental Concepts of Hazardous Chemical Interactions

In order to investigate the extent of the chemical interactions from the various wastes, it is essential to know what occurs during this chemical process and how it is measured. All chemical reactions involve changes in energy, most often in the form of heat. When the release of this energy exceeds that which can be dissipated into the immediate environment, hazardous conditions result. The most common underlying cause of the chemical incidents and accidents in the laboratory is the misunderstanding of the relationship of reaction kinetics, concentration, and temperature (Refs 17, 18). The importance of knowing the concentration of the reactants can be illustrated by the following example from Muir (Ref 17). A concentrated solution of ammonia was used instead of the diluted solution to destroy dimethyl sulfate. The net reaction was the formation of an explosive reaction.

To understand the fundamentals of the heats of reaction, let us assume that x moles of A react with y moles of B to form 1 mole of compound A_xB_y as shown in Equation 2.1.



At constant pressure, the heat generated by the transformation is equal to the increase in enthalpy of the system. In the initial state, the enthalpies of 1 mole of A and 1 mole of B is given by $H(A)$ and $H(B)$ respectively, hence the enthalpy of

the system in the initial state is $xH(A) + yH(B)$. In the final state the enthalpy of the product is equal to 1 mole of A_xB_y . Hence the net heat of reaction is as shown in Equation 2.2.

$$\Delta H = H(A_xB_y) - xH(A) - yH(B) \quad (2.2)$$

If ΔH is less than 0 it is said to be exothermic and heat is released by the system. If ΔH is greater than 0, or endothermic, heat is absorbed by the system. Equation 2.2 can be generalized to any number of reactants and products where ΔH is equal to the sum of the products minus the sum of the reactants. Analytical methods such as these could be used to assess the hazards relative to the stability and reactivity of the chemicals proposed for the Space Station. Complex mixture reaction calculations require an extensive thermophysical property data base such as DECHEMA, a registered trademark of the Deutsche Gesellschaft für Chemisches Apparatewesen, Chemische Technik und Bilstechnologies e. V. and licensed through Technical Database Service, New York, but it is not possible to evaluate all of the potential chemical interaction in this manner.

In generic terms, the types of reactions which might be anticipated are:

1. Explosion
2. Violent Exothermic (heat release and temperature rise)
3. Corrosion

4. Violent oxidation
5. Shock sensitive formation
6. Polymerization

2.4 Fundamentals Concepts of Corrosion

In selecting the proper materials for a particular application, compatibility with the constituent chemicals becomes important. The designer must acquaint himself, not only with the mechanical and physical properties of the candidate materials, but also, with the chemical properties as well. Understanding the electrochemical nature of corrosion given by the corrosion rate, materials applicability can then be assessed. The anodic and cathodic processes can be summarized as an equivalent electric current I in amperes, given by Equation 2.3:

$$Q = n F W/m \quad (2.3)$$

where:

Q = the number of Coulombs

n = the number of electrons involved in the reaction

F = Faraday = 96487 coulombs

W = weight of electroactive species

m = molecular weight of the electroactive species

By substitution and rearrangement Equation 2.3 can be rewritten as:

$$Q = it \quad (2.4)$$

where i is current amps and t is time.

Introducing m/n as the Equivalent Weight, E.W., and rearranging gives $W/t = i(\text{E.W.})/F$ as the corrosion rate of the metal in grams per second. Alternately, this can be expressed in the more familiar terms of mils per year (milli-inches per year) by dividing by the electrode area and the density and converting seconds to years, as shown in Equation 2.5.

$$W/t = 0.1288 I_{\text{corr}}(\text{E.W.})/d \quad (\text{mils/yr}) \quad (2.5)$$

where I_{corr} is the corrosion current density in $\mu\text{A}/\text{cm}^2$, E.W. is the equivalent weight of the corroding species in grams, and d is the density of the corroding species in g/cm^3 . Electrochemical measurements are applicable for alloys by defining the alloy equivalent weight as:

$$\text{Alloy E.W.} = \frac{N}{\sum_{i=1}^N} f_i M_i / n_i \quad (2.6)$$

where f_i is the atomic fraction of the i th component element in the alloy, M_i is the atomic weight of the i th component element, n_i is the electron loss required to oxidize the i th component element of the corrosion process, and N is the number of component elements in the alloy (Ref 19).

Experimental measurements can typically take hours to weeks in order to establish the corrosion rate for a particular metal or alloy. Measured corrosion rates are expressed either as the rate of metal penetration or as the rate of weight loss per unit area. The gravimetric method of

weighing the amounts of metal eroded over a rather long specified time frame is still the widely used and accepted definition of corrosion. An alternate method becoming more common for corrosion rates is the polarization technique. This method estimates the corrosion current. The rates of the anodic and cathodic reaction current typically follow the Tafel (Ref 20) equation given as:

$$E = a + b \log(I) \quad (2.7)$$

where E is the electrode potential of the specimen, I is the current density of the reaction, and a and b are constants. The constant b is usually referred to as the Tafel slope and is expressed in millivolts per decade.

Danford and Higgins (Ref 21), Knockemus (Ref 22), and Mansfield (Ref 23) have used the Tafel relationships for the cathodic overpotential (Equation 2.8),

$$\Delta E = +B_c \log(i_c/i_o) \quad (2.8)$$

and the anodic overpotential (Equation 2.9).

$$\Delta E = -B_a \log(i_a/i_o) \quad (2.9)$$

Corresponding current relationships (Equations 2.10 and 2.11) are used to establish the polarization resistance relationships shown in Equations 2.16 and 2.17.

$$i_c/i_o = e^{2.3\Delta E/B_c} \quad (2.10)$$

$$i_a/i_o = e^{-2.3\Delta E/B_a} \quad (2.11)$$

$$\Delta i = |i_c - i_a| = i_o(e^{2.3\Delta E/B_c} - e^{-2.3\Delta E/B_a}) \quad (2.12)$$

where Δi is the net current caused by overpotential, ΔE .

$$\text{Since } e^x = 1 + x + x^2/2! + \dots \quad (2.13)$$

$$\begin{aligned} i &= i_o(1 + 2.3 \Delta E/B_c - 1 + 2.3 \Delta E/B_a) \\ &= i_o(2.3 \Delta E)(B_a + B_c)/B_a B_c \end{aligned} \quad (2.14)$$

$$\text{hence } i_o = (\Delta i / 2.3 \Delta E) [(B_c B_a / B_c + B_a)] \quad (2.15)$$

$$R_p = \Delta E / \Delta i \quad (2.16)$$

$$R_p = B_c B_a / 2.3 i_o (B_a + B_c) \quad (2.17)$$

where B_a and B_c equal the Tafel slopes of ΔE vs $\log i/i_o$ plots; and i_o is the corrosion current density, I_{corr} . This current density is used to evaluate the polarization resistance R_p , and hence calculation of the corrosion current, I_{corr} and thereby the corrosion rate by means of Equation 2.5.

The polarization technique typically takes only 10 minutes to run and produce a given corrosion rate via Equation 2.5. However, measurements are typically taken daily to evaluate whether a material's corrosion rate changes as a function of time. This procedure continues until a steady state condition is reached. Corrosion values used by most engineers represents the final steady state value.

Additional factors that influence the corrosion rate are temperature, heat flux, nature of the attack (localized versus uniform dissolution), aeration, oxidizing agents, and the

presence of other chemical contaminants (Refs: 24, 25, 26).

Simply knowing that the corrosion rate for a particular metal exceeds acceptable limits, may not preclude its use in engineering design. In turn the material may have a low corrosion rate, yet be eliminated due to limited mechanical properties, machinability, price, or product contamination.

Typically corrosion rates have been grouped into four categories, <2, <20, 20 to 50, and >50 mils per year (mpy). The "ideal" material exhibits <2 mpy, whereas >2 but <20 mpy are generally acceptable. In the >20 but <50 mpy range, materials suffer appreciable corrosion and may require additional maintenance expense. Those in the final category, >50 mpy, corrode rapidly in the specified environment. They are not recommended for handling or storage of corrosives unless accompanied by liners or inhibitors.

There are many types of corrosion; pitting, stress corrosion cracking (SCC), hydrogen embrittlement, fatigue, and intergranular corrosion along the grain boundary or "weld decay." Knowing the form of corrosive attack for a material may dictate an alternate material selection or require some means of passivation.

A method of avoiding corrosion is the use of nonmetallic materials, particularly plastics and elastomers. The use of thermoplastic materials, traditionally limited to low-temperature/ low pressure services, and reinforced thermoset materials have expanded applicable ranges of service since

their development. Most notable of the thermoplastic materials are polyethylene, polypropylene, polyvinyl chloride, acrylics, styrene-synthetic rubber blends, and fluorocarbons. Thermosetting materials are polyesters, epoxies, furane resins, phenolic and epoxy resin molded, and filament wound materials.

The most chemically resistant of the commercially available plastics are the fluoropolymers tetrafluoroethylene (TFE) and fluorinated ethylene propylene (FEP), most commonly referred to as Teflon, TFE or FEP. These materials are essentially unaffected by all acids, alkalis, and organics at temperatures up to approximately 500 °F.

Polyvinylidene fluoride, although easily extrudable, is not applicable to temperatures exceeding about 350 °F. Polyethylene, the lowest cost plastic, has mechanical property limitations above 120 °F. Polyvinyl chloride can be used with all non-oxidizing and oxidizing acids except nitric and sulfuric to temperatures on the order of 150 °F. Their resistance to aromatic and aliphatic hydrocarbons, however, is generally poor. Styrene elastomer blends such as styrene-acrylonitrile-polymer with butadiene-acrylonitrile (A-B-S) are limited to non-oxidizing weak acids to temperatures of about 150 °F. They are even less suitable with organics. (Ref 26).

The general performance rating for nonmetals as identified in the National Association of Corrosion Engineer's Corrosion Survey (NACE CorSur) 2 program (Ref 23) is as

follows:

Recommended, a qualitative value that the material will withstand exposure of under the given environmental conditions; quantitative results may be required in critical applications.

Questionable, a value which reflects the uncertainty of performance of the material in a particular environment; its applicability must be tested.

Not recommended, a value whose rating suggests degradation of material properties in the particular environment.

CHAPTER III

THE CHEMICAL HAZARDS ANALYSIS MODELING PROCESS

3.1 Process Overview

This chapter presents an overview of the approach used to develop a design tool for determining chemical compatibility or corrosivity of proposed experimental effluent waste with those from other experiments or with materials of construction. Information on presently proposed on-orbit chemicals to be used in the MMPF and Life Sciences Experiments for a 10 year draft mission set spanning the PMMS chemical accommodations are contained in this model. The chemical incompatibilities specified for those listed in Table 2.1, excluding the biomedical chemicals, total more than 10,000. The present model has over 6500 datum records in the nonmetal corrosivity data base. The design tool model developed for this research, in its simplest form, allows the design engineer to generate physical and chemical property information for proposed Space Station mission sets for assessing materials usage.

The modeling process developed consists of two distinct elements. The first element is information and it gives the design engineer immediate chemical information such as: chemical and physical properties, the facilities, and the associated chemicals per facility. The design engineer also has information on chemical-chemical incompatibility reactions, including the nature of the reaction; for example -

a violent explosion occurs when mixed. The model includes information on chemical-material reactivity in terms of corrosion rates for metals and compatibility guidelines for nonmetals.

The second element of the model is called Analysis. As one might expect, this section allows the design engineer to assess the chemical-chemical hazards or chemical-material corrosivity hazards in his design of corresponding experiments or in processing of experiment effluent wastes.

Each module is typical of the data base structure and allows the designer to query or sort the information as he wishes. The model gives the engineer the option of viewing the information on the monitor or sending it to the printer. The design logic for these elements is shown in Figure 3.1.

The chemicals to be used in the experiments are primarily classified as mission dependent chemicals or as characterization chemicals. Mission dependent chemicals are those which have been identified as unique to a particular 90-day mission. These include gallium arsenide (GaAs), mercury-cadmium-tellurium (HgCdTe), or titanium carbide (TiC). Characterization chemicals are those commonly used in sample preparation, such as etching or polishing, and include most acids, alcohols, other solvents, etc.

Potential chemical-chemical interactions from any particular mission is based on facility manifesting, i.e.

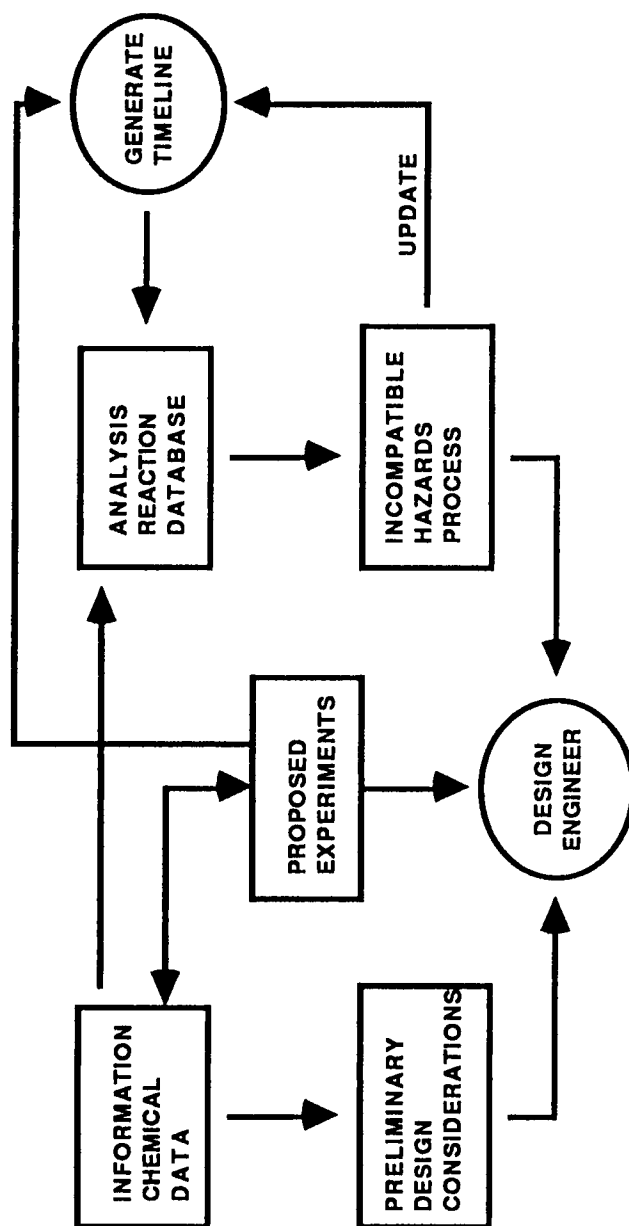


Figure 3.1 Model Element Design Logic

which of the 30 defined facilities will be carried on-board for scientific study. Factors in the current manifesting scenarios include power, weight, volume, crew time, etc. One of the objectives of this research is to consider the potential of hazardous chemical-chemical interaction as one of the factors in the manifesting decision. The experiment operation timeline could be evaluated so that known hazardous chemical interactions are not allowed to occur by simply rescheduling characterization operations. Most of these hazards are envisioned to occur from within the general workstation glovebox as materials or etchants from one experimenter are not removed thoroughly before the next characterization operation begins.

The engineering model developed uses a commercially available relational data base for both elements. The software (Paradox 386, a registered trademark of Borland International, Inc.) Application software was written in the Paradox Applications Language, PAL. PAL programs, called "scripts," provide the primary input to the model. These scripts generate specific chemical property information or specific design considerations such as corrosivity or hazardous chemical interactions. An overview of the model, called the NASA Chemical Hazards Information System (NCHIS), is illustrated in Figure 3.2. As can be seen from the figure, the mechanics of the modeling process consists of the following functions:

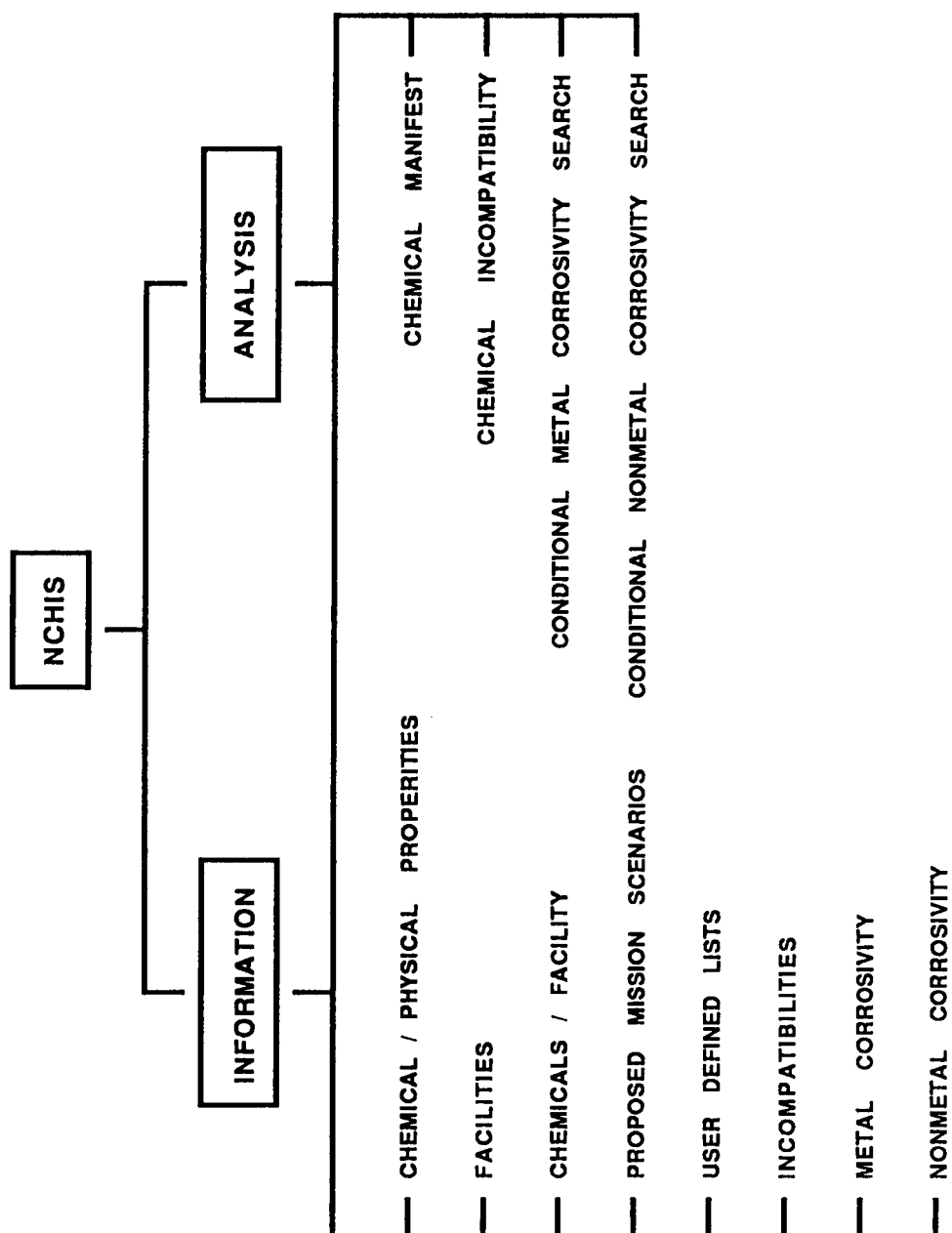


Figure 3.2 NCHIS Model Overview

1. The data base application programs sort/classify the data into tables for later processing. These tables include the physical and chemical properties, the MMPF designated facilities, user defined chemical input list, incompatibles, as well as, metal and nonmetal corrosivity information.
2. The application program contains numerous procedures embedded with the various menu selections.
3. The formatted procedure data files are used as the primary input to the modeling program.
4. The data is then displayed on the monitor with the options provided for a written report.

A detailed description of the elements involved in the process is provided in the sections that follow.

3.2 The Chemical Hazards Analysis Data Base

Several commercial data base programs were investigated for ease of application, data importing, data manipulation, customer support, output format, and cost. These included:

- (1) Lotus 1-2-3,
- (2) Dbase III,
- (3) Paradox/386,
- (4) Rbase 5000,
- (5) Oracle,

- (6) Informix,
- (7) Material Safety Data Sheets (MSDS),
- (8) Knowledgeman and,
- (9) PC-Album.

Selection proceeded at several levels, from reviewing brochures to acquisition and evaluation of complete packages. When possible, demonstration disks were obtained and evaluated at little or no cost. The demo disks were found to be somewhat unuseful, as they are often gave only a presentation and not a real copy of the data base.

Results of the evaluation indicated that some of the programs could not easily import foreign files, were difficult to format forms, screens, etc., or would not fully utilize the '386 capabilities.

After this thorough review, Paradox /386 was chosen for this project. Paradox fully utilizes the '386 computer, is very easy to program, interfaces to external programs through a shell to the Disk Operating System (DOS), is in a language similar to Dbase III and Lotus 1-2-3, and is a relational data base.

A typical Paradox data base, consists of several tables with each table composed of up to 255 fields. It is these fields which represent the actual storage of data. When the data base is established every field must be defined based on the type of data stored, such as Alphanumeric, Numeric, Date,

Time, etc. The data base and analysis system which was developed consists of 58 tables. These tables have been categorized into three groupings:

- (1) User specified tables,
- (2) Tables developed to implement the application scripts, and
- (3) Tables which contain the chemical and hazard information.

Each table has a unique structure that defines the data fields and corresponding information. A detailed listing, data description, definition of each table and its associated fields is provided in Figure 3.3, User Specified Tables, Figure 3.4, Application Script Tables, and Figure 3.5, Chemical and Hazards Information Tables. Each table is described by four basic column types which are defined below:

- (1) The symbol # represents the numbered order of each field in the table.
- (2) The NAME field identifies the PARADOX field name.
- (3) The TYPE field identifies the type of data which is to be stored in the field (i.e. Numeric, Text, Time, Date, etc.).
- (4) The DESCRIPTION field provides a definition of the data contained in each record of the fields.

Table Name: SCENAR01, SCENAR02, ... SCENAR12

General Table Description:

Tables which contain pre-defined mission set for analysis. The mission sets were identified by the MMPF study for Space Station operations from IOC to PMC.

Table Structure by field:

#	Name	Type	Description
1	Tag	Text 1	Denotes "*"
2	Facility	Text 40	Name of potential Space Station Payload/Facility.
3	Abbrev	Text 10	Abbreviation for name of potential Space Station Payload/Facility.

NOTE:

Additional tables of this structure are added to the system when the user defines new mission sets. The names of these tables are defined by the user.

Table Name: USERDEF1, USERDEF2, ... USERDEF4

Table Description:

Pre-defined list of user specified chemicals for analysis.

Table Structure by field:

#	Name	Type	Description
1	Chemical	Text 40	Name of individual chemicals.

NOTE:

Additional tables of this structure are added to the system when new chemical lists, defined by the user, are added to the data base. The names of these tables are defined by the user.

Figure 3.3 User Specified Tables

Table Name	Table Description
ALF	List of chemicals for the Acoustic Levitator Facility
ASF	List of chemicals for the Alloy Solidification Facility
BIF	List of chemicals for the Bioreactor/Incubator Facility
BSF	List of chemicals for the Bridgman, Small Facility
CFEF	List of chemicals for the Cont. Flow Electro. Fac
CPPF	List of chemicals for the Critical Pt. Phenom. Facility
DSBF	List of chemicals for the Droplet/Spray Burning Fac.
EF	List of chemicals for the Electroepitaxy Facility
ELF	List of chemicals for the Electrostatic Levitator Facility
EMF	List of chemicals for the Electromagnetic Levitator Facility
FPF	List of chemicals for the Fluid Physics Facility
HTF	List of chemicals for the High Temperature Facility
IFF	List of chemicals for the Isoelectric Focusing Facility
LRF	List of chemicals for the Latex Reactor Facility
OPCGF	List of chemicals for the Organic & Polymer Crystal Growth Facility
PGCF	List of chemicals for the Premixed Gas Combustion Facility
PCGF	List of chemicals for the Protein Crystal Growth Facility
RSCF	List of chemicals for the Rotating Spherical Convection Facility
SSBF	List of chemicals for the Solid Surface Burning Fac Facility
VCGF	List of chemicals for the Vapor Crystal Growth Facility

General Table Structure by field for the facility tables above:

#	Name	Type	Description
1	Chemical	Text 40	Name of individual chemicals, used by the facility during on-orbit operations.

NOTE:

Additional tables of this structure are added to the system when new facilities are incorporated into the data base. The names of these tables are defined by the user.

Figure 3.3 User Specified Tables (continued)

Table Name: CEMLSTAB

Table Description:

Table which contains the original listing of pre-defined chemical groupings (i.e. USERDEF1, USERDEF2, etc). This is the original table. This table provides its data to CEMHDTB which appears on the screen for the user to edit/select.

Table Structure by field:

#	Name	Type	Description
1	Name	Text 8	Name of chemical groupings.
2	Tag	Text 1	Denotes "*".

Table Name: CEMHDTB

Table Description:

Table contains a listing of all the pre-defined chemical groupings. This table appears on the screen and allows the user to select from the list a pre-defined group of chemicals for analysis. The table then holds the chemical group selected. (i.e. tagged group of chemicals).

Table Structure by field:

#	Name	Type	Description
1	Name	Text 8	Name of chemical groupings.
2	Tag	Text 1	Denotes "*".

Figure 3.4 Application Script Tables

Table Name: CHEMHLD

Table Description:

Temporary table which contains the listing of chemicals for analysis.

Table Structure by field:

#	Name	Type	Description
1	Chemical	Text 40	Name of individual chemicals.

Table Name: CLIST

Table Description:

Table which contains the code names, acronyms, and synonyms for the chemicals.

Table Structure by field:

#	Name	Type	Description
1	Code	Text 6	Code name for individual chemicals.

Table Name: CODETAB

Table Description:

Master table which links the chemical materials to their code names. Table contains the name of the chemical along with all the alias names for the chemical and links these names to a unique code.

Table Structure by field:

#	Name	Type	Description
1	Material	Text 75	Name for individual chemicals.
2	Code	Text 6	Code name for individual chemicals.

Figure 3.4 Application Script Tables (continued)

Table Name: SSFACTAB

Table Description:

Original table which contains a listing of the 20 facilities, and their code. This table provides its data to FHTAB which appears on the screen for the user to select/tag the

facilities which will comprise the mission.

Table Structure by field:

#	Name	Type	Description
1	Tag	Text 1	Denotes "*"
2	Facility	Text 40	Name of potential Space Station Payload/Facility.
3	Abbrev	Text 10	Abbreviation for name of potential Space Station Payload/Facility.

Table Name: FHTAB

Table Description:

Table contains a listing of all the facilities in the data base which can be selected for analysis. This listing appears on the screen and the user may select/tag the facilities which will comprise the mission. The table then holds the user selected facilities.

Table Structure by field:

#	Name	Type	Description
1	Tag	Text 1	Denotes "*"
2	Facility	Text 40	Name of potential Space Station Payload/Facility.

Figure 3.4 Application Script Tables (continued)

3	Abbrev	Text 10	Abbreviation for name of potential Space Station Payload/Facility.
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Table Name: FACHLD

Table Description:

Table which holds the facility abbreviations (code) for those facilities selected in FHTAB.

Table Structure by field:

#	Name	Type	Description
1	Abbrev	Text 10	Abbreviation for name of potential Space Station Payload/Facility.

Table Name: HAZLST

Table Description:

Temporary table which contains the list of user-specified chemicals used in the query to identify associated hazards/incompatibilities.

Table Structure by field:

#	Name	Type	Description
1	Chemical	Text 40	Name of individual chemicals.

Table Name: INCLST

Table Description:

Temporary table which contains list of incompatibilities for analysis.

Figure 3.4 Application Script Tables (continued)

Table Structure by field:

#	Name	Type	Description
1	Chemical	Text 40	Name of individual chemicals.

Table Name: NEWTAB

Table Description:

Temporary table which contains analysis output data of chemical incompatibilities and hazards.

Table Structure by field:

#	Name	Type	Description
1	Material Code	Text 6	Code name for each chemical.
2	Inc Code	Text 6	Incompatibility Code.
3	Material	Text 75	Name of material.
4	Incompatible	Text 75	Types of incompatibilities.
5	Why is it incompatible	Text 200	Reason for incompatibilities.

Table Name: REPTAB

Table Description:

Temporary table which contains a listing of the chemicals required by a specified facility.

Table Structure by field:

#	Name	Type	Description
1	Chemical	Text 40	Name of individual chemicals.

Figure 3.4 Application Script Tables (continued)

Table Name: TMPMET

Table Description:

Table which hold the output data from the metal corrosivity analysis.

Table Structure by field:

#	Name	Type	Description
1	Corrosive	Text 29	Name of corrosive material.
2	Metal	Text 29	Name of metal the corrosive material applied to.
3	MPY min	Numeric	Minimum milliinches per year of corrosive material.
4	MPY max	Numeric	Maximum milliinches per year of corrosive material.
5	Conc min	Numeric	Minimum concentration of corrosive material (%).
6	Conc max	Numeric	Maximum concentration of corrosive material (%).
7	Temp min	Numeric	Minimum temperature of corrosive material (F).
8	Temp max	Numeric	Maximum temperature of corrosive material (F).
9	Remarks	Text 15	Comments on material corrosivity.
10	Corrosive Code	Text 32	Corrosive Code.

Table Name: TMPNMT

Table Description:

Table which hold the output data from the non-metal corrosivity analysis.

Figure 3.4 Application Script Tables (continued)

Table Structure by field:

#	Name	Type	Description
1	Corrosive	Text 29	Name of corrosive material.
2	Non metal	Text 29	Name of non metal the corrosive material applied to.
3	Rec code	Text 19	Recommendation Code
4	Conc min	Numeric	Minimum concentration of corrosive material (%).
5	Conc max	Numeric	Maximum concentration of corrosive material (%).
6	Temp min	Numeric	Minimum temperature of corrosive material (F).
7	Temp max	Numeric	Maximum temperature of corrosive material (F).
8	Remarks	Text 15	Comments on material corrosivity.
9	Nm code	Text 4	Non metal code.

Table Name: MISSIONS

Table Description:

Table which contains the original listing of all pre-defined missions. (i.e. SCENAR01, SCENAR02, ... SCENAR012). This table provides its data to MHTAB which appears on the screen for the user to edit/select.

Table Structure by field:

#	Name	Type	Description
1	Mission	Text 8	Name of user selected mission (i.e. payload complement).
2	Tag	Text 1	Denotes "*".

Figure 3.4 Application Script Tables (continued)

Table Name: MHTAB

Table Description:

Table contains a listing of all the pre-defined mission sets. This listing appears on the screen and allows the user to select from the list a pre-defined mission set for analysis. The table then holds the user selected missions. (i.e. contains the tagged missions).

Table Structure by field:

#	Name	Type	Description
1	Mission	Text	Name of user selected mission (i.e. payload complement)
2	Tag	Text 1	Denotes "*".

Table Name: MISSHLD

Table Description:

Table which holds the facility name, abbreviations (code) and tag for those facilities selected in MHTAB.

Table Structure by field:

#	Name	Type	Description
1	Tag	Text 1	Denotes "*"
2	Facility	Text 40	Name of potential Space Station Payload/Facility.
3	Abbrev	Text 10	Abbreviation for name of potential Space Station Payload/Facility.

Figure 3.4 Application Script Tables (continued)

Table Name: TAG

Table Description:

Table which contains one field, the tag "*". Used to allow user to select (i.e. tag) facilities for a mission or chemicals for analysis.

Table Structure by field:

#	Name Type	Description
1	Tag Text 1	Denotes "*"

Figure 3.4 Application Script Tables (continued)

Table Name: SSCHEMPR

General Table Description:

Space Station Chemical Proprieties Table. Main table which contains chemical properties information.

Table Structure by field:

#	Name	Type	Description
1	Code	Text 6	Code name for each material.
2	CAS Number	Text 12	CAS number for each material.
3	Cname	Text 32	Chemical name.
4	Formula	Text 32	Chemical formula for each material.
5	Funct-class	Text 6	Functional/Chemical class for each material.
6	Mt Weight	Numeric	Molecular weight of each material.
7	State 20	Text 24	State at 20 C
8	Form phase	Text 4	Form/Phase
9	Melt. Pt.	Numeric	Melting point, Solid/Liquid
10	Boil. Pt.	Numeric	Boiling point, Liquid/Gas
11	Density_spgr	Numeric	Density/specific gravity
12	Stability	Text 36	Stability
13	Volatility	Text 8	Volatility
14	Odor	Text 16	Odor
15	Solblt_w	Numeric	Materials solubility in cold water.
16	Molar_vol	Numeric	Molar Volume
17	Vapor-Pres.	Numeric	Vapor pressure.

Figure 3.5 Chemical and Hazard Information Tables

18	Flash_point	Numeric	Flash point.
19	Vapor_heat	Numeric	Vapor Heat.
20	Crit_temp	Numeric	Critical temperature.
21	Crit_pressure	Numeric	Critical pressure.
22	Crit_volume	Numeric	Critical volume.
23	Decomp_temp	Numeric	Decomposition temperature.
24	Enthalpy	Numeric	Enthalpy.
25	Dtctin_means	Text 32	Detection means.
26	Hazard_1	Text 4	Hazard 1
27	Hazard_2	Text 4	Hazard 2
28	Haz_C1_Corr	Text 1	Hazard, Class 1, Corrositivity
29	Haz_C1_Flamma	Text 1	Hazard, Class 1, Flammability
30	Haz_C1_Irr_Vap	Text 1	Hazard, Class 1, Irritation, Vapors
31	Haz_C1_Asphy	Text 1	Hazard, Class 1, Asphyxiation
32	Haz_C1_Toxins	Text 1	Hazard, Class 1, Toxins
33	Haz_C1_Dust	Text 1	Hazard, Class 1, Dust
34	Haz_C1_Oxid	Text 1	Hazard, Class 1, Oxidation
35	Haz_C1_Unclass	Text 1	Hazard, Class 1, Unclassified
36	Decontaminatin	Text 64	Decontamination
37	Dosage_lthl_m	Numeric	Dosage, lethal,m
38	Dosg_incapt_m	Numeric	Dosage, incapt,m
39	SMAC	Numeric	Spacecraft Maximum Allowable Concentration
40	Sorce_SMAC	Text 4	Source of SMAC
41	Confidnc_SMAC	Text 2	Confidence of SMAC

Figure 3.5 Chemical and Hazard Information Tables (continued)

42	Detox_rate	Text 24	Detoxification rate
43	Toxic_e_s	Text 24	Toxicity to eye, skin
44	Action_rate	Text 16	Action rate
45	Physio_act	Text 32	Physiological action
46	Protection_req	Text 32	Protection requirements.
47	Misc_comments	Text 30	Miscellaneous comments.

Table Name: SSINDES

General Table Description:

Table which contains a description of the material incompatibilities.

Table Structure by field:

#	Name	Type	Description
1	Material Code	Text 6	Code name for each chemical.
2	Inc Code	Text 6	Incompatibility Code.
3	Material	Text 75	Name of material.
4	Incompatible	Text 75	Types of incompatibilities.
5	Why is it incompatible	Text 200	Reason for incompatibilities.

Table Name: SSMTCOR

General Table Description:

Table which contains the metal corrosivity data.

Figure 3.5 Chemical and Hazard Information Tables (continued)

Table Structure by field:

#	Name	Type	Description
1	Corrosive	Text 29	Name of corrosive material.
2	Metal	Text 29	Name of metal the corrosive material applied to.
3	MPY min	Numeric	Minimum milliinches per year of corrosive material.
4	MPY max	Numeric	Maximum milliinches per year of corrosive material.
5	Conc min	Numeric	Minimum concentration of corrosive material (%).
6	Conc max	Numeric	Maximum concentration of corrosive material (%).
7	Temp min	Numeric	Minimum temperature of corrosive material (F).
8	Temp max	Numeric	Maximum temperature of corrosive material (F).
9	Remarks	Text 15	Comments on material corrosivity.
10	Corrosive Code	Text 32	Corrosive Code.

Table Name: SSNMCOR

General Table Description:

Table which contains the non-metals corrosivity data.

Table Structure by field:

#	Name	Type	Description
1	Corrosive	Text 29	Name of corrosive material.
2	Non metal	Text 29	Name of non metal the corrosive material applied to.

Figure 3.5 Chemical and Hazard Information Tables (continued)

3	Rec code	Text 19	Recommendation Code
4	Conc min	Numeric	Minimum concentration of corrosive material (%).
5	Conc max	Numeric	Maximum concentration of corrosive material (%).
6	Temp min	Numeric	Minimum temperature of corrosive material (F).
7	Temp max	Numeric	Maximum temperature of corrosive material (F).
8	Remarks	Text 15	Comments on material corrosivity.
9	Nm code	Text 4	Non metal code.

Figure 3.5 Chemical and Hazard Information Tables (continued)

The chemical compatibility data base utilized in the modeling process is a subset of a much larger commercially available chemical safety data base. This larger data base, ChemPro, a registered trademark of Occupational Health Services, Inc., licensed for release through Fisher Scientific Co., Inc., contains over 5000 chemicals. The number of chemicals used in this engineering model is less than 200.

Designed as a laboratory reference for Material Safety Data Sheets (MSDS), ChemPro contains pertinent information such as:

1. Chemical Abstract Service Number
2. Trade Names/Synonyms
3. Occupational Service Health Administration (OSHA), Exposure Limits
4. Physical Property Data
5. Toxicity
6. Health Effects and First Aid
7. Reactivity
8. Incompatibilities
9. Conditions to Avoid
10. Spill and Leak Clean-Up Procedures
11. Protective Equipment
12. Storage and Disposal
13. Transportation

An example of a typical MSDS for perchloric acid is shown in Figure 3.6.

MATERIAL SAFETY DATA SHEET

OHS18230

OCCUPATIONAL HEALTH SERVICES, INC.
SEVENTH AVENUE, SUITE 2407
(615) 292-1180
NEW YORK, NEW YORK 10123
(800) 445-MSDS (212) 967-1100

EMERGENCY CONTACT: 450
JOHN S. BRANSFORD, JR.

SUBSTANCE IDENTIFICATION

CAS-NUMBER 7601-90-3
RTEC-NUMBER SC7500000

SUBSTANCE: PERCHLORIC ACID, 50-72%

TRADE NAMES/SYNONYMS:

DIOXONIUM PERCHLORATE: PERCHLORIC ACID: PERCHLORIC ACID
SOLUTION: PERCHLORIC ACID 50-72%: UN 1873: HClO₄: OHS18230

CHEMICAL FAMILY:
INORGANIC ACID

MOLECULAR FORMULA: H-CL-O₄

MOLECULAR WEIGHT: 100.46

CERCLA RATINGS (SCALE 0-3): HEALTH=3 FIRE=0 REACTIVITY=3
PERSISTENCE=0 NFPA RATINGS (SCALE 0-4): HEALTH=3 FIRE=0
REACTIVITY=3

COMPONENTS AND CONTAMINANTS

COMPONENT: PERCHLORIC ACID CAS# 7601-90-3 PERCENT: 50-72

COMPONENT: WATER
PERCENT: 38-50

OTHER CONTAMINANTS: NONE

EXPOSURE LIMIT:

NO OCCUPATIONAL EXPOSURE LIMITS ESTABLISHED BY OSHA,
ACGIH, OR NIOSH.

Figure 3.6 ChemPro MSDS for Perchloric Acid

PHYSICAL DATA

DESCRIPTION: COLORLESS, FUMING, VOLATILE, HYGROSCOPIC,
UNSTABLE LIQUID

BOILING POINT: 239 F (115 C)
SOLUBILITY IN WATER: SOLUBLE

SPECIFIC GRAVITY: 1.6
PH: ACIDIC

FIRE AND EXPLOSION DATA

FIRE AND EXPLOSION HAZARD

NEGLIGIBLE FIRE HAZARD WHEN EXPOSED TO HEAT OR FLAME.

OXIDIZER: OXIDIZERS DECOMPOSE, ESPECIALLY WHEN HEATED, TO YIELD OXYGEN OR OTHER GASES WHICH WILL INCREASE THE BURNING RATE OF COMBUSTIBLE MATTER. CONTACT WITH EASILY OXIDIZABLE, ORGANIC, OR OTHER COMBUSTIBLE MATERIALS MAY RESULT IN IGNITION, VIOLENT COMBUSTION OR EXPLOSION.

FLASH POINT: NONCOMBUSTIBLE

FIREFIGHTING MEDIA:

DRY CHEMICAL, CARBON DIOXIDE, HALON, WATER SPRAY OR STANDARD FOAM (1987 EMERGENCY RESPONSE GUIDEBOOK, DOT P 5800.4).

FOR LARGER FIRES, FLOOD AREA WITH WATER FROM A DISTANCE (1987 EMERGENCY RESPONSE GUIDEBOOK, DOT P 5800.4).

FIREFIGHTING:

DO NOT MOVE CONTAINERS IF EXPOSURE TO HEAT HAS OCCURRED. COOL CONTAINERS EXPOSED TO FLAMES WITH WATER FROM SIDE UNTIL WELL AFTER FIRE IS OUT. STAY AWAY FROM STORAGE TANK ENDS. FOR MASSIVE FIRE IN CARGO AREA, USE UNMANNED HOSE HOLDER OR MONITOR NOZZLES; ELSE WITHDRAW FROM AREA AND LET FIRE BURN (1987 EMERGENCY RESPONSE GUIDEBOOK, DOT P 5800.4, GUIDE PAGE 47).

USE WATER IN FLOODING AMOUNTS AS A FOG. COOL CONTAINERS WITH FLOODING QUANTITIES OF WATER, APPLY FROM AS FAR A DISTANCE AS POSSIBLE. AVOID BREATHING CORROSIVE VAPORS, KEEP UPWIND. IF THE FIRE IS NOT CONTROLLABLE EVACUATE TO A RADIUS OF 1500 FT.

TRANSPORTATION

DEPARTMENT OF TRANSPORTATION HAZARD CLASSIFICATION
49CFR172.101: OXIDIZER

DEPARTMENT OF TRANSPORTATION LABELING REQUIREMENTS
49CFR172.101 AND SUBPART E: OXIDIZER

DEPARTMENT OF TRANSPORTATION PACKAGING REQUIREMENTS:
49CFR173.269, EXCEPTIONS: NONE

TOXICITY

400 MG/KG ORAL-DOG LD50; 1100 MG/KG ORAL-RAT LD50; 250 MG/KG
SUBCUTANEOUS-MOUSE LD50; CARCINOGEN STATUS: NONE.
PERCHLORIC ACID IS CORROSIVE TO EYES, MUCOUS MEMBRANES, AND
SKIN.

HEALTH EFFECTS AND FIRST AID

INHALATION: CORROSIVE.

ACUTE EXPOSURE- INHALATION OF ACIDIC FUMES OR MIST MAY
CAUSE COUGHING, CHOKING, HEADACHE, DIZZINESS, WEAKNESS,
HYPOTENSION, AND DELAYED PULMONARY EDEMA WITH CHEST
TIGHTNESS, DYSPNEA, FROTHY SPUTUM, AND CYANOSIS. DYSPNEA
AND HEMOPTYSIS ARE POSSIBLE FOR SEVERAL WEEKS AFTER
EXPOSURE. AFTER INHALATION OF CORROSIVE ATMOSPHERES,
CONVALESCENCE MAY BE PROLONGED AND FREQUENT RELAPSES MAY
OCCUR.

CHRONIC EXPOSURE- REPEATED OR PROLONGED EXPOSURE TO
ACIDIC FUMES MAY CAUSE EROSION OF TEETH FOLLOWED BY JAW
NECROSIS. BRONCHIAL IRRITATION WITH COUGH AND FREQUENT
ATTACKS OF BRONCHIAL PNEUMONIA MAY OCCUR.
GASTROINTESTINAL DISTURBANCES ARE ALSO POSSIBLE.

FIRST AID- REMOVE FROM EXPOSURE AREA TO FRESH AIR
IMMEDIATELY. IF BREATHING HAS STOPPED, GIVE ARTIFICIAL
RESPIRATION. MAINTAIN AIRWAY AND BLOOD PRESSURE AND
ADMINISTER OXYGEN IF AVAILABLE. KEEP AFFECTED PERSON WARM
AND AT REST. TREAT SYMPTOMATICALLY AND SUPPORTIVELY.
ADMINISTRATION OF OXYGEN SHOULD BE PERFORMED BY QUALIFIED
PERSONNEL. GET MEDICAL ATTENTION IMMEDIATELY.

Figure 3.6 ChemPro MSDS for Perchloric Acid (continued)

SKIN CONTACT:

CORROSIVE.

ACUTE EXPOSURE- DIRECT CONTACT MAY CAUSE SEVERE PAIN AND BROWNISH OR YELLOW STAINS. BURNS MAY BE DEEP WITH SHARP EDGES AND HEAL SLOWLY WITH SCAR TISSUE FORMATION. SKIN BURNS ARE FREQUENTLY FOLLOWED BY EXTENSIVE SCARRING.

CHRONIC EXPOSURE- REPEATED OR PROLONGED EXPOSURE TO LOW LEVELS MAY CAUSE DERMATITIS.

FIRST AID- REMOVE CONTAMINATED CLOTHING AND SHOES IMMEDIATELY. WASH AFFECTED AREA WITH SOAP OR MILD DETERGENT AND LARGE AMOUNTS OF WATER UNTIL NO EVIDENCE OF CHEMICAL REMAINS (AT LEAST 15-20 MINUTES). IN CASE OF CHEMICAL BURNS, COVER AREA WITH STERILE, DRY DRESSING. BANDAGE SECURELY, BUT NOT TOO TIGHTLY. GET MEDICAL ATTENTION IMMEDIATELY.

EYE CONTACT: CORROSIVE.

ACUTE EXPOSURE- LIQUID MAY CAUSE CONJUNCTIVAL FLUID BUILD-UP (EDEMA) AND CORNEAL DESTRUCTION. THE SYMPTOMS ARE PAIN, TEARS, BLURRED VISION AND PHOTSENSITIZATION. **CHRONIC EXPOSURE-** PROLONGED VAPOR CONTACT MAY PRODUCE CONJUNCTIVITIS.

FIRST AID- WASH EYES IMMEDIATELY WITH LARGE AMOUNTS OF WATER, OCCASIONALLY LIFTING UPPER AND LOWER LIDS, UNTIL NO EVIDENCE OF CHEMICAL REMAINS (AT LEAST 15-20 MINUTES). CONTINUE IRRIGATING WITH NORMAL SALINE UNTIL THE PH HAS RETURNED TO NORMAL (30-60 MINUTES). COVER WITH STERILE BANDAGES. GET MEDICAL ATTENTION IMMEDIATELY.

INGESTION:

CORROSIVE.

ACUTE EXPOSURE- MAY CAUSE SEVERE, BURNING PAIN IN THE MOUTH, PHARYNX, AND ABDOMEN AND VOMITING AND DIARRHEA OF DARK PRECIPITATED BLOOD. HYPOTENSION MAY DEVELOP RAPIDLY. DISCOLORATION MAY BE FOUND AROUND THE MOUTH AND THROAT. ASPHYXIA MAY OCCUR FROM EDEMA OF THE GLOTTIS. AFTER INITIAL RECOVERY, ONSET OF FEVER INDICATES MEDIASTINITIS OR PERITONITIS FROM PERFORATION OF THE ESOPHAGUS OR STOMACH. THE PATIENT MAY HAVE A RIGID ABDOMEN WITHOUT PERFORATION. IF THE PATIENT RECOVERS, SCAR FORMATION IS MORE APT TO PRODUCE STRICTURE OF THE PYLORUS THAN STRICTURE OF THE ESOPHAGUS.

CHRONIC EXPOSURE- NOT KNOWN TO OCCUR IN HUMANS.

Figure 3.6 ChemPro MSDS for Perchloric Acid (continued)

FIRST AID- DO NOT USE GASTRIC LAVAGE OR EMESIS. DILUTE THE ACID IMMEDIATELY BY DRINKING LARGE QUANTITIES OF WATER OR MILK. IF VOMITING PERSISTS, ADMINISTER FLUIDS REPEATEDLY. INGESTED ACID MUST BE DILUTED APPROXIMATELY 100 FOLD TO RENDER IT HARMLESS TO TISSUES. MAINTAIN AIRWAY AND TREAT SHOCK. (DREISBACH, HANDBOOK OF POISONING, 12TH ED.). GET MEDICAL ATTENTION IMMEDIATELY. IF VOMITING OCCURS, KEEP HEAD BELOW HIPS TO HELP PREVENT ASPIRATION.

ANTIDOTE:

NO SPECIFIC ANTIDOTE. TREAT SYMPTOMATICALLY AND SUPPORTIVELY.

REACTIVITY SECTION

REACTIVITY:

CAN REACT EXPLOSIVELY WITH COMBUSTIBLES, ORGANIC MATTER, OXIDIZING, AND REDUCING AGENTS. CAN DECOMPOSE EXPLOSIVELY ON STORAGE AT NORMAL PRESSURES.
REACTS EXOTHERMICALLY WITH WATER.

INCOMPATIBILITIES:

EXPLOSIVE REACTION: ACETIC ACID, ACETIC ANHYDRIDE, ACETONITRILE, HOT WITH TRIVALENT ANTIMONY COMPOUNDS, HEATED WITH BISMUTH ABOVE 110 C OR IRON SULFATE, CARBON BLACK, CHARCOAL, CHARCOAL AND CHROMIUM TRIOXIDE, DIBUTYL SULFOXIDE, DIETHYL ETHER, DIMETHYL ETHER, DIMETHYL SULFOXIDE, ETHANOL, METHANOL, GLYCERIN AND LEAD OXIDE, VAPOR WITH HYDROGEN AT 400 C, OR 215 C WITH STEEL PARTICLES, HOT WITH HYPOPHOSPHITES, HYDRAZINE, NITROGEN TRIIODIDE, NITROSOPHENOL, ORGANIC MATTER, COMBUSTIBLE MATERIAL, PAPER CHLOROFORM AND PHOSPHORUS PENTOXIDE, WOOD, NITRIC ACID AND ORGANIC MATTER, HEATED WITH NITRIC ACID, SULFURIC ACID, AND PYRIDINE, BIS-1,2-DIAMINOPROPANE-CIS-DICHLOROCHROMIUM PERCHLORATE.

EXPLOSIVE IGNITION: ANILINE AND FORMALDEHYDE, AZO PIGMENT AND ORTHOPERIODIC ACID.

VIOLENT DECOMPOSITION: GLYCOL ETHERS, GLYCOLS, KETONES, ALCOHOLS, HYDROCHLORIC ACID.

VIOLENT EXOTHERMIC REACTION: SULFUR TRIOXIDE.

VIOLENT REACTION: HOT WITH ALCOHOLS OR CELLULOSE, TRIZINC DIPHOSPHIDE, ZINC PHOSPHIDE, TRICHLOROETHYLENE.

Figure 3.6 ChemPro MSDS for Perchloric Acid (continued)

IGNITION: HYDROGEN IODIDE, HYDRIODIC ACID, ORGANIC MATTER, DNA, VAPOR WITH SODIUM IODIDE AND 2-METHYLPROPENE WHEN HEATED ABOVE 250 C, OR BELOW 178 C WITH METAL OXIDES PRESENT.

EXOTHERMIC: WATER.

FORMATION OF AN EXPLOSIVE MIXTURE: ANILINE AND FORMALDEHYDE, T-ETHYLBENZENE AND THALLIUM TRIACETATE AND ACETIC ACID WHEN HEATED, NITROGENOUS EPOXIDES, 1,3-BIS(DI-N-CYCLOPENTADIENYLIRON-2-PROPEN-1-ONE WITH ACETIC ANHYDRIDE; ETHER AND METHANOL, ON HEATING WITH OLEIC ACID, PHOSPHINE.

FORMATION OF A HIGHLY REACTIVE MATERIAL: FLUORINE, DIALKYL SULFOXIDES.

CONVERSION TO ANHYDROUS ACID: HEATING WITH SULFURIC ACID, PHOSPHORUS PENTOXIDE OR PHOSPHORIC ACID.

FORMATION OF SHOCK SENSITIVE MIXTURE WITH A FLAMMABLE VAPOR: ACETIC ACID AND ACETIC ANHYDRIDE.

REACTS WITH MANY METALS TO PRODUCE FLAMMABLE HYDROGEN GAS.

DECOMPOSITION:

THERMAL DECOMPOSITION MAY RELEASE CORROSIVE FUMES OF HYDROGEN CHLORIDE OR CHLORINE DIOXIDE. ANHYDROUS FORM MAY DECOMPOSE SPONTANEOUSLY AND EXPLOSIVELY.

POLYMERIZATION:

HAZARDOUS POLYMERIZATION HAS NOT BEEN REPORTED TO OCCUR UNDER NORMAL TEMPERATURES AND PRESSURES.

STORAGE-DISPOSAL

STORAGE: REAGENT BOTTLE - MAXIMUM 1 POUND, GLASS-STOPPERED, GLASS BOTTLE; KEEP IN A HEAVY GLASS TRAY WITH LARGER CAPACITY. ADDITIONAL LABORATORY STORAGE SHOULD BE IN ORIGINAL BOTTLES INSIDE A GLASS CONTAINER PADDED WITH GLASS WOOL AND HAVING GREATER CAPACITY THAN THE CONTAINER. CARBOYS AND LARGE BOTTLES SHOULD BE STORED ON ACID-RESISTING NONCOMBUSTIBLE SHELVES, IN A NONCOMBUSTIBLE STRUCTURE. ALL STORAGE MUST BE SEPARATED FROM COMBUSTIBLE MATERIALS, ORGANIC CHEMICALS, STRONG DEHYDRATING AGENTS, OXIDIZING AND REDUCING AGENTS. PERCHLORIC ACID MUST BE STORED WHERE IT WILL NOT FREEZE (FREEZING POINT IS ABOUT -4 F). PROTECT AGAINST PHYSICAL

Figure 3.6 ChemPro MSDS for Perchloric Acid (continued)

DAMAGE. ELECTRICAL WIRING, ETC., IN STORAGE AREAS MUST BE OF WATERTIGHT TYPE TO PROTECT AGAINST CORROSIVE ACTION OF VAPORS (NFPA 49, HAZARDOUS CHEMICALS DATA, 1975).

CONDITIONS TO AVOID

MAY IGNITE WITH OTHER COMBUSTIBLE MATERIALS (WOOD, PAPER, OIL, ETC.). MIXTURE WITH FUELS MAY EXPLODE. FLAMMABLE, POISONOUS GASES MAY ACCUMULATE IN TANKS AND HOPPER CARS. CONTAINER MAY EXPLODE IN HEAT OF FIRE. MAY EXPLODE FROM FRICTION, HEAT OR CONTAMINATION. RUNOFF TO SEWER MAY CREATE FIRE OR EXPLOSION HAZARD.

SPILLS AND LEAKS

OCCUPATIONAL-SPILL:

KEEP COMBUSTIBLES (WOOD, PAPER, OIL, ETC.) AWAY FROM SPILLED MATERIAL. DO NOT TOUCH SPILLED MATERIAL. STOP LEAK IF YOU CAN DO IT WITHOUT RISK. USE WATER SPRAY TO REDUCE VAPORS. FOR SMALL SPILLS, FLUSH AREA WITH FLOODING AMOUNTS OF WATER. FOR LARGER SPILLS, DIKE SPILL FOR LATER DISPOSAL. KEEP UNNECESSARY PEOPLE AWAY. ISOLATE HAZARD AREA AND DENY ENTRY.

PROTECTIVE EQUIPMENT SECTION

VENTILATION:

PROVIDE LOCAL EXHAUST OR PROCESS ENCLOSURE VENTILATION SYSTEM.

RESPIRATOR:

HIGH LEVELS- SUPPLIED-AIR RESPIRATOR WITH A FULL FACEPIECE, HELMET, OR HOOD. SELF-CONTAINED BREATHING APPARATUS WITH A FULL FACEPIECE.

FIREFIGHTING- SELF-CONTAINED BREATHING APPARATUS WITH A FULL FACEPIECE OPERATED IN PRESSURE-DEMAND OR OTHER POSITIVE PRESSURE MODE.

CLOTHING:

EMPLOYEE MUST WEAR APPROPRIATE PROTECTIVE (IMPERVIOUS) CLOTHING AND EQUIPMENT TO PREVENT ANY POSSIBILITY OF SKIN CONTACT WITH THIS SUBSTANCE.

Figure 3.6 ChemPro MSDS for Perchloric Acid (continued)

GLOVES:

EMPLOYEE MUST WEAR APPROPRIATE PROTECTIVE GLOVES TO PREVENT CONTACT WITH THIS SUBSTANCE.

EYE PROTECTION:

EMPLOYEE MUST WEAR SPLASH-PROOF OR DUST-RESISTANT SAFETY GOGGLES AND A FACESHIELD TO PREVENT CONTACT WITH THIS SUBSTANCE. CONTACT LENSES SHOULD NOT BE WORN.

EMERGENCY WASH FACILITIES:

WHERE THERE IS ANY POSSIBILITY THAT AN EMPLOYEE'S EYES AND/OR SKIN MAY BE EXPOSED TO THIS SUBSTANCE, THE EMPLOYER SHOULD PROVIDE AN EYE WASH FOUNTAIN AND QUICK DRENCH SHOWER WITHIN THE IMMEDIATE WORK AREA FOR EMERGENCY USE.

AUTHORIZED BY- OCCUPATIONAL HEALTH SERVICES, INC.

CREATION DATE: 01/30/85

REVISION DATE: 07/06/89

The ChemPro data base uses an IBM PC AT with a compact disc player. Quarterly updates on new information relative to the chemical hazards and toxicity are provided on disc. ChemPro was chosen for use to support the activities within the Analytical and Physical Chemistry Branch at the Marshall Space Flight Center. Familiarity of the data base, ease of operation, and the extensive chemical listings made ChemPro the obvious choice for incorporation in the model.

Corrosivity data was obtained from the National Association of Corrosion Engineers, NACE, Corrosion Survey, CorSur, for the metals and CorSur2, for the nonmetals. As with the ChemPro data base, CorSur and CorSur2 are PC based software programs. CorSur provides an easy-to-follow menu selection for specific corrosion information or graphic description of the selected data. The data base contains over 25 materials in more than 1000 corrosive environments. CorSur2 provides the performance of 36 nonmetals in 850 corrosive environments. As mentioned earlier, material selection and approval does not depend on chemical or corrosion compatibility alone. Other factors such as expected life, wear, cost, etc., should be considered. It must also be noted, that as the Space Station evolves, so does the anticipated payload manifest. Revisions and updates to the experimental hardware and facility will dictate continuous refinement of this model.

3.3 The Chemical Hazards Analysis Programs

Paradox provides the user with the capability of developing application programs (called scripts) which will sort and classify the chemical data in accordance with the commands in the programs or scripts. Twenty Paradox application scripts were developed to implement the data manipulation and hazard analyses incorporated in the NASA Chemical Hazards Information System (NCHIS). The scripts developed have been classified into two categories:

- (1) Scripts which call screens (i.e help screens or main database screens), and
- (2) Procedural scripts.

Within these two categories, thirteen scripts were developed in which their function is to call screens. Twelve of these scripts call help screen during program operations and one script was developed to customize the introductory screen which appears when the programs are executed. The remaining seven scripts developed are procedural scripts which contain thirty-eight procedures. These procedures are similar to subroutines in classical programming. It is these procedures which perform the data manipulation and analysis. These scripts and associated procedures have been documented, and are provided in Appendix B. To access the modeling programs, the user must first establish a directory which will contain the Paradox data base software. For example, this directory will be called PARADOX2. A second directory

containing the Chemical Hazards applications programs and data bases must also be established. This will be a subdirectory of the PARADOX directory and will be called NCHIS. A path is then established between the two directories. Once this has been completed. The user may access the NCHIS by entering the Paradox command PDOX386. This will load the Paradox application software and the Paradox commands will appear at the top of the screen. To execute or play (as called in Paradox) the applications programs developed for the NCHIS the user must select the Paradox commands Scripts, and Play. The user will then be asked which script to play and the script name of NCHIS should be selected or entered. This is the initial application script which begins the system. An introductory or splash screen will appear. This screen is depicted in Figure 3.7. From this screen the user is asked to enter his/her password, if required for security purposes, or simple press return to continue the application. The programs will then generate a variety of menu options which comprise two major groupings:

- (1) Display Information contained in the NCHIS or
- (2) Perform a Chemical Incompatibility, Imminent Hazard or Corrosivity Analysis on:
 - (a) an individual chemical,
 - (b) a grouping of chemicals,
 - (c) a facility or,
 - (d) a mission set.

Password:

Enter password for the application; [ESC] to cancel;
[ENTER] for no password

NASA CHEMICAL HAZARDS INFORMATION SYSTEM
(NCHIS)

Developed by:

NASA
Marshall Space Flight Center
Richard T. Congo
Analytical & Physical Chemistry
MSFC, Al 35812

Developed for:

University of Tennessee
Space Institute
Doctoral Dissertation
Distribution Limited
Version 1.1
Copyright 1990

Figure 3.7 NCHIS Introductory Splash Screen

Figures 3.8 and 3.9 are menu trees for the NCHIS Information and Analysis menu options, respectively. These menu trees provide a detailed overview of the menu options and their locations in the system provided by the NCHIS. Sections 3.4 and 3.5 of this chapter provide a detailed description of the Information and Analysis menu options.

As was stated earlier, the NCHIS consist of twenty scripts, thirteen to call screens and seven to execute the data manipulation and analysis. These seven data manipulation and analysis scripts are:

- (1) NCHIS.SC
- (2) UPDATE.SC
- (3) MAIN.SC
- (4) CEMCAL.SC
- (5) MISSION.SC
- (6) IMHAZ.SC
- (7) CORSUR.SC

The primary function of the script NCHIS.SC is to display the introductory splash screen and call for the execution of the script UPDATE.SC which updates all the libraries for the applications programs. The functions of the remaining five scripts are illustrated in Figures 3.10 and 3.11. The figures identify the scripts which are responsible for performing the menu options as displayed in the menu trees. The names of the scripts are displayed above each shadowed grouping of menu options. As an example, the script CORSUR.SC is responsible

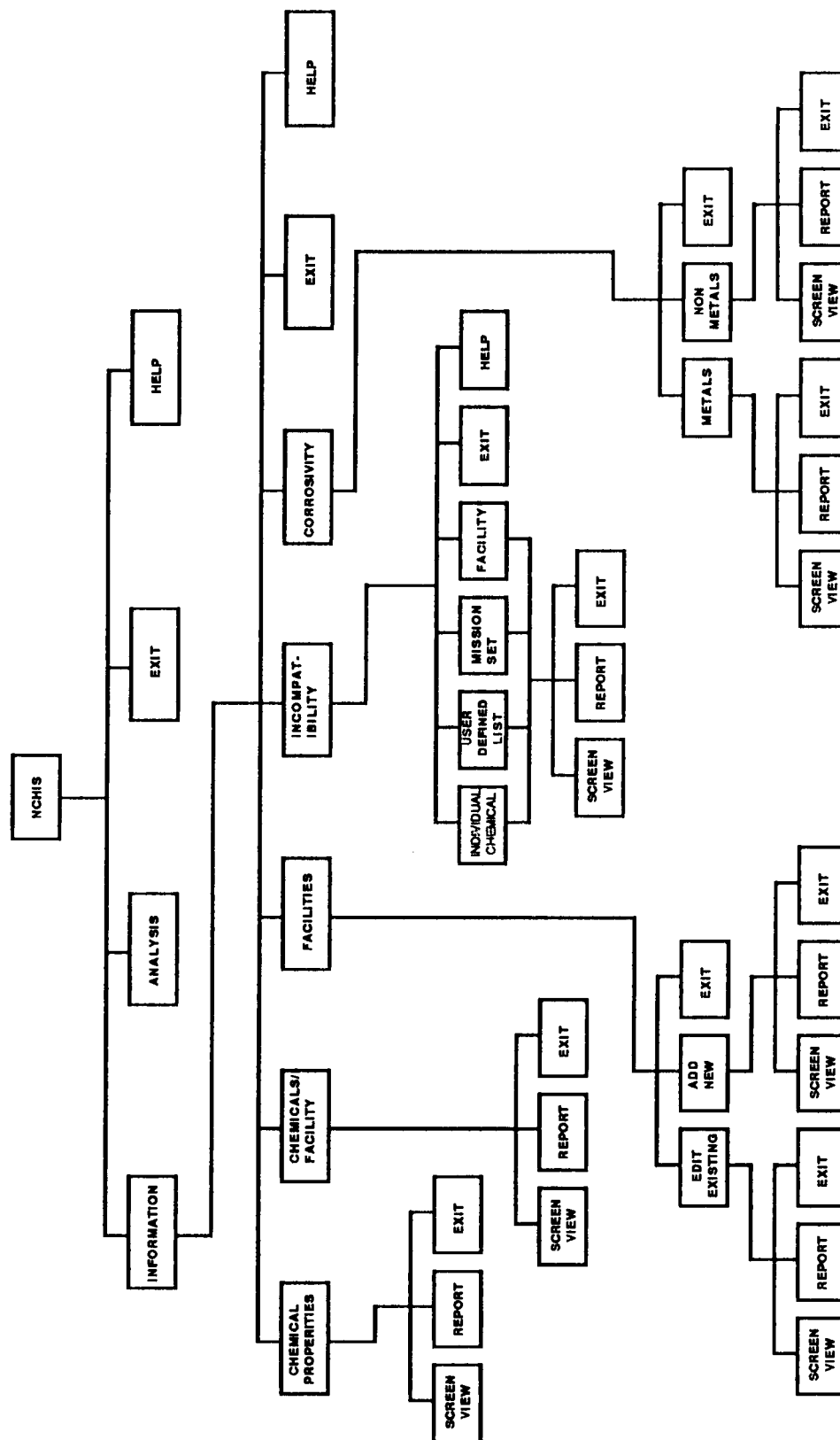


Figure 3.8 NCHIS Information Menu Tree

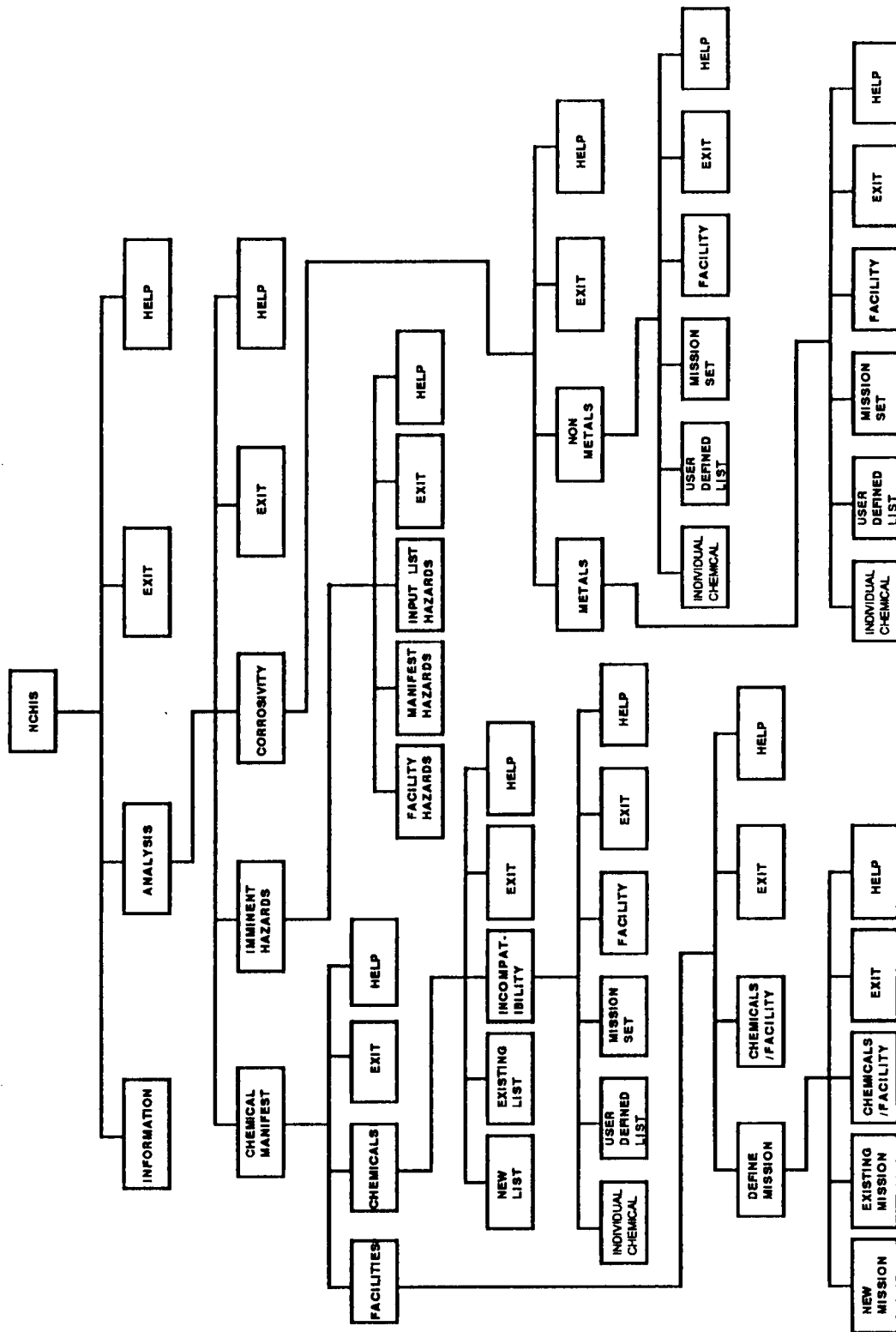


Figure 3.9 NCHIS Analysis Menu Tree

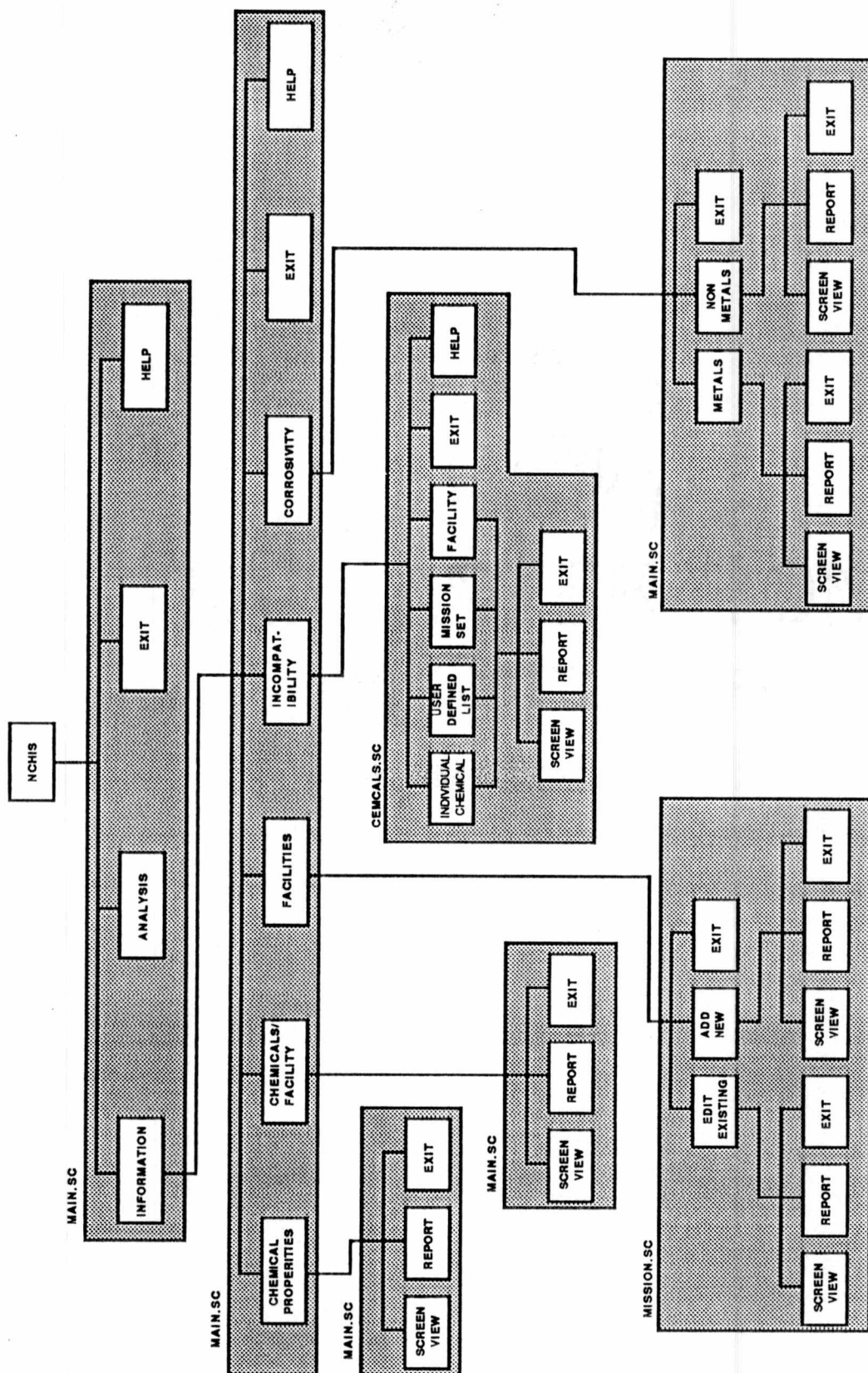


Figure 3.10 Information Script Functions

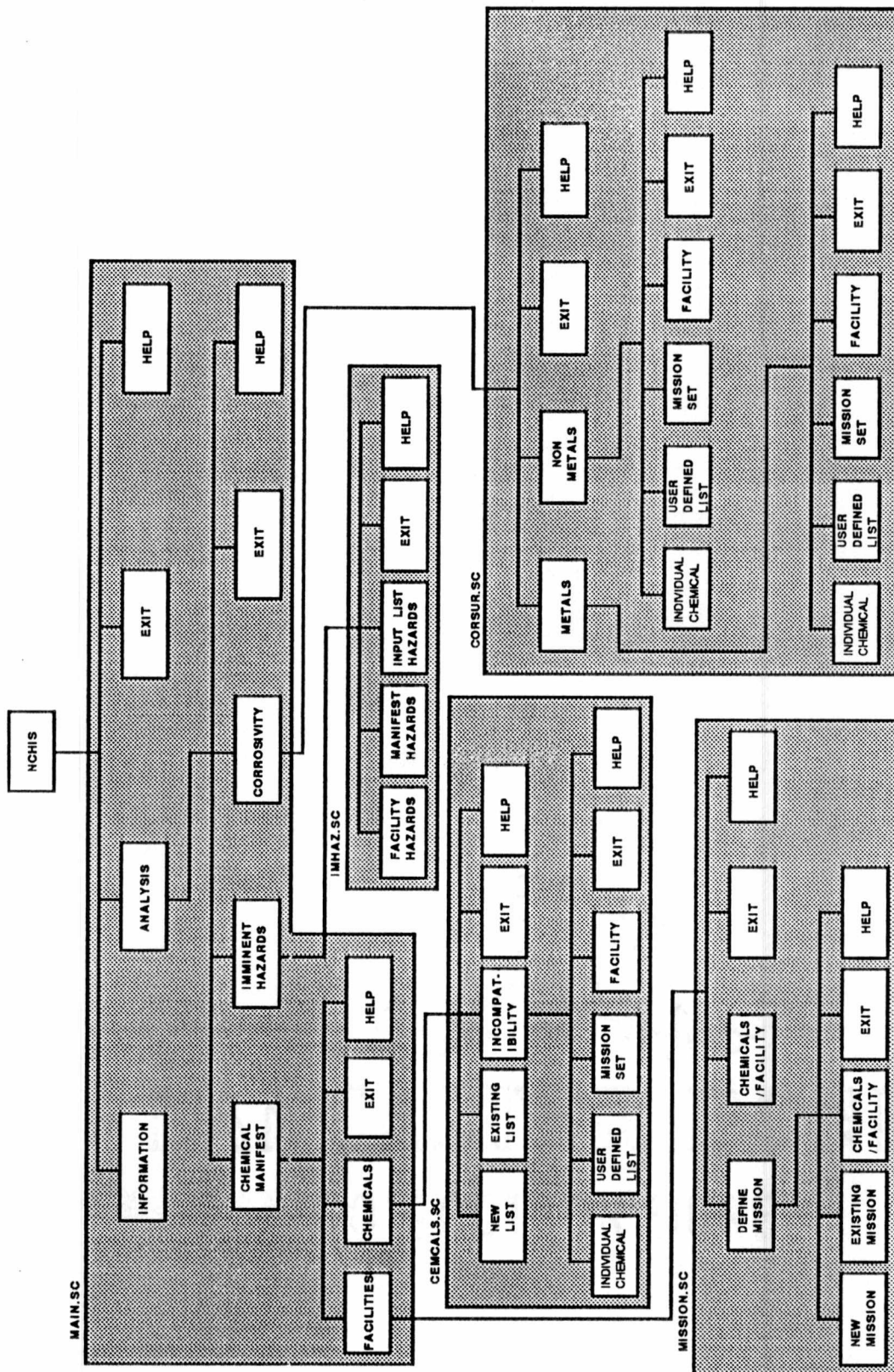


Figure 3.11 Analysis Script Functions

for performing all the menu options under the Analysis option for Corrosivity. A brief description of the major functions of each of these scripts is provided in Table 3.1. However, the reader is referred to Appendix B for a detailed commentary and documentation of these scripts.

The functions of the twelve help screen scripts are displayed in a similar fashion in Figures 3.12 and 3.13. These figures identify the help screen associated with the Information options, and the Analysis options. The names of the help screen scripts are displayed directly above each shadowed grouping of menu options. As an example, the script HAZHLP.SC displays the help screen for the Analysis option for Imminent Hazards.

Table 3.1 Brief Description of Data Manipulation
and Analysis Scripts

SCRIPT NAME	FUNCTIONS
NCHIS.SC	Script calls the execution of the UPDATE.SC script, displays the introductory splash screen, asked ad verifies a user password and executes the initial NCHIS application programs.
UPDATE.SC	Script updates the primary scripts and libraries utilized by and developed for the NCHIS.
MAIN.SC	Script performs several functions. It implements the Chemical Properties, Chemicals per Facility, and Corrosivity options under the Information side of the system as well as displaying the top-level menu options for the Analysis side. Additionally, this script contains the procedure which produces the pull-down menus which are utilized by the NCHIS.
CEMCALS.SC	Script performs the Incompatibility analysis menu options under both the Information and Analysis branches. In the Analysis branch the script is located under the Chemicals option for Chemical Manifest. While under the information branch it is listed under Incompatibility. Chemical Incompatibilities are identified for individual chemicals, lists of chemicals, facilities and mission sets
MISSION.SC	Script allows the user to define a new mission set, edit an existing mission set or edit the on-orbit chemical required by each facility. This script is located on the both the Information and Analysis branches.

Table 3.1 Brief Description of Data Manipulation
and Analysis Scripts (Continued)

SCRIPT NAME	FUNCTIONS
IMHAZ.SC	Script performs the Imminent Hazards analysis under the Analysis Branch. Imminent Hazards are identified for individual facilities, missions sets or pre-defined list of chemicals.
CORSUR.SC	Script performs both the metal and non-metal Corrosivity Analysis under the Analysis Branch. Corrosivities are identified for individual chemicals, facilities, missions sets or pre-defined list of chemicals.

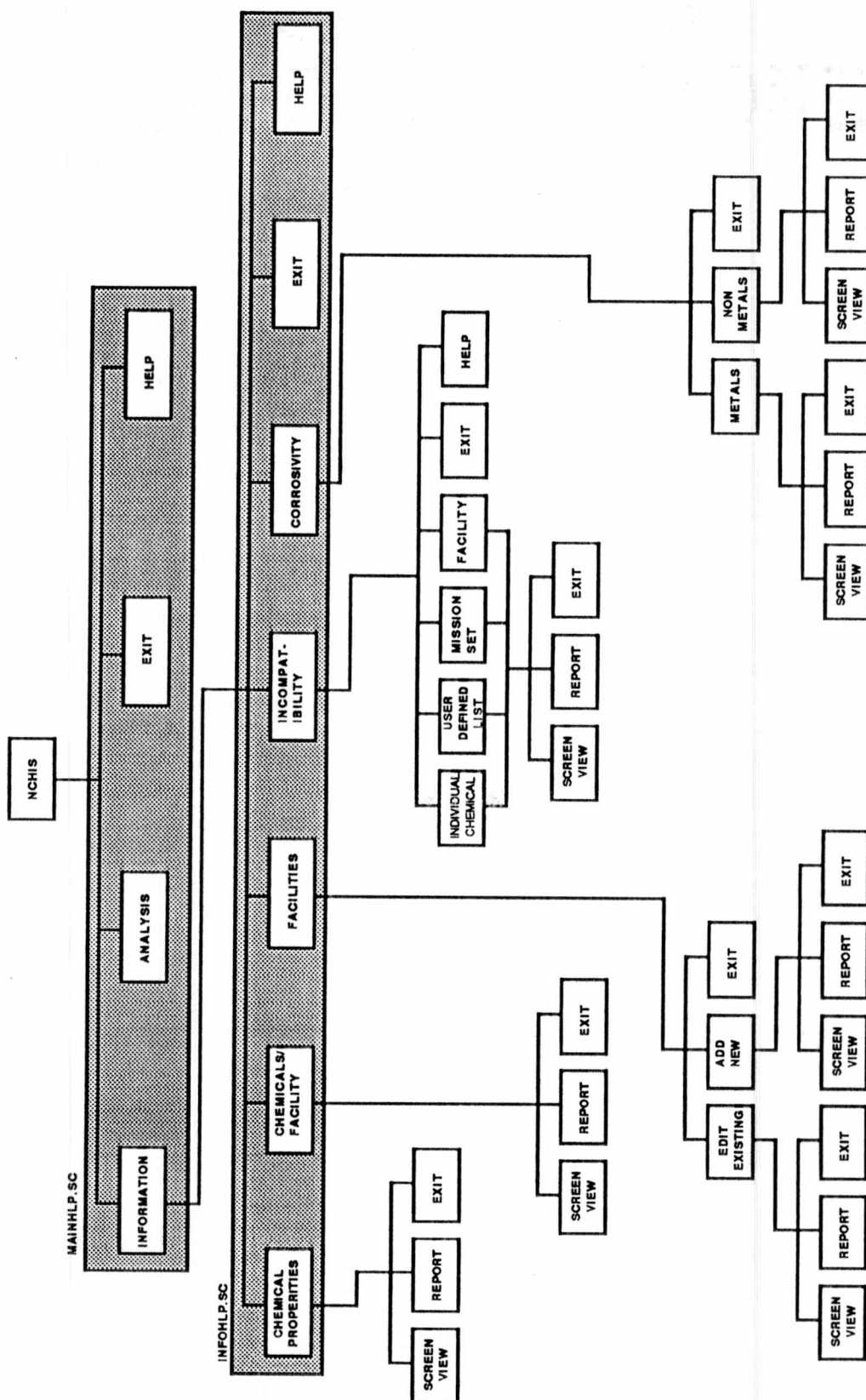


Figure 3.12 Information Help Screens/Scripts

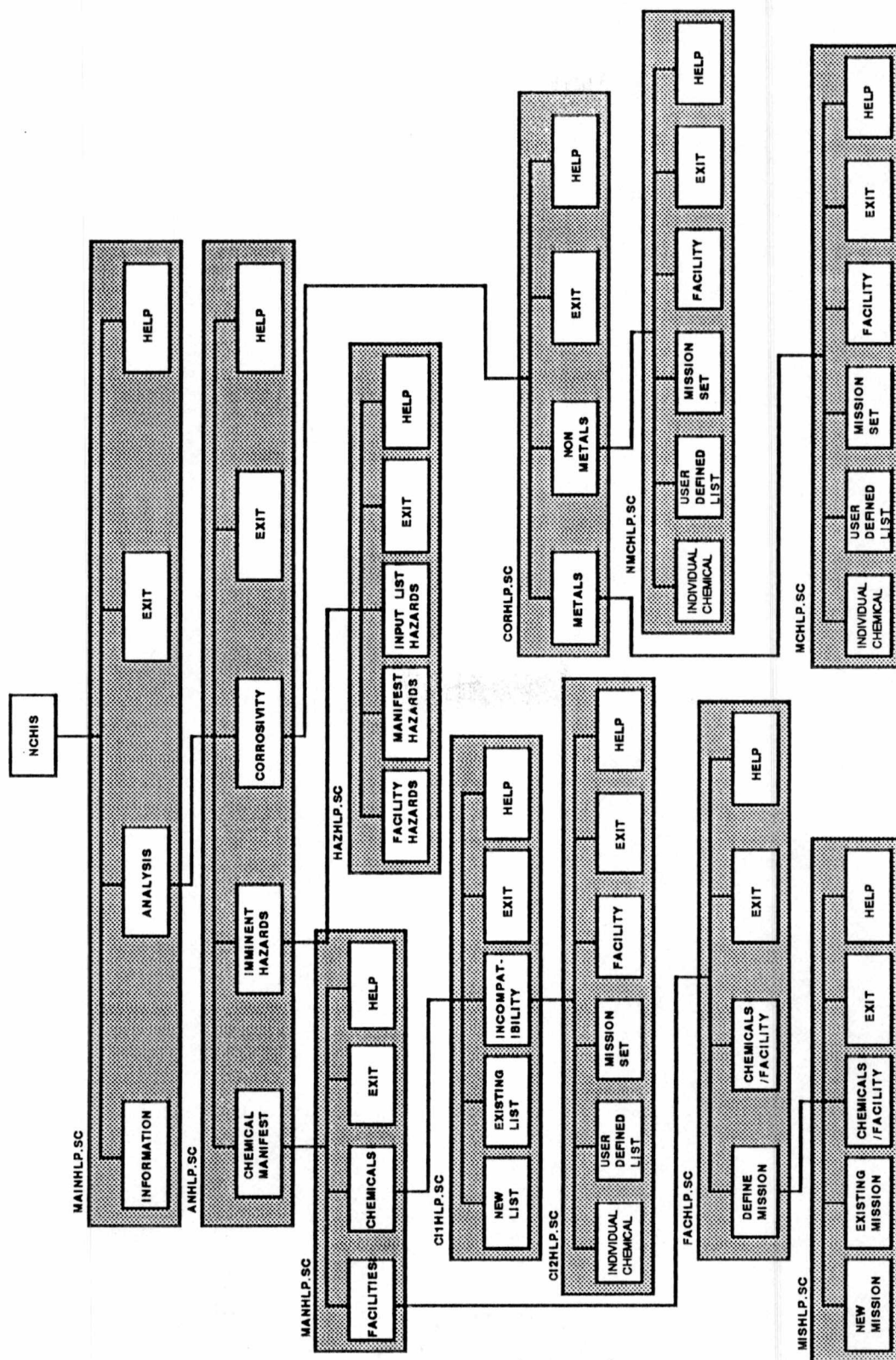


Figure 3.13 Analysis Help Screens/Scripts

3.4 Description of NCHIS Information Menu Options

Scripts written to add new data to the system, edit existing data, view data or develop reports of the data currently in the system are located in the Information section of the model. This section of the dissertation will provide a detailed description of the menu options available under the Information section of the model. Each selection is identified in a tiered structure and can be followed from the menu tree provided in Figure 3.8.

Information
 Chemical Properties

Selection allows the user to view and report data which is currently in the chemical properties table called SSCHEMPR. This table contains the physical and chemical properties on individual elements, compounds and mixtures. The reader is referred to Section 3.2 of this dissertation which provides a detailed description of this table.

Information
 Chemical Properties
 Screen View

Selection allows the user to view the chemical properties table on the screen.

Information
 Chemical Properties
 Report

Selection allows the user to produce a report of the current chemical properties table.

Information
Chemical Properties
Exit

Selection returns the user to the previous menu option.
This selection serves the same purpose as the ESC key.

Information
Chemicals/Facility

Selection allows the user to view or report the current listing of chemicals required during on-orbit operations for any of the facilities currently in the data base. A listing of the current facilities will appear on the screen and the user is asked to select a facility. Once the facility has been selected the current listing of chemicals required by the facility will appear on the screen.

Information
Chemicals/Facility
Screen View

Selection allows the user to view the chemicals required by the selected facility during on-orbit operations.

Information
Chemicals/Facility
Report

Selection allows the user to produce a report of the chemicals required by the selected facility during on-orbit operations.

Information
Chemicals/Facility
Exit

Selection returns the user to the previous menu option.
This selection serves the same purpose as the ESC key.

Information
Facilities

Selection allows the user to add new facility names and acronyms for use in the model or edit existing facility names and acronyms currently in the data base. The model will produce a new table for each facility in which the chemicals required by each facility may be entered under the Information, Chemicals/Facility option.

Information
Facilities
Edit Existing

Selection produces a current listing of the facilities in the data base and their acronym. The user may edit the name or acronyms of any of these facilities. Once editing is completed the model saves the results and asks the user if he wishes a report of the changes.

Information
Facilities
Edit Existing
Screen View

Selection allows the user to view all revisions made to facility names and acronyms on the screen.

Information
Facilities
Edit Existing
Report

Selection produces a report which includes all the revisions made to the facility names and acronyms.

Information
Facilities
Edit Existing
Exit

Selection returns the user to the previous menu option.
This selection serves the same purpose as the ESC key.

```
Information
  Facilities
    Add New
```

Selection produces a current listing of the facilities in the data base and their acronyms. The user may add new facility names and acronyms to the data base. Once all new facility names and acronyms have been added the model saves the results and asks the user if he wishes a report of the new facility listings.

```
Information
  Facilities
    Add New
      Screen View
```

Selection allows the user to view a new listing of all the facilities names and associated acronyms currently in the data base.

```
Information
  Facilities
    Add New
      Report
```

Selection produces a report listing of all the facilities names and associated acronyms currently in the data base.

```
Information
  Facilities
    Add New
      Exit
```

Selection returns the user to the previous menu option.
This selection serves the same purpose as the ESC key.

```
Information
  Facilities
    Exit
```

Selection returns the user to the previous menu option.
This selection serves the same purpose as the ESC key.

Information
Incompatibility

Selection allows the user to identify all chemical incompatibilities associated with an individual chemical, a user defined list of chemicals, a mission set, or a facility. The specific details of these menu options are provided below.

Information
Incompatibility
Individual Chemical

Selection allows the user to identify all chemicals which are incompatible with any given input chemical. The user is asked to enter in the chemical name, trade name or any synonym for the chemical in question. The model then searches the data base to identify all the chemicals which are incompatible with the input chemical. The output of this search identifies all the chemicals which are incompatible with the specified chemical and a description of why the chemicals are incompatible. Once this has been completed the user may either send the results of the search to the printer or view the results on the screen.

Information
Incompatibility
Individual Chemical
Screen View

Selection allows the user to view the results of the chemical incompatibility search on the screen.

Information
 Incompatibility
 Individual Chemical
 Report

Selection allows the user to produce a report of the results of the chemical incompatibility search.

Information
 Incompatibility
 Individual Chemical
 Exit

Selection returns the user to the previous menu option. This selection serves the same purpose as the ESC key.

Information
 Incompatibility
 User Defined List

Selection allows the user to identify all chemical which are incompatible with a pre-defined list of chemicals. The user is first asked to select the list of chemicals to be used in the search. The model then searches the data base to identify all the chemical which are incompatible with the list of chemicals. The output of this search identifies all the chemicals which are incompatible with the specified list of chemicals and a description of why the chemicals are incompatible. Once this has been completed the user may either send the results of the analysis to the printer or view the results on the screen.

Information
 Incompatibility
 User Defined List
 Screen View

Selection allows the user to view the results of the chemical incompatibility search on the screen.

Information
 Incompatibility
 User Defined List
 Report

Selection allows the user to produce a report of the results of the chemical incompatibility search.

Information
 Incompatibility
 User Defined List
 Exit

Selection returns the user to the previous menu option. This selection serves the same purpose as the ESC key.

Information
 Incompatibility
 Mission Set

Selection allows the user to identify all chemical which are incompatible with a pre-defined mission set (i.e. payload complement). The user is first asked to select the mission set for the search from a listing of pre-defined mission sets. The model first searches the data base to identify the facilities in the mission, and the chemicals required by each facility. The model then searches to identify all the chemical which are incompatible with the chemicals required by each facility in the mission set.

The output of this analysis identifies all the chemical which are incompatible with the chemicals required by each facility in the mission set and a description of why the chemicals are incompatible. Once this has been completed the user may either send the results of the analysis to the printer or view the results on the screen.

Information
 Incompatibility
 Mission Set
 Screen View

Selection allows the user to view the results of the chemical incompatibility search on the screen.

Information
 Incompatibility
 Mission Set
 Report

Selection allows the user to produce a report of the results of the chemical incompatibility search.

Information
 Incompatibility
 Mission Set
 Exit

Selection returns the user to the previous menu option. This selection serves the same purpose as the ESC key.

Information
 Incompatibility
 Facility

Selection allows the user to identify all chemicals which are incompatible with any of the facility chemicals currently in the data base. The user is first asked to select the facility for the search from a current listing of facilities. The model first searches the data base to identify the chemicals required by the facility and then searches to identify all the chemicals which are incompatible with the facility chemicals. The output of this analysis identifies all the chemicals which are incompatible with the chemicals required by the facility and a description of why the chemicals are incompatible. Once this has been completed the

user may either send the results of the analysis to the printer or view the results on the screen.

- Information
 - Incompatibility
 - Facility
 - Screen View

Selection allows the user to view the results of the chemical incompatibility search on the screen.

- Information
 - Incompatibility
 - Facility
 - Report

Selection allows the user to produce a report of the results of the chemical incompatibility search.

- Information
 - Incompatibility
 - Facility
 - Exit

Selection returns the user to the previous menu option. This selection serves the same purpose as the ESC key.

- Information
 - Incompatibility
 - Exit

Selection returns the user to the previous menu option. This selection serves the same purpose as the ESC key.

- Information
 - Incompatibility
 - Help

Selection displays a help screen for the menu options under the Information, Incompatibility, selections.

- Information
 - Corrosivity
 - Metals

Selection allows the user to view and report data which

is currently in the Metal Corrosivity table called SSMTCOR. This table contains the metal corrosivity data on individual elements, compounds and mixtures. The reader is referred to Section 1.2 of this chapter which provides a detailed description of this table.

- Information
 - Corrosivity
 - Metals
 - Screen View

Selection allows the user to view the contents of the metal corrosivity table on the screen.

- Information
 - Corrosivity
 - Metals
 - Report

Selection allows the user to produce a report of the data in the metal corrosivity table.

- Information
 - Corrosivity
 - Metals
 - Exit

Selection returns the user to the previous menu option. This selection serves the same purpose as the ESC key.

- Information
 - Corrosivity
 - Non-Metals

Selection allows the user to view and report data which is currently in the Non-Metals incompatibility table called SSNMCOR. This table contains the non-metal incompatibility data on individual elements, compounds and mixtures. The reader is referred to Section 3.2 of this chapter which provides a detailed description of this table.

Information
Corrosivity
Non-Metals
Screen View

Selection allows the user to view the contents of the non-metal incompatibility table on the screen.

Information
Corrosivity
Non-Metals
Report

Selection allows the user to produce a report of the data in the non-metal incompatibility table.

Information
Corrosivity
Non-Metals
Exit

Selection returns the user to the previous menu option. This selection serves the same purpose as the ESC key.

Information
Corrosivity
Exit

Selection returns the user to the previous menu option. This selection serves the same purpose as the ESC key.

Information
Exit

Selection returns the user to the previous menu option. This selection serves the same purpose as the ESC key.

Information
Help

Selection displays a help screen for the menu options under the Information, Corrosivity selections.

3.5 Description of NCHIS Analysis Menu Options

Scripts written to perform analyses for engineering design support are located in the Analysis section of the model. These scripts allow the user to define a list of chemicals, individual facilities or mission sets to perform the following analyses:

- (1) Chemical Incompatibility,
- (2) Imminent Hazards and,
- (3) Metal and Non Metal Corrosivity.

This section of the dissertation will provide a detailed description of the analyses which can be performed under each Analysis menu selection. Each selection is identified in a tiered structure and can be followed from the menu tree provided in Figure 3.9.

```
Analysis
  Chemical Manifest
    Facilities
      Define Mission
        New Mission
```

Selection allows the user to define a new mission set (i.e. payload complement) for analysis. The user is allowed to select from those facilities currently in the data base. Additional facilities may be added under the information section to increase the user's choices. Each mission set is defined by an 8 character name. It is this mission set name which will appear throughout the analysis sections when the user is asked to select a mission set for analysis.

Analysis
Chemical Manifest
Facilities
Define Mission
Existing Mission

Selection allows the user to edit an existing mission set (i.e. payload complement) for analysis. The user is allowed to select from a listing of previously defined mission sets currently established in the data base. Once the mission set has been selected the facilities which comprise the mission set will appear on the screen and the user may add new facilities to the mission or delete existing facilities. When the user is finished editing the mission set the revisions are saved under the same mission name.

Analysis
Chemical Manifest
Facilities
Define Mission
Chemicals/Facility

Selection allows the user to edit the current listing of chemicals required during on-orbit operations for any of the facilities currently in the data base. A listing of the current facilities will appear on the screen and the user is asked to select a facility. Once the facility has been selected the current listing of chemicals required by the facility will appear on the screen. The user may then add or delete chemicals to the list. When all editing is complete the program saves the changes for the facility and incorporates all changes into any further analyses performed.

```
Analysis
  Chemical Manifest
    Facilities
      Define Mission
        Exit
```

Selection returns the user to the previous menu option.

This selection serves the same purpose as the ESC key.

```
Analysis
  Chemical Manifest
    Facilities
      Define Mission
        Help
```

Selection displays a help screen for the menu options under the Analysis, Chemical Manifest, Facilities, Define Mission selections.

```
Analysis
  Chemical Manifest
    Facilities
      Chemicals/Facility
```

Selection allows the user to edit the current listing of chemicals required during on-orbit operations for any of the facilities currently in the data base. A listing of the current facilities will appear on the screen and the user is asked to select a facility. Once the facility has been selected the current listing of chemicals required by the facility will appear on the screen. The user may then add or delete chemicals to the list. When all editing is complete the program saves the changes for the facility and incorporates all changes into any further analyses performed.

```
Analysis
  Chemical Manifest
    Facilities
      Exit
```

Selection returns the user to the previous menu option.
This selection serves the same purpose as the ESC key.

```
Analysis
  Chemical Manifest
    Facilities
      Help
```

Selection displays a help screen for the menu options under the Analysis, Chemical Manifest, Facilities, selections.

```
Analysis
  Chemical Manifest
    Chemicals
      New List
```

Selection allows the user to define a new list of chemicals for analysis. The user is asked to enter an 8 character name for his/her list. The user may then type in the chemicals which comprise this new list. Once all the chemicals have been entered, the program saves this new list under the 8 character name. It is this chemical list name which will appear throughout the analysis section when the user is asked to select from a chemical list.

```
Analysis
  Chemical Manifest
    Chemicals
      Existing List
```

Selection allows the user to edit an existing list of chemicals for analysis. The user is allowed to select from a listing of previously defined chemicals list currently established by the user. Once the chemical list has been selected, the chemicals which comprise the listing will appear on the screen and the user may add or delete chemicals to the list. When the user is finished editing the list the

revisions are saved under the same chemical list name.

```
Analysis
  Chemical Manifest
    Chemicals
      Incompatibility
```

Selection allows the user to perform a chemical incompatibility analysis on an individual chemical, a user defined list of chemicals, a mission set, or a facility. The specific details of these analysis are provided in the following menu options.

```
Analysis
  Chemical Manifest
    Chemicals
      Incompatibility
        Individual Chemical
```

Selection allows the user to identify all chemicals which are incompatible with any given input chemical. The user is asked to enter in the chemical name, trade name or any synonym for the chemical in question. The model then searches the data base to identify all the chemical which are incompatible with the input chemical. The output of this analysis identifies all the chemical which are incompatible with the specified chemical and a description of why the chemicals are incompatible. Once this has been completed the user may either send the results of the analysis to the printer or view the results on the screen.

```
Analysis
  Chemical Manifest
    Chemicals
      Incompatibility
        User Defined List
```

Selection allows the user to identify all chemicals which

are incompatible with a pre-defined list of chemicals. The user is first asked to select the list of chemicals to be used in the analysis. The model then searches the data base to identify all the chemicals which are incompatible with the list of chemicals. The output of this analysis identifies all the chemical which are incompatible with the specified list of chemicals and a description of why the chemicals are incompatible. Once this has been completed the user may either send the results of the analysis to the printer or view the results on the screen.

Analysis
 Chemical Manifest
 Chemicals
 Incompatibility
 Mission Set

Selection allows the user to identify all chemicals which are incompatible with a pre-defined mission set (i.e. payload complement). The user is first asked to select the mission set for analysis from a listing of pre-defined mission sets. The model first searches the data base to identify the facilities in the mission, and the chemicals required by each facility. The model then searches to identify all the chemicals which are incompatible with the chemicals required by each facility in the mission set. The output of this analysis identifies all the chemicals which are incompatible with the chemicals required by each facility in the mission set and a description of why the chemicals are incompatible. Once this has been completed the user may either send the

results of the analysis to the printer or view the results on the screen.

```
Analysis
  Chemical Manifest
    Chemicals
      Incompatibility
        Facility
```

Selection allows the user to identify all chemicals which are incompatible with any of the facility chemicals currently in the data base. The user is first asked to select the facility for analysis from a current listing of facilities. The model first searches the data base to identify the chemicals required by the facility and then searches to identify all the chemicals which are incompatible with the facility chemicals. The output of this analysis identifies all the chemical which are incompatible with the chemicals required by the facility and a description of why the chemicals are incompatible. Once this has been completed the user may either send the results of the analysis to the printer or view the results on the screen.

```
Analysis
  Chemical Manifest
    Chemicals
      Incompatibility
        Exit
```

Selection returns the user to the previous menu option. This selection serves the same purpose as the ESC key.

```
Analysis
  Chemical Manifest
    Chemicals
      Incompatibility
        Help
```

Selection displays a help screen for the menu options under the Analysis, Chemical Manifest, Chemicals, Incompatibility, selections.

```
Analysis
  Chemical Manifest
    Chemicals
      Exit
```

Selection returns the user to the previous menu option. This selection serves the same purpose as the ESC key.

```
Analysis
  Chemical Manifest
    Chemicals
      Help
```

Selection displays a help screen for the menu options under the Analysis, Chemical Manifest, Chemicals, selections.

```
Analysis
  Imminent Hazards
    Facility Hazards
```

Selection allows the user to identify the imminent hazards associated with any of the facilities currently in the data base. The user is first asked to select the facility for analysis from a current listing of facilities. The model first searches the data base to identify the chemicals required by the facility and then searches to identify all the chemicals which are incompatible with the facility chemicals. Once all the incompatible chemicals are identified, the model then cross references the incompatible chemicals with those chemicals required by the facility. The intersection of this cross reference is identify as the Imminent Hazards for the facility (i.e. chemicals which are incompatible with the

chemicals required by the facility). The output of this analysis identifies all the Imminent Hazards for the facility and a description of the potential hazard. Once this analysis has been completed the user may either send the results of the analysis to the printer or view the results on the screen.

Analysis
 Imminent Hazards
 Mission Hazards

Selection allows the user to identify the imminent hazards associated with any of the pre-defined mission sets (i.e. payload complements). The user is first asked to select the mission set for analysis from a current listing of mission sets. The model first searches the data base to identify the facilities in the mission set and the chemicals required by each facility. The model then searches to identify all the chemicals which are incompatible with each of the facility chemicals. Once all the incompatible chemicals are identified, the model then cross references the incompatible chemicals with those chemicals required by each facility. The intersection of this cross reference is identified as the Imminent Hazards for the mission set (i.e. chemicals which are incompatible with the chemicals required by each facility in the mission set). The output of this analysis identifies all the Imminent Hazards for the mission set and a description of the potential hazard. Once this analysis has been completed the user may either send the results of the analysis to the printer or view the results on the screen.

Analysis
 Imminent Hazards
 Input List Hazards

Selection allows the user to identify the imminent hazards associated with any of the pre-defined lists of chemicals. The user is first asked to select the chemical listing for analysis from the current listings. The model searches the data base to identify the chemicals which are incompatible with the chemicals on the list. Once all the incompatible chemicals are identified, the model then cross references these incompatible chemicals with those chemicals on the list. The intersection of this cross reference is identified as the Imminent hazards for the chemical list (i.e. chemicals which are incompatible with the chemicals on the list). The output of this analysis identifies all the Imminent Hazards for the chemical list and a description of the potential hazard. Once this analysis has been completed the user may either send the results of the analysis to the printer or view the results on the screen.

Analysis
 Imminent Hazards
 Exit

Selection returns the user to the previous menu option. This selection serves the same purpose as the ESC key.

Analysis
 Imminent Hazards
 Help

Selection displays a help screen for the menu options under the Analysis, Imminent Hazards selections.

Analysis
Corrosivity
Metals

Selection allows the user to perform a metal corrosivity analysis on an individual chemical, a user defined list of chemicals, a mission set, or a facility. The specific details of these analysis are provided in the following menu options.

Analysis
Corrosivity
Metals
Individual Chemical

Selection allows the user to identify the metals which are corroded by any given chemical. The user is first asked to enter the chemical name, trade name or synonym for the chemical in question. The model then searches the data base to identify the metals which are corroded by the specified chemical at various temperature and concentration ranges for the corrosivity. The output of this analysis identifies all the chemical corrosivities and the temperature and concentration ranges. Once this analysis has been completed the user may either send the results of the analysis to the printer or view the results on the screen.

Analysis
Corrosivity
Metals
User Defined List

Selection allows the user to identify the metals which are corroded by any of the chemicals in a pre-defined lists of chemicals. The user is first asked to select the chemical listing for analysis from the current listings. The model

searches the data base to identify the metals which are corroded by the chemicals on the list and the various temperature and concentration ranges for the corrosivity. The output of this analysis identifies all the chemical corrosivities and the temperature and concentration ranges for the list of chemicals. Once this analysis has been completed the user may either send the results of the analysis to the printer or view the results on the screen.

Analysis
Corrosivity
Metals
Mission Set

Selection allows the user to identify the metals which are corroded by any of the chemicals required by each of the facilities in a pre-defined mission set. The user is first asked to select the mission set for analysis from the current listing. The model first searches to identify the facilities which comprise the mission and the chemicals required by each facility. The model then searches the data base to identify the metals which are corroded by each of the facility chemicals and the various temperature and concentration ranges for the corrosivity. The output of this analysis identifies all the chemical corrosivities and the temperature and concentration ranges for each facility in the mission set. Once this analysis has been completed the user may either send the results of the analysis to the printer or view the results on the screen.

```
Analysis
  Corrosivity
    Metals
      Facility
```

Selection allows the user to identify the metals which are corroded any of the chemicals required by any of the facilities currently in the data base. The user is first asked to select the facility for analysis from the current listing. The model searches to identify the chemicals required by the facility and then identifies the metals which are corroded by each of the facility chemicals and the various temperature and concentration ranges for the corrosivity. The output of this analysis identifies all the chemical corrosivities at various temperature and concentration ranges for each of the facility chemicals. Once this analysis has been completed the user may either send the results of the analysis to the printer or view the results on the screen.

```
Analysis
  Corrosivity
    Metals
      Exit
```

Selection returns the user to the previous menu option. This selection serves the same purpose as the ESC key.

```
Analysis
  Corrosivity
    Metals
      Help
```

Selection displays a help screen for the menu options under the Analysis, Corrosivity, Metals selections.

```
Analysis
  Corrosivity
    Non-Metals
```

Selection allows the user to perform a non-metal incompatibility analysis on an individual chemical, a user defined list of chemicals, a mission set, or a facility. The specific details of these analysis are provided in the following menu options.

- Analysis
 - Corrosivity
 - Non-Metals
 - Individual Chemical

Selection allows the user to identify the non-metals which are incompatible by any given chemical. The user is first asked to enter the chemical name, trade name or synonym for the chemical in question. The model then searches the data base to identify the non-metals which are incompatible with the specified chemical and the various temperature and concentration ranges for the incompatibility. The output of this analysis identifies all the chemical/non-metal incompatibilities and the temperature and concentration ranges. Once this analysis has been completed the user may either send the results of the analysis to the printer or view the results on the screen.

- Analysis
 - Corrosivity
 - Non-Metals
 - User Defined List

Selection allows the user to identify the non-metals which are incompatible with any of the chemicals in a pre-defined lists of chemicals. The user is first asked to select the chemical listing for analysis from the current listing.

The model searches the data base to identify the non-metals which are incompatible with the chemicals on the list at various temperature and concentration ranges for the incompatibility. The output of this analysis identifies all the chemical/non-metal incompatibilities at various temperature and concentration ranges for the chemical list. Once this analysis has been completed the user may either send the results of the analysis to the printer or view the results on the screen.

Analysis
 Corrosivity
 Non-Metals
 Mission Set

Selection allows the user to identify the non-metals which are incompatible with any of the chemicals required by each of the facilities in a pre-defined mission set. The user is first asked to select the mission set for analysis from the current listing. The model first searches to identify the facilities which comprise the mission and the chemicals required by each facility. The model then searches the data base to identify the non-metals which are incompatible with each of the facility chemicals and the various temperature and concentration ranges for the incompatibility. The output of this analysis identifies all the chemical/non-metal incompatibilities at various temperature and concentration ranges for each facility in the mission set. Once this analysis has been completed the user may either send the results of the analysis to the printer or view the results on

the screen.

```
Analysis
  Corrosivity
    Non-Metals
      Facility
```

Selection allows the user to identify the non-metals which are incompatible with any of the chemicals required by any of the facilities currently in the data base. The user is first asked to select the facility for analysis from the current listing. The model searches to identify the chemicals required by the facility and then identifies the chemicals which are incompatible with each of the facility non-metals at various temperature and concentration ranges for the incompatibility. The output of this analysis identifies all the chemical/non-metal incompatibilities at various temperature and concentration ranges for each of the facility chemicals. Once this analysis has been completed the user may either send the results of the analysis to the printer or view the results on the screen.

```
Analysis
  Corrosivity
    Non-Metals
      Exit
```

Selection returns the user to the previous menu option. This selection serves the same purpose as the ESC key.

```
Analysis
  Corrosivity
    Non-Metals
      Help
```

Selection displays a help screen for the menu options under the Analysis, Corrosivity, Non-Metals selections.

Analysis
Corrosivity
Exit

Selection returns the user to the previous menu option.
This selection serves the same purpose as the ESC key.

Analysis
Corrosivity
Help

Selection displays a help screen for the menu options
under the Analysis, Corrosivity, selections.

Analysis
Exit

Selection returns the user to the previous menu option.
This selection serves the same purpose as the ESC key.

Analysis
Help

Selection displays a help screen for the menu options
under the Analysis, selections.

CHAPTER IV

MODEL VALIDATION PROCESS

4.1 Experiment to Assess Model Validity

In order to assess the validity of the model developed, the author chose to use the proposed ten year draft manifest as developed by Teledyne Brown Engineering (Ref 15). As mentioned earlier, these manifest scenarios represent the various scientific disciplines by grouping appropriate facilities based on power, weight, volume, and crew time constraints. It should be emphasized that the scenarios are only used for determining the amount of resources required during a 90 day mission. A listing of the manifest scenarios and the facilities which comprise them are found in Table 4.1.

The validation experiment consisted of utilizing the model to perform the following chemical analyses,

- (1) Chemical incompatibility analyses,
- (2) Imminent Hazards analyses and,
- (3) Corrosivity analyses for metals and nonmetals.

These analyses were initially performed utilizing a list of on-orbit operational chemicals/materials required by a singular facility in which the number of chemical incompatibilities, imminent hazards and corrosivities were identified. The model then performed the same analyses utilizing a modified list of chemical/material requirements for the facility. This modified list consisted of "substitute" chemicals/materials, where applicable, which

Table 4.1 Ten Year Manifest Scenarios for the
Space Station MMPF

SCENARIO NUMBER	FACILITIES
1	Alloy Solidification Facility Bridgman, Small Facility Continuous Flow Electrophoresis Facility Critical Point Phenomena Facility Electroepitaxy Facility Protein Crystal Growth Facility Vapor Crystal Growth Facility
2	Alloy Solidification Facility Bridgman, Small Facility Continuous Flow Electrophoresis Facility Critical Point Phenomena Facility Electroepitaxy Facility Protein Crystal Growth Facility Solid Surface Burning Facility Vapor Crystal Growth Facility
3	Acoustic Levitation Facility Alloy Solidification Facility Bridgman, Small Facility Continuous Flow Electrophoresis Facility Droplet/Spray Burning Facility Electroepitaxy Facility Protein Crystal Growth Facility Solid Surface Burning Facility Vapor Crystal Growth Facility
4	Acoustic Levitation Facility Alloy Solidification Facility Bridgman, Small Facility Continuous Flow Electrophoresis Facility Droplet/Spray Burning Facility Electroepitaxy Facility Protein Crystal Growth Facility Rotating Spherical Convection Facility Solid Surface Burning Facility Vapor Crystal Growth Facility

Table 4.1 Ten Year Manifest Scenarios for the
Space Station MMPF (Continued)

SCENARIO NUMBER	FACILITIES
5	Acoustic Levitation Facility Alloy Solidification Facility Bridgman, Small Facility Continuous Flow Electrophoresis Facility Electroepitaxy Facility Protein Crystal Growth Facility Rotating Spherical Convection Facility Solid Surface Burning Facility Vapor Crystal Growth Facility
6	Acoustic Levitation Facility Alloy Solidification Facility Bridgman, Small Facility Continuous Flow Electrophoresis Facility Electroepitaxy Facility Fluid Physics Facility Protein Crystal Growth Facility Rotating Spherical Convection Facility Vapor Crystal Growth Facility
7	Acoustic Levitation Facility Alloy Solidification Facility Bridgman, Small Facility Continuous Flow Electrophoresis Facility Electromagnetic Levitator Facility Fluid Physics Facility Premixed Gas Combustion Facility Rotating Spherical Convection Facility Vapor Crystal Growth Facility
8	Acoustic Levitation Facility Alloy Solidification Facility Continuous Flow Electrophoresis Facility Electromagnetic Levitator Facility Fluid Physics Facility Organic and Polymer Crystal Growth Facility Premixed Gas Combustion Facility Rotating Spherical Convection Facility

Table 4.1 Ten Year Manifest Scenarios for the
Space Station MMPF (Continued)

SCENARIO NUMBER	FACILITIES
9	Alloy Solidification Facility Electromagnetic Levitator Facility Fluid Physics Facility Isoelectric Focusing Facility Latex Reactor Facility Organic and Polymer Crystal Growth Facility Premixed Gas Combustion Facility
10	Electrostatic Levitator Facility Electromagnetic Levitator Facility Fluid Physics Facility Isoelectric Focusing Facility Latex Reactor Facility Organic and Polymer Crystal Growth Facility
11	Bioreactor Incubator Facility Electromagnetic Levitator Facility Fluid Physics Facility High Temperature Furnace Facility Isoelectric Focusing Facility Latex Reactor Facility Organic and Polymer Crystal Growth Facility
12	Bioreactor Incubator Facility Electromagnetic Levitator Facility High Temperature Furnace Facility Isoelectric Focusing Facility Latex Reactor Facility Organic and Polymer Crystal Growth Facility

would hopefully reduce the number of chemical incompatibilities, hazards and corrosivities for the facility. By reducing the number of chemical incompatibilities, hazards and corrosivities the validate experiment would prove the usefulness of this tool in performing design and re-design activities necessary to reduce potential safety problem aboard the Space Station MMPF. Table 4.2 lists the chemicals required during the on-orbit operations of each of the facilities utilized in the analysis. To further validate the model, a second validation experiment of the same type was implemented utilizing the ten year MMPF scenarios from TBE. The scenarios were evaluated by the model and then modified (i.e. facility changes were made) in an attempt to reduce the number of potential chemical safety problems per mission. The details, results and conclusions from these validation experiments are provided in the following sections.

Table 4.2 Chemicals Required During On-orbit Operations of the Space Station Facilities

SPACE STATION FACILITY	CHEMICALS REQUIRED DURING ON-ORBIT OPERATIONS
Acoustic Levitator	Argon Calcium Oxide Gallium Oxide Germanium Dioxide Helium Silicon Silicon Dioxide
Alloy Solidification	Acetone Air Aluminum-Copper Aluminum-Lead-Bismuth Aluminum Alloys Argon Ethanol Iron Chloride, hexahydrate Hydrochloric Acid Lapping Oil Levigated Aluminum Nickel Alloys Nitric Acid Silicon-Arsenide-Tellurium Sodium Hydroxide Water
Bioreactor/Incubator	Carbon Dioxide Cell Medium Cells Ceramic Beads Glass Beads Glutaraldehyde Oxygen Sodium Chloride Sodium Hydroxide Sodium Nitrate Water

Table 4.2 Chemicals Required During On-orbit Operations of the Space Station Facilities (Continued)

SPACE STATION FACILITY	CHEMICALS REQUIRED DURING ON-ORBIT OPERATIONS
Bridgeman, Small	Acetone Aluminum-Lead-Bismuth Argon Ethanol Cadmium Telluride Acetic Acid Diamond Paste Gallium Arsenide Germanium Hydrogen Peroxide Hydrofluoric Acid Hydrochloric Acid Indium-Gallium-Arsenide Lapping Oil Mercury-Cadmium-Telluride Nitric Acid Lead-Tin-Telluride Selenium Silicon-Carbon Silicon Sodium Hydroxide Sulfuric Acid Water Zinc-Selenium
Continuous Flow Electrophoresis	Biological Raw Material Buffer Solution Glutaraldehyde Sodium Nitrate Water
Critical Point Phenomena	Argon Nitrogen Hydrogen Helium Liquid Helium-4 Liquid Helium Liquid Hydrogen Liquid Neon & Gaseous Neon Liquid Nitrogen Liq. & Gas. Propane Liquid Xenon

Table 4.2 Chemicals Required During On-orbit Operations of the Space Station Facilities (Continued)

SPACE STATION FACILITY	CHEMICALS REQUIRED DURING ON-ORBIT OPERATIONS
Droplet/Spray Burning	Air/Fuel Combust. Products Argon Cabin Air Carbon Dioxide Decane Detergent/Water Dilute Water Fuel Oil Helium Heptane Hexadecane Kerosene Methanol Nitrogen Oxygen Solid Combust. Products
Electroepitaxy	Cadmium Telluride Gallium Arsenide Germanium Nitrogen Hydrogen Indium-Gallium-Arsenide Indium-Antimony Mercury-Cadmium-Telluride Lead-Tin-Telluride Selenium Silicon-Carbon Silicon
Electrostatic Levitator	Acetone Air Argon Calcium Oxide Diamond Paste Gallium Oxide Germanium Dioxide Hydrofluoric Acid Nitric Acid Lapping Oil Silicon Silicon Dioxide Water

Table 4.2 Chemicals Required During On-orbit Operations of the Space Station Facilities (Continued)

SPACE STATION FACILITY	CHEMICALS REQUIRED DURING ON-ORBIT OPERATIONS
Electromagnetic Levitator	Acetone Argon Cadmium Telluride Calcium Oxide Chromium Oxide Dehumidified Air Diamond Paste Gallium Oxide Gallium Arsenide Germanium Dioxide Helium Hydrofluoric Acid Nitric Acid Lapping Oil Silicon Silicon Dioxide Silver Nitrate Water
Fluid Physics	Air Ammonium Chloride Argon Carbon Dioxide Acetic Acid Copper Sulfate Decane Ethanol Freon 113 Hydrogen Sulfuric Acid Helium Mercury-Iodine Iodine Iodide Methane Methanol Methyl Iodide Ammonium Oxygen Potassium Chloride Silane Silicon Oils Triglycine Sulfate (TGS)

Table 4.2 Chemicals Required During On-orbit Operations of the Space Station Facilities (Continued)

SPACE STATION FACILITY	CHEMICALS REQUIRED DURING ON-ORBIT OPERATIONS
High Temperature Furnace	Air Argon Glycerin Carbon Monoxide Chromium Iron-Nickel Water Hydrogen Peroxide Helium Hydrofluoric Acid Nitric Acid Hydrochloric Acid Ammonium Nitrate Nickel Alloys Nitrogen-Tungsten Sodium Hydroxide Titanium-Carbon
Isoelectric Focusing	Acetic Acid Acid Violet 17 Acids Amine Ampholyte Bases Biological Raw Material Biomaterial Fat Red 7B Glutaraldehyde Hydrogen Oxygen Phosphoric Acid Sodium Hydroxide Water
Latex Reactor	Aluminum Salt AMBN Process Initiator Seed Latex Silicon Salt Styrene (Monomer) Water

Table 4.2 Chemicals Required During On-orbit Operations of the Space Station Facilities (Continued)

SPACE STATION FACILITY	CHEMICALS REQUIRED DURING ON-ORBIT OPERATIONS
Organic & Polymer Crystal Growth	Acetonitrile Argon Buffer Solution Cleaning Fluids Copper Phthalocyanine Cyanide Tosylate Nitrogen Helium Methanol Naphthalene Polydiacetylene Toluene Urea Water Xenon
Premixed Gas Combustion	Air/Fuel Combust. Products Ammonia Argon Butane Cabin Air Carbon Dioxide Detergent/Water Ethane Helium Heptane Hexane Hydrogen Methane Nitrogen Propane Water

Table 4.2 Chemicals Required During On-orbit Operations of the Space Station Facilities (Continued)

SPACE STATION FACILITY	CHEMICALS REQUIRED DURING ON-ORBIT OPERATIONS
Protein Crystal Growth	2-(N-Cyclohexylamino)- Ethanesulfonic Acid 2-(N-Monpholine)- EthaneSulphonic Acid 2-Methyl-2,4-Pentanediol 3-Nitropropionate Acetic Acid Ammonium Hydroxide C-Reactive Protein Canavalin Dithiothreitol Ethylenediame Tetraacetate Glutathione Glutaraldehyde Human Purine Human Serum Albumin Isocitrate Lyase Magnesium Acetate Monobasic Sodium Phosphate Nitrogen Peptide Percine Elastase Phospholipase Polyethylene Glycol Potassium Chloride R Interferon Renin Sodium Acetate Sodium Azide Sodium Chloride Sodium Citrate Sodium Sulfate Tris(Hydroxymethyl)- Aminomethane Water

Table 4.2 Chemicals Required During On-orbit Operations of
the Space Station Facilities (Continued)

SPACE STATION FACILITY	CHEMICALS REQUIRED DURING ON-ORBIT OPERATIONS
Rotating Spherical Convection	Isopropyl Alcohol Carbon Tetrachloride Trichloromethane Acetaldehyde Acetonitrile Dimethyl Sulfate Chlorobenzene Chloroform Cyclohexanol Cyclohexanone Dimethylindolino- benzopyrlospiran Ethylene Glycol Formic Acid Nitrogen M-Tolunitrile Malachite Levocyanide Water
Solid Surface Burning	Argon Cabin Air Decane Detergent/Water Dilute Water Fuel Oil Helium Heptane Hexadecane Kerosene Methanol Nitrogen Solid Combust. Products Water

Table 4.2 Chemicals Required During On-orbit Operations of
the Space Station Facilities (Continued)

SPACE STATION FACILITY	CHEMICALS REQUIRED DURING ON-ORBIT OPERATIONS
Vapor Crystal Growth	Air Argon Bromide Ethanol Cadmium Selenide Cadmium Telluride Methanol Chromium Oxide Gallium Arsenide Germanium Hydrogen Peroxide Sulfuric Acid Hydrochloric Acid Indium Phosphorus Mercury Cadmium Telluride Selenium Silicon-Carbon Silicon Sodium Hydroxide Water Zinc-Tellurium

4.2 Facility Validation Experiment

In selecting the facility which would be utilized in the validation experiment, the model first determined the number of chemical incompatibilities, hazards and corrosivities for all the facilities currently in the data base. These results are illustrated in Table 4.3. The table identifies the number of chemical incompatibilities, imminent hazards and corrosivities and incompatibilities of metal and nonmetal for each facility respectively. Additionally the table depicts the total number of chemicals required by each facility during on-orbit operations. In selecting a facility to use in the validation experiment, the author wished to use the facility which had the most or highest number of associated potential safety problems. To accomplish this the total number of incompatibilities, hazards and corrosivities for each payload were summed and divided by the total number of chemicals required by each facility. This would provide a means of determining the number of safety problems per chemical. The results of this mathematical exercise are illustrated in Table 4.3. As can be seen from the table the Bridgman, Small Facility exhibited 102.71 problems/chemical, thus, making it the most safety critical (by this definition) of all the payloads. Therefore, this facility was selected for use in the validation experiment. It was hoped that if the number of potential safety problem could be reduced for this payload,

Table 4.3 Potential Safety Problems Per Facility

Space Station Facilities	# of Chemicals	# of Incompt	# of Imm Hzds	# of Corrosivities		Total Problems	Problems/Chemical
				Metals	Nonmetals		
Acoustic Levitator	7	37	0	0	25	62	8.86
Alloy Solidification	16	444	12	300	661	1417	88.56
Bioreactor/Incubator	11	223	8	251	327	809	73.55
Bridgman, Small	24	820	78	522	1045	2465	102.71
Continuous Flow Electrophoresis	5	31	1	46	75	153	30.60
Critical Point Phenomena	13	68	2	48	153	271	20.85
Droplet Spray Burning	16	161	3	25	99	288	18.00
Electroepitaxy	12	108	0	25	71	204	17.00
Electrostatic Levitator	13	407	15	149	375	946	72.77
Electromagnetic Levitator	18	488	18	241	540	1287	71.50
Fluid Physics	26	432	14	199	534	1179	45.35
Hight Temperature Furnace	17	565	20	319	716	1620	95.29
Isoelectric Focusing	16	227	10	323	630	1190	74.38
Latex Reactor	6	25	1	0	25	51	8.50
Organic & Polymer Crystal Growth	17	82	1	44	206	333	19.59
Premixed Gas Combustion	16	226	7	121	299	653	40.81
Protein Crystal Growth	32	64	1	459	577	1101	34.41
Rotating Spherical Convection	21	118	0	172	267	557	26.52
Solid Surface Burning	14	47	1	25	200	273	19.50
Vapor Crystal Growth	21	486	19	271	672	1448	68.95

then the model would have proven it usefulness.

Table 4.4 identifies the chemicals required by the Bridgman, Small Facility during on-orbit operations at the Space Station, MMPF. These chemicals produced over 2465 potential safety problems, as identified by the model. Substitute chemicals therefore needed to be identified in an attempt to reduce these potential safety problems. The proposed substitute chemicals are also identified in Table 4.4.

In determining which chemical substitutions could be made, the purpose of each chemical during the on-orbit operations of the facility had to be determined. Substitute chemicals were then identified which would serve the same function but reduce the number of potential safety problems. For some chemicals, no substitutions could be made, since any substitution would affect the actual experiment operations. As an example, no substitute chemical/compound could be made for Gallium Arsenide or Mercury Cadmium Telluride, since these are the primary materials which are to be processed by the furnace. Any change in these material would affect the on-orbit operations and defeat the purpose of the validation experiment. Therefore, substitute materials were primarily found for cleaning materials, purge gases and soaking solutions. Freon 113 was used as a substitute for Acetone, since these two chemicals are commonly substituted based on their similarities. 1-Butanol, is a primary alcohol with

Table 4.4 Facility Chemical Substitutions

CHEMICAL	SUBSTITUTE CHEMICAL
Acetone	Freon 113
Aluminum-Lead-Bismuth	
Argon	
Ethanol	1-Butanol
Cadmium Telluride	
Acetic Acid	Propionic Acid
Diamond Paste	
Gallium Arsenide	
Germanium	
Hydrogen Peroxide	
Sulfuric Acid	Hydrofluoric Acid
Hydrofluoric Acid	
Nitric Acid	Hydrofluoric Acid
Hydrochloric acid	Hydrofluoric Acid
Indium-Gallium-Arsenide	
Lapping oil	
Mercury Cadmium Telluride	
Lead-Tin-Telluride	
Selenium	
Silicon Carbide	
Sodium Hydroxide	
Water	
Zinc Selenide	

similar physical properties as ethanol, thus these two alcohols were substituted. Propionic acid, was substituted for acetic acid, since both chemicals are aliphatic acids with similar acidity constants or K_a values, and characteristics. These substitution were deemed appropriate considering their intended use. The cleaning fluid required by the glove box and the Fourier Infrared Spectrometer are identified as being water plus a weak concentration of acid solutions, such as, sulfuric acid, hydrofluoric acid, nitric acid, and

hydrochloric acid. For the purpose of cleaning this equipment it was determined that water and hydrofluoric acid would provide the best results. Therefore, hydrofluoric acid was substituted for each of these acids.

Once these chemical substitutions were made, the model was utilized to determine the number of incompatibilities, hazards and corrosivities exhibited by the new chemical listing. Table 4.5 provides a summary of the results of the analysis. As can be seen from the table these substitutions reduced the total number of potential safety problems by 69.91%. Thus, proving the usefulness of the model as a design tool in reducing potential safety problems aboard the Space Station MMPF. Additional chemical substitutions could be made by further analysis of chemical requirements in relation to their use in the experiment operations, which would reduce the potential safety problem even more. Theoretically, the model could aid in eliminating all potential chemical safety problems for any given facility.

It should be noted that the number of metal and non-metal corrosive materials for the revised list of chemicals was reduced by 66.28% and 66.41% respectively. Currently, the model identifies those materials which are corrosive regardless of the conditions (i.e. temperature, concentration, mils per year, etc.). By implementing additional conditional statements into the model this corrosivity number could be reduced even greater. As an example, the model could be asked

Table 4.5 Reduction In Potential Safety Problems Through
Chemical Substitution

Space Station Facility	# of Chemicals	# of Incompt	# of Imm Hzds	# of Corrosivities		Total Problems	Problems/ Chemical
				Metals	Nonmetals		
Bridgman, Small Original chemicals	24	820	78	522	1045	2465	102.71
Bridgman, Small Substitute chemicals	20	220	2	176	351	749	37.45
Potential Safety Problem Reduction (%)	N/A	73.17	97.44	66.28	66.41	69.61	63.54

to identify all the materials which are corrosive to any given chemical under the following conditions:

- (1) Temperature between X and (X+Y) °C
- (2) Concentration between Z and (Z+Q) %
- (3) Less then "P" mils per year
- (4) Etc.

Implementation of the option of added conditional queries would also provide additional filters in selecting substitute chemicals. For example, if a designer or experimenter were trying to select one of several substitute chemical and all the chemical exhibited approximately the same number of corrosive materials, then he/she could place these additional conditions on each material to see which one provided the best results. Thus, utilizing the model will aid in the material selection process.

4.3 Mission Validation Experiment

Upon the successful completion of the facility validation experiment, the mission validation experiment was initiated and conducted in the same fashion. The facilities comprising the ten year Space Station MMPF mission scenarios were analyzed. As before the model determined the number of chemical incompatibilities, hazards and corrosivities associated with each scenario or mission set. The results of

this analysis are shown in Table 4.6. Additionally, Appendix D provides a detailed listing of the chemical types and quantity required by each of the scenarios. Because of the nature of the scenarios it was not necessary to select one mission, note its safety problems, substitute new facilities for the mission and re-run the analysis. This has essentially already been done in looking at the facilities which comprise each scenario. As an example, the facilities which comprise scenarios 01 and 02 (Table 4.1) are exactly the same except for the omission of the Solid Surface Burning Facility (SSBF) from scenario 01. Thus, as can be seen from the table by removing this facility the number of potential safety problem were reduced, but not by the total number of safety problems for the SSBF itself. Since 47 chemical incompatibilities, 1 imminent hazard and 25 metal and 200 nonmetal corrosivities existed for the SSBF the number of incompatibilities, hazards and corrosivities for scenario 01 were not reduced by this amount. Thus, showing that these chemical incompatibilities are not additive. The same results were exhibited for each of the scenarios. By reducing or exchanging the number of facilities in the mission the potential safety problems were reduced. The reader is referred to Table 4.1 which identified the facilities which comprise each of the scenarios. It should be noted that no relationship could be established between the number of payloads in the mission and the total number of potential safety problems. As an example scenario

Table 4.6 Potential Safety Problems Per Scenario

Space Station Scenarios	# of Facilities	# of Incompt	# of Imm Hzds	# of Corrosivities		Total Problems	Problems/ Facility
				Metals	Nonmetals		
01	7	1015	102	973	1773	3863	551.86
02	8	1024	102	998	1876	4000	500.00
03	9	1132	118	975	1853	4078	453.11
04	10	1250	146	1147	2120	4663	466.30
05	9	1136	127	1147	2090	4500	500.00
06	9	1320	155	1231	2297	5003	555.89
07	9	1447	165	1104	2322	5038	559.78
08	8	1447	129	907	2089	4572	571.50
09	7	1231	128	880	2145	4384	626.29
10	6	1086	107	782	1737	3712	618.67
11	7	1279	146	983	2172	4580	654.29
12	6	1049	97	809	1811	3766	627.67

10 consisted of the maximum number of facilities, 10, but did not exhibit the maximum number of potential safety problems. Scenario 07 which consisted of only 9 facilities exhibited the most potential safety problems. The results of this experiment have further validated the usefulness of this tool in providing important chemical analysis data to reduce the number of potential safety problems aboard the Space Station MMPF.

CHAPTER V

CONCLUSIONS

5.1 Conclusions

The results of two model validation experiments have shown that the proposed NASA Chemical Hazards and Information System developed herein provides a viable engineering tool to reduce the number of potential chemical safety problems aboard the Space Station MMPF. The underlying hypothesis behind the proposed process is that by knowing the number of chemical incompatibilities, hazards and corrosivities for any given facility or mission, one can modify or substitute chemicals for a facility or facility manifest to reduce the number of chemical incompatibilities, hazards and corrosivities thus, reducing the number of potential on-board safety problems. This was proven to be an accurate hypothesis based on the results of the validation experiments. The model is shown to be a valuable tool to use in performing design and redesign activities to eliminate a the number of potential safety problems during design stages. While the processes implemented in this model only provided limited conditional statement for the corrosivity analyses, it is concluded that the model could be expanded to include additional conditional statements that would reduce the number of potential safety problems and provide additional filters in selecting substitute chemicals.

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APPENDICES

APPENDIX A
POTENTIAL SPACE STATION FACILITIES

Appendix A provides a brief description of the 30 potential facilities which will utilize the Space Station MMPF. Each facility has the capability of conducting numerous experiments. These experiments, as well as their operating parameters, are included in the appendix for each of these facilities.

Acoustic Levitator Facility

This facility utilizes acoustic drivers to position a sample in space where it can be processed. This could serve as a positioner for melting specimens via lasers or hot furnaces without contacting the container walls.

Example Experiments:

1. Alloy Segregation
2. Containerless Processing of Materials
3. Crystal Growth in Melts for In-Situ Development of Composites
4. Layered Systems and Phase Separation Composites
5. Particle Sintering
6. Reactive Materials in Molten States
7. Viscosity Measurements

Operating Parameters:

Size: Up to 100 ml

Temp: 20-2500 °C

Time: 0.5-48 hours

Alloy Solidification Facility

This facility will allow precision measurements of metallurgical properties in microgravity. The facility will probably consist of a Multiple Experiment Processing Furnace (MEPF), and isothermal furnace with quench capability, a Bridgman-Stockbarger furnace, high temperature differential scanning calorimeter, and an x-ray diagnostic system for molten state image analyses.

Example Experiments:

1. Alloy Segregation
2. Casting/Dendrite Growth
3. Mercury-Cadmium-Telluride Casting
4. Heat Treatment in Microgravity Studies
5. Thermophysical Properties
6. Solidification of Immiscible Alloys
7. Organic Conductors
8. Diffusive Mixing of Organics

Operating Parameters:

Size: 1-5 cm dia. x 5-20 cm length

Temp: 200-1600 °C

Time: 0.5-12 hours

Atmospheric Microphysics Facility

This facility will be used to create artificial clouds and ice particles in chambers whose pressure, temperature, and atmospheric composition is controlled. The system will consist of an expansion chamber, temperature monitoring and control, internal sampling ports, continuous flow diffusion chamber, saturator, static diffusion liquid chamber, fluid subsystem, and optical/imaging subsystem.

Example Experiments:

1. Cloud Formation Microphysics
2. Mass Transport in Clouds
3. Turbulence Effects on Cloud Formation
4. Droplet Coalescence Phenomena
5. Ice Crystal Growth

Operating Parameters:

Size: 20 ml seed production modules with 1 ml acid

Temp: -40 to 100 °C

Time: 0.5-12 hours

Autoignition Furnace Facility

Enclosed in a high precision temperature controlled electric furnace, a pressure vessel with optical viewing and sampling ports is the goal of this facility. Combustion processes will be studied and photographed.

Example Experiments:

1. Autoignition Studies
2. Combustion of Large Solids
3. Fire Safety
4. Liquid Pool Burning
5. Flame Propagation and Extinction
6. Thermophysical Properties

Operating Parameters:

Size: 6x20x1 cm solid, 0.5 ml droplets, or 0.21 l gas

Temp: 100-1800 °C

Time: 1-10 hours

Bioreactor/Incubator Facility

This facility will be used to study properties of cellular growth of materials separated by the Continuous Flow Electrophoresis Facility. It consists of a bioreactor main chamber, temperature monitoring and control system, gas distribution, pH monitoring and control, cell growth monitor, mass transport monitor, and data acquisition system.

Example Experiments

1. Biological Growth in Microgravity
2. Biomaterials Properties
3. Cell Fusion
4. Cellular Biodynamics

Operating Parameters:

Size 0.005-2.0 l

Temp: 20-40 °C

Time: 1 week to 90 days

Bridgman Large Facility

This facility contains a high temperature large bore directional solidification furnace (up to 1600 °C at 0.5 °C increments) with variable thermal gradient capability for applicable solidification rates (minutes to hours per cm).

Example Experiments:

1. Bridgman Growth
2. Directional Solidification
3. Eutectic Alloy Solidification
4. Immiscible Alloy Solidification
5. Vapor Phase Crystal Growth

Operating Parameters:

Size: 1-7.854 l

Temp: 400-1600 °C

Time: 6 hours to 4 weeks

Bridgman, Small Facility

This facility has the same capabilities as the larger Bridgman and will examine the same types of experiments. The difference lies in the sample size being 0.05 to 0.315 liter and operating times of 1 hour to 4 weeks.

Bulk Crystal Facility

This facility will produce 10-30 cm diameter crystals from a controllable heat leak sting in a large isothermal furnace. The heat leak prevents the seed from melting as the sample temperature is raised above the melt.

Example Experiments:

1. Monotectic Dispersions
2. Convection/Diffusion Transfer
3. Diffusive Mixing
4. Immiscible Alloy Solidification
5. Thermal Bubble Migration

Operating Parameters:

Size: 10-30 cm dia. x 15-50 cm length

Temp: 75-1800 °C

Time: 11-30 days

Continuous Flow Electrophoresis Facility

This facility will be used to separate biological materials by their respective mobilities in a buffer medium when an electric field is applied perpendicular to the flowing buffer and sample. The system includes buffers, culture medium, cleaning/disinfectants/sterilization fluids, biomaterials and staining solution. The system pumps, chambers, electrodes, temperature monitoring and control are microprocessor controlled.

Example Experiments:

1. Cellular Biodynamics
2. Continuous Flow Electrophoresis
3. Purification of Biomaterials

Operating Parameters:

Size: 2.7 liters concentrated buffer
0.05-0.3 liters raw biomaterials
Temp: 0-40 °C
Time: 3.5-20 hours

Critical Point Phenomena Facility

This facility will house an apparatus to study liquified gas. The system will consist of a cryostat, sensor module, optic system, and an electronics package.

Example Experiments:

1. Critical Point Phenomena
2. Critical and Off-Critical Point Measurements
3. Low-Temperature Critical Wetting Phenomena

Operating Parameters:

Size: 0.1-20 liters

Temp: 1-300 °K (-272 to 27 °C)

Time: 10-30 days

Droplet/Spray Burning Facility

This facility will measure the physical properties of fuel undergoing ignition and combustion. Temperature, pressure, and atmospheric composition will be obtained through numerous sensors and sampling ports available. High speed video monitoring will also be used with the gas/vacuum distribution and control system, as well as, the droplet/spray generation system.

Example Experiments:

1. Combustion Phenomena
2. Droplet Cloud Combustion
3. Fire Safety Combustion Studies
4. High Pressure Vapor Combustion

Operating Parameters:

Size: 1-30 ml

Temp: -40 to 100 °C

Time: 0.1-30 minutes

Electroepitaxy Facility

Using the method of electroepitaxy, this facility will grow high quality research and commercial electronic crystals from aqueous solutions. Crystal growth techniques will be developed leading to improved electronic crystals.

Example Experiments:

1. Electroepitaxial Crystal Growth
2. Thin Film Crystal Growth
3. Electrodeposition
4. Bulk Compound Semiconductor Growth

Operating Parameters:

Size: 5-15 cm dia. x 0.5-4 cm length

Temp: 600-1200 °C

Time: 1-10 days

Electrostatic Levitator Facility

By applying an electric field from electrodes, charged samples may be positioned so that they could be heated to melting by use of a laser. This containerless processing method prevents irregularities caused by wall contact.

Example Experiments:

1. Containerless Processing of Metals and Alloys
2. Fiber Production
3. Phase Transformation Phenomena
4. Thermophysical Properties
5. Reactive Materials in Molten State

Operating Parameters:

Size: 177 ml

Temp: 200-2000 °C

Time: 1-48 hours

Electromagnetic Levitator Facility

Lorentz forces, induced by a coil when excited by radio frequency, positions metallic and alloy samples for heating and melting. An electron beam source is provided for auxiliary heating.

Example Experiments:

1. Casting/Dendrite Growth
2. Containerless Processing of Conductive Materials
3. Diffusion Coefficients
4. Eutectic Alloy Solidification
5. Specific Heats of Materials
6. Oxide Particle Formation in Metals
7. Melt Dynamics
8. Iridium Crucible Production

Operating Parameters:

Size: 177 ml

Temp: 20-3500 °C

Time: 72 minutes to 3 hours

Float Zone Facility

The Float Zone Crystal Growth Facility will consists of two long axial tube furnaces (temperatures up to 1600 °C) and an independently controlled high temperature zone (up to 2200 °C) near the center. The axial tube furnaces are used to hold the starting material and the grown crystal just below the melting point. The molten zone, produced by the central high temperature zone, is then moved along the rod material by furnace movement. As the sample rotates, the furnace is translated across it.

Example Experiments:

1. Float Zone Crystal Growth
2. Float Zone Purification of Materials
3. Directional Solidification

Operating Parameters:

Size: 5-129 ml

Temp: 400-2200 °C

Time: 7 hours to 1 week

Fluid Physics Facility

This facility will provide a research area for investigating fluid phenomena in microgravity. Physical properties such as fluid convection, phase transition, surface physics, and bubble behavior will be examined.

Example Experiments:

1. Free Surface Phenomena
2. Thermophysical Properties
3. Fluid Physics
4. Surface Dynamics
5. Solution Crystal Growth

Operating Parameters:

Size: 5 ml to 1.00 liter/ cell
Temp: 10-100 °C
Time: 12 hours to 2 weeks

Free Float Facility

This facility will be used to process metals and alloys, as well as, metal matrix composites. The facility utilizes an electron beam source to melt the samples in a completely quiescent environment so that it can undercool and solidify.

Example Experiments:

1. Glassy Alloys
2. Undercooling Effects

Operating Parameters:

Size: 5.3 ml

Temp: 20-2500 °C

Time: 1-12 hours

High Temperature Furnace Facility

This unique facility will provide high temperature, high pressure furnaces for processing high melting point materials such as ceramics. Capable of reaching 2500 °C and 300 psi, the system will also provide cooling and rapid quenching for metals, alloys, composites, etc.

Example Experiments:

1. Casting Processes
2. Ceramic Reinforcement
3. Metals, Alloys, and Metal Matrix Composite Production
4. Polymers and Polymer Composite Production
5. Unique Quenching Methods
6. Transcrystallization Phenomena

Operating Parameters:

Size: 16-47 ml

Temp: 1100-2500 °C

Time: 2 hours to 10 days

Isoelectric Focusing Facility

This facility uses an electric potential applied across a pH gradient to separate biological materials by their isoelectric points. It utilizes a focusing cell, heat exchanger, pH monitor, UV monitors, and electrical conductivity sensors.

Example Experiments:

1. Cellular Biodynamics
2. Isoelectric Focusing
3. Isoenzyme Production

Operating Parameters:

Size: 100-150 ml ampholyte per run
Temp: 2-40 °C
Time: 2.75-10 hours

Latex Reactor Facility

This facility will be used to investigate polymerization processes and growth of designated crystals such as the monodispersed latex sphere production.

Example Experiments:

1. Morphology Studies
2. Polymerization Phenomena
3. Crystallization Phenomena
4. Solution Crystal Growth
5. Polymer Synthesis

Operating Parameters:

Size: 0.25 liter process initiator
1.0 liter latex solution
0.75 liter styrene

Temp: 20-150 °C

Time: 32-120 hours

Membrane Production Facility

This facility will be used to produce inorganic polymeric Langmuir Blodgett type membranes by using a Fluid Surface Generation Mechanism and a microprocessor controlled temperature monitoring and controlling system.

Example Experiments:

1. Membrane Production
2. Polymer Film Casting

Operating Parameters:

Size: 0.01-0.05 liter selected monomer/polymer materials

0.008 liter catalyst solution

Temp: 20-150 °C

Time: 0.5-6 hours

Optical Fiber Pulling Facility

Information learned from this facility would lead to development of containerless fiber-pulling technology for commercial applications. Elimination of contaminants by avoiding physical contact with the glass or fiber-forming material at high temperatures has lead to two possible techniques. The "quasi-containerless" method with its two high temperature furnaces mounted head to head and the "acoustic" method utilizing the acoustic levitator furnace to levitate the melt in which high quality fibers are drawn and wound on a spool.

Example Experiments:

1. Glass/Ceramic Fiber Production
2. Metal/Alloy Fiber Production
3. Polymer Fiber Production

Operating Parameters:

Size: Up to 0.1 liter per run

Temp: 20-2500 °C (only for interface area to acoustic levitator)

Time: 0.5-8 hours

Organic and Polymer Crystal Growth Facility

This facility will be used to investigate organic and polymeric crystalline materials which have unique electrical, magnetic, and optical properties. The facility will have growth modules for melt, directional solidification, solution growth, and vapor growth (either chemical or physical vapor transport methods.)

Example Experiments:

1. Crystallization Phenomena
2. Crystal Growth of Optoelectronic Materials
3. Polymerization Phenomena
4. Solidification of Molten Organics/Polymers

Operating Parameters:

Size: 25-70 liters

Temp: 20-500 °C

Time: 1-45 days

Premixed Gas Combustion Facility

This facility studies the ignition and combustion properties of premixed gas and liquid systems. Species composition, temperature, pressure, and optical measurements will be monitored via a microprocessor controller.

Example Experiments:

1. Combustion Phenomena
2. Fire Safety Combustion Studies
3. Gas Phase Combustion
4. Premixed Gas Combustion
5. Stratified Mixture Combustion

Operating Parameters:

Size: 5-500 ml
Temp: -40 to 200 °C
Time: 0.5-1 hour

Protein Crystal Growth Facility

This facility provides the user three methods of producing protein crystals from a temperature controlled thermoelectric unit. Available to the user will be x-ray diffraction analysis instrumentation to determine the molecular structure from crystals produced by either vapor equilibrium, liquid diffusion, or dialysis methods.

Example Experiments:

1. Protein Crystal Growth
2. Virus Crystal Growth
3. Organic Crystal Molecules
4. Macromolecular Crystallization

Operating Parameters:

Size: 1.0-5.0 liter growth solution
0.01-0.02 liter protein solution

Temp: 0-40 °C

Time: 12 hours to 10 weeks

Rotating Spherical Convection Facility

This facility is designed to investigate the full range of convection flows in planetary and terrestrial systems. The facility uses dimensional similtude and dielectric forces to produce a working spherical model of planetary atmospheres.

Example Experiments:

1. Geophysical Fluid Flow Model
2. Fluid Physics
3. Convection/Diffusion Transfer

Operating Parameters:

Size: 0.05-0.5 liters

Temp: 0-100 °C

Time: 3-48 hours

Solid Surface Burning Facility

This facility utilizes a pressurized flow apparatus that generates a laminar flow profile across a chamber that holds solid samples and nozzles for gas and liquid fuels. The facility will be used in support of ignition and combustion studies.

Example Experiments:

1. Fire Safety Combustion Studies
2. Flame Propagation and Extinction
3. Solid Surface Burning
4. Combustion Phenomena

Operating Parameters:

Size: 1.2-50 ml
Temp: 20-100 °C
Time: 0.5-2 hours

Solution Crystal Facility

This unique facility will provide a variety of experimental cells for producing crystals in microgravity. One cell will have the capability to rotate about an axis perpendicular to the orbital plane. The facility will be used to perform a wide range of solution crystal growth procedures including cooled sting, seeded, and unseeded methods.

Example Experiments:

1. Solution Crystal Growth
2. Collagen Processing
3. Crystallization Phenomena
4. Protein Crystal Growth
5. Crystal Growth of Electro-optical and Optical Materials

Operating Parameters:

Size: 0.1-2.0 liter/cell

Temp: 20-200 °C

Time: 1-30 days

Vapor Crystal Facility

This facility will house up to 24 different growth modules or gradient furnaces for production of diffusion gradients and vapor transport.

Example Experiments:

1. Convection/Diffusion Transfer
2. Directional Solidification
3. Organic Conductors
4. Synthesis of Silicon Dihalides/Suboxides
5. Vapor Phase Crystal Growth

Operating Parameters:

Size: 1-30 cm dia. x 0.05-51 cm length

Temp: 100-1100 °C

Gradient Temp: 10-200 °C/cm

Time: 2 hours to 4 weeks

Variable Flow Shell Generator Facility

This facility will be used to produce perfect or near perfect spheres by eliminating levitator positioner or container wall effects. It consists of an environmental control unit, sample injection system, and a free float observation tube. It will incorporate halographic and/or Schlieren imaging systems.

Example Experiments:

1. Biomaterial Polymer Encapsulation
2. Droplet Coalescence
3. Surface Tension Measurements
4. Glass Micro and Macro-Balloon Production
5. Surface Dynamics

Operating Parameters:

Size: 0.05-3 cm diameter sphere
Temp: -170 to 750 °C
Time: 10 hours to 30 days

APPENDIX B

PARADOX APPLICATION SCRIPTS

Twenty Paradox application scripts were developed to implement the data manipulation and hazard analyses incorporated in the NASA Chemical Hazards Information System. The scripts developed have been classified into two categories:

- (1) Scripts which call screens (i.e. help screens or main data base screens), and
- (2) Procedural scripts

Within these two categories, thirteen scripts were developed in which their function is to call screens. Twelve of these scripts call help screens during program operations and one script was developed to customize the introductory screen which appears when the programs are executed. The remaining seven scripts developed are procedural scripts which contain thirty-eight procedures. These procedures are similar to subroutines in classical programming. It is these procedures which perform the data manipulation and analysis. These scripts and associated procedures have been documented, via the comment statements within the code, and are provided in this appendix. The names of each script appears on the first line of commented text followed by an overview of the script's function.

```

*****
Script SCREEN.SC - Produces the main introductory screen for the Space Station
Chemical Hazards Analysis Data Base System.
*****

```

```

Style Attribute 30
Text

```

```

Developed for:      Developed by:
NASA Marshall Space Flight Center  Richard T. Congo
                                   NASA/MSFC

```

```

EndText
Style Attribute 12
@ 6,20
?? "NASA CHEMICAL HAZARDS INFORMATION SYSTEM"
Style Attribute 113
@ 8,36
?? " (NCHIS) "
Style

```

```

*****
Script FACHLP.SC - Produces the second branch of help screens under the chemical
manifest analysis selection.
*****

text
    "Define Mission Set" --
        Define a set of facilities for a mission set. Existing mission sets can
        also be modified.

    "Chemicals/Facility" --
        View/Edit the set of chemicals defined for a particular facility.

    "Exit" --
        Return to previous menu.

    "Help" --
        Display this help screen.

endtext

```

```

*****
Script CORHLP.SC - Produces the first branch help screens for the corrosivity
analysis menu selection.
*****

```

```

text

```

```

"Metals" ---

```

```

    This selection takes the user to a sub-menu that allows the user to look at
    Metal Corrosivity information for an individual chemical or for the "What
    If?" list of chemicals.

```

```

"Non-metals" ---

```

```

    This selection takes the user to a sub-menu that allows the user to look at
    Non-metal Corrosivity information for an individual chemical or for the
    "What If?" list of chemicals.

```

```

"Exit" ---

```

```

    This selection returns the user to the previous menu.

```

```

"Help" --

```

```

    Display this help screen.

```

```

endtext

```

```

*****
Script HAZHLP.SC - Produces the first branch help screen for the imminent hazards
analysis selection menu.
*****

```

text

"Facility Hazards" ---

After prompting the user for a facility name or acronym this selection will identify (by querying incompatibility data) potential hazards associated with the input facility; A hard copy report is then optional.

"List Hazards" ---

This selection will identify potential hazards associated with the used-defined "What If?" list. (The hazards are identified by querying incompatibility data)

"Manifest Hazards" ---

This selection will identify (by querying incompatibility data the potential hazards associated with the missions manifest defined under the "Select Facilities" option.

"Exit" ---

This selection returns the user to the previous menu.

"Help" --

Display this help screen.

endtext

Script INFOHLP.SC - Produces the first branch help screen for the information
selection menu.

text

"Chemical Properties"---

Add, update, view or produce a report of the chemicals properties data
base.

"Chemicals/Facility"---

Add, update, view or produce a report of the chemicals required during on-
orbit operations of each potential Space Station facility currently in the
data base.

"Facilities"---

View or produce a report of the potential Space Station facility currently
in the data base.

"Incompatibility"---

Add, update, view or produce a report of the incompatibilities associated
with (1) any given chemical or list of chemicals, (2) any given facility,
or (3) any mission set.

"Corrosivity"---

View or produce a report of the metals or nonmetals corrosivity tables.

"Exit"--

Return to the previous menu selection.

"Help" --

Display this help screen.

endtext

Script MAINHELP.SC - Produces the main help screen for the Space Station Chemical
Hazards Analysis Data Base.

text

"Information"--

 This option allows the user to add, extract, or modify data in the
 database, using standard database operations.

"Analysis" --

 This option accesses the system functions that analyze the data by certain
 pre-programmed functions. These functions provide specific information
 quickly and efficiently.

"Leave" --

 This option allows the operator to exit the system.

"Help" --

 Display this help screen.

endtext

Script MANHLP.SC - Produces the first branch help screen for the chemical manifest
analysis selection menu.

text

"Facilities" --

This selection allows the user to select from a list of pre-defined
facilities to define a mission set as well as View or Edit any of the pre-
defined facilities.

"Chemicals" --

This selection allows the user to define a list of chemicals for "What If?"
type scenarios, edit a list of chemicals previously defined as a missions
manifest, View or Edit the chemicals with a particular facility, or look at
incompatibility data.

"Exit" --

Return to previous menu.

"Help" --

Display this help screen.

endtext

```

*****
Script MISHLP.SC - Produces the third branch help screen for the chemical
manifest/facilities analysis menu selection.
*****

text

    "New Mission" --
        Define and save a new mission set.

    "Old Mission" --
        Modify/Edit an existing mission set.

    "Chemical/Facility" --
        View/Edit the chemicals in a particular facility.

    "Exit" --
        Return to previous menu.

    "Help" --
        Display this help screen.

endtext

```

Script ANHLP.SC - Produces the first branch help screen for the analysis menu
selection.

text

"Chemical Manifest"---

This selection allows the user to define a list of chemicals for a "What
If?" condition, view the defined set of chemicals or select different
facilities for a missions manifest.

"Imminent Hazards"---

This selection identifies potential hazards associated with an individual
facility, an entire missions manifest or the user defined "What If?" list.

"Corrosivity Analysis"---

This selection allows the user to perform engineering related corrosivity
analysis for different types of metals and non-metals.

"Exit" --

Return to previous menu.

"Help" --

Display this help screen.

endtext

```

*****
Script CIIHLP.SC - Produces the first branch help screen under the chemical
manifest/chemicals analysis selection.
*****

text
    "Define New List"---
        This selection allows the user to define a new list of chemicals for a
        "What If?" analysis.

    "Edit Existing List"---
        This allows the user to edit an existing list of chemicals for a "What If?"
        analysis.

    "Incompatibility"---
        This selection allows the user to perform a chemical incompatibility
        analysis on (1) any given chemical, (2) a list of chemicals, (3) a mission
        set or (4) an individual facility.

    "Exit" --
        Return to previous menu.

    "Help" --
        Display this help screen.

endtext

```

```

*****
Script CI2HLP.SC - Produces the second branch help screen under the chemical
manifest/chemicals analysis selection.
*****
text

"Individual Chemical"---

    This selection allows the user to perform an incompatibility analysis on a
    single chemical selected by the user.

"User Defined List"---

    This selection allows the user to perform an incompatibility analysis on a
    pre-defined list of chemicals.

"Mission Set"---
    This selection allows the user to perform an incompatibility analysis on a
    pre-defined list of facilities (i.e., mission set).

"Facility"---

    This selection allows the user to perform an incompatibility analysis on
    any one of the Space Station facilities currently in the data base.

"Exit" --

    Return to previous menu.

"Help" --

    Display this help screen.

endtext

```

Script NMCHLP.SC - Produces the first branch help screen under the corrosivity/non-
metals analysis branch.

text

"Individual Chemical"---

This selection allows the user to perform an analysis to identify all the
non-metals which are corrosive with a user specified chemical.

"User Defined List"---

This selection allows the user to perform an analysis to identify all the
non-metals which are corrosive with a pre-defined list of chemicals.

"Mission Set"---

This selection allows the user to perform an analysis to identify all the
non-metals which are corrosive with a pre-defined list of facility (i.e.
mission set) chemicals.

"Facility"---

This selection allows the user to perform an analysis to identify all the
non-metals which are corrosive with any of the Space Station facilities in
the data base.

"Exit" --

Return to previous menu.

"Help" --

Display this help screen.

endtext

Script MCHLP.SC - Produces the first branch help screen under the corrosivity/metals
analysis branch.

text

"Individual Chemical"---

This selection allows the user to perform an analysis to identify all the
metals which are corrosive with a user specified chemical.

"User Defined List"---

This selection allows the user to perform an analysis to identify all the
metals which are corrosive with a pre-defined list of chemicals.

"Mission Set"---

This selection allows the user to perform an analysis to identify all the
metals which are corrosive with a pre-defined list of facility (i.e.
mission set) chemicals.

"Facility"---

This selection allows the user to perform an analysis to identify all the
metals which are corrosive with any of the Space Station facilities in the
data base.

"Exit" --

Return to previous menu.

"Help" --

Display this help screen.

endtext

```

*****
Script NCHIS.SC - Program implements the update program, displays the main
introductory screen, asks and verifies a user password and executes the application
program.
*****
autolib = "main"
if (sysmode() <> "Main") then
  Message "The application can only be started from Paradox main mode" Sleep 3000
return
endif

*****
Update the libraries
*****
if (not isfile("main.lib")) then
  play "update"
endif

Echo Off
Clear
Reset
Cursor Off
SETSWAP 12000

*****
Display the greeting screen
*****
@ 2, 0
Play "Screen"

*****
Ask for the password to the application; this password determines the access to the
tables in the application allowed for the current user of the application.
*****
@ 1, 0
?? "Enter password for the application; [Esc] to cancel; [Enter] for no password." @

```

```

0, 0
?? "Password: "
Cursor Normal
Accept "a50" To pword
EscEnter = not retval
Cursor Off

if (EscEnter) then
Message "Cancelling the application"
Sleep 2000
Clear
return
endif

if (pword <> "") then
Password pword
endif

*****
Start the application
*****
Readlib "main" mainMenu
mainMenu()
Release Procs mainMenu

Clearall
if (pword <> "") then
UnPassword pword
endif

```

```

*****
Script UPDATE.SC - This is the first script executed by the main script (NCHIS.SC)
which updates the primary scripts and libraries utilized by the Space Station
Chemical Hazards Analysis Data Base.
*****

;update
? "Updating Libraries..."
play "main"
play "imhaz"
? "Please Stand By..."
play "coursur"
play "mission"
? "Loading Chemical Information..."
play "cemcals"

```

```

*****
Script MAIN.SC - Main script which is executed to call the primary branch menu
options, and implement all of the information branch procedures.
*****

*****
Procedure displays the first branch of menu options for the Space Station Chemical
Hazards Data Base and implements the procedures based on the users selection.
*****
; Main

if (not isfile("main.lib")) then
    createlib "main"
endif

proc mainmenu()
    private x, escape, zzzmexit, zzzzexit, pword
    autolib = "main"
    escape = true
    zzzzexit = false
    x = "Information"
    while (true)
        clear
        showmenu
        "Information": "Extract Information from Data Base",
        "Analysis": "Analysis of Space Station Operations",
        "Leave": "Return to System",
        "Help": "Help selection"
        default x
        to x
    switch
    case x = "Information":
        information_menu()
        escape = true

```

```

case x = "Analysis":
    analy_menu()
    escape = true

case x = "Leave":
    showmenu
    "No": "Do not leave the application.",
    "Yes": "Leave the application."
    to zzzmexit

    zzzzexit = (zzzmexit = "Yes")
    escape = (zzzmexit = "Esc")

case x = "Esc" :
    escape = false

case x = "Help":
    @ 2, 0
    Play "mainhlp"
    @ 0, 0
    ?? "Press any key to end the help"
    retval = getchar()
    Clear
    escape = false

endswitch

reset
if (zzzzexit) then
    return true
endif
if (not escape) then
    x = "Information"
endif
endwhile

```

```

endproc

writelib "main" mainmenu
release procs mainmenu

*****
Procedure displays the menu selections for the analysis branch and implements the
procedures based on the users selection.
*****

proc analy_menu()
private x,escape

    x = "Chemical Manifest"
    while (true)
        clear

        showmenu
        "Chemical Manifest": "Define Chemical Manifest",
        "Imminent Hazards": "Identify Imminent Chemical Hazards",
        "Corrosivity Analysis": "Corrosivity Analysis selection",
        "Exit": "Exit This Menu",
        "Help": "Help with this menu"
        default x
    to x

    switch
        case x = "Chemical Manifest":
            manifest_menu()
            escape = true

        case x = "Imminent Hazards":
            imhaz_menu()
            escape = true

        case x = "Corrosivity Analysis":
            corrosive_menu()

```

```

        escape = true

    case x = "Esc" :
        escape = false

    case x = "Exit":
        escape = false

    case x = "Help":
        @ 2, 0
        play "anhlp"
        @ 0, 0
        ?? "Press any key to end the help"
        retval = getchar()
        clear
        escape = true

    endswitch

    if (not escape) then
        return true
    endif
endwhile
endproc
writelib "main" analy_menu
release procs analy_menu

```

```

*****
Procedure displays the first branch menu selections for the analysis/chemical
manifest branch and implements the procedures based on the users selection.
*****
proc manifest_menu()
private x,escape

x = "Facilities"
while (true)
Clear

ShowMenu
  "Facilities": "Define Mission Set, View/Edit Chemicals/Facility",
  "Chemicals": "Define list, Mission Set, Facilities, Incompatibility",
  "Exit": "Exit this menu",
  "Help": "Help with this Menu"
Default x
To x

switch
case x = "Facilities":
  facilities_menu()
  escape = true

case x = "Chemicals":
  chemicals_menu()
  escape = true

case x = "Exit":
  return false

case x = "Help":
  @ 2, 0
  play "manhlp"
  @ 0, 0
  ?? "Press any key to end the help"

```

```

    retval = getchar( )
    clear
    escape = true

    case x = "Esc" :
        escape = false

    endswitch

    if (not escape) then
        return true
    endif
    endwhile
endproc
writelib "main" manifest_menu
release procs manifest_menu

*****
Procedure displays the menu selections for the information branch and implements the
procedures based on the users selection.
*****
proc information_menu()
    private x, escape

    x = "Properties"
    while (true)
        clear

    showmenu
        "Properties": "Add, Update or Review Chemicals in Main Chemical Table",
        "Chem/Fac": "Add, Update or View Table of Chemicals per Facility",
        "Facs": "Add, Update of View Table of Facilities",
        "Incompats": "Add, Update or View the Incompatibility Table",
        "Corrosivity": "Add, Modify, View or Delete Corrosivity Data",
        "Exit": "Return to Main Menu",
        "Help": "Help selection"

```

```
default x
to x
```

```
switch
```

```
case x = "Properties":
    properties_info()
    escape = true

case x = "Chem/Fac":
    chemicals_per_facility()
    escape = true

case x = "Facs":
    facility_info()
    escape = true

case x = "Incompats":
    incompatible_menu()
    escape = true

case x = "Corrosivity":
    corrosive_information()
    escape = true

case x = "Exit":
    return false

case x = "Help":
    @ 2, 0
    play "infohlp"
    @ 0, 0
    ?? "Press any key to end the help"
    retval = getchar()
    clear
    escape = true
```

```

        case x = "Esc" :
            return false
        endswitch

        if (not escape) then
            return true
        endif
    endwhile
endproc

writelib "main" information_menu
release procs information_menu

*****
Procedure displays a pull-down menu as the first selection option under the
information/chemical properties branch. The user is asked if he wishes to view the
chemical property data, produce a report or quit.
*****
proc properties_info()
    private ans, escape
    ans = pullmenu(6,6,"View;Report;Quit")
    switch

        case ans = "View":
            view "Sschempr"
            formkey
            pickform "2"
            wait table
            prompt "Press [F2] when finished"
            until "F2"

            case ans = "Report":
                report "Sschempr" "5"
                escape = true

        endswitch
    endswitch
endproc

```

```
writelb "main" properties_info
release procs properties_info
```

```
*****
Procedure displays a pull-down menu as the first selection option under the
information/facilities branch. The user is asked if he wishes to view existing
facilities in the data base or add new facilities. The user is then prompted by a
second menu asking him if he wishes to produce a report of the current/revisted list
of facilities currently in the data base.
*****
```

```
proc facility_info()
*****
```

```
private ans, facnam, aknym
ans = pullmenu(5,5,"View Existing;Add New")
if (ans = "View Existing") then
view "Ssfactab"
wait table
```

```
prompt "Press [F2] when finished viewing",
"Total number of entries is " + strval(nrecords("Ssfactab"))
```

```
until "F2"
```

```
ans=pullmenu(2,2,"Report;Exit without Report")
IF ( ans = "Report" ) THEN REPORT "Ssfactab" "R";
ENDIF
```

```
return
```

```
endif
```

```
@ 2,4 ? "Enter the Name for the new facility "
```

```
accept "A20" to facnam
```

```
@ 4,4 ? "Enter the acronym for the new facility "
```

```
accept "A5" to aknym
```

```
create aknym like "bif"
```

```
edit aknym
```

```
wait table
```

```
prompt "Enter the Chemicals -- one per line",
```

```
"Press [F2] when finished editing"
```

```
until "F2"
```

```
do it!
```

```
if_(nrecords(aknym) = 0) then
```

```

message "You didn't enter any chemicals "
beep
sleep 1000
delete aknym
return
endif
edit "Ssfactab"
end
down
[Facility] = facnam
[Abbrev] = aknym
do_it!
ans=pullmenu(2,2,"Report;Exit without Report")
IF ( ans = "Report" ) THEN REPORT "Ssfactab" "R";
ENDIF
endproc
writelib "main" facility_info
release procs facility_info

```

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```

*****
Procedure displays a pull-down menu as the first selection option under the
information/corrosivity branch. The user is asked to select between the metals or
the nonmetals option to identify material corrosivity.
*****
proc corrosive_information()
private ans
ans = pullmenu(6,6,"Metals;Nonmetals")
if (ans = "Metals") then
metal_information() else
nonmetal_information()
endif
endproc
writelib "main" corrosive_information
release procs corrosive_information
*****

```

Procedure displays a pull-down menu as the second selection option under the information/corrosivity branch. The user is asked if he wishes to view the non-metal corrosivity data, produce a report or quit.

```
*****
proc nonmetal_information()
private ans, escape
ans = pullmenu(6,6,"View;Report;Quit")
switch
```

```
case ans = "View":
view "Ssnmcor"
formkey
wait table
prompt "Press [F2] when finished"
until "F2"
```

```
case ans = "Report":
report "Ssnmcor" "1"
escape = true
```

```
endswitch
endproc
writelib "main" nonmetal_information
release procs nonmetal_information
```

```
*****
Procedure displays a pull-down menu as the second selection option under the information/corrosivity branch. The user is asked if he wishes to view the metal corrosivity data, produce a report or quit.
```

```
*****
proc metal_information()
private ans, escape
ans = pullmenu(6,6,"View;Report;Quit")
switch
```

```
case ans = "View":
```

```

view "Ssnmcor"
formkey
wait table
prompt "Press [F2] when finished"
until "F2"

```

```

case ans = "Report":
  report "Ssmtcor" "1"
  escape = true

```

```

endswitch
endproc
writelib "main" metal_information
release procs metal_information

```

```

*****
Pull down procedure menu utilized throughout the Space Station Chemical Hazards Data
Base.

```

```

*****
PROC pullmenu(row_num, col_num, menu_choices_a)

```

```

PRIVATE num_choices, a, x, max_length, key_pressed, curr_choice, choiceslist,
start_choice, box_color, text_color, cursor_color

```

```

box_color = 10 ; border will be light green on black
text_color = 2 ; text will be green on black
cursor_color = 112; cursor will be black on light grey

```

```

num_choices = 0 ; start number of choices variable at 0
a = ""
max_length = 0 ; start width of longest menu choice at 0
ARRAY choiceslist[22] ; define maximum of 22 array elements

```

```

FOR x FROM 1 TO LEN(menu_choices_a) ; loop once for each character in string
  IF SUBSTR(menu_choices_a,x,1) <> ";" THEN ; find delimiter
    a = a + SUBSTR(menu_choices_a,x,1) ; add current char to temp string
  
```

```

ELSE
    num_choices = num_choices + 1 ; add a menu choice
    choiceslist[num_choices] = a ; assign the menu choice to an array
    IF LEN(a) > max_length THEN ; is this menu choice the biggest so far
        max_length = LEN(a) ; assign its length to the counter
    ENDIF
    a = "" ; clear out the temp text string
    ENDIF
ENDFOR

; at this point, there is one menu choice left in the string

num_choices = num_choices + 1 ; add a menu choice
choiceslist[num_choices] = a ; assign the menu choice to an array

IF LEN(a) > max_length THEN ; is this menu choice the biggest so far?
    max_length = LEN(a) ; assign its length to the counter
ENDIF
IF num_choices=0 THEN ; there were no strings passed to the routine
    RETURN ""
ENDIF
ECHO OFF
CURSOR OFF

;Draw menu box
@row_num,col_num
STYLE ATTRIBUTE box_color
?? "r",FILL("-",max_length+2),"r"
STYLE ATTRIBUTE box_color
FOR x FROM 1 TO num_choices
    @row_num+x,col_num
    STYLE ATTRIBUTE box_color
    ?? "r"
; put menu choices on screen
STYLE ATTRIBUTE text_color
?? " "+SUBSTR(STRVAL(choiceslist[x])+SPACES(max_length),1,max_length+1)

```

```

STYLE ATTRIBUTE box_color
?? "|"
ENDFOR
@row num+1+num_choices,col_num
STYLE ATTRIBUTE box_color
?? "L",FILL("-",max_length+2),"J"
curr_choice=1
WHILE true
    @curr_choice+row_num,col_num+2
    STYLE ATTRIBUTE cursor_color ;Highlight current selection ??
    choiceslist[curr_choice] ; write the choice
    key_pressed=GETCHAR()
    @curr_choice+row_num,col_num+2
    STYLE ATTRIBUTE text_color
    ?? choiceslist[curr_choice] ; write the choice
    SWITCH
        CASE (key_pressed>=65 AND key_pressed<=90) OR
            (key_pressed>=97 AND key_pressed<=122) :
            start_choice = curr_choice
            FOR x FROM start_choice-1 TO 1 STEP -1
                IF UPPER(SUBSTR(choiceslist[x],1,1)) = UPPER(CHR(key_pressed)) THEN
                    curr_choice = x
                ENDIF
            ENDFOR
            FOR x FROM num_choices TO start_choice+1 STEP -1
                IF UPPER(SUBSTR(choiceslist[x],1,1)) = UPPER(CHR(key_pressed)) THEN
                    curr_choice = x
                ENDIF
            ENDFOR
        CASE key_pressed=-71: ;Key was [Home]
            curr_choice=1 ;Select first item
        CASE key_pressed=-79: ;Key was [End]
            posind=num_choices ;Position at bottom of menu
            curr_choice=num_choices ;Select last item
        CASE key_pressed=-72: ;Key was [Up]

```

```

    IF curr_choice<>1 THEN ; are we somewhere other than the top?
        curr_choice=curr_choice-1 ;Select new curr_choice
    ELSE
        curr_choice=num_choices ; go to the last choice
    ENDIF
    CASE key_pressed=-80: ;Key was [Down]
        IF curr_choice<>num_choices THEN ;Are we somewhere except the bottom?
            curr_choice=curr_choice+1 ;Select new curr_choice
        ELSE
            curr_choice=1 ; goto the top
        ENDIF
        CASE key_pressed=13: ;Key was [Enter]
            CURSOR NORMAL
            @curr_choice+row_num,col_num+2
            STYLE ATTRIBUTE cursor_color
            ?? choiceslist[curr_choice] ; write the choice
            STYLE
            RETURN choiceslist[curr_choice] ;Return selection
        CASE key_pressed=27: ;Key was [Esc]
            CURSOR NORMAL
            RETURN ""
        OTHERWISE: ;Illegal key
            BEEP
        END SWITCH
    ENDWHILE
ENDPROC

writelib "main" pullmenu
release procs pullmenu

```

```
*****
Script MISSION.SC - Script which is executed to perform the menu options in the
chemical manifest/facilities analysis branch.
*****
```

```
*****
Procedure displays the first branch menu selections for the analysis/chemical
manifest/facilities branch and implements the procedures based on the users
selection.
*****
```

```
*****
proc facilities_menu()
private x,escape
x = "Define Mission Set"
while (true)
clear
showmenu
*****
```

```
    "Define Mission Set": "Tag Facilities for a Mission Set",
    "Chemicals/Facility": "View/Edit chemicals for a particular Facility",
    "Exit": "Return to previous menu",
    "Help": "Help with this menu"
default x
to x
```

```
switch
case x = "Define Mission Set":
mission_menu()
escape = true
```

```
case x = "Chemicals/Facility":
chemicals_per_facility()
escape = true
```

```
case x = "Exit":
return false
```

```
case x = "Help":
```

```

@ 2, 0
play "fachlp"
@ 0, 0
?? "Press any key to end the help"
retval = getchar( )
clear
escape = true

case x = "Esc" :
escape = false

endswitch

if (not escape) then
return true
endif

endwhile
endproc
writelib "main" facilities_menu
release procs facilities_menu

*****
Procedure displays the second branch of the chemical manifest/facilities selection
menu. Procedure implements the appropriate procedures based on the users selection.
*****
;mission
proc mission_menu()
private x,escape
x = "New Mission"
while (true)
clear
showmenu
"New Mission": "Define a New Mission Set",
"Old Mission": "View/Edit a pre-defined Mission Set",
"Chemicals/Facility": "View/Edit chemicals for a particular Facility",
"Exit": "Return to previous menu",

```

```

    "Help": "Help with this menu"
    default x
    to x

    switch

        case x = "New Mission":
            new_mission()
            escape = true

        case x = "Old Mission":
            old_mission()
            escape = true

        case x = "Chemicals/Facility":
            chemicals_per_facility()
            escape = true

        case x = "Exit":
            return false

        case x = "Help":
            @ 2, 0
            play "mishlp"
            @ 0, 0
            ?? "Press any key to end the help"
            retval = getchar( )
            clear
            escape = true

        case x = "Esc" :
            escape = false

    endswitch

    if (not escape) then
        return true

```

```

endif
endwhile
endproc
writelib "main" mission_menu
release procs mission_menu

*****
Procedure allows the user develop and store a specified mission set (i.e. complement
of payloads). The mission set is given a name and the user may select this new
mission set to perform a variety of analyses in future procedures.
*****

proc new_mission()
private ans, misnam
@2,4 ? "Enter a name (up to 8 characters long) for the new mission:
"accept "A8" to misnam
if (misnam = "") then
return
endif
if (istable(misnam))
then
message misnam + "is already being used, please try again"
beep
sleep 2000
return
endif
edit "missions"
end
down
[mission] = misnam
do_it!
copy "ssfctab" misnam
edit misnam
wait table
prompt "Put a star in the tag column to select the facilities",
"Press [F2] when finished "
until "F2"

```

```

do_it!
endproc
writelib "main" new_mission
release procs new_mission

```

```

*****
Procedure allows the user edit a pre-defined mission set (i.e. complement of
payloads). The revised mission set may be selected by the user to perform a variety
of analyses in future procedures.
*****

```

```

proc old_mission()
private ans, tabl
copy "missions" "mhtab"
edit "mhtab"
wait table

```

```

    prompt "Put a star in the tag column to select the desired mission",
    "Press [F2] when finished (note: Select only ONE!) "
until "F2"
do_it!

```

Query

Tag	Tag
	_xyz

Mhtab	Mission	Tag
	Check	_xyz

```

Endquery
do_it!
if_(isempty("answer"))
then

```

```

return
endif
view "answer"
if (nrecords("answer") > 1)
then
message "You have selected more than one"
beep
sleep 3000
return
endif
moveto [Mission]
tabl = [Mission]
view tabl
wait table
prompt "Press [F2] to edit or quit"
until "F2"
ans = pullmenu(2,2,"Edit;Continue")
IF ( ans = "Edit" )
THEN
edit tabl
wait table
prompt "Press [F2] when finished editing the table" until "F2"
do_it!
return
ENDIF
endproc
writelib "main" old_mission
release procs old_mission

*****
Procedure allows the user edit the chemicals required by the potential Space Station
facilities in the data base. The user selects the facility from a current list. The
procedure then find the chemicals required by the facility. The user may edit the
list and print a report if required.
*****
proc chemicals_per_facility()

```

```

private ans, tabl
copy "ssfactab" "fhtab"
edit "fhtab"
wait table
  prompt "Put a star in the tag column to select the desired facility",
  "Press [F2] when finished (note: Select only ONE!) "
until "F2"
do it!
? "First Query (Selecting facilities) . . ."
Query

```

Tag	Tag			
	_xyz			
fhtab	TAG	ABBREV		
	_xyz	Check		

```

Endquery
do_it!
if (isempty("answer"))
  then
  return
endif
;view "answer"
if (nrecords("answer") > 1)
  then
  message "You have selected more than one"
  beep
  sleep 3000
  return
endif
moveto [ABBREV]
tabl = [ABBREV]

```

```

clearall
view tabl
wait table
    prompt "Press [F2] when finished viewing the table" until "F2"
    ans=pullmenu(5,5,"Edit this Facility;Return without Editing")
    IF ( ans = "Edit this Facility" )
        THEN
            edit tabl
            wait table
                prompt "Press [F2] when finished editing the table"
                until "F2"
                do_it!
            ENDIF
        copy tabl "reptab"
        ans=pullmenu(2,2,"Report;Exit without Report")
        IF ( ans = "Report" ) THEN REPORT "reptab" "R";
        ENDIF
    endproc
    writelib "main" chemicals_per_facility
    release procs chemicals_per_facility
    *****
    Script CEMCALS.SC - Script which is executed to perform the menu options in the
    second branch of the chemical manifest/chemicals analysis selection menu.
    *****
    *****
    Procedure displays the menu options in the second branch of the chemical
    manifest/chemicals analysis selection and calls the procedures based on the users
    selection.
    *****
    proc chemicals_menu()
    private x,escape
    x = "Start New List"
    while (true)
        clear

```

```

showmenu
    "Start New List": "Start a new list for (What If?) type scenario",
    "Edit a Predefined List": "Edit a predefined (What If?) list",
    "Incompatibles": "Individual chemical, What If? list, mission set, or facility",
    "Exit": "Return to previous menu",
    "Help": "Help with this menu"
default x
to x

switch
    case x = "Start New List":
        new_chem_list()
        escape = true

    case x = "Edit a Predefined List":
        edit_old_list()
        escape = true
    case x = "Incompatibles":
        Incompatible_menu()
        escape = true

    case x = "Exit":
        return false

    case x = "Help":
        @ 2, 0
        play "cilhlp"
        @ 0, 0
        ?? "Press any key to end the help"
        retval = getchar( )
        clear
        escape = true

    case x = "Esc" :
        escape = false

```

```

endswitch

if (not escape) then
  return true
endif
endwhile
endproc
writelib "main" chemicals_menu
release procs chemicals_menu

*****
Procedure which allows the user to develop and store a new list of chemicals for
analysis.
*****
proc new_chem_list()
private ans, lisnam, last
@2,4 ? "Enter a name (up to 8 characters long) for the list "
accept "A8" to lisnam
if (istable(lisnam)) then
  message lisnam + "is already being used please use another name"
  sleep 3000
  return
endif
namhld = lisnam
create lisnam like "bif"
edit lisnam
wait table
  prompt "Press [F2] when finished editing",
    "Be sure CAPS-LOCK is on"
until "F2"
do_it!
if_(not isempty(lisnam)) then
  edit "cemplstab"
end
down

```

```

[name]=namhld
do_it!
endif
ans=pullmenu(2,4,"Report;Continue")
if (ans = "Report") then
  report lisnam "R"
endif
endproc
writelib "main" new_chem_list
release procs new_chem_list

```

```

*****
Procedure which allows the user to edit and existing list of chemicals for analysis.
*****
proc edit_old_list()
private tabl, ans, lisnam, last
copy "cemlstab" "cemhdtb"
edit "cemhdtb"
wait table
    prompt "Put a star in the tag column to select the desired mission",
    "Press [F2] when finished (note: Select only ONE!) "
until "F2"
do_it!

```

Query

Tag	Tag			
	_xyz			
cemhdtb		name	Tag	
		Check	_xyz	

```

Endquery
do_it!
if_(isempty("answer"))
then
return
endif
view "answer"
if (nrecords("answer") > 1)
then
message "You have selected more than one"
beep

```

```

        sleep 3000
        return

    endif
    moveto [name]
    tabl = [name]
    clearall
    view tabl
    wait table
        prompt "Press [F2] to edit or quit"
    until "F2"
        ans = pullmenu(2,2,"Edit;Continue")
        IF ( ans = "Edit" )
            THEN
                edit tabl
                wait table
                    prompt "Press [F2] when finished editing the table",
                        "Be sure CAPS-LOCK is on"
                until "F2"
                DO IT!
            endif
        endproc
        writelib "main" edit_old_list
        release procs edit_old_list

*****
Procedure which displays the incompatibility analysis selection menu and executes the
appropriate procedures to implement the selections.
*****
proc Incompatible_menu()
private x,escape
x = "Individual Chemical"
while (true)
clear
showmenu
    "Individual Chemical": "List the incompatibles for an input chemical",
    "User-defined List": "List incompatibles for a predefined (What If?) list",

```

```

    "Mission Set": "List the Incompatibles for an entire Mission Set",
    "Facility": "List the Incompatibles for a pre-defined Facility",
    "Exit": "Exit this menu",
    "Help": "Help with this menu"
default x
to x

switch
  case x = "Individual Chemical":
    Individual_chemical()
    escape = true

  case x = "User-defined List":
    List_Incompatibles()
    escape = true

  case x = "Mission Set":
    Mission_incompatibles()
    escape = true

  case x = "Facility":
    Facility_incompatibles()
    escape = true

  case x = "Exit":
    return false

  case x = "Help":
    @ 2, 0
    play "CI2hlp"
    @ 0, 0
    ?? "Press any key to end the help"
    retval = getchar()
    clear
    escape = true

```

```
if (not escape) then
    return true
endif
while
```

 Procedure which identifies all the materials which are incompatible with a specified chemical. The user inputs the chemical by typing the name of the chemical at the prompt. The procedure then performs a structured query to identify all incompatible material.

```

*****
proc Individual_chemical()
private chem,code
empty "newtab"
@2,4 ? "Enter the chemical name, trade name or synonym "
accept "A30" to chem
view "Codetab"
moveto [Material]
locate pattern chem
code = [Code]
? "Retrieving Incompatibles..."
Query
*****

```

[illegible]

```

Endquery
do_it!
add "answer" "newtab"
if (isempty("newtab")) then
  message "Sorry no incompatibles found"
  sleep 2000
  return
endif
view "newtab"
FORMKEY
WAIT TABLE
  PROMPT "Press [F2] when finished viewing the table",
  "Total records: " + strval(nrecords("newtab"))
  UNTIL "F2"
ans=pullmenu(2,2,"Report;Exit without Report")
IF ( ans = "Report" ) THEN REPORT "newtab" "1";
ENDIF
endproc
writelib "main" Individual_chemical
release procs Individual_chemical

```

```

*****
Procedure which identifies all the materials which are incompatible with a specified
list of chemicals. The user selects from a pre-defined list of chemical groupings
(grouping were specified by the user in previous menu to develop new or edit existing
list). The procedure then performs a structured query to identify all incompatible
material for the list of chemicals.
*****

```

```

*****
proc List_Incompatibles()
private ans,tabl
copy "cemlstab" "cemhdtb"
edit "cemhdtb"
wait table
    prompt "Put a star in the tag column to select the desired list",
    "Press [F2] when finished (note: Select only ONE!) "
until "F2"
do_it!
empty "clist"
Query

```

Tag	Tag
	_xyz

cemhdtb	name	Tag
	Check	_xyz

```

Endquery
do_it!
if (isempty("answer"))
then
return
endif
view "answer"

```

```

if (nrecords("answer") > 1)
then
message "You have selected more than one"
beep
sleep 3000
return

endif
moveto [name]
tabl = [name]
clearall
view tabl
wait table
    prompt "Press [F2] to process or quit"
until "F2"
ans = pullmenu(2,2,"Process;Quit")
if (ans="Quit") then
return
endif

copy tabl "inclst"
clearall
RESET
? "First Query (Locating Chemicals) . . ."
Query

```

Codetab	Material	Code
	_xyz	Check

```

inclst | Chemical |
      | _xyz |
      | |
      | |

```

```

Endquery
do_it!
add "answer" "clist"
empty "newtab"

```

```

? "Second Query (Retrieving incompatibles) . . ."
Query

```

```

Ssindes | Material | Incompatible | Why is it incompatible | Inc Code |
      | Check | Check | Check | Check |
      | | | | |
      | | | | |

```

```

Ssindes | Material Code |
      | Check _xyz |
      | |
      | |

```

```

Clist | Code |
      | _xyz |
      | |
      | |

```

```

Endquery
do_it!

add "answer" "newtab"
if (isempty("newtab")) then
message "No Incompatibles for this list"
beep
sleep 2000

```

```

return
endif
view "newtab"
FORMKEY
WAIT TABLE
  PROMPT "Press [F2] when finished viewing the table",
    "Total records: " + strval(nrecords("newtab"))
  UNTIL "F2"
  ans=pullmenu(2,2,"Report;Exit without Report")
  IF ( ans = "Report" ) THEN REPORT "newtab" "1";
  ENDIF
endproc
writelib "main" List_Incompatibles
release procs List_Incompatibles

*****
Procedure which identifies all the materials which are incompatible with a specified
mission set. The user selects from a pre-defined list of mission sets (missions were
specified by the user in chemical manifest/facilities menu). The procedure then
performs a structured query to identify all incompatible material for the mission
set.
*****
proc Mission_incompatibles()
private ans
clearall
autolib="utllib"
copy "missions" "mhtab"
edit "mhtab"
wait table
  prompt "Put a star in the tag column to select the desired mission",
    "Press [F2] when finished (note: Select only ONE!) "
  until "F2"
  do_it!
  empty "clist"
  clear
Query

```

Tag	Tag
	_xyz

Mhtab	Mission	Tag
	Check	_xyz

```

Endquery
do_it!
if (isempty("answer"))
then
return
endif
view "answer"
if (nrecords("answer") > 1)
then
message "You have selected more than one"
beep
sleep 3000
return
endif
moveto [Mission]
tabl = [Mission]
copy tabl "misshld"
empty "chemhld"
? "First Query (Selecting facilities) . . ."
Query

```

Tag	Tag
	_xyz

misshld	TAG	ABBREV
	_xyz	Check

```

Endquery
do_it!
copy "answer" "fachld"
view "fachld"
for i from 1 to nrecords("fachld")
  copytoarray A
  faci = A["ABBREV"]
  add faci "chemhld"
  do_it!
  moveto 4
  down
endfor
empty "clist"
? "Second Query (Locating Chemicals) . . ."
Query

```

Codetab	Material	Code
	_xyz	Check

Chemhld	Chemical			
	_xyz			

```
Endquery
do_it!
add "answer" "clist"
empty "newtab"
```

```
? "Third Query (Retrieving incompatibles) . . ."
```

Ssindes	Material Check	Incompatible Check	Why is it incompatible Check	Inc Code Check

Ssindes	Material Code Check _xyz

Clist	Code
	_xyz

```
Endquery
do_it!
add "answer" "newtab"
view "newtab"
view "newtab"
FORMKEY
WAIT TABLE
```

```
PROMPT "Press [F2] when finished viewing the table",
```

```

"Total records: " + strval(nrecords("newtab"))
UNTIL "F2"
ans=pullmenu(10,10,"Report;Exit without Report")
IF ( ans = "Report" ) THEN REPORT "newtab" "1";
ENDIF
endproc
writelib "main" Mission_incompatibles
release procs Mission_incompatibles
*****
Procedure which identifies all the materials which are incompatible with a specified
facility. The user selects a facility from a pre-defined list. The procedure then
performs a structured query to identify all incompatible material for the facility.
*****
proc Facility_incompatibles()
private ans
empty "clist"
empty "chemhld"
copy "ssfactab" "fhtab"
edit "fhtab"
wait table
  prompt "Put a star in the tag column to select the desired facility",
  "Press [F2] when finished (note: Select only ONE!) "
until "F2"
empty "clist"
do_it!
clear
? "First Query (Selecting facilities) . . ."
Query

```

Tag		Tag					
		_xyz					
		fhtab		TAG		ABBREV	
				_xyz		Check	

```

Endquery
do_it!
if (isempty("answer"))
then
return
endif
if (nrecords("answer") > 1)
then
message "You have selected more than one"
beep
sleep 3000
return
endif
moveto [ABBREV]
facn = [ABBREV]
add facn "Chemhld"
? "First Query (Locating Chemicals) . . ."
Query

```

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Codetab	Material _xyz	Code Check

Chemhld	Chemical _xyz

```

Endquery
do_it!
add "answer" "clist"
empty "newtab"

```

```

? "Second Query (Retrieving incompatibles) . . ."

```

Query

Ssindes	Material Check	Incompatible Check	Why incompatible Check	Inc Code Check

Ssindes	Material Code Check _xyz

Clist	Code _xyz

```

Endquery
do_it!
add "answer" "newtab"
view "newtab"
FORMKEY
WAIT TABLE
  PROMPT "Press [F2] when finished viewing the table",
  "Total records: " + strval(nrecords("newtab"))
  UNTIL "F2"
ans=pullmenu(2,2,"Report;Exit without Report")
IF ( ans = "Report" ) THEN REPORT "newtab" "1";
ENDIF
endproc
writelib "main" Facility_incompatibles
release procs Facility_incompatibles

```

```

*****
Script IMHAZ.SC - Script which is executed to perform the menu options in the
imminent hazards analysis branch.
*****

*****
Procedure displays the first branch of the imminent hazards analysis selection menu
and implements the procedures based on the users selection.
*****
; Imhaz
autolib="main"

proc imhaz_menu()
private x, escape

x = "Facility Hazards"
while (true)
  Clear

  ShowMenu
    "Facility Hazards": "Identifies all of the Potential Hazards of a Facility",
    "Manifest Hazards": "Identifies all Potential Hazards for a Predefined Mission",
    "Input List Hazards": "Identify Hazards Associated with a user defined list",
    "Exit": "Return to previous menu",
    "Help": "Help with this menu"
  Default x
  To x

  switch
    case x = "Facility Hazards":
      facil_haz()
      escape = true

    case x = "Manifest Hazards":
      manifest_haz()
      escape = true

```

```

case x = "Input List Hazards":
    input_list_hazards()
    escape = true

case x = "Esc" :
    escape = false

    case x = "Help":
        @ 2, 0
        play "Hazhlp"
        @ 0, 0
        ?? "Press any key to end the help"
        retval = getchar( )
        clear
        escape = true

    case x = "Exit":
        escape = false

    endswitch

    if (not escape) then
        return true
    endif
    endwhile
    endproc

    Writelib "main" imhaz_menu
    Release Procs imhaz_menu

```

```

*****
Procedure asks the user to select a list of chemicals from a table of list previously
defined by the user. Once the list of chemicals has been selected the procedure
performs a structured query to identify all the imminent hazards associated with the
list of chemicals.
*****
proc input_list_hazards()
private tabl,ans
empty "cemhdtb"
empty "clist"
copy "cemlstab" "cemhdtb"
create "hazlst" like "bif"
edit "cemhdtb"
wait table
    prompt "Put a star in the tag column to select the desired list",
    "press [F2] when finished (note: Select only ONE!)"
until "F2"
do_it!
RESET
Query

```

Tag	Tag			
	_xyz			
cemhdtb		name	Tag	
		Check	_xyz	

```

Endquery
do_it!
if_(isempty("answer"))
then
return

```

```

endif
view "answer"
if (nrecords("answer") > 1)
then
message "You have selected more than one"
beep
sleep 3000
return

endif
moveto [name]
tabl = [name]
clearall
view tabl
wait table
prompt "Press [F2] to process or quit"
until "F2"
ans = pullmenu(2,2,"Process;Quit")
IF ( ans = "Quit" )
THEN
return
ENDIF
add tabl "hazlst"
edit "hazlst"
moveto [Chemical]
clearall
RESET
? "First Query (Locating Chemicals) . . ."
Query

```

Codetab	Material _xyz	Code Check
hazlst	Chemical _xyz	

Endquery

do it!

add "answer" "clist"

empty "newtab"

? "Second Query (Retrieving incompatibles) . . ."

Query

Ssindes	Material Check	Incompatible Check	Why is it incompatible Check	Inc Code Check
---------	-------------------	-----------------------	---------------------------------	-------------------

Ssindes	Material Code Check _xyz
---------	-----------------------------

Clist	Code _xyz
-------	--------------

Endquery

do it!

? "Last Query (Processing incompatibles) . . ."

Query

Clist	Code _xyz
-------	--------------

Answer	Material Check	Incompatible Check	Why is it incompatible Check	Inc Code Check _xyz

Answer	Material Code Check

```

Endquery
DO IT!
add "answer" "newtab"
if (isempty("newtab")) then
message "No Imminent Hazards Detected"
beep
sleep 2000
return
endif
view "newtab"
FORMKEY
WAIT TABLE
PROMPT "Press [F2] when finished viewing the table",
"Total records: " + strval(nrecords("newtab"))
UNTIL "F2"
ans=pullmenu(2,2,"Report;Exit without Report")
IF ( ans = "Report" ) THEN REPORT "newtab" "1";
ENDIF
endproc
writelib "main" input_list_hazards
release procs input_list_hazards

```

```

*****
Procedure asks the user to select a potential Space Station facility currently in
the data base. Once the user has selected the facility the procedure performs a
structured query to identify all the imminent hazards associated with all the
chemicals required during the on-orbit operations of the facility.
*****

```

```

proc facil_haz()
  empty "clist"
  empty "chemhld"
  copy "ssfctab" "fhtab"
  edit "fhtab"
  wait table
  prompt "Put a star in the tag column to select the desired facility",
  "Press [F2] when finished (note: Select only ONE!) "
  until "F2"
  do_it!
  clear
  ? "First Query (Selecting facilities) . . ."
  Query

```

Tag	Tag
	_xyz

fhtab	TAG	ABBREV
	_xyz	Check

```

Endquery
do it!
if_(isempty("answer"))
  then
  return
endif
if (nrecords("answer") > 1)
  then

```

```

message "You have selected more than one"
beep
sleep 3000
return

endif
moveto [ABBREV]
facn = [ABBREV]
add facn "Chemhld"
? "First Query (Locating Chemicals) . . ."
Query

```

Codetab	Material	Code
	_xyz	Check

Chemhld	Chemical
	_xyz

```

Endquery
do_it!
add "answer" "clist"
empty "newtab"

```

```

? "Second Query (Retrieving incompatibles) . . ."
Query

```

Ssindes	Material	Incompatible	Why is it incompatible	Inc Code
	Check	Check	Check	Check

Ssindes	Material Code	
	Check _xyz	

Clist	Code	
	_xyz	

Endquery
do_it!
? "Last Query (Processing incompatibles) . . ."

Clist	Code	
	_xyz	

Answer	Material Check	Incompatible Check	Why is it incompatible Check	Inc Code check _xyz
--------	-------------------	-----------------------	---------------------------------	------------------------

Answer	Material Code	
	Check	

```

Endquery
DO IT!
add "answer" "newtab"
view "newtab"
FORMKEY
WAIT TABLE
PROMPT "Press [F2] when finished viewing the table",
"Total records: " + strval(nrecords("newtab"))
UNTIL "F2"
ans=pullmenu(2,2,"Report;Exit without Report")
IF ( ans = "Report" ) THEN REPORT "newtab" "1";

```

```

ENDIF
endproc
writelib "main" facil_haz
release procs facil_haz

*****
Procedure asks the user to select a mission set from a table of mission sets
previously defined by the user. Once the mission set has been selected the procedure
performs a structured query to identify all the imminent hazards associated with the
all the chemicals required by all the chemicals for all the facilities in the mission
set.
*****
proc manifest_haz()
clearall
copy "missions" "mhtab"
edit "mhtab"
wait table
    prompt "Put a star in the tag column to select the desired mission",
    "Press [F2] when finished (note: Select only ONE!) "
until "F2"
do_it!
clear
Query

```

Tag	Tag			
	_xyz			

Mhtab	Mission	Tag
	Check	_xyz


```

Endquery
do_it!
if (isempty("answer"))
then

```

```

return
endif
view "answer"
if (nrecords("answer") > 1)
then
message "You have selected more than one"
beep
sleep 3000
return
endif
moveto [Mission]
tabl = [Mission]
copy tabl "misshld"
empty "chemhld"
? "First Query (Selecting facilities) . . ."
Query

```

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Tag	Tag			
	_xyz			
misshld	TAG	ABBREV		
	_xyz	Check		

```

Endquery
do_it!
copy "answer" "fachld"
view "fachld"
for i from 1 to nrecords("fachld")
copytoarray A
faci = A["ABBREV"]
add faci "chemhld"
do_it!

```

```

moveto 4
down
endfor "clist"
empty "clist"
? "Second Query (Locating Chemicals) . . ."
Query

```

Codetab	Material _xyz	Code Check
---------	------------------	---------------

Chemhld	Chemical _xyz
---------	------------------

```

Endquery
do_it!
add "answer" "clist"
empty "newtab"

```

```

? "Third Query (Retrieving incompatibles) . . ."
Query

```

Ssindes	Material Check	Incompatible Check	Why is it incompatible Check	Inc Code Check
---------	-------------------	-----------------------	---------------------------------	-------------------

Ssindes	Material Code Check _xyz
---------	-----------------------------

Clis	Code _xyz
------	--------------

```

Endquery
do_it!
? "Last Query (Processing incompatibles) . . ."
Query

```

Clist	Code _xyz			
Answer	Material Check	Incompatible Check	Why is it incompatible Check	Inc Code Check _xyz
Answer	Material Check	Material Code		

```

Endquery
DO_IT!
add "answer" "newtab"
view "newtab"
view "newtab"
FORMKEY
WAIT TABLE
PROMPT "Press [F2] when finished viewing the table",
"Total records: " + strval(nrecords("newtab"))
UNTIL "F2"
ans=pullmenu(10,10,"Report;Exit without Report")
IF ( ans = "Report" ) THEN REPORT "newtab" "1";
ENDIF
endproc

```

writelib "main" manifest_haz
release procs manifest_haz

```

*****
Script CORSUR.SC - Script which is executed to perform the menu options in the
corrosivity analysis branch.
*****
*****
*****
Procedure displays the first branch of the corrosivity analysis selection menu and
implements the procedures based on the users selection.
*****
*****
;corsur
proc corrosive_menu()
private x,escape
x = "Metals"
while (true)
clear
showmenu
    "Metals": "Metal Corrosivity Analysis",
    "Nonmetals": "Nonmetal Corrosivity Analysis",
    "Exit": "Leave this menu",
    "Help": "Help with this menu"
    default x
to x

switch
case x = "Metals":
    metals_menu()
    escape = true

case x = "Nonmetals":
    non_metals_menu()
    escape = true

case x = "Esc":
    return false

case x = "Exit":
    return false

```

```

case x = "Help":
    @ 2, 0
    play "Corhlp"
    @ 0, 0
    ?? "Press any key to end the help"
    retval = getchar( )
    clear
    escape = true

endswitch
if (not escape) then
    return true
endif
endwhile
endproc
writelib "main" corrosive_menu
release procs corrosive_menu

*****
Procedure displays the menu selections for the corrosivity/metal analysis and
implements the procedures based on the users selection.
*****
proc metals_menu()
    private x,escape
    x = "Individual Chemical"
    while (true)
        clear
        showmenu
        "Individual Chemical": "List the corrosives for an input chemical",
        "User-defined List": "List the corrosives for a predefined (What If?) list",
        "Mission Set": "List the corrosives for an entire Mission Set",
        "Facility": "List the corrosives for a pre-defined Facility",
        "Exit": "Exit this menu",
        "Help": "Help with this menu"
        default x

```

```

to x
switch
case x = "Individual Chemical":
individual_mcorrosive()
escape = true
case x = "User-defined List":
list_mcorrosives()
escape = true
case x = "Mission Set":
mission_mcorrosives()
escape = true
case x = "Facility":
facility_mcorrosives()
escape = true
case x = "Exit":
return false
case x = "Help":
@ 2, 0
play "MCHLP"
@ 0, 0
?? "Press any key to end the help"
retval = getchar()
clear
escape = true
case x = "Esc":
return false
endswitch
if (not escape) then
return true

```

```

endif
endwhile
endproc
writelib "main" metals_menu
release procs metals_menu

*****
Procedure asks the user to input an individual chemical by typing the chemical name
at the prompt. Once the user has entered the chemical name the procedure then
performs a structured query to identify all the metals which are corrosive with the
input chemical.
*****
proc indiviual_mcorrosive()
private ans,chem,code
empty "tmpmet"
@2,4 ? "Enter the chemical name, trade name or synonym "
accept "A30" to chem
view "Codetab"
moveto [Material]
locate pattern chem
code = [Code]
? "Retrieving metal corrosive information..."
Query

```

Ssmtcor	Corrosive	Metal	Check	Mpy min	Check	Mpy max	Check	[min]	Check	[max]	Check
	Check										
Ssmtcor	Tmin	Tmax	Check	Remmarks	Check	Corrosive code	Check	code			
	Check										

```

Endquery
do_it!
add "answer" "tmpmet"

```

```

if (isempty("tmpmet")) then
    message "Sorry no incompatibles found"
    sleep 2000
    return
endif
view "tmpmet"
FORMKEY
WAIT TABLE
    PROMPT "Press [F2] when finished viewing the table",
    "Total records: " + strval(nrecords("tmpmet"))
UNTIL "F2"
ans=pullmenu(2,2,"Report;Exit without Report")
IF ( ans = "Report" ) THEN REPORT "tmpmet" "1";
ENDIF
endproc
writelib "main" individual_mcorrosive
release procs individual_mcorrosive

*****
Procedure asks the user to select a list of chemicals from a table of lists
previously defined by the user. Once the list of chemicals has been selected the
procedure performs a structured query to identify all the metals which are corrosive
with the input list of chemicals.
*****
proc list_mcorrosives()
private ans,tabl
copy "cemlstab" "cemhdtb"
edit "cemhdtb"
wait table
    prompt "Put a star in the tag column to select the desired list",
    "Press [F2] when finished (note: Select only ONE!) "
until "F2"
do_it!
Query

```

Tag	Tag
	_xyz

cemhdtb	name	Tag
	Check	_xyz

```

Endquery
do it!
if_(isempty("answer"))
then
return
endif
view "answer"
if (nrecords("answer") > 1)
then
message "You have selected more than one"
beep
sleep 3000
return
endif
moveto [name]
tabl = [name]
clearall
view tabl
wait table
    prompt "Press [F2] to process or quit"
until "F2"
ans = pullmenu(2,2,"Process;Quit")
if (ans="Quit") then
return
endif

```

```

copy tabl "inclst"
clearall
RESET
? "First Query (Locating Chemicals) . . ."
Query

```

Codetab	Material _xyz	Code Check

inclst	Chemical _xyz

```

Endquery
do it!
add "answer" "clist"
empty "tmpmet"
Query

```

Clst	Code _a

Ssmtcor	Corrosive Check	Metal Check	Mpy min Check	Mpy max Check	[min] Check	[max] Check

Ssmtcor	Tmin Check	Tmax Check	Remmarks Check	Corrosive code Check _a

```

Endquery
do_it!
add "an
swer" "tmpmet"
if (isempty("tmpmet")) then
    message "Sorry no incompatibles found"
    sleep 2000
    return
endif
view "tmpmet"
FORMKEY
WAIT TABLE
    PROMPT "Press [F2] when finished viewing the table",
    "Total records: " + strval(nrecords("tmpmet"))
UNTIL "F2"
ans=pullmenu(2,2,"Report;Exit without Report")
IF ( ans = "Report" ) THEN REPORT "tmpmet" "1";
ENDIF
endproc
writelib "main" list_mcorrosives
release procs list_mcorrosives

```

```

*****
Procedure asks the user to select a mission set from a table of mission sets
previously defined by the user. Once the mission set has been selected the procedure
performs a structured query to identify all the metals which are corrosive with all
the chemicals for all the facilities in the mission set.
*****
proc mission_mcorrosives()
private ans
clearall
copy "missions" "mhtab"
edit "mhtab"
wait table
    prompt "Put a star in the tag column to select the desired mission",

```

```

    "Press [F2] when finished (note: Select only ONE!) "
until "F2"
do_it!
clear
Query

```

Tag	Tag
	_xyz

Mhtab	Mission	Tag
	Check	_xyz

```

Endquery
do_it!
if (isempty("answer"))
then
return
endif
view "answer"
if (nrecords("answer") > 1)
then
message "You have selected more than one"
beep
sleep 3000
return
endif
moveto [Mission]
tabl = [Mission]
copy tabl "misshld"
empty "chemhld"
? "First Query (Selecting facilities) . . ."
Query

```

Tag	Tag
	_xyz

misshld	TAG	ABBREV
	_xyz	Check

```

Endquery
do_it!
copy "answer" "fachld"
view "fachld"
for i from 1 to nrecords("fachld")
  copytoarray A
  faci = A["ABBREV"]
  add faci "chemhld"
  do_it!
  moveto 4
  down
endfor
empty "clist"
? "Second Query (Locating Chemicals) . . ."
Query

```

Codetab	Material	Code
	_xyz	Check

Chemhld	Chemical
	_xyz

```
Endquery
do_it!
add "answer" "clist"
empty "tmpmet"
```

? "Third Query (Retrieving corrosive information) . . ."
Query

Clst	Code _a	Corrosive Check	Metal Check	Mpy min Check	Mpy max Check	[min] Check	[max] Check
Ssmtcor							
Ssmtcor	Tmin Check	Tmax Check	Remmarks Check	Corrosive code Check _a			

```

Endquery
do it!
  add "answer" "tmpmet"
  if (isempty("tmpmet")) then
    message "Sorry no incompatibles found"
    sleep 2000
  return
endif
view "tmpmet"
FORMKEY
WAIT TABLE

```

```

PROMPT "Press [F2] when finished viewing the table",
"Total records: " + strval(nrecords("tmpmet"))
UNTIL "F2"
ans=pullmenu(2,2,"Report;Exit without Report")
IF ( ans = "Report" ) THEN REPORT "tmpmet" "1";
ENDIF
endproc
writelib "main" mission_mcorrosives
release procs mission_mcorrosives

```

```

*****
Procedure asks the user to select a potential Space Station facility currently in the
data base. Once the user has selected the facility the procedure performs a
structured query to identify all the metals which are corrosive with all the
chemicals for the facility.
*****

```

```

*****
proc facility_mcorrosives()
private ans
empty "clist"
empty "chemhld"
copy "ssfactab" "fhtab"
edit "fhtab"
wait table
prompt "Put a star in the tag column to select the desired facility",
"press [F2] when finished (note: Select only ONE!)"
until "F2"
do_it!
clear
? "First Query (Selecting facilities) . . ."
Query

```

Tag	Tag					
	_xyz					
fhtab		TAG	ABBREV			
		_xyz	Check			

```

Endquery
do_it!
if_(isempty("answer"))
then
return

```

```

endif
if (nrecords("answer") > 1)
then
message "You have selected more than one"
beep
sleep 3000
return
endif
moveto [ABBREV]
facn = [ABBREV]
add facn "Chemhld"
? "First Query (Locating Chemicals) . . ."
Query

```

Codetab	Material	Code
	_xyz	Check

Chemhld	Chemical
	_xyz

```

Endquery
do it!
add "answer" "clist"
empty "tmpmet"

```

```

? "Third Query (Retrieving corrosive information) . . ."
Query

```

Clis	Code
	_a

Ssmtcor	Corrosive Check	Metal Check	Mpy min Check	Mpy max Check	[min] Check	[max] Check

Ssmtcor	Tmin Check	Tmax Check	Remmarks Check	Corrosive code Check _a

```

Endquery
do_it!
add "answer" "tmpmet"
if (isempty("tmpmet")) then
    message "Sorry no incompatibles found"
    sleep 2000
    return
endif
view "tmpmet"
FORMKEY
WAIT TABLE
    PROMPT "Press [F2] when finished viewing the table",
    "Total records: " + strval(nrecords("tmpmet"))
UNTIL "F2"
ans=pullmenu(2,2,"Report;Exit without Report")
IF ( ans = "Report" ) THEN REPORT "tmpmet" "1";
ENDIF
endproc
writelib "main" facility_mcorrosives
release procs facility_mcorrosives

```

```

*****
Procedure displays the menu selections for the corrosivity/non-metal analysis and
implements the procedures based on the users selection.
*****

```

```

proc non_metals_menu()
  private x,escape
  x = "Individual Chemical"
  while (true)
    clear
    showmenu
    "Individual Chemical": "List the corrosives for an input chemical",
    "User-defined List": "List the corrosives for a predefined (What If?) list",
    "Mission Set": "List the corrosives for an entire Mission Set",
    "Facility": "List the corrosives for a pre-defined Facility",
    "Exit": "Exit this menu",
    "Help": "Help with this menu"
  default x
  to x

  switch
    case x = "Individual Chemical":
      individual_nmcorsive()
      escape = true
    case x = "User-defined List":
      list_nmcorsives()
      escape = true
    case x = "Mission Set":
      mission_nmcorsives()
      escape = true
    case x = "Facility":
      facility_nmcorsives()
      escape = true
    case x = "Exit":
      return false
    case x = "Help":

```

```

@ 2, 0
play "NMCHLP"
@ 0, 0
?? "Press any key to end the help"
retval = getchar()
clear
escape = true

case x = "Esc":
return false
endswitch

if (not escape) then
return true
endif
endwhile
endproc
writelib "main" non_metals_menu
release procs non_metals_menu

```

```

*****
Procedure asks the user to input an individual chemical by typing the chemical name
at the prompt. Once the user has entered the chemical name the procedure then
performs a structured query to identify all the non-metals which are corrosive with
the input chemical.

```

```

*****
proc individual_nmcorrosive()
  private ans,chem,code
  empty "tmpnmt"
  @2,4 ? "Enter the chemical name, trade name or synonym "
  accept "A30" to chem
  view "Codetab"
  moveto [Material]
  locate pattern chem
  code = [Code]
  ? "Retrieving non-metal corrosive information..."
  Query

```

Ssnmcor	Corrosive Check	Non metal Check	Rec code Check	[max] Check	[min] Check	Tmin Check

Ssnmcor	Tmax Check	[c] & t comments Check	Field-9 Check	Nm code Check	Code Check	~code

```

Endquery
do it!
add "answer" "tmpnmt"
if (isempty("tmpnmt")) then
  message "Sorry no incompatibles found"
  sleep 2000
  return
endif

```

```

view "tmpnmt"
FORMKEY
WAIT TABLE
  PROMPT "Press [F2] when finished viewing the table",
  "Total records: " + strval(nrecords("tmpnmt"))
UNTIL "F2"
ans=pullmenu(2,2,"Report;Exit without Report")
IF ( ans = "Report" ) THEN REPORT "tmpnmt" "1";
ENDIF
endproc
writelib "main" individual_nmcorrosive
release procs individual_nmcorrosive

*****
Procedure asks the user to select a list of chemicals from a table of lists
previously defined by the user. Once the list of chemicals has been selected the
procedure performs a structured query to identify all the non-metals which are
corrosive with the input list of chemicals.
*****

proc list_nmcorrosives()
private ans,tabl
copy "cemlstab" "cemhdtb"
edit "cemhdtb"
wait table
  prompt "Put a star in the tag column to select the desired list",
  "Press [F2] when finished (note: Select only ONE!) "
until "F2"
do_it!

Query

```

Tag	Tag
	_xyz

cemhdtb	name	Tag
	Check	_xyz

```

Endquery
do_it!
if (isempty("answer"))
then
return
endif
view "answer"
if (nrecords("answer") > 1)
then
message "You have selected more than one"
beep
sleep 3000
return
endif
moveto [name]
tabl = [name]
clearall
view tabl
wait table
prompt "Press [F2] to process or quit"
until "F2"
ans = pullmenu(2,2,"Process;Quit")
if (ans="Quit") then
return
endif

```

```

copy tabl "inclst"
clearall
RESET
? "First Query (Locating Chemicals) . . ."
Query

```

Codetab	Material _xyz	Code Check

inclst	Chemical _xyz

```

Endquery
do_it!
add "answer" "clist"
empty "tmpnmt"
Query

```

Clst	Code _a

Ssnmcor	Corrosive Check	Non metal Check	Rec code Check	[max] Check	[min] Check	Tmin Check

Ssnmcor	Tmax Check	[c] & t comments Check	Field-9 Check	Nm code Check	Code Check _a

```

Endquery
do_it!
add "answer" "tmpnmt"
if (isempty("tmpnmt")) then
    message "Sorry no incompatibles found"
    sleep 2000
    return
endif
view "tmpnmt"
FORMKEY
WAIT TABLE
PROMPT "Press [F2] when finished viewing the table",
"Total records: " + strval(nrecords("tmpnmt"))
UNTIL "F2"
ans=pullmenu(2,2,"Report;Exit without Report")
IF ( ans = "Report" ) THEN REPORT "tmpnmt" "1";
ENDIF
endproc
writelib "main" list_nmcorrosives
release procs list_nmcorrosives

```

```
*****
Procedure asks the user to select a mission set from a table of mission sets
previously defined by the user. Once the mission set has been selected the procedure
performs a structured query to identify all the non-metals which are corrosive with
all the chemicals for all the facilities in the mission set.
*****
```

```
*****
```

```
proc mission_nmcorrosives()
```

```
private ans
```

```
clearall
```

```
copy "missions" "mhtab"
```

```
edit "mhtab"
```

```
wait table
```

```
prompt "Put a star in the tag column to select the desired mission",
```

```
"Press [F2] when finished (note: Select only ONE!) "
```

```
until "F2"
```

```
do_it!
```

```
clear
```

```
Query
```

Tag	Tag
	_xyz

Mhtab	Mission	Tag
	Check	_xyz

```
Endquery
```

```
do_it!
```

```
if_(isempty("answer"))
```

```
then
```

```
return
```

```
endif
```

```
view "answer"
```

```

if (nrecords("answer") > 1)
  then
    message "You have selected more than one"
    beep
    sleep 3000
    return
endif
moveto [Mission]
tabl = [Mission]
copy tabl "misshld"
empty "chemhld"
? "First Query (Selecting facilities) . . ."
Query

```

Tag	Tag			
	_xyz			
misshld	TAG	ABBREV		
	_xyz	Check		

```

Endquery
do_it!
copy "answer" "fachld"
view "fachld"
for i from 1 to nrecords("fachld")
  copytoarray A
  faci = A["ABBREV"]
  add faci "chemhld"
  do_it!
  moveto 4
  down
endfor

```

```
empty "clist"
? "Second Query (Locating Chemicals) . . ."
Query
```

Codetab	Material _xyz	Code Check
---------	------------------	---------------

Chemhld	Chemical _xyz
---------	------------------

```
Endquery
do_it!
add "answer" "clist"
empty "tmpnmt"
```

```
? "Third Query (Retrieving corrosive information) . . ."
Query
```

Clist	Code _a
-------	------------

Ssnmcor	Corrosive Check	Non metal Check	Rec code Check	[max] Check	[min] Check	Tmin Check
Ssnmcor	Tmax Check	[c] & t comments Check	Field-9 Check	Nm code Check	Code Check	_a

```

Endquery
do_it!
add "answer" "tmpnmt"
if (isempty("tmpnmt")) then
    message "Sorry no incompatibles found"
    sleep 2000
    return
endif
view "tmpnmt"
FORMKEY
WAIT TABLE
    PROMPT "Press [F2] when finished viewing the table",
    "Total records: " + strval(nrecords("tmpnmt"))
UNTIL "F2"
ans=pullmenu(2,2,"Report;Exit without Report")
IF ( ans = "Report" ) THEN REPORT "tmpnmt" "1";
ENDIF
endproc
writelib "main" mission_nmcorrosives
release procs mission_nmcorrosives

```

```

*****
Procedure asks the user to select a potential Space Station facility currently in the
data base. Once the user has selected the facility the procedure performs a
structured query to identify all the non-metals which are corrosive with all the
chemicals for the facility.
*****
proc facility_nmcorrosives()
private ans
empty "clist"
empty "chemhld"
copy "ssfactab" "fhtab"
edit "fhtab"
wait table
    prompt "Put a star in the tag column to select the desired facility",
    "press [F2] when finished (note: Select only ONE!) "
until "F2"
do_it!
clear
? "First Query (Selecting facilities) . . ."
Query

```

Tag	Tag						
	_xyz						
fhtab		TAG	ABBREV				
		_xyz	Check				

```

Endquery
do_it!
if_(isempty("answer"))
then
return

```

```

endif
if (nrecords("answer") > 1)
then
message "You have selected more than one"
beep
sleep 3000
return
endif
moveto [ABBREV]
facn = [ABBREV]
add facn "Chemhld"
? "First Query (Locating Chemicals) . . ."
Query

```

Codetab	Material	Code
	_xyz	Check

Chemhld	Chemical
	_xyz

```

Endquery
do_it!
add "answer" "clist"
empty "tmpnmt"

```

```

? "Third Query (Retrieving corrosive information) . . ."
Query

```

Clst	Code
	_a

Ssnmcor	Corrosive Check	Non metal Check	Rec code Check	[max] Check	[min] Check	Tmin Check
---------	--------------------	--------------------	-------------------	----------------	----------------	---------------

Ssnmcor	Tmax Check	[c] & t comments Check	Field-9 Check	Nm code Check	Code Check _a
---------	---------------	---------------------------	------------------	------------------	------------------

```

Endquery
do it!
add "answer" "tmpnmt"
if (isempty("tmpnmt")) then
    message "Sorry no incompatibles found"
    sleep 2000
    return
endif
view "tmpnmt"
FORMKEY
WAIT TABLE
PROMPT "Press [F2] when finished viewing the table",
"Total records: " + strval(nrecords("tmpnmt"))
UNTIL "F2"
ans=pullmenu(2,2,"Report;Exit without Report")
IF ( ans = "Report" ) THEN REPORT "tmpnmt" "1";
ENDIF
endproc
writelib "main" facility_nmcorrosives
release procs facility_nmcorrosives

```

VITA

Richard Thomas Congo was born in Huntsville, Alabama on October 12, 1954. He is the son of J.T. Congo and the former Evelyn Juanita Dotson. He has two brothers, Mickey Lee Congo and Mark Raymond Congo. He received his high school education at Huntsville High School in Huntsville, Alabama, graduating in May 1973. In the summer of 1973 he entered the University of Alabama in Huntsville where he received his Bachelor of Science degree in Chemistry in 1977.

After graduation, Mr. Congo joined the technical staff at the University of Alabama in Huntsville - Johnson Environmental and Energy Center as an Environmental Research Analyst. He began his graduate work in chemistry in 1978 and was awarded the Master of Science degree in Chemistry in 1982.

Mr. Congo joined the National Aeronautics and Space Administration/ Marshall Space Flight Center in March 1980 and has held increasingly responsible positions. He is currently in a management position as a "Team Leader" in the Analytical and Physical Chemistry Branch. Mr. Congo's activities at MSFC are focused primarily with contamination modeling of planetary spacecraft and with Space Station Freedom. He is responsible for developing analytical chemistry methods for new alloys and contaminants using various spectrographic techniques.

Mr. Congo is married to the former Teresa Ann Luna of Huntsville, Alabama. They have a son, Richard Thomas Congo,

Jr. The author resides with his family in Huntsville,
Alabama.