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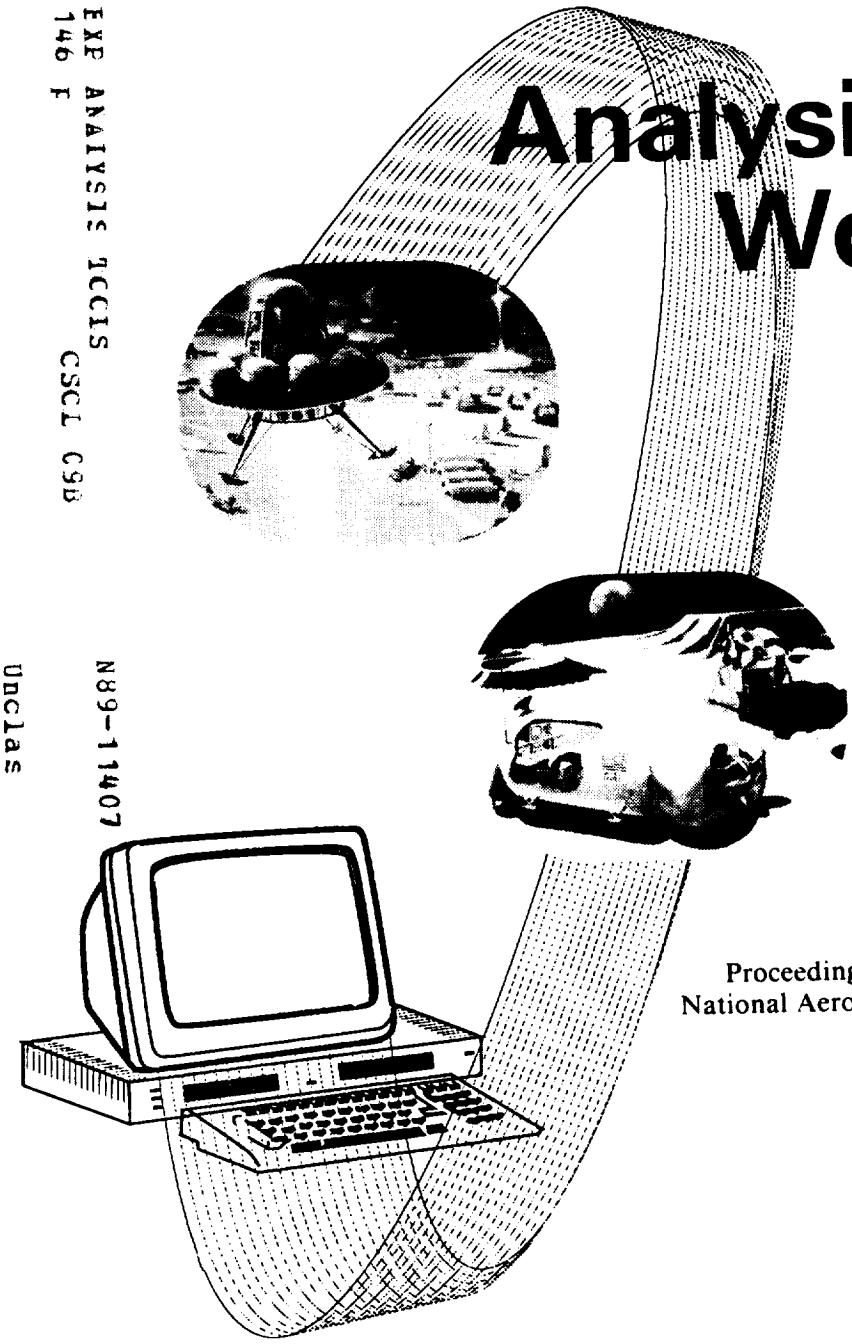
OEXP Analysis Tools Workshop



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SUMMARY

New initiatives in the exploration of the Moon and Mars are under consideration by the National Aeronautics and Space Administration. Among these initiatives are scenarios for extending man's presence beyond low Earth orbit, including manned lunar and Martian surveillance missions and the development of bases on the Moon and Mars. A workshop was held at the NASA Langley Research Center, Hampton, Virginia, on June 21-22, 1988, to provide a forum for defining the analysis tools (software) that will be needed to assist the OEXP Integration Agents (IA's) and Special Assessment Agents (SAA's) in the early mission and conceptual design phases of the OEXP new initiatives. Primary emphasis was on those software tools needed to support the early conceptual phases of these lunar and Mars programs. Although primary emphasis of the workshop was on individual programs, integrated systems analyses were also addressed. Guidelines dictated that subsystems analyses be addressed to the depth required to focus the technology development programs of the other NASA offices, and a conscious effort be made to "earmark" but defer certain software for later phases of the programs. Alternate software sources and new software development requirements were addressed.

INTRODUCTION

The NASA Office of Exploration (OEXP) Analysis Tools Workshop was held at the NASA Langley Research Center, Hampton, Virginia, on June 21-22, 1988. The objectives of the workshop were:

1. Identify potentially relevant and available analysis and design tools.
2. Identify tool needs.
3. Match needs with available tools and determine deficiencies.
4. Arrange for software transfers, as appropriate.
5. Identify lead centers/contractors for supporting analysis.
6. Define strategy/approach to modifications and new software development.

In order for the workshop to be effective, it was necessary to understand the existing needs of the various Integration Agents (IA's) and Special Assessment Agents (SAA's). Itemized lists of software needs (Appendix A) and software description worksheets (Appendix B) were generated from each IA/SAA prior to the workshop to assist in evaluating the lunar/Martian mission needs and the available software. By matching these needs to the available analysis tools, it is possible to consolidate or combine similar software, enhance and upgrade existing software, and define areas where software is inadequate or nonexistent and new software development is needed.

The workshop was opened with introductory remarks relative to the goals and objectives of the workshop and the guidelines for a road map for applying software tools to the IA/SAA requirements (Appendix C).

Dr. L. Bernard Garrett defined the tasks and described the software tools available, under development, or needed to support the analysis and integration of orbital nodes within the framework of OEXP lunar and Martian studies (Appendix D). Then the IA's and SAA's (or their designated representatives) reviewed their existing software. Each software program was discussed as to its capabilities, limitations, and potential applicability to the needs of the IA's and SAA's. Of the 74 software programs evaluated, 65 were selected as appropriate for the current and near term effort required to develop OEXP lunar and Mars missions. There was considerable interest in many of the programs, and a mechanism was established to provide transfer from center to center. In some instances, it was considered best if a particular center continued to provide supporting analyses to the agents, since the expertise was already in place and considerable effort would be necessary to transfer the software and adequately train personnel. Whereas the review was worthwhile and considerable capabilities were exchanged, it should be noted that several programs for which there was a broad interest (Parameter Optimization Programs, Lunar Trajectory, Interplanetary Program to Optimize Simulated Trajectories) are still in the development stages, and thus the deliveries will be deferred accordingly. Finally, alternate software sources and new software development requirements were identified.

AVAILABLE ANALYSIS TOOLS

The lunar and Martian mission scenarios consider all mission phases. Consequently, the analysis tool needs and software availability were arranged into nine broad mission phases and system categories as follows:

Interplanetary trajectory analysis
Planetary orbital analysis
Reentry/aerobraking analysis
Vehicle system and subsystem performance and engineering analysis
Spacecraft system and subsystem performance and engineering analysis
Surface system and subsystem performance and engineering analysis
Other discipline analysis tools (i.e. thermal, structural, etc.)
Operations simulation and costing programs
Integrated systems analyses

Each IA and SAA (or their designated representatives) submitted an initial list of software needs and available software to perform their tasks.

Initial Software Needs

Itemized listings of the software needs as received from the NASA centers (IA's and SAA's) are presented in Appendix A.

Available Software

The available software is listed by category in Table I. A total of 74 software packages were submitted in the nine categories. Each software package was discussed in detail at the workshop and evaluated as to its appropriateness for current or near term utilization. Factors used in the evaluation were:

1. Capabilities of the software
2. Level of maturity
3. Redundancy of programs
4. Degree of portability

Of the 74 software programs submitted by the IA's and SAA's, 65 were selected as appropriate for current and near term studies of OEXP lunar and Mars missions. (One additional software tool was received after the workshop and was therefore not evaluated, but it is included in the listing for completeness.) The results of the evaluation are shown in Table II (by category), and the listing of those analysis tools that were deemed appropriate to the needs of the IA's and SAA's is given in Table III. Included in the table are the applicability of the program to Earth, lunar and/or Mars missions and the organizations that requested the program and documentation. The software description worksheets for the software of Table III are presented in Appendix B. Worksheets for some software were not available, as noted.

Table I. Available Software

INTERPLANETARY TRAJECTORY	PLANETARY ORBITAL	REENTRY/ AEROBRAKING	VEHICLE SYSTEM & SUBSYSTEM PERFORMANCE & ENGINEERING	SPACECRAFT SYSTEM & SUBSYSTEM PERFORMANCE & ENGINEERING	SURFACE SYSTEM & SUBSYSTEM PERFORMANCE & ENGINEERING	OPERATIONS SIMULATION AND COSTING	OTHER DISCIPLINE	INTEGRATED SYSTEMS
Lunar Trajectory	SPASIS	CFD	Lunar Vehicle Sizing	SDCM	SHIELD	Mission Capture	NASTRAN	IDEAS
IPOST	SE_POT	POST		RANKIN	BRYNTRN	SODS	EAL	
MULIMP	DEEP	ATENT	SMART	CCEP	ECLSS Exp.	STOPS	IDEAS	IDEAS
MTDB	POST		MSMASS	NUCBRAY	EXSUMNEW	MSCOST	Thermal Analyzer	SMART
POP	MODORBIT		MMPE	NUCSTIR	GTHERM	OPSMODEL	SSPTA	
DUKSUP	DRAG			SOLSTIR		THURIS	TRASYS/ SINDA	
POD	ATOMO			LUNAR WK.1			NASTRANTA	
ODP/DPTRAJ	SHAPES			SP WK.1			SHIELD	
SWISTO	ATMOS			COOLANT			BRYNTRN	
SWISTO II	ASAP			SPASIS			CFD	
LAMBERT	LOP			ECLSS			TRANSLATOR	
Quicktop III							PLUME	
CHEBYTOP III (w/drivers)							WTRAJ	
CHEBYTOP III, Quicktop III							GAAP	
MMPE							TGAP	
FOM								
NBODY								
NBODY (Orig.)								
VARITOP								

Table II. Summary of Software Evaluation

Category	No. Programs Submitted	No. Programs Selected
Interplanetary Trajectory Analysis	19	16*
Planetary Orbital Analysis	11	5
Reentry/Aerobraking	3	3
Vehicle System and Subsystem Performance and Engineering Analysis	4	4
Spacecraft System and Subsystem Performance and Engineering Analysis	11	11
Surface System and Subsystem Performance and Engineering Analysis	5	5
Other Discipline Analysis	15	12
Operations Simulation and Costing	6	6**
Integrated Systems Analysis	3	3
TOTAL	74	65

* Several programs have redundant capability. See Table III.

** THURIS was received after workshop. Not evaluated, but included for completeness.

Table III. Selected Software

INTERPLANETARY TRAJECTORY ANALYSIS

Program	Cognizant Individual	Applicability E	L	M	Requesting Organization
Lunar Trajectory	Petro, JSC	x	x		LaRC, LeRC, MSFC, JPL
IPOST	Powell, LaRC				LeRC
MULIMP	Friedlander, SAIC	x		x	LaRC, JSC
MTDB	Pearson, SRS			x	LaRC, LeRC
POP	Tucker, SRS	x	x	x	All centers
DUKSUP	Spurlock, LeRC	x	x	x	LeRC will run for agents
POD	Findlay, FMC	x		x	NA for this phase
ODP/DPTRAJ	Breckheimer, JPL	x	x	x	NA for this phase
The following are similar					
SWISTO	Braun, LaRC	x		x	LeRC
SWISTO II	Young, SRS	x		x	
LAMBERT	Young, SRS	x	x	x	JSC, LaRC, LeRC SRS could run for agents
The following are similar					
Quicktop III	Blersch, LaRC	x		x	(These programs are already available at other centers)
CHEBYTOP III (w/drivers)	Riehl, LeRC	x		x	
CHEBYTOP III, Quicktop III	Young, SRS	x		x	
The following are similar					
NBODY (Orig.)	Riehl, LeRC			x	(These programs are already available at other centers)
VARITOP	Riehl, LeRC	x		x	

E - Earth, L - Lunar, M - Mars

Table III. Continued

NOTES:

1. MULIMP is more capable and better documented than SWISTO and SWISTO II. However it requires some training. It is currently being transferred to MSFC.

2. POP provides a major capability. It is a combination of 4 programs (LAMPOP, LOTSPOP, DSDVPOP AND SWINGPOP) providing both high and low thrust analysis. It needs support for user transportability.

3. POD can be used for navigation assessments of low thrust missions.

4. SWISTO II can constrain total trip time.

5. LAMBERT can handle aerobraking.

6. Quicktop III will be available in October 1988.

7. NBODY uses Calculus of Variations solutions to one-way trip. NBODY also handles hybrid propulsion.

8. VARITOP handles optimum two-way trips.

Table III. Continued

PLANETARY ORBITAL ANALYSIS

Program	Cognizant Individual	Applicability E	L	M	Requesting Organization
SPASIS	Stecklein, JSC	x			LaRC
SE_POT	Alexander, LeRC	x			
POST	Powell, LaRC Alexander, LeRC	x		x	Already available at other centers
ASAP	Yen, JPL	x	x	x	LeRC, LaRC
LOP	Yen, JPL	x	x	x	LeRC, LaRC
NOTES:					
1. SPASIS is also included in SPACECRAFT SYSTEMS AND SUBSYSTEMS					
2. POST is already available at other centers. POST needs to be updated for lunar missions.					
3. ASAP and LOP can be obtained from COSMIC.					

REENTRY/AEROBRAKING

Program	Cognizant Individual	Applicability E	L	M	Requesting Organization
CFD	Sutton, LaRC	x		x	
POST	Powell, LaRC	x		x	Already available at other centers
ATENT	McAdams, SAIC	x		x	Status TBD
NOTES:					
1. Status of ATENT is to be determined (TBD).					

Table III. Continued

VEHICLE SYSTEM AND SUBSYSTEM PERFORMANCE AND ENGINEERING ANALYSIS

Program	Cognizant Individual	Applicability E	L	M	Requesting Organization
Lunar Vehicle Sizing	Petro, JSC	x	x		
SMART	Rehder, LaRC	x	x	x	LaRC will run for agents
MSMASS	Montgomery, SRS			x	
MMPE	McAdams, SAIC	x		x	

SPACECRAFT SYSTEM AND SUBSYSTEM PERFORMANCE AND ENGINEERING ANALYSIS

Program	Cognizant Individual	Applicability E	L	M	Requesting Organization
SDCM	Ferebee, LaRC	x			
RANKIN	Mason, LeRC		x	x	*
CCEP	Mason, LeRC	x	x	x	*
NUCBRAY	Mason, LeRC	x	x	x	*
NUCSTIR	Mason, LeRC	x	x	x	*
SOLSTIR	Mason, LeRC	x			*
Lunar.WK 1	Hickman, LeRC		x	x	*
Sp Wk.1	Lu, LeRC	x			*
COOLANT	Tucker, MSFC	x	x	x	LaRC, LeRC, JSC
SPASIS	Stecklein, JSC	x			LaRC, MSFC (TBD)
ECLSS	Hall, LaRC		x	x	LaRC will run for agents

(*) Interested centers to work on individual basis. Contact is Joe Nainiger, NASA LeRC (297-5401)

Table III. Concluded

SURFACE SYSTEM AND SUBSYSTEM PERFORMANCE AND ENGINEERING ANALYSIS

Program	Cognizant Individual	Applicability E	L	M	Requesting Organization
SHIELD	Nealy, LaRC		x	x	LaRC will run for agents
BRYNTRN	Wilson, LaRC		x	x	LaRC will run for agents
ECLSS Expanded	Parker, LaRC		x	x	LaRC will run for agents
EXSUMNEW	Hall, LaRC		x	x	LaRC will run for agents
GTHERM	Hall, LaRC	x	x	x	LaRC will run for agents

OPERATIONS SIMULATION AND COSTING

Program	Cognizant Individual	Applicability E	L	M	Requesting Organization
Mission Capture	Petro, JSC				
SODS	Morris, LaRC				
STOPS	Morris, LaRC				
MSCOST	Montgomery, SRS			x	
OPSMODEL	Davis, LaRC	x			
THURIS(*)	Hall, MSFC				

(*) Received after workshop, not evaluated.

INTEGRATED SYSTEMS ANALYSIS

Program	Cognizant Individual	Applicability E	L	M	Requesting Organization
IDEAS	Garrett, LaRC	*	*	*	
IDEAS^2	Garrett, LaRC	*	*	*	
SMART	Rehder, LaRC	x	x	x	

(*) Specific programs within the integrated package are applicable

MATCHING OF NEEDS AND AVAILABILITY

The workshop participants matched the 65 selected software programs in Table III to the needs specified by the IA's and SAA's in Appendix A. To assist in the matching of needs and available software, the applicability of the software to Earth, lunar and/or Mars missions was identified and is shown in Table III. Some major concerns with respect to much of the software were 1) the vintage of the software (Apollo era, Viking era, etc.) and therefore its availability as well as the availability of the technical expertise to run the software, and 2) the fact that documentation for many of the programs reviewed was either incomplete or nonexistent. The consensus of the workshop participants was that even though the technical expertise is available in the aerospace community, many of the older programs have, to a large extent, been lost. Likewise, because of the lack of documentation, much of the software is not transferable (portable), and reviewers indicated that the cognizant (host) center would support the agents and run the software as required. Software requiring center support is indicated in Table III.

Requests were made for those selected programs that were easily portable and well documented. These requests are also shown in Table III, but it is the responsibility of the requesting organization to contact the cognizant organization to ensure that the transfer is made.

ANALYSIS TOOL NEEDS/WORK IN PROGRESS

After matching the available software to the needs of the IA's and SAA's, the workshop participants determined those areas where software was either inadequate or totally lacking. Analysis capabilities needing development, modification, or enhancement to support manned exploration studies were then identified. These needs are summarized by category below. Any current or planned development, modification, or enhancement of an existing analysis tool to meet these needs (work in progress) is noted. Areas where there is no known work underway to develop missing software are noted by an asterisk (*).

Trajectory/Mission Design

- o LEO to lunar and return targeter program
  (A program is under development by Andrew Petro at JSC and will be available in October 1988)

- o Low thrust transfer from lunar orbit to Mars
  (The LAMBERT program can be enhanced by SRS)

- o LEO to libration points/libration points to Mars for both high and low thrust missions (*)

- o Abort constrained trajectories
  (MULIMP is being enhanced to provide this capability)

- o Multi-vehicle phasing optimizer trajectories (*)

Planetary Orbital Analysis

- o Lunar orbit with Earth influence
  (LOP and ASAP need enhancement to provide this capability)
- o Mission planning geometry/graphics for lunar/Mars orbiting ..... vehicles/nodes (*)
- o Small natural satellite proximity orbital analysis (*)
- o Navigation preliminary analysis software for lunar missions (*)

Reentry/Aerobraking

Mission requirements have not reached the maturity level that specific analysis tool needs for reentry/aerobraking assessments can be identified. A recommendation was made that a workshop or seminar be planned to address this issue. Also, it was recommended that JSC identify the aero-thermal needs of these missions.

Vehicle System and Subsystem Engineering Analysis and Design

- o MMPE enhancement (NEP and SEP assessment program)
  (The MMPE enhancement is under development at SAIC)

Spacecraft System and Subsystem Performance and Engineering Analysis

- o Subsystem assessment
  1. First order power and propulsion subsystem assessment (*)
  2. Communications and tracking
     (MRSR communications under development at SAIC)

Surface System and Subsystem Performance and Engineering Analysis

- o Propellant boiloff
  (COOLANT program under development at MSFC)
- o Power
  (See LeRC software shown under Spacecraft Systems and Subsystems in Table III)
- o Thermal
  (GTHERM in final validation at LaRC)
- o Radiation
  (SHIELD in final validation at LaRC)
- o Surface operations resource program
  (OPSMODEL framework available)

Discipline Analysis

- o Tether structure static and dynamic modeling and analysis
  1. 6 DOF (RIGID)
     (Paul Penzo, JPL is potential contact)
  2. Flex models (*)

- o Selective factor of safety modeling (based on different structural failure criteria) (*)

- o Incremental structural analysis (failure of selected memebers) (*)

Operations Simulation and Costing

- o Populate data bases/develop analytical models for numerous..... applications (*)

- o In-space assembly (*)
  1. Mass in LEO, manhours on ground and in orbit
  2. Mars Teleoperations simulation software
  3. Communications links (Earth to Mars time delays)

In addition to the analysis tool needs in the nine categories, several models were identified that could improve the accuracy of the results from various programs. These included:

1. Atmospheric model of Mars (possible sources are JPL and Georgia Tech via MSFC)
2. Gravity models of the Moon and Mars
3. Thermal models of the Moon and Mars

APPROACHES TO NEW SOFTWARE DEVELOPMENT

The workshop identified a number of areas where there is no known work underway for software that will be needed for near-term lunar and Mars missions. The consensus of the workshop participants was that the results of this workshop be reviewed with OEXP personnel at the next available opportunity with particular emphasis on additional software required and establishing future needs. It was also recommended that each IA and SAA conduct additional independent and more comprehensive searches for software to meet their specific needs. The following potential software sources were identified:

COSMIC

APOLLO software (pre-existing software used in planning and conducting the Apollo lunar program)

Viking software (pre-existing software used in planning and conducting the Viking Mars program)

Mars Rover Sample Return Program software

CONCLUDING REMARKS

An analysis Tools Workshop was held at the NASA Langley Research Center on June 21-22, 1988. The workshop was sponsored by the NASA Office of Exploration (OEXP) to assist the OEXP Integration Agents (IA's) and Special Assessment Agents (SAA's) in defining the analysis tools that will be needed in the early mission and conceptual design phases of new initiative lunar and Mars missions. The needs were identified and matched with selected software, and mechanisms for transferring the needed software were addressed. Areas where software is inadequate or nonexistent and new software development is needed were defined.

APPENDIX A

ANALYSIS CAPABILITIES NEEDING DEVELOPMENT TO SUPPORT MANNED EXPLORATION STUDIES

Itemized List of Needs
NASA Langley Research Center

Discipline/Subsystem Area	Technical Need
Lunar Mission Analysis	Trajectory program applicable for lunar satellites, including: 1) Earth and Sun as perturbing bodies 2) Lunar gravity harmonics 3) Computation of Earth and Sun angles and view periods
	Orbital lifetime for lunar satellites, including: 1) Remote body perturbations 2) Gravity harmonics 3) Solar radiation pressure effects
Spacecraft	Subsystem reliability (orbital replacement units)
	Cost and weight estimation models
Propulsion	Propulsion system assessment
Communications	Communication subsystems assessment and link analysis

Itemized List of Needs
Jet Propulsion Laboratory

Discipline/Subsystem Area	Technical Need
Lunar Mission Analysis	Earth-Moon transfer trajectory design 1) Inexpensive medium-precision trajectory propagator (including effects of Earth, Moon, Sun?, J2 of Earth?) 2) Targeting design tool based on above 3) Parameter study tools based on 1) above for launch and arrival condition studies 4) Trajectory presentation based on 1) above Lunar orbit design and analysis (including Earth effects) 1) Low-cost long-term orbit propagator 2) Trajectory presentation and analysis tools based on the above 3) Navigation analysis tools 4) Orbit determination tools 5) Maneuver analysis (orbit maintenance) tools Launch-from-Moon design and analysis (including Earth effects) 1) Launch profile generation and analysis tools 2) Targeting and parameter study tools 3) Trajectory presentation tools
Mars Mission Analysis	Near-small-body orbit design and analysis 1) Inexpensive medium-precision trajectory propagator (including effects of Mars, Moon, Sun?, Jupiter?, J2 of Mars? Phobos, Deimos) 2) Targeting/rendezvous tools based on above 3) Maneuver analysis (stationkeeping) tools 4) Trajectory presentation and analysis tools based on 1) above 5) Navigation analysis tools

Itemized List of Needs
NASA Johnson Space Center

Discipline/Subsystem Area	Technical Need
Spacecraft Propulsion	Propellant boiloff model
Aero/Thermal	Safe payload envelope for aerobraking spacecraft
Power	Power system sizing program to size solar and nuclear power systems and energy storage hardware
Power/Thermal	Thermal radiator sizing program to size radiators for use on the lunar surface
Crew Systems	Radiation transport program to (1) simulate qualities of various materials as radiation shielding, and (2) size the amount of shielding required for various protection levels given the size and shape of the habitat
Mission Operations	Relational database allowing the user to input tasks (e.g., set-up science experiment, fill bag with lunar soil, perform minor vehicle repair, unload payload from Lunar Lander) and receive as output the manpower and time required to complete the task. It would also be useful to couple this information with a timeline or scheduling program.

Itemized List of Needs
NASA Marshall Space Flight Center

Discipline/Subsystem Area	Technical Need
Structures	Statics and dynamics of tethers, with tether elongation, snap-back with and without rotation, deployment, etc.
	Selective factor-of-safety based on difference failure criteria (based on worst-case load factor)
	Incremental structural analysis that includes initial failure with redistribution of load
Mission and Operations Analysis; Control, Guidance and Navigation; and Thermal and Structural Dynamics analysis capabilities	Standard, documented, widely-accepted FORTRAN routines for a wide range of mathematical operations including numerical linear algebra, special functions, ordinary and partial differential equations/quadrature, constrained and unconstrained optimization, and statistical

APPENDIX B

SOFTWARE DESCRIPTION WORKSHEETS

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INTERPLANETARY TRAJECTORY

Lunar Trajectory
MULIMP
MTDB
POP
DUKSUP
POD
ODP/DPTRAJ
SWISTO
SWISTO II
LAMBERT
Quicktop III
CHEBYTOP III (w/drivers)
CHEBYTOP III, Quicktop III
NBODY (Original)
VARITOP

Worksheets Not Available
IPOST (Software will be available in early 1990)

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SOFTWARE DESCRIPTION

Program Name:	Lunar Trajectory Program
(Abbreviation):	
Purpose:	Determines delta-V's for impulsive-burn trajectories between Earth orbit and lunar orbit.
Contact:	Andrew Petro, ED 23, NASA Johnson Space Center, Houston, TX 77058, FTS 525-6622, (713)483-6622.
Functional Capabilities:	Determines delta-V's for 3-burn trajectories from low-Earth orbit to lunar orbit and return trips. The program accounts for changing geometry of Earth-moon system. User can specify desired initial orbit inclination, destination orbit inclination, and specific departure date.
Recent Applications:	Under development.
Current Users:	ED23, NASA JSC, Advanced Programs Office
Program Limitations:	Impulsive maneuvers are assumed.
Enhancements in Progress:	Plan to add trajectories between Earth orbit and Earth-moon libration points. (By October 1988).

(Lunar Trajectory Program) Andrew Petro

Check Appropriate Status

Status of Computer Codes	
Fully Operational	
Undergoing Validation	
In Coding	X
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	
Partial Documentation	
In Review	
Being Written	X
Remarks -	

Potential Cost to Acquire Program, $	
Program Software	-
Math Libraries	-
Graphics Libraries	-
Data Base Software	-
Remarks -	

Portability Issues:

Languages: Fortran

Computer Hosts: DEC VAX

Terminal/Workstations Supported:

Graphics Capabilities: None at this time

Output Options: Tabular Data

User Interface Description: Terminal prompts

Other Interfaces Supported:

Notes:

SOFTWARE DESCRIPTION

Program Name:	Multi-Impulse Trajectory and Mass Optimization Program
(Abbreviation):	MULIMP
Purpose:	Heliocentric and planetocentric trajectory and mass optimization
Contact:	Alan Friedlander/SAIC/(312)885-6800
Functional Capabilities:	-- Program generates heliocentric, ballistic trajectories to any solar system body in the JPL AST*COM file by a series of matched 2-body problems. -- Departure conditions user may specify include: orbit, rendezvous, gravity assist. -- Arrival conditions user may specify include: rendezvous, target-body orbit capture, satellite orbit capture, unconstrained or constrained flyby, orbital elements. -- Mid course impulses added automatically if desired. -- Multi-revolution options. -- Conjugate gradient optimization. -- Total ΔV or mass minimization.
Recent Applications:	-- Used for all ballistic trajectory calculations by SAIC Space Sciences Dept. -- Used by JPL Advanced Planning Group.
Current Users:	SAIC, JPL, MSFC
Program Limitations:	
Enhancements in Progress:	Version complete, June 1988, that is IBM-PC compatible.

Check Appropriate Status

A. Friedlander/MULIMP

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	X
Partial Documentation	
In Review	
Being Written	
Remarks -	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks - Developed under contract to JPL	

Portability Issues:

Languages: Fortran

Computer Hosts: Originally coded for Univac 1100 (at JPL); transferred to SAIC DEC PDP-1144; currently being modified for MSFC DEC VAX; also available in IBM PC version.

Terminal/Workstations Supported:

Graphics Capabilities: None

Output Options: Short form (standard); long-form provides orbital elements used as input to heliocentric orbit plotting program; a third output format lists the primer vector history.

User Interface Description: NAMELIST input, Interactive mode

Other Interfaces Supported:

Notes:

SOFTWARE DESCRIPTION

Program Name:	Mars Trajectory Data Base
(Abbreviation):	MTDB
Purpose:	Used to support Mars mission planning by providing a reference source for selection of trajectory profiles.
Contact:	Jim Pearson, SRS Technologies, 990 Explorer Blvd., NW, Cummings Research Park West, Huntsville, AL 35806, (205)895-7000.
Functional Capabilities:	Provides high thrust, chemical propulsion mission milestone dates,ΔV's C3's, and other orbital trajectory data for a broad range of direct opposition and conjunction class missions to Mars around the local optimums of oppositions between 1999 and 2018. Essentially a catalog of SWISTO summary output data. Also a set of low thrust trajectory data from CHEBYTOP included.
Recent Applications:	Contract NAS8-36643 "Manned Mars Mission and Program Analysis", 1987-88: 1) Used as a reference in selecting mission profiles for alternate program/scenario options. 2) Used as a data sources to construct plots of variations in parameters across mission opportunities.
Current Users:	SRS Technologies, Systems Technology Division, Aerospace & Commercial Products Department, Huntsville, AL.
Program Limitations:	1) Currently exists as a single package only in printed form. Individual entries exist in separate data files. 2) No Venus SWINGBY data, 3) Same inherent limitations as SWISTO for high thrust data and CHEBYTOP for the low thrust data.
Enhancements in Progress:	None Considered: 1) Translation into a computer data base. 2) Development of search, analysis, and reporting applications. 3) Inclusion of existing Venus SWINGBY data.

Check Appropriate Status

J. Pearson (MTDB)

Status of Computer Codes	
Fully Operational	
Undergoing Validation	
In Coding	
~~Algorithms~~ Data Only	X
Remarks - Has not been implemented in a data base shell.	

Status of Documentation	
Fully Documented	
Partial Documentation	X
In Review	
Being Written	
Remarks - Summary listings from computer runs.	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks - TBD	

Portability Issues:

Languages: Photocopies, VAX Data Files (1 record in each)

Computer Hosts: VAX 11/780 & Hardcopy

Terminal/Workstations Supported:

Graphics Capabilities:

Output Options:

User Interface Description:

Other Interfaces Supported:

Notes: Further definition requires DBMS selection and user needs specifications.

SOFTWARE DESCRIPTION

Program Name: Parameter Optimization Programs

(Abbreviation): POP
-- LAMPOP (Basic Lambert/POP)
-- LOTSPOP (Chebytop III/POP)
-- DSDVPOP (Deep Space WV Lambert/POP)
-- SWINGPOP (Venus Swingby Lambert/POP)

Purpose: Uses simplex algorithm of linear programming to determine the quasi-optimum trajectory of a multistage rocket vehicle. Routine is a driver for other trajectory programs. User selects which variables are constrained and which are fixed. Algorithm converges on multiple parameter optimum solution without recourse to complex, time-consuming calculus of variations approach.

Contact: Byrd Tucker, SRS Technologies, 990 Explorer Blvd., NW, Cummings Research Park West, Huntsville, AL, 35806, (205)895-7000.

Functional Capabilities: By selection of variables for optimization and constraints, a broad range of trade studies on steering parameters, propulsion technologies, vehicle design concepts, and mission planning can be supported. POP is a driving routine which can be interfaced with any existing mission/system code when it is necessary to determine local optimum solution of a many variable problem. It enables an analyst to solve problems traditionally requiring calculus of variation treatments in significantly less time.

Recent Applications: Contract NAS8-36643 "Manned Mars Mission and Program Analysis" 1987-88: 1) LOTSPOP program refined earlier Chebytop low thrust mission energy requirements, reducing them by as much as 15%; 2) In conjunction with a modified version of Lambert (i.e., DSDVPOP), this routine enabled the identification of optimum deep space maneuver location and timing; 3) In conjunction with another modified version of Lambert (i.e., LAMPOP), this routine was used to survey the growth in interplanetary vehicle size rquired for local optimum opposition class mission length for varying staytimes. Subsequently, the high energy anomaly around 650 days and the skewing of the longer duration missions for 2010-2020 missions were identified; and 4) SWINGPOP program refined earlier Venus swingby trajectories calculated with the Lambert routine.

Current Users: SRS Technologies, Systems Technology Division, Aerospace and Commercial Products Dept., Huntsville, AL

Program Limitations: CPU time requirement grows as the number of free variables is increased. Since solution utilizes empirically approximated partial derivatives, the quality of results can be affected by the parameter step size and initial estimates. Convergence is sometimes slow. A local optimum is expected, rather than a global optimum.

Enhancements in Progress: None

Check Appropriate Status

B. Tucker (POP)

Status of Computer Codes	
Fully Operational	
Undergoing Validation	X
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	
Partial Documentation	
In Review	
Being Written	
Remarks - None	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks - TBD	

Portability Issues:

Languages: FORTRAN 77

Computer Hosts: VAX 11/780

Terminal/Workstations Supported: VT 100 Compatible

Graphics Capabilities: None

Output Options: Payoff value

User Interface Description: Interactive stepsize & parameter selection

Other Interfaces Supported: Any Fortran code

Notes:

SOFTWARE DESCRIPTION

Program Name:	DUKSUP
(Abbreviation):	
Purpose:	ELV Trajectory Optimization
Contact:	Frank Spurlock, MS 501-6, NASA, LeRC, (216)433-5416
Functional Capabilities:	Very flexible three degree of freedom trajectory optimization program employing calculus of variations. Can be used to model a wide variety of vehicles starting from launch on Earth (or a planet) or on orbit. Includes detailed gravitational model of Earth and the Earth's atmosphere. Primary applications are to high thrust launch vehicles and upper stages.
Recent Applications:	7-86 to present. Used to model U.S. expendable launch vehicles (Titan II, III, IV; Atlas/Centaur; Delta 3920, 6920, 7920) and various upper stages.
Current Users:	Systems Analysis Branch of Advanced Space Analysis, Office at NASA/LeRC. Analex Corp. - Support service contractor.
Program Limitations:	High degree of user familiarity with program is essential as no documentation exists. Some knowledge of calculus of variations is needed to appreciate how the program can be applicable to the particular problem at hand (i.e., movement from one solution to another).
Enhancements in Progress:	None

F. Spurlock (DUKSUP)

Check Appropriate Status

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	
Partial Documentation	
In Review	
Being Written	
Remarks - no documentation	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks - unknown	

Portability Issues:

Languages: FORTRAN

Computer Hosts: IBM 370 - used as front end, runs on Cray XMP

Terminal/Workstations Supported: IBM 3180, IBM PC AT 3270

Graphics Capabilities: None

Output Options: Standard trajectory info. is output.
Options exist to receive tracking site output and performance margin output.

User Interface Description: Code peculiar input routine.

Other Interfaces Supported: None

Notes:

SOFTWARE DESCRIPTION

Program Name: (Abbreviation): POD: Parametric Orbit Determination Program

Purpose: ASSESS NAVIGATION ACCURACY FOR EARTH/MARS TRANSFER TRAJECTORY

Contact: (Name, Address, Phone) JOHN FINDLAY, FLIGHT MECHANICS & CONTROL, INC. (804) 722-7545

Date: June 9, 1988

Functional Capabilities:
(Can Include Sketches)

Software utilizes optional filtering algorithms and user prescribed DSN range and Doppler (range rate-formulation) tracking scheduling to determine trajectory accuracy (statistical) during interplanetary (MARS) cruise. Applicable from trans-Mars insertion to encounter. State and variational partials generated using patched conics. Observation and dynamic parameters are included as either solve-for or consider parameters. Optionally can obtain state from satellite ephemeris tape such that software could be adaptable for low-thrust interplanetary trajectories.

Recent Applications:
(Include Approximate Dates)

LAST UTILIZED CIRCA 1975 DURING VIKING PROGRAM

Current Users:
(What Organizations)

NONE

Program Limitations:
(Limiting Assumptions, Algorithms)

Vintage software. Fortran code could be upgraded to run on current systems but modifications would require expertise in trajectory mechanics and strong navigation (orbit determination) background. Software utilizes NAMELIST input and, with experience, is easy to use.

Enhancements in Progress:
(Include Anticipated Completion Date if Known)

NONE

Check Appropriate Status Findlay (POD)

Status of Computer Codes	
Fully Operational	
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks - VINTAGE	

Status of Documentation	
Fully Documented	
Partial Documentation	X
In Review	
Being Written	
Remarks -	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks -	

Portability Issues:

Languages:

FORTRAN II

Computer Hosts:

CDC (LaRC ICOPS system when utilized)

Terminal/Workstations Supported:

Graphics Capabilities:

NONE

Output Options:

User Interface Description:

Other Interfaces Supported:

Notes:

SOFTWARE DESCRIPTION

Program Name:	ODP/DPTRAJ
(Abbreviation):	ODP/DPTRAJ
Purpose:	Very high precision orbit determination, propagation
Contact:	P. Breckheimer, JPL/COSMIC
Functional Capabilities:	Estimates orbit & model parameters from Earth-based observations of spacecraft, predicts states.
Recent Applications:	Everything
Current Users:	JPL
Program Limitations:	Can only estimate 100 parameters. Can't use spacecraft-to-spacecraft data. Has excessive output file storage needs.
Enhancements in Progress:	

Check Appropriate Status

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	X
Partial Documentation	
In Review	
Being Written	
Remarks -	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks - COSMIC	

Portability Issues:

Languages: Fortran, assembler

Computer Hosts: Unisys 1100, VAX 11/785 - COSMIC

Terminal/Workstations Supported: ASCII

Graphics Capabilities:

Output Options: Printout
Data files (P-files, PV-files)

User Interface Description: namelist input

Other Interfaces Supported:

Notes: available from COSMIC

SOFTWARE DESCRIPTION

Program Name: SWISTO

(Abbreviation): SWISTO

Purpose: Interplanetory trajectory design based on minimal energy requirements.

Contact: Robert Braun, MS 365, NASA, LaRC, Hampton, Va 23665, (804)865-4900.

Functional Capabilities: Interplanetary missions requiring up to 4 impulsive maneuvers. Six mission modes:

1. Direct capture
2. Swingby capture

} One-way transfers

3. Outbound swingby stopover
4. Inbound swingby stopover
5. Direct flyby
6. Direct stopover

} Round-trip transfers

Recent Applications: Earth-Mars trajectory study--2/88 to present.

Current Users: Robert Braun--Vehicle Analysis Branch, LaRC
Chris Edelen--Vehicle Analysis Branch, LaRC
SRS Technologies, Contractor, MSFC

Program Limitations:
--patched conic approach
--at most 4 propulsive maneuvers
--no perturbations
--transfers to planetary moons not included

Enhancements in Progress: No fundamental theory enhancement. Enhancements made to suit VAB needs--batch operation.

Check Appropriate Status

Robert Braun (SWISTO)

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	X
In Coding	
Algorithms Only	
Remarks - can be operationally difficult to run	

Status of Documentation	
Fully Documented	X
Partial Documentation	
In Review	
Being Written	
Remarks - only helpful with theory	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks - unknown	

Portability Issues:

Languages: Fortran

Computer Hosts: VAX

Terminal/Workstations Supported: VAB MicroVax

Graphics Capabilities: None

Output Options: Data tables

User Interface Description: Namelist input file that can be modified interactively

Other Interfaces Supported: None

Notes: A firm understanding of orbital mechanics is required to operate the code in a manner beneficial to specific needs. Age of code (1968) prevents help from original programmers.

SOFTWARE DESCRIPTION

Program Name:	Swingby Stop-Over Program, Version II Update
(Abbreviation):	SWISTO II
Purpose:	Uses Lambert's theorem to calculate ephemeridal parameters for direct or swingby stopover and flyby interplanetary trajectories between selected solar system planets/locations. Searches through specified range of launch dates to determine optimum date for a mission of specified total trip time and stopover duration. Launch windows durations may be specified.
Contact:	Roy Young, SRS Technologies, 990 Explorer Blvd.,NW, Cummings Research Park West, Huntsville, AL 35806 (205)895-7000
Functional Capabilities:	Calculates mission launch, arrival, departure, and return dates. Calculates required high thrust ΔV's , C3's, asymptotes, orbital geometries. Calculates vehicle mass fraction.
Recent Applications:	Produced catalog of manned Mars mission trajectory data requirements for a range of fixed trip times and stay times for each opposition between 1999 and 2018. Contract NAS8-36643, "Manned Mars Mission and Program Analysis" 1987-88.
Current Users:	SRS Technologies, Systems Technology Div., Aerospace & Commercial Products Dept., Huntsville, AL.
Program Limitations:	High thrust only, Newtonian central force mechanics, patched conics, single burn departures and captures, currently only data in ephemeris for 9 planets, internal mass fraction analysis: -- three stages in series -- only basic maneuvers (no midcourse or deep space) -- all propulsive
Enhancements in Progress:	None

Check Appropriate Status

R. Young (SWISTO II)

Status of Computer Codes	
Fully Operational	
Undergoing Validation	X
In Coding	
Algorithms Only	
Remarks - Some option paths lead to program abort	

Status of Documentation	
Fully Documented	
Partial Documentation	X
In Review	
Being Written	
Remarks - Documentation exists of SWISTO. Update only necessary.	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks - TBD	

Portability Issues:

Languages: FORTRAN (VAX extension of FORTRAN 77)

Computer Hosts: VAX 11/780

Terminal/Workstations Supported: VT100 compatible

Graphics Capabilities: None

Output Options: 1) Detailed
2) Summary

User Interface Description: Options: Data file set-up externally, pass thru on execution
: Realtime modification to data set during execution

Other Interfaces Supported:

Notes:

SOFTWARE DESCRIPTION

Program Name:	Lambert High Thrust Trajectory Program
(Abbreviation):	LAMBERT
Purpose:	Uses Lambert's theorem to calculate ephemeridal parameters for direct or swingby stopover and flyby interplanetary trajectories between selected solar system planets/locations. Optionally, allows departure and/or arrival at Earth's moon. Searches through specified range of launch dates to determine optimum date for a mission of specified total trip time and stopover duration.
Contact:	Roy Young, SRS Technologies, 990 Explorer Blvd.,NW, Cummings Research Park West, Huntsville, AL, 35806, (205)895-7000.
Functional Capabilities:	Calculates mission launch, arrival, departure, and return dates. Calculates required high thrust ΔV's , C3's, asymptotes, orbital geometries. Calculates vehicle mass fraction using propulsion system scaling equations. Has aerobraking options. Allows mass drop after each maneuver. Allows midcourse ΔV to be specified.
Recent Applications:	Produced data supporting trade study of the feasibility of utilizing lunar produced LOX for manned Mars opposition class missions. Contract NAS8-36643 "Manned Mars Mission and Program Analysis" 1987-88.
Current Users:	SRS Technologies, Systems Technology Div., Huntsville, AL
Program Limitations:	High thrust only, Newtonian central force mechanics, patched conics, only basic (i.e., no deep space) maneuvers, single burn departures and captures, currently only data in ephemeris for 9 planets and Earth's moon, internal mass scaling analysis assumes three stages in series, does not calculate/check departure inclination.
Enhancements in Progress:	None Considered: -- Addition of subroutine to calculate and check departure/arrival inclinations. -- Addition of routines for supporting lunar orbital transfer vehicle mass analysis.

Check Appropriate Status

R. Young (LAMBERT)

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	
Partial Documentation	
In Review	
Being Written	
Remarks - None planned some comments in code	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks - TBD	

Portability Issues:

Languages: Fortran 77 (VAX Extension)

Computer Hosts: VAX 11/780

Terminal/Workstations Supported: VT100

Graphics Capabilities: None

Output Options: Detailed, followed by a summary

User Interface Description: NAMELIST driven

Other Interfaces Supported: Output format in Macintosh readable

Notes:

SOFTWARE DESCRIPTION

Program Name:	Quick trajectory and mass optimization computer program.
(Abbreviation):	QUICKTOP III
Purpose:	Determines the system and performance requirements of electrically propelled spacecraft in combination with either specific launch vehicles (including shuttle) and high or low thrust departure or capture stages.
Contact:	Donald Blersch; MS 365, LaRC, Space Systems Division, VAB, #865-4900
Functional Capabilities:	Program can simulate entire missions accurately and can define their requirements with short execution times. Options include: solar or nuclear energy; orbiter or flyby mode; optimum or constrained (power, specific impulse, thrust time, thrust attitude, hyperbolic velocities, launch dates, arrival date); built-in ephimiris for variety of targets or user input elements for both home and target; built-in characteristics for variety of launch vehicles or user input characteristics; high or low thrust departure or arrival; sphere of influence matching, all ballistic, high thrust comparisons. Numerous cases with large range of parameters can also be run.
Recent Applications:	5/87 - present. Nuclear electric propulsion transportation study - "Low thrust" Mars mission studies (manned and cargo).
Current Users:	Donald Blersch - Vehicle Analysis Branch, LaRC Chris Edelen - Vehicle Analysis Branch, LaRC SRS Technologies, Contractor, MSFC
Program Limitations:	-- Capable of full 3-D trajectory analysis; however, code optimizes one-way transfers only. Thus round trip missions must be "patched" from out-bound and in-bound runs; works but greatly slows analysis process. -- No perturbations. -- Transfers to planetary moons not included.
Enhancements in Progress:	-- No fundamental enhancements in code. -- Working on method to automate round trip mission analysis.

Check Appropriate Status

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks - Validated No starting solutions required.	

Status of Documentation	
Fully Documented	X
Partial Documentation	
In Review	
Being Written	
Remarks - very user friendly manual	

Donald Blersch

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks -	

Portability Issues:

Languages: Fortran 77

Computer Hosts: VAX

Terminal/Workstations Supported: MicroVax VAB

Graphics Capabilities: None

Output Options: Three: (1) Standard data output on vehicle, trajectory (data)
(2) Intermediate hyperbolic velocity interactions(help)
(3) Standard data w/time history of the trajectory (path) and thrust profile

User Interface Description: NAMELIST input file

Other Interfaces Supported: None

Notes: For unmanned "Viking Level" missions code completely user friendly from launch on ground to final orbit insertion. One-way missions (cargo) also automatic, two way roundtrip missions possible but require user to spend large amounts of time "patching" proper trajectory legs and dates together and keeping payload and vehicles on legs consistent (tends to be tedious)

SOFTWARE DESCRIPTION

Program Name:	CHEBYTOP III and DRIVERS
(Abbreviation):	
Purpose:	Compute approximate performance for heliocentric power limited trajectories.
Contact:	(John Riehl, LeRC)
Functional Capabilities:	CHEBYTOP III is a collection of routines for approximating power limited and constrained thrust trajectories. LeRC personnel have written a driver for computing round-trip performance and use a JPL-supplied driver for one-way trips.
Recent Applications:	
Current Users:	SAIC, LaRC, MSFC, LeRC, JPL (Carl Saver). Developed under Ames Research Center contract to Boeing.
Program Limitations:	Analytic approximations for spirals. Massless planets.
Enhancements in Progress:	

Check Appropriate Status

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	X
Partial Documentation	
In Review	
Being Written	
Remarks - Refer to Boeing D180-15371-1 & D180-12916-1	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks - Available from COSMIC	

Portability Issues:

Languages: Fortran IV & Fortran 77 (drivers)

Computer Hosts: VM/CMS

Terminal/Workstations Supported: ASCII

Graphics Capabilities: None

Output Options: Standard CHEBYTOP VTout file to line printer plus approximated constant ISP, constant power solution parameters.

User Interface Description: Non-interactive operation

Other Interfaces Supported:

Notes:

SOFTWARE DESCRIPTION

Program Name:	Chebychev Trajectory Optimization Program
(Abbreviation):	CHEBYTOP III/QUICKTOP III
Purpose:	Uses Chebychev optimization method to solve for rendezvous, flyby, or excess velocity interplanetary trajectories. Models variable thrust or constrained thrust, multiple coast mission profiles. This is a VAX computer compatible version of the program developed and improved by the Boeing Company in the early 1970's.
Contact:	Roy Young, SRS Technologies, 990 Explorer Blvd., NW, Cummings Research Park West, Huntsville, AL 35806, (205)895-7000.
Functional Capabilities:	Constant or variable power source for nuclear/solar electric thrusters. Two major functions are the solution of 1) unconstrained continuous thrust (variable thrust mode) case; and 2) constant specific impulse, thrust limited case. Ephemeris contains the nine solar planets.
Recent Applications:	Produced catalog of manned Mars mission trajectory data requirements for a range of ISP and specific mass values for each opposition between 1999 and 2018. Simulated missions using all-NEP system and a hybrid NEP/chemical system, with and without aerobraking at the target and on return to the departure point. Contract NAS8-36643 "Manned Mars Mission and Program Analysis" 1987-88.
Current Users:	SRS Technologies, Systems Tech. Div., Aerospace & Commercial Products Dept., Huntsville, AL
Program Limitations:	
Enhancements in Progress:	None

Check Appropriate Status

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks - Just a rehost to VAX 11/780 of an exist. program.	

Status of Documentation	
Fully Documented	
Partial Documentation	X
In Review	
Being Written	
Remarks - Particulars of rehost mods not documt. Or wtih OOP driver it will need documentation.	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks - TBD	

Portability Issues:

Languages: FORTRAN 77 (VAX Version)

Computer Hosts: VAX 11/780

Terminal/Workstations Supported: VT 100

Graphics Capabilities: None

Output Options: 1) Partial
2) Full

User Interface Description: NAMELIST

Other Interfaces Supported: Output of Macintosh readable data file

Notes:

SOFTWARE DESCRIPTION

Program Name:	NBODY (original version of 1973)
(Abbreviation):	
Purpose:	Compute optimal heliocentric trajectories
Contact:	John Riehl, NASA, LeRC, 21000 Brookpark Rd., Cleveland, OH 44135
Functional Capabilities:	Optimal multistage-launch-vehicle ascent trajectories may be determined by variational thrust steering during the upper phase. Optimal low-thrust interplanetary spacecraft trajectories may also be calculated with solar power or constant power, all-propulsion or embedded coast arcs, fixed or optimal thrust angles, and a variety of terminal end conditions. A hybrid iteration scheme solves the boundary-value problem, while either transversality conditions or a univariate search scheme optimize vehicle or trajectory parameters. NBODY includes planetary sphere-of-influence gravitational effects and changes its point of reference accordingly.
Recent Applications:	Nuclear ion propulsion study by Diane Galecki and Mike Patterson (NASA TMX)
Current Users:	John Riehl/NASA, LeRC and Diane Galecki/NASA, LeRC
Program Limitations:	Our experience indicates NBODY must have at least a 36 bit single precision word to converge properly.
Enhancements in Progress:	None planned.

Check Appropriate Status

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	X
Partial Documentation	
In Review	
Being Written	
Remarks - NASA TND-7543	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks - send request to NASA-LeRC (no longer at COSMIC)	

Portability Issues:

Languages: Fortran IV (Compiler must allocate all named common blocks into contiguous locations-even across common blocks) must support namelist input.

Computer Hosts: VM/CMS & CRAY currently

Terminal/Workstations Supported: ASCII

Graphics Capabilities: None

Output Options: Lineprinter output only of initial conditions, final trajectory and intermediate convergence history.

User Interface Description: User prepares input data set and executes program as a batch task. NBODY predates interactive operations.

Other Interfaces Supported:

Notes: NBODY can be very difficult to operate because of its generalized variational solution technique which is extremely sensitive to initial guesses. Developed by William C. Strack of Lewis Research Center.

SOFTWARE DESCRIPTION

Program Name:	VARITOP
(Abbreviation):	
Purpose:	Compute optimal heliocentric trajectories for low thrust vehicles.
Contact:	John Riehl-NASA,LeRC, 21000 Brookpark Rd., Cleveland, OH 44135
Functional Capabilities:	Compute optimal one way and round trip 3-D heleicentric trajectories for low-thrust vehicles. Program includes an analytic ephemeris to determine planetary positions and velocities. The program permits the user to incorporate known solutions and modify them to solve a new problem. Can handle solar or nuclear power models.
Recent Applications:	SSTA-C presentation on N.E.P. in March by LeRC SPIOO applications analysis.
Current Users:	Carl Saver, JPL (author) John Riehl - NASA, LeRC Kurt Hack - NASA, LeRC
Program Limitations:	2-body variational solutions, analytic approximations for escape/arrival spirals per saver and Melbourne, uses finite differences to calculate partial derivatives.
Enhancements in Progress:	

Check Appropriate Status

J. Riehl (VARITOP)

Status of Computer Codes	
Fully Operational	
Undergoing Validation	X
In Coding	
Algorithms Only	
Remarks - became operational at LeRC in March '88.	

Status of Documentation	
Fully Documented	
Partial Documentation	
In Review	
Being Written	X
Remarks - by C. Sauer JPL	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks -	

Portability Issues:

Languages: Fortran 77 (must support namelist input)

Computer Hosts: VM/CMS (FORTVSZ compiler)
Cray X-MP-(CFT77 compiler)

Terminal/Workstations Supported: ASCII

Graphics Capabilities: No direct graphics. Program can generate output files for off-line plotting.

Output Options: Covergence history on-line. Detailed printable trajectory history to separate file.

User Interface Description: User prepares batch input file. Program runs in a primitive interactive (univac demand mode).

Other Interfaces Supported:

Notes:

PLANETARY ORBITAL

SPASIS
SE_POT
POST
ASAP
LOP

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SOFTWARE DESCRIPTION

Program Name: Space Systems Integrated Simulation

(Abbreviation): SPASIS

Purpose: SPASIS is a 6 degree-of-freedom, rigid body simulation for analyzing orbiting spacecraft. The spacecraft is entirely user-defined and may be of any type. SPASIS will then simulate the spacecraft in orbit and calculate environmental effects (forces and moments on the spacecraft) and control system responses. Many other systems-related analyses may be performed including articulation, plume impingement, and docking.

Contact: Jonette M. Stecklein/ED23, NASA, Johnson Space Center, Houston, TX 77058, (713)483-6624, FTS 525-6624.

Functional Capabilities:

- -- fourth-order Runge-Kutta-Gill integrator
- -- 6 degree-of-freedom equations of motion
- -- spacecraft may be initialized in circular, elliptical, parabolic, or hyperbolic orbits
- -- on-orbit environmental models
  - -- aerodynamic, solar, and gravity gradient
  - -- variable density Jacchia atmosphere
- -- both RCS and CMG control systems may be modeled
- -- three-dimensional solar array/radiator modeling
  - -- Sun tracking or anti-Sun tracking
  - -- feathering capability
- -- forces and moments due to jet plume impingement impact the motion of the spacecraft (attached control jets and unattached moveable jets)
- -- docking analysis capability
- -- propellant dynamics simulation
- -- mobile mass modeling
- -- on-orbit maneuver

Recent Applications: Flight Dynamics of a Transportation Node - 6/88
Space Station Buildup Sudies

Current Users: 1) NASA JSC - Advanced Programs Office, 2)Lockheed (LEMSCO), engineering support contractor for JSC, 3) Grumman, SS Program Support Division, contractor for SS Level II

Program Limitations: Limited to Earth-orbiting spacecraft

Enhancements in Progress: SPASIS is being modified to allow the calculation of the micro-gravity acceleration experienced by any location on a spacecraft over the course of the simulation. A complementary post-processing capability is being generated so that micro-g contours can be superimposed over a representation of the spacecraft.

Assumptions: 1) Only the first order gravitational acceleration term is used, 2) Each RCS jet is allowed to fire in both the positive and negative direction. The duration of the firing lasts over the complete time step, 3) All CMGs are assumed to maintain constant angular momentum of user-defined magnitude, 4) The plume impingement model assumes that the plume flows from a point source, 5) A maximum of 10 tanks may be modeled by the Rolling Ball Slosh Model. Each tank contains a nonvariant propellant mass. The ball representing the propellant is constrained to roll along the surface of the tank. 6) The entire mobile mass (platform plus payload) is completely rigid and moves along a linear path with constant velocity. 7) The Earth is assumed to remain stationary during the course of a simulation run (non-rotating Earth).

Check Appropriate Status

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks - latest released version: 6.0	

Status of Documentation	
Fully Documented	X
Partial Documentation	
In Review	
Being Written	
Remarks -	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks - VAXPLOT requires a graphics library. 2.0 is interfaced with the DI3000 graphics library and has also been interfaced with a DISSPLA graphics library.	

Portability Issues:

Languages: Fortran 77

Computer Hosts: Many of the utilities and a large percentage of the user interface take advantage of the Digital Command Language and the Screen Management System available in the VAX VMS Operating System. In this respect, SPASIS is very VAX-specific. However, a non-VAX user interface in standard FORTRAN is also in place and utilizes when SPASIS is run from non-Digital terminals. The utilities can be easily replaced on any non-VAX system. For further information, refer to the SPASIS Software Directory and Installation Guide.

Graphics Capabilities: VAXPLOT displays the time histories of all SPASIS output data. GRIDPLOT generates a graphical representation of the gridpoint model (SPASIS' interpretation of the spacecraft geometric data).

Output Options: Tabular or plotted data for single or multiple orbits.

User Interface Description: User creates or modifies the input data files. The program is menu-driven, and inputs may be modified interactively.

Other Interfaces Supported: SPASIS may be run interactively or in batch mode.

Notes: -SPASIS Version 6.0 is the latest released version
-SPASIS 6.0 is integrated with the IDEASAPO Modeling and Analysis Software and also operates in a stand-alone mode. (IDEASAOP is the JSC Advanced Program Office version of IDEAS**2).
-SPASIS 6.0 is currently being integrated with SSP IDEAS**2.

SOFTWARE DESCRIPTION

Program Name:	SE_ _ _ POT
(Abbreviation):	
Purpose:	Low thrust transfers about a planet.
Contact:	Steve Alexander, LeRC, FTS 297-5377
Functional Capabilities:	A time optimal or nearly time optimal trajectory program has been developed for solar electric geocentric transfer with or without attitude constraints and with an optional initial high thrust stage. The method of averaging reduces computation time. A nonsingular set of orbital elements is ued. The constraints, which are those of one of the SERT-C designs, introduce complexities into the analysis and the solution yields possible discontinuous changes in thrust direction. The power degradation due to VanAllen radiation is modeled analytically. A wide range of solar cell characteristics may be assumed. Effects such as oblateness and shadowing may be included. This report contains the analysis and the results of many example runs.
Recent Applications:	
Current Users:	LeRC 6820
Program Limitations:	-- Orbit averaging is used so low thrust escape trajectories are not possible. -- Convergence becomes difficult if shadowing and attitude constraints are introduced.
Enhancements in Progress:	Graphics

Check Appropriate Status

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	X
Partial Documentation	
In Review	
Being Written	
Remarks - NASA CR 134927	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks - in COSMIC	

Portability Issues:

Languages: Fortran

Computer Hosts: Cray XMP

Terminal/Workstations Supported:

Graphics Capabilities: None

Output Options:

User Interface Description:

Other Interfaces Supported:

Notes: Developed by Lester L. Sackett, Harvey L. Malchow and Theodore N. Edelhaum of the Charles Stark Draper Labs.

SOFTWARE DESCRIPTION

Program Name: (Abbreviation): Program to Optimize Trajectories
POST

Purpose: To simulate orbital trajectories about a planet

Contact: (Name, Address, Phone) Steve Alexander, NASA, LeRC, FTS 297-5377
Richard Powell, NASA, LaRC, FTS 928-4959

Functional Capabilities: (Can Include Sketches) Program can simulate a great variety of missions. Options include: 1) heating models, 2) atmosphere models, 3) planet parameters, 4) propulsion models, 5) integration methods, 6) velocity losses, 7) vehicle models, 8) guidance methods. POST is a generalized point mass, discrete parameter targeting and optimization program. POST provides the capability to target and optimize point mass trajectories for a powered or unpowered vehicle near an arbitary rotating, oblate planet. POST has been used successfully to solve a wide variety of atmospheric ascent and reentry problems, as well as exoatmospheric orbital transfer problems. The generality of the problem is evidenced by its N-phase simulation capability which features generalized planet and vehicle models. This flexible simulation capability is augmented by an efficient discrete parameter optimization capability that includes equality and inequality constraints.

Recent Applications: (Include Approximate Dates)
Aerobrake trade studies
Advanced manned launch systems
Assured crew return capability
Shuttle II, CERV, NASP (at Langley)

Current Users: (What Organizations) JSC, LaRC, LeRC, MSFC, most aerospace companies

Program Limitations: (Limiting Assumptions, Algorithms)
No lunar effects
Parametric optimization only
No low thrust optimization

Enhancements in Progress: (Include Anticipated Completion Date if Known) LeRC is trying to rehost on the Cray (10/88)

Check Appropriate Status

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	X
Partial Documentation	
In Review	
Being Written	
Remarks -	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks -	

Portability Issues:

Languages: FORTRAN

Computer Hosts: VAX, Cyber

Terminal/Workstations Supported: All batch program

Graphics Capabilities: Download data to a PC graphics routine. Plotting available on VAX.

Output Options:

User Interface Description: VAX com files prompt name of input file

Other Interfaces Supported: Batch capable

Notes:

SOFTWARE DESCRIPTION

Program Name:	ASAP
(Abbreviation):	ASAP
Purpose:	High order orbit propagation
Contact:	Chen-Wan Yen, JPL/COSMIC
Functional Capabilities:	Orbit propagation, where the model includes high-order gravity fields, other body gravity, drag.
Recent Applications:	Magellan (Venus Mapper), ongoing Mars Observer, ongoing
Current Users:	JPL
Program Limitations:	Uses analytic approximations for natural body ephemerides. Slow. Limited output options.
Enhancements in Progress:	

Check Appropriate Status

ASAP

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	X
Partial Documentation	
In Review	
Being Written	
Remarks -	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks -	

Portability Issues:

Languages: Fortran 77

Computer Hosts: MS-DOS PCs, many others

Terminal/Workstations Supported: ASCII

Graphics Capabilities: interfaces to Lotus 1-2-3

Output Options:

User Interface Description: namelist input

Other Interfaces Supported: Lotus 1-2-3

Notes: Available from COSMIC

SOFTWARE DESCRIPTION

Program Name:	LOP
(Abbreviation):	LOP
Purpose:	Long-term orbit prediction
Contact:	Chen-Wan Yen, JPL - COSMIC
Functional Capabilities:	Predicts long-term effects on orbit parameters from high-order gravity fields, external bodies, drag, solar pressure.
Recent Applications:	Magellan (Venus Mapper), ongoing Mars Orbiter
Current Users:	JPL
Program Limitations:	Uses analytic approximations for natural body ephemerides. Has limited data presentation/analysis options.
Enhancements in Progress:	

Check Appropriate Status

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	X
Partial Documentation	
In Review	
Being Written	
Remarks -	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks -	

Portability Issues:

Languages: Fortran 77

Computer Hosts: MS-DOS PCs

Terminal/Workstations Supported: ASCII

Graphics Capabilities: interfaces to Lotus 1-2-3

Output Options:

User Interface Description: namelist input

Other Interfaces Supported: Lotus 1-2-3

Notes: available from COSMIC

REENTRY/AEROBRAKING

POST (see Interplanetary Trajectory)

Worksheets Not Available

CFD
ATENT

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VEHICLE SYSTEM & SUBSYSTEM PERFORMANCE & ENGINEERING

Lunar Vehicle Sizing
SMART
MSMASS
MMPE

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SOFTWARE DESCRIPTION

Program Name:	Lunar Vehicle Sizing Program
(Abbreviation):	
Purpose:	To estimate spacecraft and propellant mass and tank dimensions for multi-stage lunar spacecraft.
Contact:	Andrew J. Petro, ED 23, NASA Johnson Space Center, Houston, TX 77058 FTS 525-6622, (713)483-6622.
Functional Capabilities:	-- UP to 7 major maneuvers, 1 to 7 stage vehicles, user defines stage configuration. -- One-way or roundtrip missions. -- Propulsive or aerobraking Earth capture. -- User specifies payload, can be different for different portions of mission. -- 6 propellant combination options for each stage. -- Spacecraft dry mass is estimated as a function of delta-V magnitude and payload mass.
Recent Applications:	Currently being used in lunar spacecraft conceptual design as part of in-house lunar base systems study.
Current Users:	A. Petro, NASA JSC, ED23, Advanced Programs Office
Program Limitations:	-- Impulsive Maneuvers are assumed. -- Delta-V's must be provided by user. -- Dry spacecraft mass estimates are crude at this point.
Enhancements in Progress:	Wide range of improvements are planned but not yet scheduled for implementation.

Check Appropriate Status

A. Petro (Lunar Veh.Siz.Pro.

Status of Computer Codes	
Fully Operational	
Undergoing Validation	X
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	
Partial Documentation	X
In Review	
Being Written	
Remarks -	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks -	

Portability Issues:

Languages: Fortran

Computer Hosts: DEC VAX

Terminal/Workstations Supported:

Graphics Capabilities: None

Output Options: Tabular data
Data file for plotting

User Interface Description: User created input file
Terminal prompts

Other Interfaces Supported:

Notes:

SOFTWARE DESCRIPTION

Program Name:	Solid Modeling Aerospace Research Tool
(Abbreviation):	SMART
Purpose:	Generate 3-D geometric representation of advanced launch vehicles
Contact:	Joe Rehder, NASA, LaRC, MS 365, Hampton, VA 23665, (804)865-4967
Functional Capabilities:	Dynamically generates vehicle configurations built up from components that can be made of primitive objects (spheres, cubes, etc.), automatically generated wings and tanks, or skinning of cross-sections, components or groups, can be manipulated interactively. Geometric properties (volume, area, etc.) can be calculated. Realistic shaded images can be produced.
Recent Applications:	Design of Shuttle II, NASP, CERV configurations
Current Users:	NASA Langley, Vehicle Analysis Branch
Program Limitations:	
Enhancements in Progress:	

Check Appropriate Status

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	
Partial Documentation	X
In Review	
Being Written	
Remarks -	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks - Public Domain	

Portability Issues:

Languages: C

Computer Hosts: IRIS Workstation

Terminal/Workstations Supported:

Graphics Capabilities: Extensive 3D, Color, Real-Time, Motion

Output Options:

User Interface Description: Menu-driven

Other Interfaces Supported: LaWGS, PATRAN, EMTAC

Notes:

SOFTWARE DESCRIPTION

Program Name: Mars Sizing-Mass Estimator

(Abbreviation): MSMASS

Purpose: Uses trajectory energy requirements supplied by orbital analysis programs employed in parametric vehicle sizing relationships to estimate dry and propellant weights for a Mars transfer vehicle and supporting orbital transfer vehicles. An elegant representation of dry weight scaling equations, boil-off calculations, and the rocket equation for estimating propellant requirements of a multistage, chemical propellant, impulsive maneuver scenario are represented by a system of simultaneous equations which are solved for propellant weights using Gaussian elimination. The results are used to reconstruct a comprehensive mass summary for each stage and the total vehicle.

Contact: Sandy Montgomery, SRS Technologies, 990 Explorer Blvd.NW, Cummings Research Park West, Huntsville, AL 35806 (205)895-7000.

Functional Capabilities: Currently, the program is set-up to model 29 mission events associated with a manned mission to Mars. Options include variable payload and drop weights, aerobraking and all-propulsive maneuvers, integral or OTV-delivered propulsive capabilities, propellant boil-off (passive insulation), midcourse and pre-& post-aerobraking alignment/ correction burns, and expendable or reusable hardware elements are modeled.

Recent Applications: Contract NAS8-36643 "Manned Mars Mission and Program Analysis" 1987-88.

Current Users: SRS Technologies, Systems Technology Div., Aerospace and Commercial Products Dept., Huntsville, AL.

Program Limitations: 1) Gravity losses not calculated, input through correction factors to specific impulse in rocket equation, 2) currently equations implemented for two stage direct mission, but modifiable, 3) relationship between linear dry weight scaling equation and exponential rocket equation makes solutions susceptible to instability for high ΔV's. , 4) only impulsive, high thrust chemical propulsion solutions, 5) Newtonian central force (point mass) gravity model (assumed by rocket equation), 6) only discrete events, and 6) all-up (not split) vehicle concepts only.

Enhancements in Progress: None.

Considered: 1) development of split mission version, 2) development of capsule reentry model, 3) development of lunar LOX version, 4) development of one, three, and four stage model, 5) storing common ΔV values for maneuvers in program rather than requiring them as inputs, and 6) integration as subroutine in trajectory optimization programs.

Check Appropriate Status

Status of Computer Codes	
Fully Operational	
Undergoing Validation	X
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	
Partial Documentation	
In Review	
Being Written	
Remarks - None	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks - TBD	

Portability Issues:

Languages: Microsoft Basic 2.0

Computer Hosts: Apple Macintosh (512K)

Terminal/Workstations Supported: Apple Macintosh

Graphics Capabilities: None

Output Options: Screen & file

User Interface Description: Uses Basic interpreter to change data statements
Some user input prompting

Other Interfaces Supported: Most other Macintosh software

Notes:

SOFTWARE DESCRIPTION

Program Name: Mars Mission Performance Evaluator (MMPE)

(Abbreviation):

Purpose: Enables rapid systematic evaluations of mass performance for a wide variety of piloted Mars missions.

Contact: Jim McAdams/SAIC
1701 E. Woodfield Rd., Suite 819
Schaumburg, IL 60173

Functional Capabilities: Vehicle mass and ΔV summaries provided for 48 Mars mission types. 48 mission types include any combination selected from two launch options, four recovery options, and six orbit capture options, which are as follows:

Launch Options:
-- Combined (one self-contained spacecraft with crew)
-- Split (Mars departure and Earth return propellant arrives at Mars before crew departs Earth orbit)

Recovery Options:
-- Earth Crew Capture Vehicle (ECCV) or Interplanetary Mission Modules (IMM) only
-- ECCV or IMM and Trans Mars Injection Stages

Orbit Capture Options
-- Aerocapture at Mars and/or Earth (propulsive capture used in place of aerocapture)
-- Aerocapture at Mars, direct entry at Earth
-- Propulsive capture at Mars, direct entry at Earth
-- Propulsive capture at Mars and Earth

Recent Applications: Spring 1988 - Software provided data in support of NASA's Office of Exploration at Johnson Space Center (Barney Roberts).

Current Users: Science Applications International Corporation (Schaumburg, IL)
Martin Marietta Astronautics (Littleton, CO)

Program Limitations:
Split Launch Option:
-- Common first stage is sized for use with both the cargo and piloted vehicles at trans Mars injection.
-- Primary function of cargo vehicle is transportation of:
1. All high ΔV propellant, tankage, and cooling system for the Mars to Earth piloted return trip.
2. Mars landed modules and operations equipment.
3. Mars ascent vehicle to Mars parking orbit prior to piloted vehicle launch.

Enhancements in Progress: Chemical propulsion model to be completed by late summer, 1988. Low-thrust NEP and SEP models to be completed by next year.

Check Appropriate Status

J. McAdams (MMPE)

Status of Computer Codes	
Fully Operational	
Undergoing Validation	
In Coding	X
Algorithms Only	
Remarks - Coding about 90% complete; testing reqd.	

Status of Documentation	
Fully Documented	
Partial Documentation	
In Review	
Being Written	X
Remarks -	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks - Microsoft Excel needed	

Portability Issues:

Languages: Excel

Computer Hosts: Macintosh SE with hard disk...minimum requirement
Macintosh II with hard disk...preferred

Terminal/Workstations Supported: n/a

Graphics Capabilities: n/a

Output Options: Tabular form output provided via dot matrix or laserjet printer.

User Interface Description: Mouse/pull-down menus (standard Macintosh)

Other Interfaces Supported: n/a

Notes:

SPACECRAFT SYSTEM & SUBSYSTEM PERFORMANCE & ENGINEERING

SDCM
RANKIN
CCEP
NUCBRAY
NUCSTIR
SOLSTIR
LUNAR WK.1
SP WK.1
COOLANT
SPASIS (See Planetary Orbital)
ECLSS Exp.

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SOFTWARE DESCRIPTION

Program Name:	Spacecraft Design/Cost Model.
(Abbreviation):	SDCM
Purpose:	To design spacecraft concepts given mission/performance requirements.
Contact:	Melvin J. Ferebee, Jr., MS 364, NASA, LaRC, Hampton, VA 23665, FTS 928-3440, (804)865-3440.
Functional Capabilities:	SDCM allows a user to define a set of mission, subsystem and equipment performance requirements and then perform a "bottoms-up" synthesis of a spacecraft by utilizing a comprehensive equipment database.
Recent Applications:	GPS Block II Spacecraft Validation (7/87) Space Station Polar Platform (6/86)
Current Users:	SSD/SAB NASA, LaRC
Program Limitations:	-- Limited to fidelity of equipment database. -- Equipment components must be ordered in ascending technical performance characteristics. -- Limited to Earth-orbiting systems. -- Reliability module omitted pending further enhancement--not a robust system!!
Enhancements in Progress:	None

Melvin J. Ferebee (SDCM)

Check Appropriate Status

Status of Computer Codes	
Fully Operational	
Undergoing Validation	X
In Coding	
Algorithms Only	
Remarks - Reliability Module Omitted	

Status of Documentation	
Fully Documented	
Partial Documentation	X
In Review	
Being Written	
Remarks -	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks -	

Portability Issues:

Languages: Fortran Requires RIM V.6 or 7

Computer Hosts: Prime, CYBER, DEC VAX

Terminal/Workstations Supported: All-no graphics output

Graphics Capabilities: None

Output Options: 3 Levels of output-System Performance Description
Subsystem Performance Description
Individual Component Performance Description

User Interface Description: Menu driven input editor/Database Editor

Other Interfaces Supported: Batch capable

Notes:

SOFTWARE DESCRIPTION

Program Name: RANKIN

(Abbreviation):

Purpose: Performance analysis of solar dynamic organic RANKIN cycle.

Contact: Robert Stochl, NASA, LeRC, (216)433-5403

Functional Capabilities: This program calculates thermodynamic conditions of each component in a Rankin cycle power system using toluene as the working fluid. The program utilizes a toluene property data base to determine thermodynamic properties such as enthalpy and entropy. An off-design capability has recently been added to examine system characteristics as a function of varying solar insolation. Component mass approximations are also included. The program is adaptable to nuclear or isotope heat sources.

Recent Applications: Space Station Work Package 4 Contract Source Evaluation Board (SEB) 8/87

Current Users: LeRC ASAO 6820
LeRC Space Station SE&I - 8510 (Bob Stoch)

Program Limitations: Configured only for sub-critical pressure boiling.

Enhancements in Progress: More detailed mass estimates
Analysis of other working fluids

L. Mason (RANKIN)

Check Appropriate Status

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	X
Partial Documentation	
In Review	
Being Written	
Remarks - Documentation will be complete in next several months.	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks - Gov't property	

Portability Issues:

Languages: Fortran

Computer Hosts: VM/CMS, IBM 370

Terminal/Workstations Supported: IBM 3270, Selanar Graphics

Graphics Capabilities: X-Y plots for off-design conditions

Output Options: Dependent on input parameters
Formatted output

User Interface Description: NAMELIST input

Other Interfaces Supported:

Notes:

SOFTWARE DESCRIPTION

Program Name:	Closed Cycle Engine Program
(Abbreviation):	CCEP
Purpose:	Closed Brayton cycle analysis program.
Contact:	John Klann, NASA, LeRC, (216)433-5404.
Functional Capabilities:	-- Brayton cycle component optimization and design code with off-design capability. -- Fluid property data base. -- Adaptable for nuclear reactor.
Recent Applications:	-- Space Station Work Package 4 Contract Review 8/87
Current Users:	LeRC Space Station Directorate (8500) LeRC ASAO (6820)
Program Limitations:	None
Enhancements in Progress:	Heat exchanger design routine.

Check Appropriate Status

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	
Partial Documentation	X
In Review	
Being Written	
Remarks -	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks - Gov't. property	

Portability Issues:

Languages: Fortran

Computer Hosts: VM/SP, VAX

Terminal/Workstations Supported: All

Graphics Capabilities: None

Output Options: Input dependent
Formatted output

User Interface Description: NAMELIST input

Other Interfaces Supported:

Notes:

SOFTWARE DESCRIPTION

Program Name:	NUCBRAY
(Abbreviation):	
Purpose:	Closed Brayton cycle with nuclear reactor
Contact:	Lee Mason, NASA, LeRC, (216)433-5394
Functional Capabilities:	-- Mass and performance of closed Brayton cycle as a function of turbine inlet temperature and compress or pressure ratio for given reactor thermal power. -- Graphics capability. -- Configured for SP-100 type reactor.
Recent Applications:	None
Current Users:	LeRC, ASAO (6820)
Program Limitations:	None
Enhancements in Progress:	None

Check Appropriate Status

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	
Partial Documentation	
In Review	
Being Written	
Remarks - None	

L. Mason (NUCBRAY)

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks - Gov't. property	

Portability Issues:

Languages: Fortran

Computer Hosts: VM/SP

Terminal/Workstations Supported: All

Graphics Capabilities: X-Y plots

Output Options: Formatted output

User Interface Description: NAMELIST input

Other Interfaces Supported:

Notes:

SOFTWARE DESCRIPTION

Program Name: NUCSTIR

(Abbreviation):

Purpose: Mass and performance of stiring cycle engine w/nuclear reactor

Contact: Lee Mason, NASA, LeRC, (216)433-5394

Functional Capabilities:

-- Electrical power and cycle efficiency as a function of temperature ratio for given reactor thermal power.
-- Component mass estimates.
-- Graphics capability.
-- Configured for SP-100 type reactor.

Recent Applications: Power system performance for nuclear electric propulsion studies (8/87 - current).

Current Users: LeRC, ASAO (6820)

Program Limitations: None

Enhancements in Progress: None

Check Appropriate Status

L. Mason (NUCSTIR)

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	
Partial Documentation	
In Review	
Being Written	
Remarks - None	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks - Gov't. property	

Portability Issues:

Languages: Fortran

Computer Hosts: VM/CMS

Terminal/Workstations Supported: All

Graphics Capabilities: X-Y plots

Output Options: formatted output

User Interface Description: NAMELIST input

Other Interfaces Supported:

Notes:

SOFTWARE DESCRIPTION

Program Name:	SOLSTIR
(Abbreviation):	
Purpose:	Mass and performance of solar dynamic stiring engine
Contact:	Lee Mason, NASA, LeRC, (216)433-5394
Functional Capabilities:	-- Electrical power and cycle efficiency as a function of temperature ratio. -- Solar insolation as a function of thermal energy storage salt. -- Component mass estimates -- Graphics capability -- Configured for LEO applications
Recent Applications:	Early Space Station solar dynamic comparisons 1984.
Current Users:	LeRC, ASAO (6820)
Program Limitations:	None
Enhancements in Progress:	None

Check Appropriate Status

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	
Partial Documentation	
In Review	
Being Written	
Remarks - None	

L. Mason (SOLSTIR)

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks - Gov't. property	

Portability Issues:

Languages: Fortran

Computer Hosts: VM/SP

Terminal/Workstations Supported: all

Graphics Capabilities: X-4 plots

Output Options: formatted output

User Interface Description: NAMELIST input

Other Interfaces Supported:

Notes:

SOFTWARE DESCRIPTION

Program Name: Photovoltaic Power Systems Summary - Lunar Mission Study

(Abbreviation): LUNAR.WK1

Purpose: Spreadsheet to compare model & system masses and specific mass.

Contact: Cheng-Yi Lu, LeRC, (216)433-6137
Mark Hickman, LeRC, (216)433-5394

Functional Capabilities: Compares various PV technologies with different storage options.
Allowed input parameters:

cell efficiency	storage mass
packing factor	storage PMAD efficiency
optical efficiency	array mass (kg/m^2)
eclipse to Sun ratio	PV PMAD efficiency
eclipse time (hours)	storage efficiency

Recent Applications: 6/9/88 reconfigured spreadsheet to approximate power system masses for Mars surface.

Current Users: ASAO/6820
Power Technology Division/5400

Program Limitations:

Enhancements in Progress:

Check Appropriate Status

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	
Partial Documentation	
In Review	
Being Written	
Remarks - no documentation	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks - public domain	

Portability Issues:

Languages: Lotus 1-2-3

Computer Hosts:

Terminal/Workstations Supported:

Graphics Capabilities:

Output Options:

User Interface Description:

Other Interfaces Supported:

Notes:

SOFTWARE DESCRIPTION

Program Name:	Solar Power
(Abbreviation):	SP.WK1
Purpose:	Compare PV vs. thermal and various hybrid systems
Contact:	Cheng-Yi Lu, LeRC, (216)433-6137 Mark Hickman, LeRC, (216)433-5394
Functional Capabilities:	For given input, will generate power system and component masses for solar PV, thermal, and hybrid systems.
Recent Applications:	
Current Users:	Advanced Space Analysis Office/6820 Power Technology Division/5400
Program Limitations:	
Enhancements in Progress:	

Check Appropriate Status

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	
Partial Documentation	
In Review	
Being Written	
Remarks - no documentation	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks - public domain	

Portability Issues:

Languages: Lotus 1-2-3

Computer Hosts:

Terminal/Workstations Supported:

Graphics Capabilities:

Output Options:

User Interface Description:

Other Interfaces Supported:

Notes:

SOFTWARE DESCRIPTION

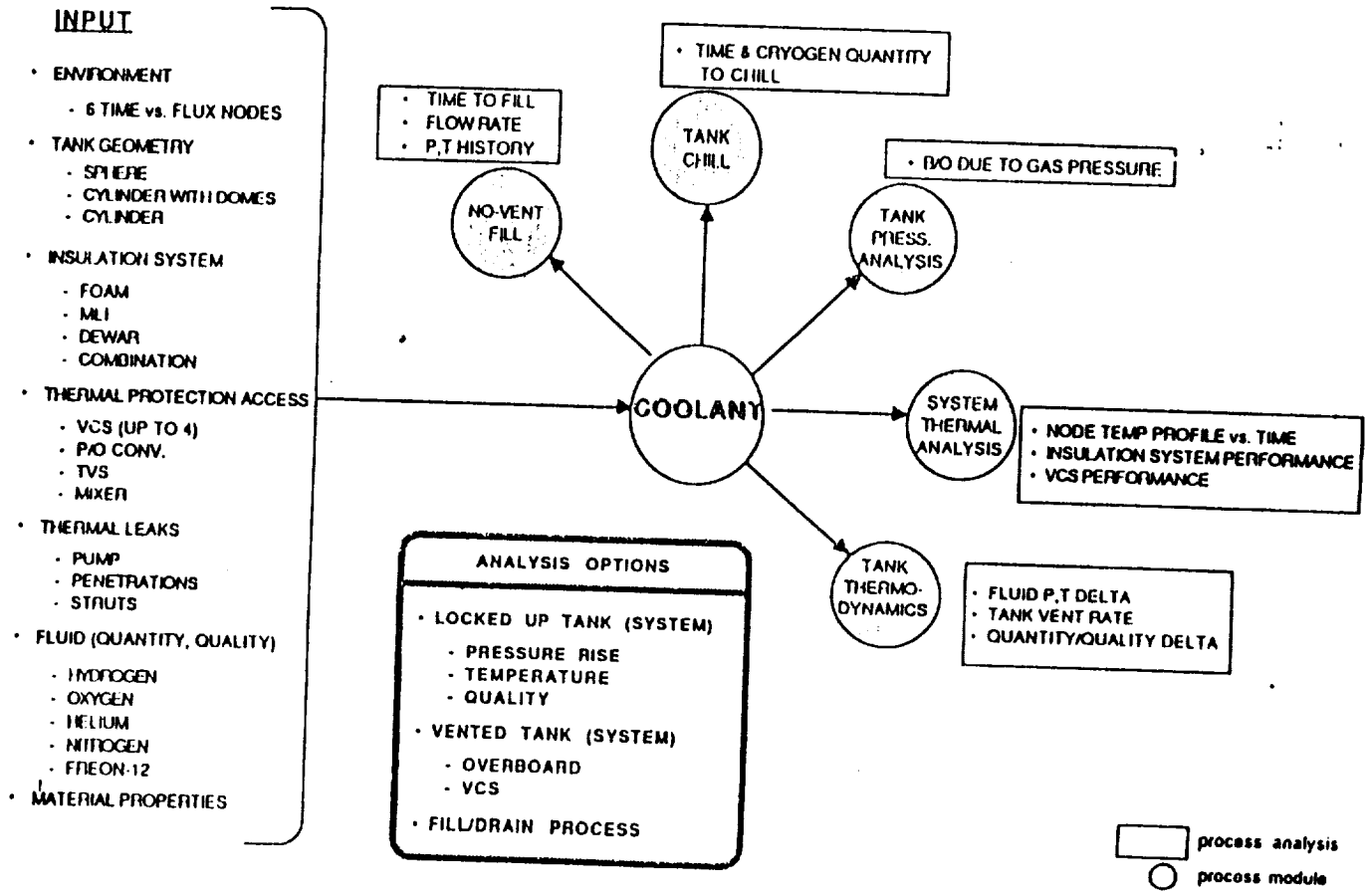
Program Name: Cryogenic On-Orbit Liquid Analytical Tool

(Abbreviation): COOLANT

Purpose: Evaluates performance characteristics of cryogenic storage depot systems.

Contact: Steve Tucker, PD22, Marshall Space Flight Center, Huntsville, AL 35812, (205)544-0500. FTS 824-0500.

Functional Capabilities:



Recent Applications: N/A

Current Users: N/A

Program Limitations: TBD

Enhancements in Progress: N/A

Check Appropriate Status

Status of Computer Codes	
Fully Operational	
Undergoing Validation	
In Coding	
Algorithms Only	X
Remarks -	

Status of Documentation	
Fully Documented	
Partial Documentation	
In Review	
Being Written	X
Remarks -	

S. Tucker (COOLANT)

Potential Cost to Acquire Program, $	
Program Software	TBD
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks -	

Portability Issues:

Languages: FORTRAN

Computer Hosts: DEC VAX/VMS

Terminal/Workstations Supported: VT 100

Graphics Capabilities: TBD

Output Options:

User Interface Description:

Other Interfaces Supported:

Notes:

SOFTWARE DESCRIPTION

Program Name:	Environmental Control Life Support System Technology Assessment Program
(Abbreviation):	ECLSS Expanded Version
Purpose:	To analyze integrated systems as well as separate technologies to evaluate possible advanced space systems.
Contact:	Wanda R. Parker, NASA LaRC, MS 364, Hampton, VA 23665, (804)865-4980.
Functional Capabilities:	To aid in the evaluation of candidate technology options which provide air revitalization, contaminant control, water reclamation, clothing, waste management, food, extravehicular activity, habitability, and oxidation of wastes for advanced space missions. The program is composed of menus to allow the user to change mission variables and update the technology data base in response to changing mission requirements.
Recent Applications:	Lunar base studies in conjunction with NASA Johnson Space Center--currently being used.
Current Users:	Rockwell, NASA/JSC, Battelee Corp., USRA Universities, Grumman PSC
Program Limitations:	
Enhancements in Progress:	Plans to convert program to run on a PC for ease in transport.

Check Appropriate Status

Wanda Parker

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	
Partial Documentation	
In Review	
Being Written	X
Remarks -	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	plt10
Data Base Software	RIM
Remarks -	

Portability Issues:

Languages: Fortran 77
Relational Information Management System RIMS Version 7
Plot10 Graphics Package

Computer Hosts: VAX 11/785
VMS Operating System

Terminal/Workstations Supported: Tektronix 4010

Graphics Capabilities: Bar Plots

Output Options: To the screen and can be saved in file

User Interface Description: Interactive Menu Driven

Other Interfaces Supported: None

Notes:

SURFACE SYSTEM & SUBSYSTEM PERFORMANCE & ENGINEERING

SHIELD
BRYNTRN
ECLSS Exp. (See Spacecraft System)
EXSUMNEW
GTHERM

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SOFTWARE DESCRIPTION

Program Name:	Shield
(Abbreviation):	
Purpose:	Radiation Shielding & Dosimetry Analysis
Contact:	John E. Nealy, MS 364, LaRC, Hampton, VA 23665, (804)865-4983.
Functional Capabilities:	-- Generation of predicted radiation fields within shielded configurations (both directional and integrated). -- Provides dosimetric quantities (rads and/or rem) in simulated human tissue for specified field of target points. (Uses data base generated with radiation transport code for given shield materials or composites.)
Recent Applications:	Lunar base solar flare radiation protection studies for regolith shields (Jan.-May '88).
Current Users:	SAB
Program Limitations:	-- Requires data base appropriate to specific materials. -- Complex geometries require user-supplied subroutine (or grid-point data describing shield geometries).
Enhancements in Progress:	Consolidation of analytic geometry algorithms with discrete grid-point code into single, option-driven program. (Dec. '88)

C-2

Check Appropriate Status

J. Nealy (Shield)

Status of Computer Codes	
Fully Operational	
Undergoing Validation	
In Coding	
Algorithms Only	X
Remarks -	

Status of Documentation	
Fully Documented	
Partial Documentation	
In Review	
Being Written	X
Remarks -	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks - IDL software cost ~$4K	

Portability Issues:

Languages: IDL and/or Fortran V

Computer Hosts: VAX, Cyber

Terminal/Workstations Supported:

Graphics Capabilities: 3-D directional dose patterns
Isodose contour maps in shielded configuration

Output Options: Printed/Graphic/Storage file
-- Interactive graphics option
-- Stored plot vector file options

User Interface Description:

Other Interfaces Supported:

Notes: IDL Versions more suitable for graphic output
Fortran Versions more suitable for numeric output

SOFTWARE DESCRIPTION

Program Name:	Baryon Transport Code
(Abbreviation):	BRYNTRN
Purpose:	Calculation of nucleon transport through material slabs for dosimetric predictions.
Contact:	J. W. Wilson, MS 493, LaRC, Hampton, VA (804)865-4211 L. W. Townsend, MS 493, LaRC, Hampton, VA (804)865-4223
Functional Capabilities:	-- Input options of discrete or continuous radiation fields descriptive of space radiation environment. -- Practically unlimited applicability regarding shield material composition; multilayer slab shields also optional. -- Efficient computational procedure conducive to parametric studies and data base generation.
Recent Applications:	-- Lunar regolith shield studies (Jan.-May '88). -- Aluminum/water shield effectiveness studies for solar flare protection (Mar. '88). -- Cosmic ray proton transport in simulated Martian atmosphere and polymeric material (Apr. '88).
Current Users:	LaRC (HESB, SAB); JSC (Planet & Space Sci. Lab.)
Program Limitations:	1-D slab transport only Limited LEO Applications (proton belts only)
Enhancements in Progress:	Addition of heavy ion transport for complete cosmic ray applications (Aug. '88).

Check Appropriate Status

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	
Partial Documentation	X
In Review	
Being Written	
Remarks -	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks -	

Portability Issues:

Languages: Fortran V

Computer Hosts: VAX, Cyber

Terminal/Workstations Supported:

Graphics Capabilities:

Output Options: Printed/Stored files

User Interface Description:

Other Interfaces Supported:

Notes:

SOFTWARE DESCRIPTION

Program Name:	ECLSS Integration Program
(Abbreviation):	EXSUMNEW Program
Purpose:	To evaluate pieces of equipment in spread sheet format.
Contact:	Wanda R. Parker, NASA LaRC, MS 364, Hampton, VA 23665, (804)865-4980.
Functional Capabilities:	A spread sheet format of the pieces of equipment for a 12-module system. The user has the capability of deciding which of the 12 modules will be in operation for the analysis. The program breaks down representative costs for such things as weight, volume, power, design development test and evaluation costs, and flight unit costs. These costs are broken down module by module, and the user is able to save the analsis and run a post processor that enhances these results through the use of bar plots and charts.
Recent Applications:	Lunar base system studies in conjunction with NASA Johnson Space Center--currently being used.
Current Users:	Rockwell, NASA/JSC, Battelle Corp., USRA Universities, Grumman PSC
Program Limitations:	
Enhancements in Progress:	Plans to convert program to run on a PC for ease in transport.

Wanda Parker (EXSUMNEW)

Check Appropriate Status

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	
Partial Documentation	X
In Review	
Being Written	
Remarks -	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	plt10
Data Base Software	RIM
Remarks -	

Portability Issues:

Languages: Fortran 77
Relational Information Management System RIMS Version 7
Plot10 Graphics Package

Computer Hosts: VAX 11/785
VMS Operating System

Terminal/Workstations Supported: Tektronix 4014

Graphics Capabilities: Bar Plots

Output Options: To the screen and the user has the option of saving analysis as a file

User Interface Description: Interactive Menu Driven

Other Interfaces Supported: None

Notes:

SOFTWARE DESCRIPTION

Program Name: Emulation-Simulation Thermal Control Model

(Abbreviation): GTHERM

Purpose: To evaluate active thermal control technologies for Space Station, other orbiting spacecraft, and planetary applications.

Contact: John B. Hall, MS 364, NASA Langley Research Center, Hampton, VA 23666, 804-865-4971

Functional Capabilities: Techniques for the acquisition, transport, and rejection of heat can be evaluated. Currently there are nine options available which include both single-phase and two-phase operation. Each option is sized according to user specified mission model parameters and design loads. These include variables such as mission duration, resupply interval, power penalty, and metabolic and equipment heat loads. User supplied system specifications include working fluid, operating temperature, and material selections, the number of cold plates, internal and external line lengths, and an autonomous or integrated system design. These inputs are then used to size each option selected using basic heat transfer laws, optimization subroutines minimizing weight and power, and a database which includes resupply and costing information. The results include weight, volume, power, resupply, and costs associated with each individual option selected as well as the integrated system total. In addition, an optional detailed design output file can be examined by the user. The detailed design specifications include fluid properties, heat exchanger sizing details, pipe specifications, and equipment pressure drops.

Recent Applications: The program has been used to size different lunar base thermal control systems (1988).

Current Users: GTHERM is still under development and in the process of being validated. To date, the only users are Georgia Institute of Technology and the Spacecraft Analysis Branch at Langley.

Program Limitations: The sizing subroutines for some of the more advanced technologies, such as the liquid droplet radiator and capillary cold plate, require further modifications.

Enhancements in Progress: Graphic options, output summary tables, and ranking techniques are being considered. Anticipated completion date--late 1988.

Check Appropriate Status

John B. Hall

Status of Computer Codes	
Fully Operational	
Undergoing Validation	X
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	X
Partial Documentation	
In Review	
Being Written	
Remarks -	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks -	

Portability Issues:

Languages: Fortran 77

Computer Hosts: NOS

Terminal/Workstations Supported: Any terminal that scrolls.

Graphics Capabilities: None

Output Options: Output is viewed directly on the screen. Output files can be saved. A local file is also generated which includes data that cannot be called from the program.

User Interface Description: Interactive menu driven

Other Interfaces Supported: None at present.

Notes:

OPERATIONS SIMULATION & COSTING

Mission Capture
SODS
STOPS
MSCOST
OPSMODEL
THURIS

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SOFTWARE DESCRIPTION

Program Name:	Mission Capture Program
(Abbreviation:)	
Purpose:	Manifesting payloads on a launch vehicle.
Contact:	Andrew J. Petro, ED 23, NASA Johnson Space Center, Houston, TX 77058, FTS 525-6622, (713)483-6622
Functional Capabilities:	Given an input file with payload data, program will sort payloads by year of launch and inclination, add upper stages as needed, and fit payloads into user defined payload bays as efficiently as possible, accounting for length, width, height, and mass of the payloads and upper stages.
Recent Applications:	Shuttle II payload accommodation studies. Civil needs data base (Spring, 1987). Space Station transportation studies (Summer, 1986).
Current Users:	NASA JSC, ED 23 Advanced Programs Office
Program Limitations:	Currently, only one type of launch vehicle can be used.
Enhancements in Progress:	None currently planned.

Check Appropriate Status

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	X
Partial Documentation	
In Review	
Being Written	
Remarks -	

Andrew J. Petro (Mission Captur

Potential Cost to Acquire Program, $	
Program Software	-
Math Libraries	-
Graphics Libraries	-
Data Base Software	-
Remarks -	

Portability Issues:

Languages: Fortran

Computer Hosts: DEC VAX

Terminal/Workstations Supported:

Graphics Capabilities: None

Output Options: Tabular Data

User Interface Description: Input file (payload data)
Terminal prompts

Other Interfaces Supported:

Notes:

SOFTWARE DESCRIPTION

Program Name:	Space Applications Decision Support Model
(Abbreviation):	SODS
Purpose:	To evaluate the effectiveness of alternative space transportation systems, on-orbit maintenance options, and payload configuration choices.
Contact:	W. Douglas Morris, LaRC, MS 365, (804)865-2768
Functional Capabilities:	Runs Monte Carlo simulations of operating scenarios to evaluate their effectiveness in terms of traffic statistics, number of payload failures, and life cycle cost.
Recent Applications:	
Current Users:	
Program Limitations:	
Enhancements in Progress:	

Check Appropriate Status

D. Morris (SODS)

Status of Computer Codes	
Fully Operational	
Undergoing Validation	X
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	X
Partial Documentation	
In Review	
Being Written	
Remarks -	

Potential Cost to Acquire Program, $	
Program Software	0
Math Libraries	0
Graphics Libraries	0
Data Base Software	0
Remarks -	

Portability Issues:

Languages: Requires Lotus software

Computer Hosts: PC/MS DOS Compatibles

Terminal/Workstations Supported: PC/MS DOS Compatibles

Graphics Capabilities: Lotus

Output Options: Screen or print or files

User Interface Description: Friendly

Other Interfaces Supported:

Notes:

SOFTWARE DESCRIPTION

Program Name:	Space Transportation Operations Model
(Abbreviation):	STOPS
Purpose:	To assess the operational support requirements of a space transportation system.
Contact:	W. Douglas Morris, LaRC, MS 365, (804)865-2768
Functional Capabilities:	Discrete event simulation modeling of user defined scenarios required to support different missions. Output is in terms of transportation system support requirements.
Recent Applications:	
Current Users:	LarC
Program Limitations:	
Enhancements in Progress:	

Check Appropriate Status

D. Morris (STOPS)

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	X
Partial Documentation	
In Review	
Being Written	
Remarks -	

Potential Cost to Acquire Program, $	
Program Software	0
Math Libraries	0
Graphics Libraries	0
Data Base Software	0
Remarks -	

Portability Issues:

Languages: SLAM, FORTRAN

Computer Hosts: PC/VAX/others

Terminal/Workstations Supported: PC/VAX/Others

Graphics Capabilities: Limited

Output Options:

User Interface Description:

Other Interfaces Supported:

Notes:

SOFTWARE DESCRIPTION

Program Name: Mars Sizing-Cost Estimator

(Abbreviation): MSCOST

Purpose: Uses vehicle masses supplied by other programs (specifically developed to use inputs from MSMASS) employed in parametric cost estimating relationships to provide life cycle for a manned Mars mission program consisting of single or multiple missions and expendable or reusable hardware concepts.

Contact: Sandy Montgomery, SRS Technologies, 990 Explorer Blvd., NW, Cummings Research Park West, Huntsville, AL 35806 (205)895-7000.

Functional Capabilities: Elements considered are the Mars transfer vehicle, supporting orbital transfer vehicles, LEO assembly node, launch vehicles, and launch facilities. Cost structure includes DDT&E, production, and operations costs. Production costs based on input learning curve. Launch, mission control, and on-orbit servicing operations modeled. For each phase, CERS are available for different hardware types (manned modules, propulsive stages, launch vehicles, instruments, servicing hardware, etc.). CERS are a power function of weight. Cost in millions of 1985 dollars. MASCOST based on applicable portions of the NASA program cost model (NAPCOM).

Recent Applications: Contract NAS8-3664 "Manned Mars Mission and Program Analysis" 1987-88: 1) Used to establish the impacts on a three mission program cost of reusable propulsive stage concepts, 2) Used in a number of trade studies to investigate cost leverage of technology and trajectory options on MTV stage reuse:-- aerobraking versus all propulsive, -- OTV-delivered services versus MTV provided, -- aerobraking versus close orbital transfer, versus high apogee maneuver,versus Mars flyby recovery trajectories of first stage, -- combinations of expending or reusing first stage, second stage, and portions of the payload.

Current Users: SRS Technologies, Systems Technology Div., Aerospace & Commercial Products Dept., Huntsville, AL.

Program Limitations: 1) First order cost approximations useful for assessing engineering design alternatives. Not suitable for detail program cost estimate. Costs not spread, no specific wrap-around. 2) Complexity factor on DDT&E cost requires subjective judgement and/or external verification. 3) Weight of refurbishment masses and launch facility requirements must be input and justified externally. 4) On-orbit build-up sequence must be derived and justified externally. 5) Currently set-up for all-up (not split), two-stage chemical propulsion vehicle concepts only, but modifiable.

Enhancements in Progress: None

Considered: 1) Addition of routine to optimize build-up sequence based on cost within the constraints of time available for build-up and ETO infrastructure, 2) Inclusion within "merit factor" analysis routines for commonality cost/risk assessments, 3) Integration with trajectory optimization routines and MSMASS to produce end-to-end program hardware optimization tool.

Check Appropriate Status

Status of Computer Codes	
Fully Operational	
Undergoing Validation	X
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	
Partial Documentation	
In Review	
Being Written	
Remarks - None	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks - TBD	

Portability Issues:

Languages: MICROSOFT Basic 2.0

Computer Hosts: Apple Macintosh

Terminal/Workstations Supported: Apple Macintosh

Graphics Capabilities: None

Output Options: Screen & file

User Interface Description: Mod to data statements through basic interpreter functions
Some user prompting

Other Interfaces Supported: Most other Macintosh software

Notes:

SOFTWARE DESCRIPTION

Program Name:	Space Station On-Orbit Operations Model
(Abbreviation):	OPSMODEL
Purpose:	Operations modeling and analysis of on-orbit Space Station crew operations.
Contact:	William T. Davis, MS 364, NASA Langley Research Center, Hampton, VA 23665 (804)865-4984
Functional Capabilities:	The program uses the concept of table (data base) driven simulation (i.e., separate the simulation program from the user-defined problem to be analyzed or data base) to provide a simulated operation laboratory where user defined scheduled operations execute within user-defined resource and priority constraints.
Recent Applications:	None - in final checkout
Current Users:	NASA-LaRC-SSD-SAB
Program Limitations:	No major limitations
Enhancements in Progress:	Graphical display operations status

Check Appropriate Status

Status of Computer Codes	
Fully Operational	
Undergoing Validation	X
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	
Partial Documentation	X
In Review	
Being Written	
Remarks - some up-to-date some not up-to-date	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks -	

Portability Issues:

Languages: FORTRAN, SIMSCRIPT II, RBASE 5000

Computer Hosts: PC XT/AT

Terminal/Workstations Supported:

Graphics Capabilities: (See "enhancements in progress")

Output Options: Tabular engineering performance data
Tabular cost performance data
Time tagged event log

User Interface Description: Interactive templates via PC keyboard

Other Interfaces Supported:

Notes:

SOFTWARE DESCRIPTION

Program Name:	The Human Role In Space
(Abbreviation):	THURIS
Purpose:	Determine cost-effective man/machine allocations.
Contact:	Stephen Hall/NASA MSFC/PD24/205-544-0517
Functional Capabilities:	o Considers three fundamental allocation factors: support equip. costs, performance requirements, and technology readiness. o THURIS calculates costs for implementing man/machine mode generated tabular and graphic cost-effectiveness outputs, and generates technology tables and displays. o THURIS outputs provide the user the capability to select cost-effective man/machine modes for a specified mission application.
Recent Applications:	Validation scenarios based on operations involving the Orbital-Maneuvering Vehicle (OMV), Orbital Transfer Vehicle (OTV), Space Station Research Laboratory Modules, and a geosynchronous orbit platform concept.
Current Users:	
Program Limitations:	
Enhancements in Progress:	

Check Appropriate Status

Stephen Hall(THURIS)

Status of Computer Codes	
Fully Operational	?
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	?
Partial Documentation	?
In Review	
Being Written	
Remarks -	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks -	

Portability Issues:

Languages: Cost model program is in BASIC. Equipment Availability Display is in BASICA. THURIS Technology Readiness Database is in Ribase 5000.

Computer Hosts: PC (clone)

Terminal/Workstations Supported:

Graphics Capabilities:

Output Options: Relative costs for all man/machine modes-tabular and graphic technology research info., support equipment/facility definition tables, equipment availability display.

User Interface Description: User inputs: mission data (i.e., task descriptions, performance times, task repetitions, date of initial operational capability), cost model changes (i.e., equipment complement, equip. allocation, cost & performance estimates) if required.

Other Interfaces Supported:

Notes: Potential use by the Major 1--space Operations SAA, Robert C. Trevino, NASA/JSC DF42 FTS 525-2597

OTHER DISCIPLINE

SHIELD (See Surface Systems)
BRYNTRN (See Surface Systems)
TRANSLATOR
SFPLIMP 3.2
WTRAJ
GAAP
TGAP

Worksheets Not Available

CFD
NASTRAN
EAL
IDEAS
Thermal Analyzer
SSPTA
TRASYS/SINDA
NASTRANTA

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SOFTWARE DESCRIPTION

Program Name:	Translator
(Abbreviation):	
Purpose:	File Translator
Contact:	Ed Limoge, PD22, Marshall Space Flight Center, Huntsville, AL 35812, (205)544-0502, FTS:824-0502
Functional Capabilities:	Translates COSMIC NASTRAN files to MOVIE-BYU format.
Recent Applications:	N/A
Current Users:	N/A
Program Limitations:	N/A
Enhancements in Progress:	N/A

Check Appropriate Status

E. Limoge (Translator)

Status of Computer Codes	
Fully Operational	
Undergoing Validation	X
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	
Partial Documentation	
In Review	
Being Written	X
Remarks -	

Potential Cost to Acquire Program, $	
Program Software	None
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks -	

Portability Issues:

Languages: FORTRAN 77

Computer Hosts: DEC VAX/VMS

Terminal/Workstations Supported: 4014 graphics and compatibles

Graphics Capabilities: None

Output Options: Screen

User Interface Description:

Other Interfaces Supported:

Notes:

SOFTWARE DESCRIPTION

Program Name:	Source Flow Plume Impingement Program Version 3.2
(Abbreviation):	SFPLIMP 3.2
Purpose:	To compute forces, moments, contamination, and heating rates on an object due to the impinging exhaust plume of a jet.
Contact:	Mary P. Cerimele, NASA-JSC, Mail Code ED2, Houston, TX 77062, (713)483-6621.
Functional Capabilities:	Contaminant deposition rates and evaporation rates are modeled for each side of the object. Forces and moments are computed for continuum, transition, and free molecular flow. Continuum region enhanced by incorporating data tables for orbiter PRCS and VRC. Impact theories supported: Newtonian, modified Newtonian and corrected, modified Newtonian.
Recent Applications:	Analysis of plume effects from the solid rocket booster-booster separation motors (SRB-BSM) on the orbiter external tank during 51-S mission. (Photos showed some ET charring).
Current Users:	JSC Advanced Programs Office, JSC Systems Engineering Simulator, JSC Propulsions Division.
Program Limitations:	Up to 40 jets can be analyzed. Shadowing effects are not considered. Static simulation--forces, moments, etc. are not integrated over time. For vacuum environments.
Enhancements in Progress:	None

Check Appropriate Status

M. Cerimele (SFPLIMP 3.2)

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	
Partial Documentation	X
In Review	
Being Written	
Remarks -	

Potential Cost to Acquire Program, $	
Program Software	0
Math Libraries	0
Graphics Libraries	?
Data Base Software	
Remarks -	

Portability Issues:

Languages: FORTRAN 77

Computer Hosts: VAX 8650, HARRIS

Terminal/Workstations Supported:

Graphics Capabilities: Will produce color contour plots of plume characteristics on the object, if interfaced to IDEAS^2, will produce a picture of the object the user inputs as a check.

Output Options: 1) Forces and moments only, 2) F&M and contamination results, 3) F&M and contamination and heating rates, and 4) Output to screen and files or just to files.

User Interface Description: 2 input data files. One to define the object, and one to define the jet.

Other Interfaces Supported: Interfaced to the IDEAS^2 package resident at JSC's Advanced Programs Office. (IDEASAPO)

Notes:

SOFTWARE DESCRIPTION

Program Name:	WTRAJ
(Abbreviation):	
Purpose:	Aerobraking trajectory simulation
Contact:	Steve Alexander, LeRC, FTS 297-5377
Functional Capabilities:	-- aeroglide capabilities -- multiple atmospheric models This program will be used to do quick studies. It is very easy to use and provides quick answers with reasonable accuracy.
Recent Applications:	Aerobraking studies
Current Users:	Program written by John Wilson at ARC (FTS 464-6204)
Program Limitations:	Does not optimize
Enhancements in Progress:	-- plotting capabilities on PC (7/88) -- conic calculation (7/88)

Check Appropriate Status

S. Alexander (WTRAJ)

Status of Computer Codes	
Fully Operational	
Undergoing Validation	X
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	
Partial Documentation	
In Review	
Being Written	
Remarks - None	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks -	

Portability Issues:

Languages: Fortran

Computer Hosts: VAX

Terminal/Workstations Supported:

Graphics Capabilities: Download data to PC graphic package

Output Options:

User Interface Description:

Other Interfaces Supported:

Notes:

SOFTWARE DESCRIPTION

Program Name:	GAAP
(Abbreviation):	
Purpose:	To compute spacecraft injection accuracy.
Contact:	Gary Bollenbacher, NASA, LeRC, 21000 Brookpark Rd., Cleveland, OH 44135
Functional Capabilities:	Computes S/C orbit injection errors caused by INS hardware inaccuracies. Also, simulates the effect of external state vector updates, attitude updates, or in-flight accelerometer bias calibration.
Recent Applications:	Accuracy analyses for Shuttle/Centaur (1985) and several interplanetary missions (1987-1988)
Current Users:	NASA-LeRC, Software Engineering Office (4010)
Program Limitations:	Limited to simulating gimballed inertial navigation systems.
Enhancements in Progress:	Incorporation of Strapdown and Carouselling INS.

Check Appropriate Status

G. Bollenbacker (GAAP)

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	
Partial Documentation	X
In Review	
Being Written	
Remarks - Only limited documentation available	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks -	

Portability Issues:

Languages: Fortran

Computer Hosts: Cray

Terminal/Workstations Supported:

Graphics Capabilities: None

Output Options: Various coordinate systems and units.

User Interface Description: Batch

Other Interfaces Supported:

Notes:

SOFTWARE DESCRIPTION

Program Name:	TGAP
(Abbreviation):	
Purpose:	Verification of Atlas/Centaur guidance and navigation software
Contact:	Clarence Pierce, NASA, LeRC, MS 11-2, Cleveland, OH 44135, FTS 297-2281
Functional Capabilities:	Provides a 3-degree-of-freedom simulation of the Atlas/Centaur combination for flight trajectory analysis and software verification.
Recent Applications:	AC-68 software verification (1987)
Current Users:	Lewis Research Center
Program Limitations:	Program is limited to 3 degrees of freedom (simple response to steering commands).
Enhancements in Progress:	None

Check Appropriate Status

C. Pierce (TGAP)

Status of Computer Codes	
Fully Operational	X
Undergoing Validation	
In Coding	
Algorithms Only	
Remarks -	

Status of Documentation	
Fully Documented	X
Partial Documentation	
In Review	
Being Written	
Remarks -	

Potential Cost to Acquire Program, $	
Program Software	
Math Libraries	
Graphics Libraries	
Data Base Software	
Remarks -	

Portability Issues:

Languages: FORTRAN 77

Computer Hosts: CRAY XMP

Terminal/Workstations Supported: All

Graphics Capabilities: None

Output Options: Trajectory data at selected flight intervals. Software simulation data at selected flight intervals.

User Interface Description: Batch submission to Cray using VM/370 on AMDAHL as front-end and COS.

Other Interfaces Supported: Considering use of UNICOS for job execution.

Notes:

INTEGRATED SYSTEMS

IDEAS (flowchart only)
IDEAS^2 (flowchart only)
SMART (See Vehicle Systems)

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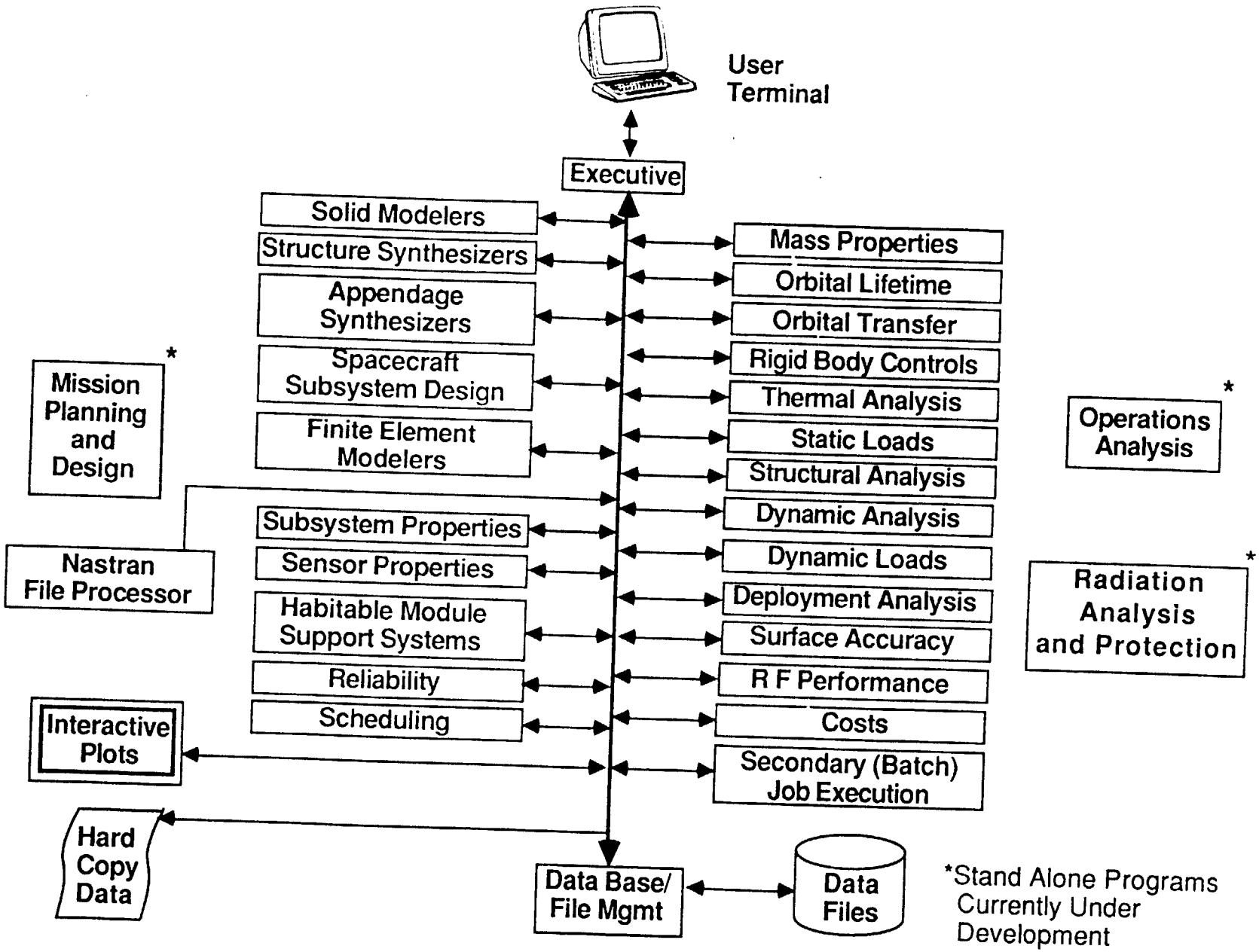
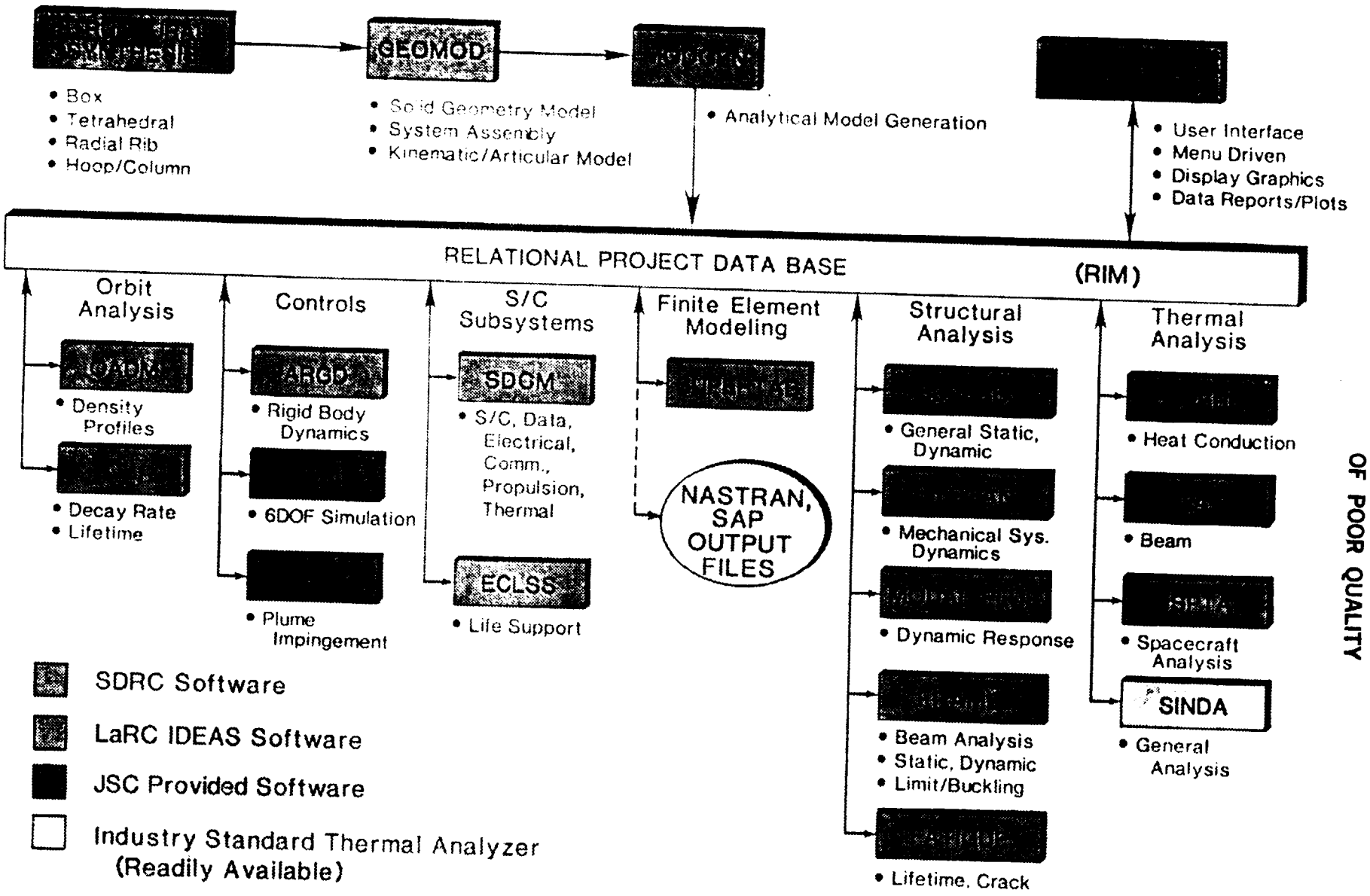
IDEAS SOFTWARE



NASA IDEAS/SDRC I-DEAS INTEGRATED CAPABILITY



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APPENDIX C

ANALYSIS TOOLS WORKSHOP FOR
INTEGRATION AND SPECIAL ASSESSMENT AGENTS
INTRODUCTION

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ANALYSIS TOOLS WORKSHOP FOR INTEGRATION AND SPECIAL ASSESSMENT AGENTS

Held at Langley Research Center
June 21-22, 1988

Ames Research Center

Jet Propulsion Laboratory

Johnson Space Center

Langley Research Center

Lewis Research Center

Marshall Space Flight Center

Flight Mechanics and Controls

SRS Technologies

Science Applications International Corporation

OBJECTIVES

- Identification of Software Tools Available and Needed
  - Interplanetary Trajectory Analysis
  - Planetary Orbital Analysis
  - Reentry/Aerobraking Analysis
  - Vehicle System and Subsystem Performance and Engineering Analysis
  - Spacecraft System and Subsystem Performance and Engineering Analysis
  - Surface System and Subsystem Performance and Engineering Analysis
  - Other Disciplines Analysis Tools
  - Operations Simulation and Costing Programs?
- Make Arrangements for Software Transfers as Appropriate
- Identification of Lead Centers/Contractors for Supporting Analysis
- Strategy/Approach to Modifications and New Software Development

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SOME PROPOSED GUIDELINES FOR IA/SAA SOFTWARE

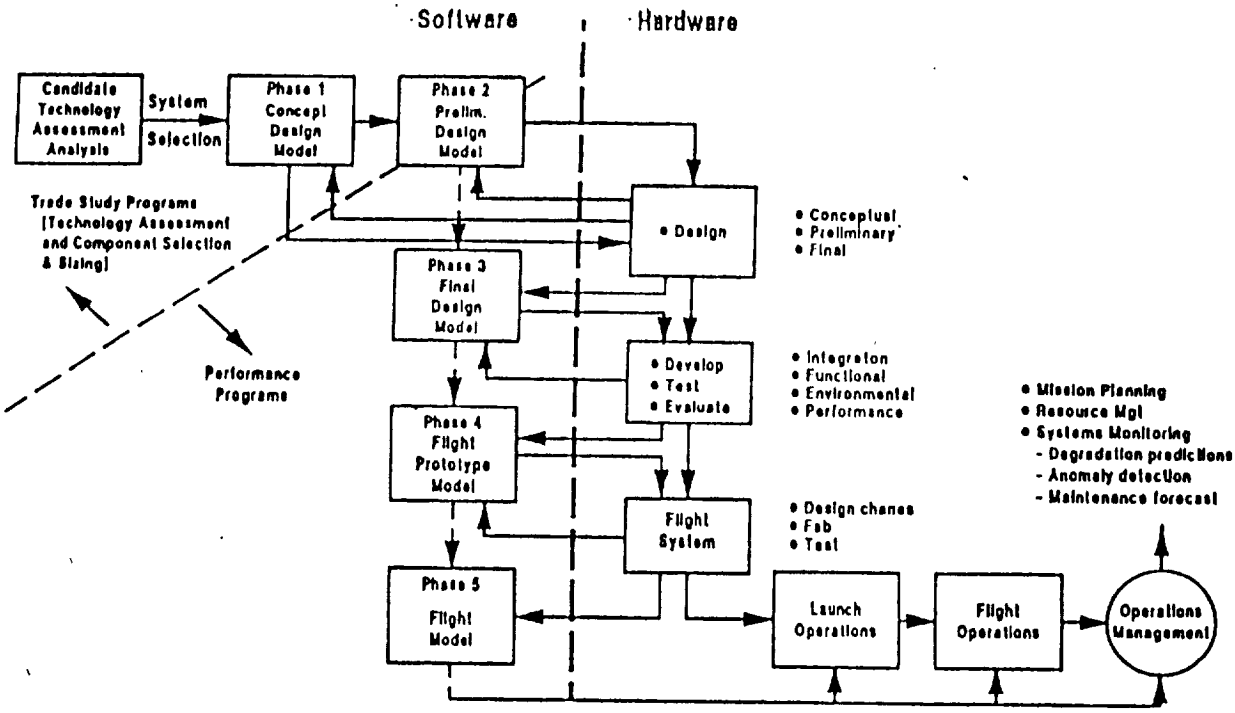
We Are in the Early Mission and Conceptual Design Phases of OEXP's Program

- Early Software Tools Should Fully Support This Phase
  - Initial Emphasis of workshop is on Individual Programs
  - Should Address Integrated Systems Analysis Also

- Must Penetrate the Subsystems to the Depth Required to Focus the Technology Development Programs of the Other NASA Offices

- Make a Conscious Effort to "Earmark" But Defer Certain Software for Later Phases in the Program

APPLICATION OF SOFTWARE TOOLS TO THE DESIGN AND OPERATIONAL PHASES OF A FLIGHT SYSTEM



APPENDIX D

ORBITAL NODES INTEGRATION AGENT'S TASKS AND SOFTWARE TOOLS

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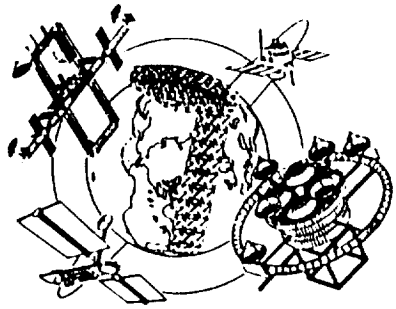
• SAB • SSD • LaRC •



SPACECRAFT

ANALYSIS

BRANCH

ORBITAL NODES INTEGRATION AGENTS TASKS AND SOFTWARE TOOLS

L. B. GARRETT

Table 3.4-2 OEXP Managed Studies

WBS	Task	Responsible Organization
2.1	**Mission Analysis and Synthesis Support** • Scenario(s) Development and Definition • Top Level Architecture and Trade Studies (nodes, transportation, surface systems, mission techniques) • Requirements definition and partitioning • Science and engineering precursor requirements analysis (JPL) • Requirements integration/bookkeeping • Results synthesis/bookkeeping (technical and programmatic) • Analysis and data base support (LaRC) • Commonality assessment and leverage • Incorporation of Special Assessment results	JSC
2.2	**Space Transfer Vehicle Integration** • Configuration definition and integration • Integrated transfer vehicle configuration analysis • Vehicle element definitions and trades • Vehicle element descriptions (including cost) • Personnel carriers (Human Capsules) definition (JSC) • Integration of special assessment results	MSFC
2.3	**Orbital Node Analysis and Integration** • Node requirements collection and synthesis • Node integrated analysis (LEO, GEO, LO, MO, etc.) • Assembly and turnaround integrated assessment • Propellent depot definition/analysis support (LeRC) • Node element descriptions (including cost) • Integration of special assessment results	LaRC

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ORBITAL NODES SOFTWARE

- Mission Design/Trajectory Programs
- Orbital Mechanics
- Spacecraft Design
- Subsystem Assessment
- Discipline Analysis
- Operations Simulation

SOFTWARE FOR ORBITAL NODES IA

a) Operational at LaRC

Category	Operational Software at LaRC
Mission Design/Trajectory Programs	Quicktop III, SWISTO, SODA (E)
Orbital Mechanics	Post (E,M), ARCD (E), Orbital Lifetime (E)
Spacecraft Design	Spacecraft Design and Cost Model (E)
Subsystem Assessment	ECLSS (E,M,L), Emulation-Simulation Thermal Control Model (E,M,L)
Disciplines Analysis	Structures (IDEAS^2, NASTRAN, EAL) Thermal (TA, SSPTA, TRASYS/SINDA) Radiation (Bryntrn,Shield) Entry CFD and Aerodynamic Heating Assembly (Adams)
Planetary Models Data Base	Solar Flare, Cosmic Radiation (Bryntrn)
Integrated Engineering and Analysis*	IDEAS, IDEAS^2, SMART, IMAT

Current Applicability: (E) Earth, (M) Mars, (L) Lunar
* Applicable Principally to Earth Vehicles and Spacecraft

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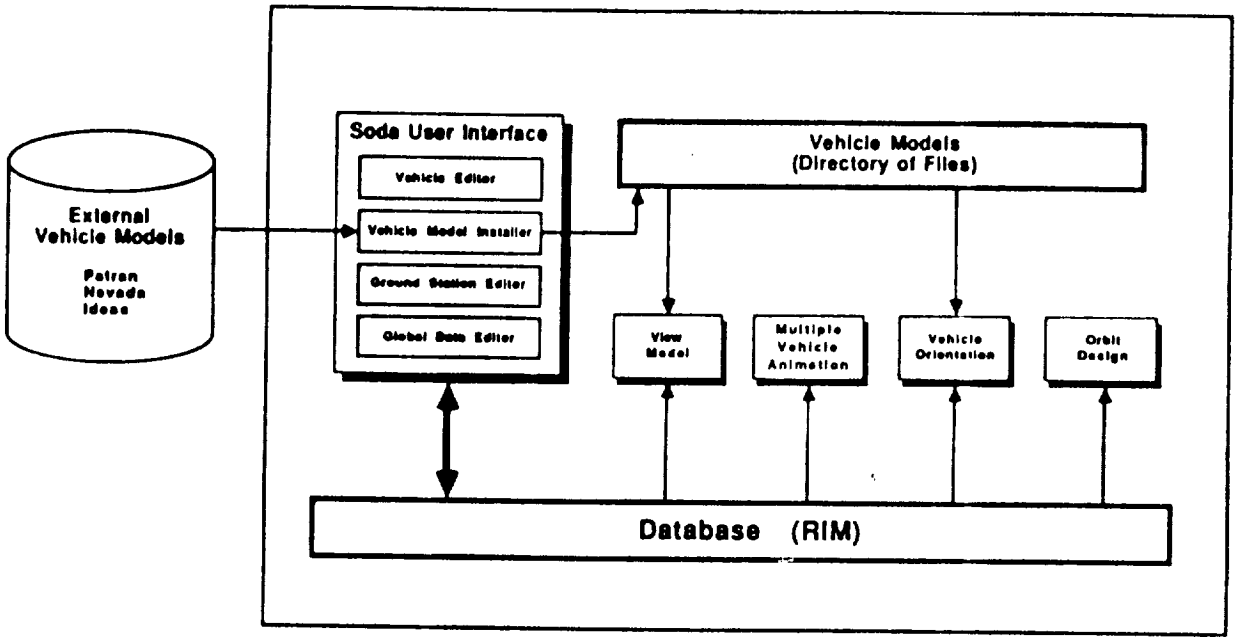
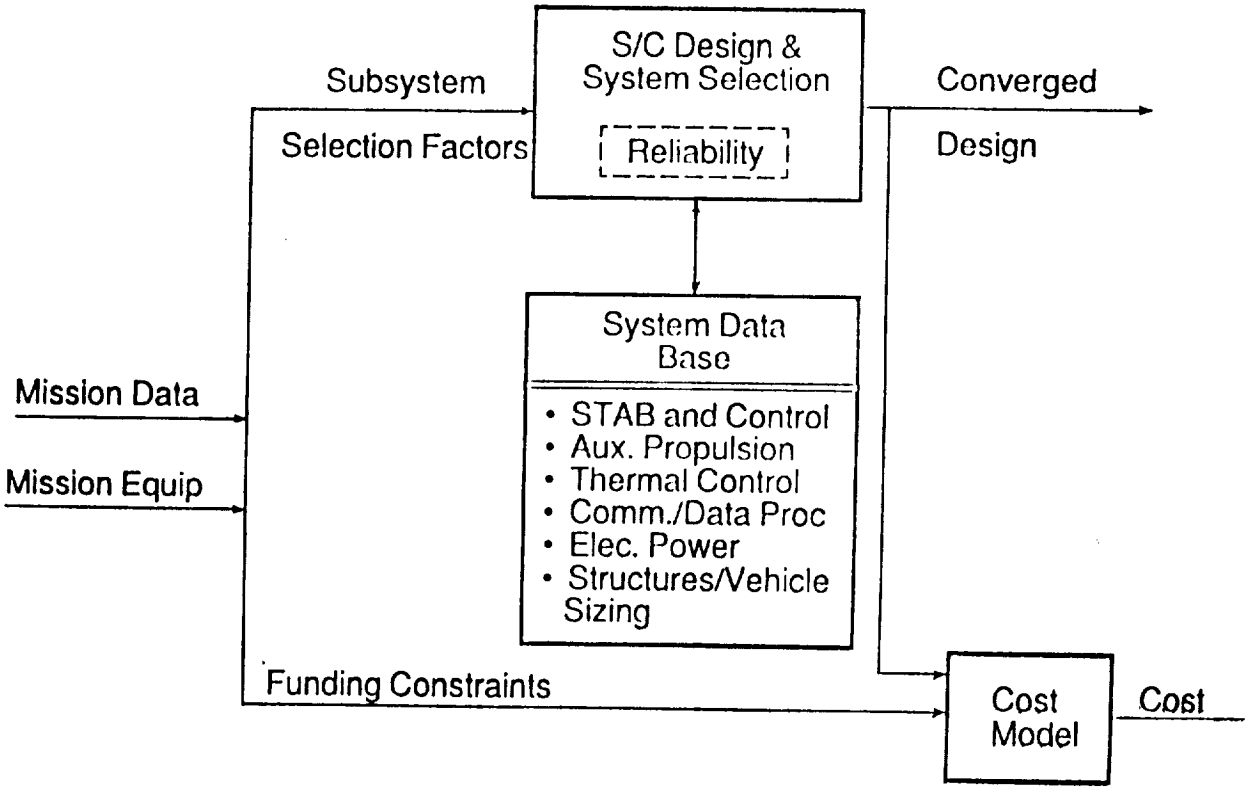
Spacecraft Orbit Design and Analysis (SODA)



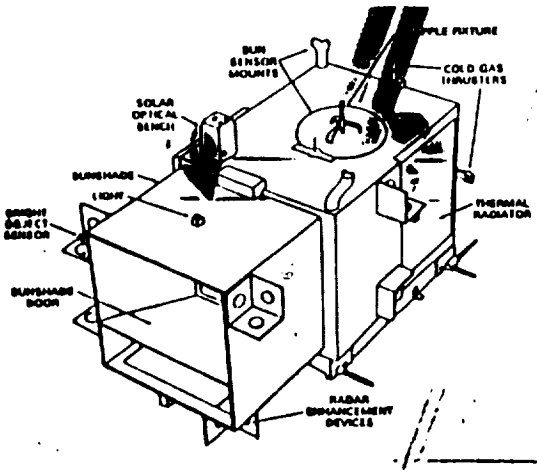
SPACECRAFT DESIGN & COST MODULE OVERVIEW



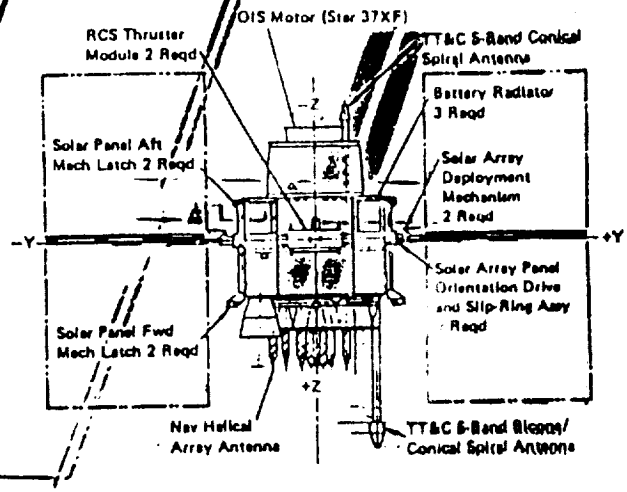
SPACECRAFT DESIGN AND COST MODEL

Verification Using Existing Spacecraft

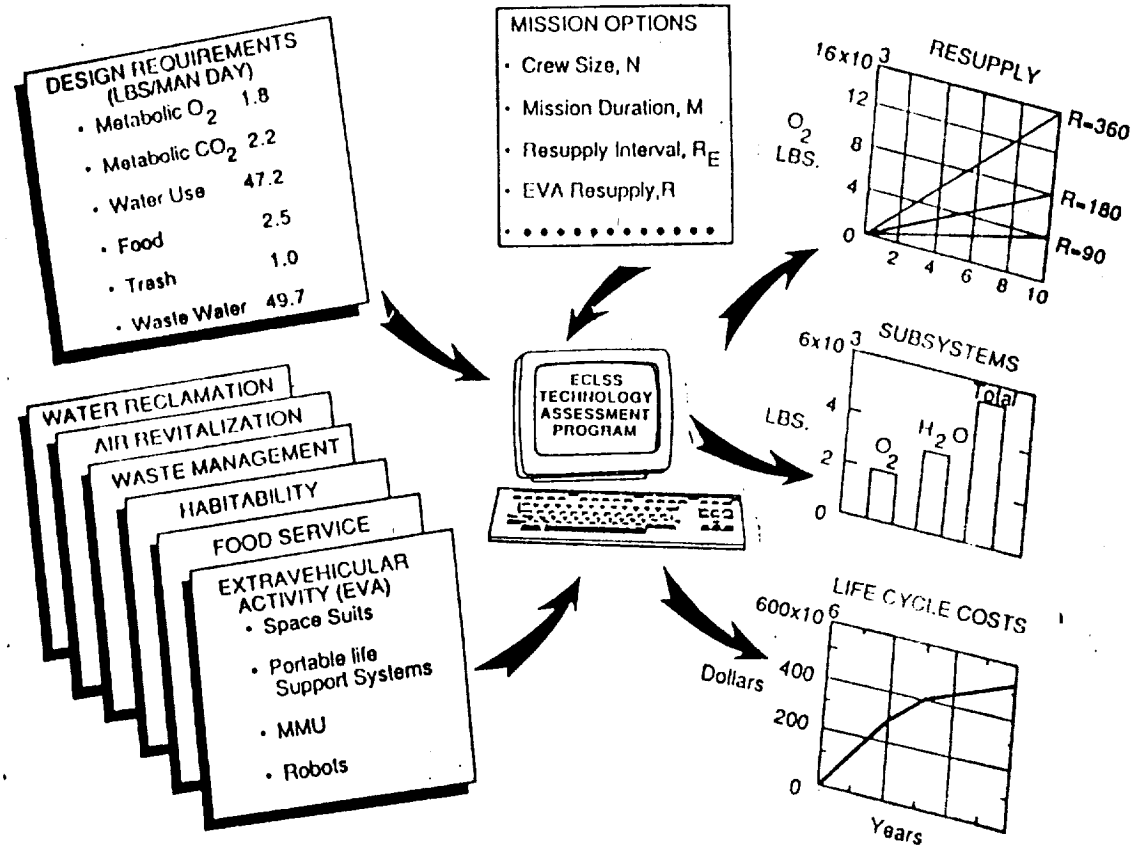
SPARTAN



GLOBAL POSITIONING SATELLITE



ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM (ECLSS) COMPUTER AIDED TECHNOLOGY ASSESSMENTS PROGRAM



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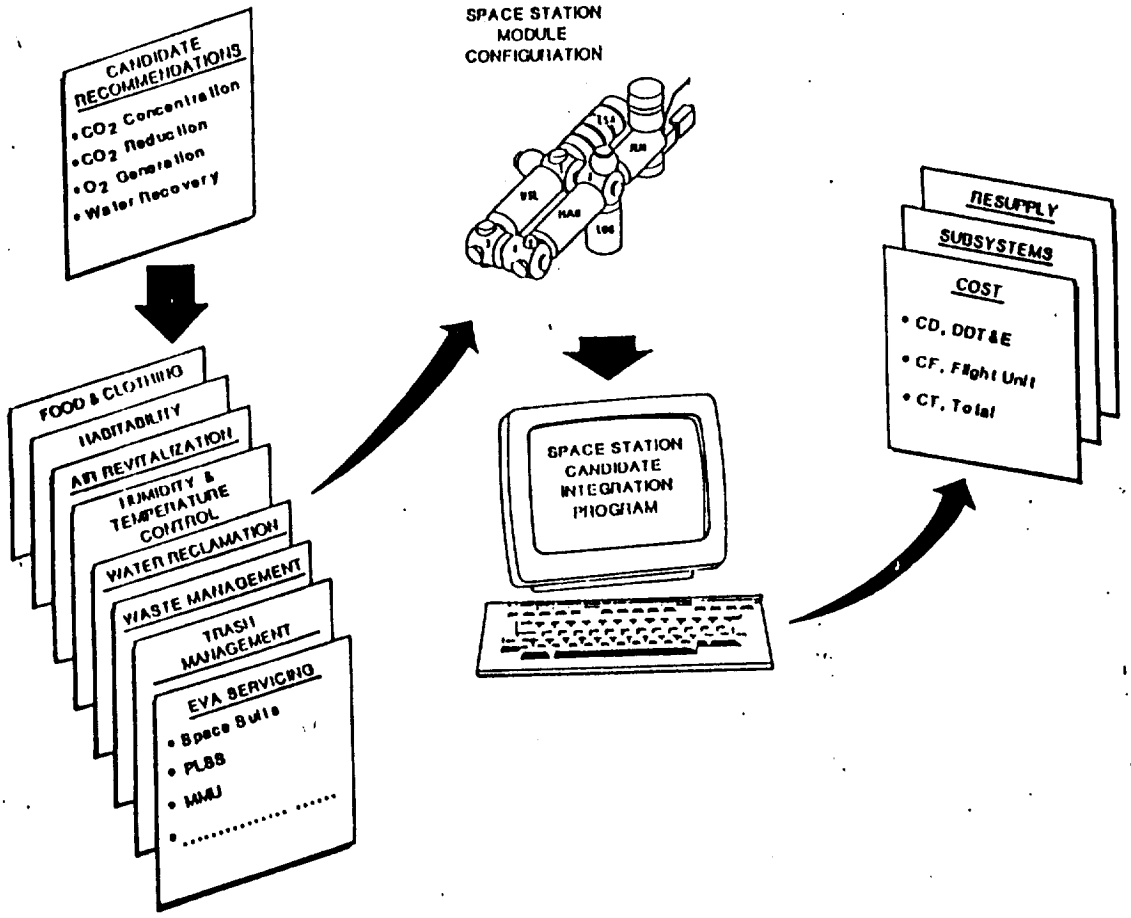
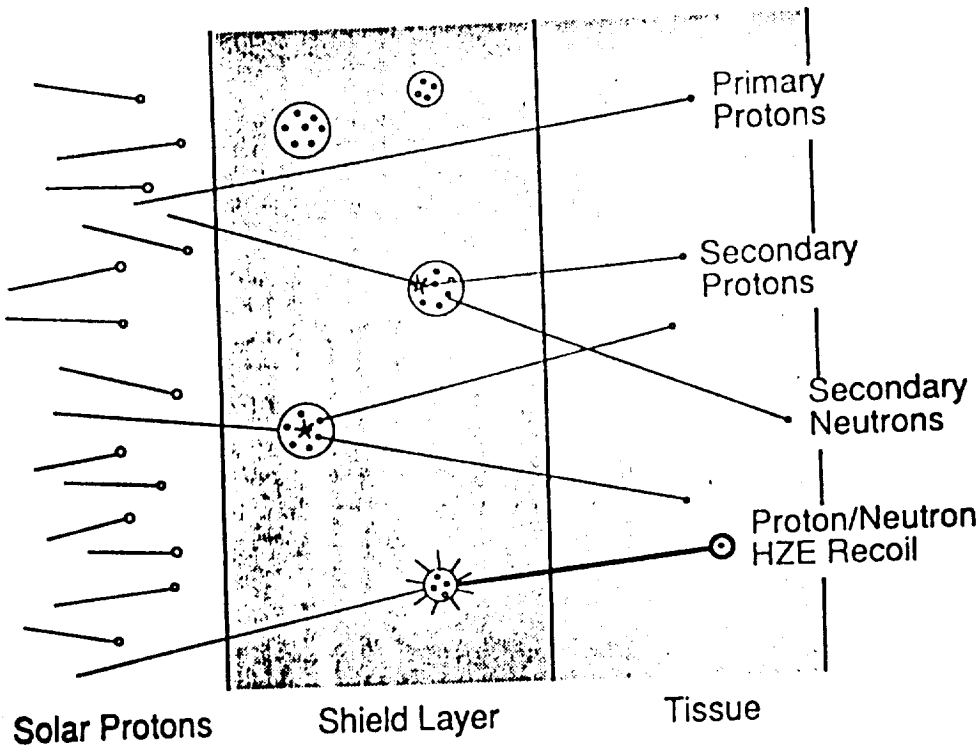
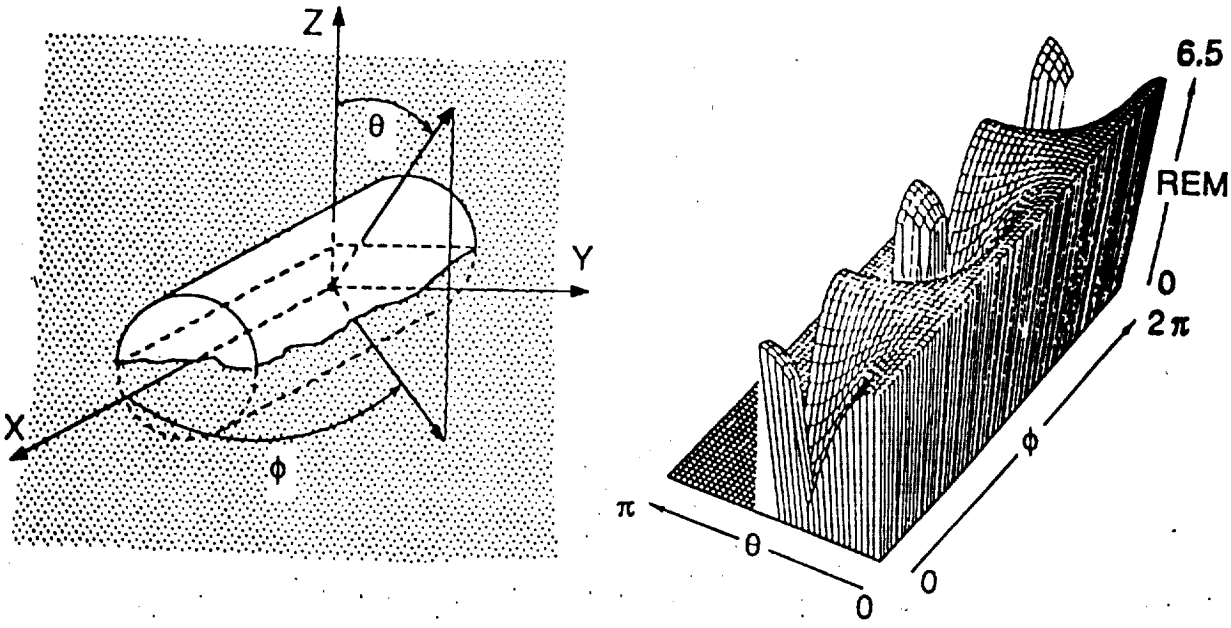
ECLSS TECHNOLOGY ASSESSMENT/INTEGRATION PROGRAM





DIRECTIONAL DOSE PATTERN FOR SHIELDED CYLINDER GEOMETRY



CFD CAPABILITY

Continuum Analyses

LAURA*	— 3D Navier–Stokes, Real gas, Equilibrium, and Nonequilibrium
PNS–VRT	— 3D Parabolized Navier Stokes, Equilibrium, Any gas, Cones, and Biconics
SOFIA	— Axisymmetric, Navier Stokes, Any gas, and Equilibrium
HALIS*	— 3D, Inviscid, and Equilibrium
AA3DBL*	— 3D, Viscous, and Equilibrium
VSL3DNQ*	— 3D, Viscous, and Nonequilibrium
STEIN	— 3D, Inviscid, and Equilibrium
HYVIS	— 2D, Viscous, Radiation, Ablation, Any gas, and Equilibrium
IRF	— 2D, Inviscid, Radiation, and Any gas

Free–Molecular Analyses

DSMC*	— 1 to 3D, Real gas, Chemical and Thermal Nonequilibrium
SAR*	— 1D Navier Stokes, Nonequilibrium, and Slip Boundary Conditions

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IDEAS SOFTWARE

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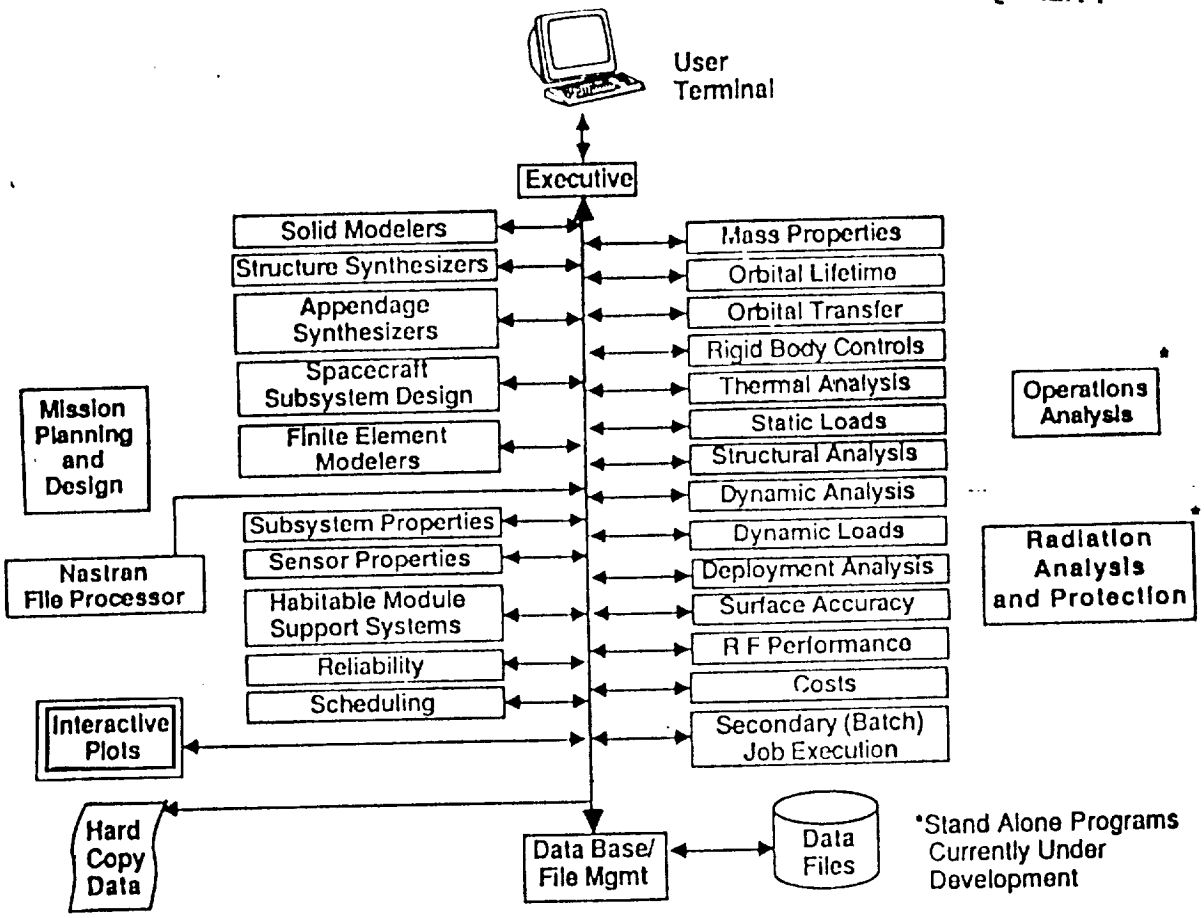
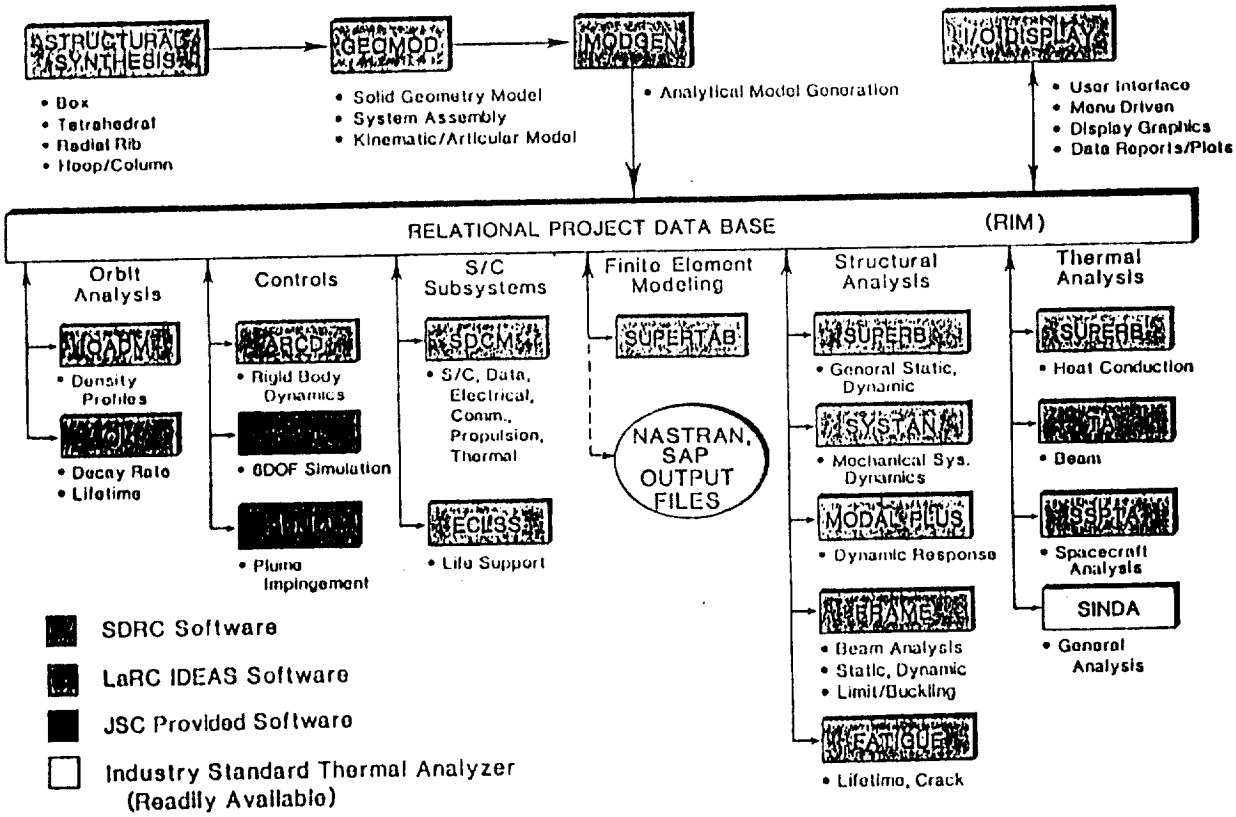
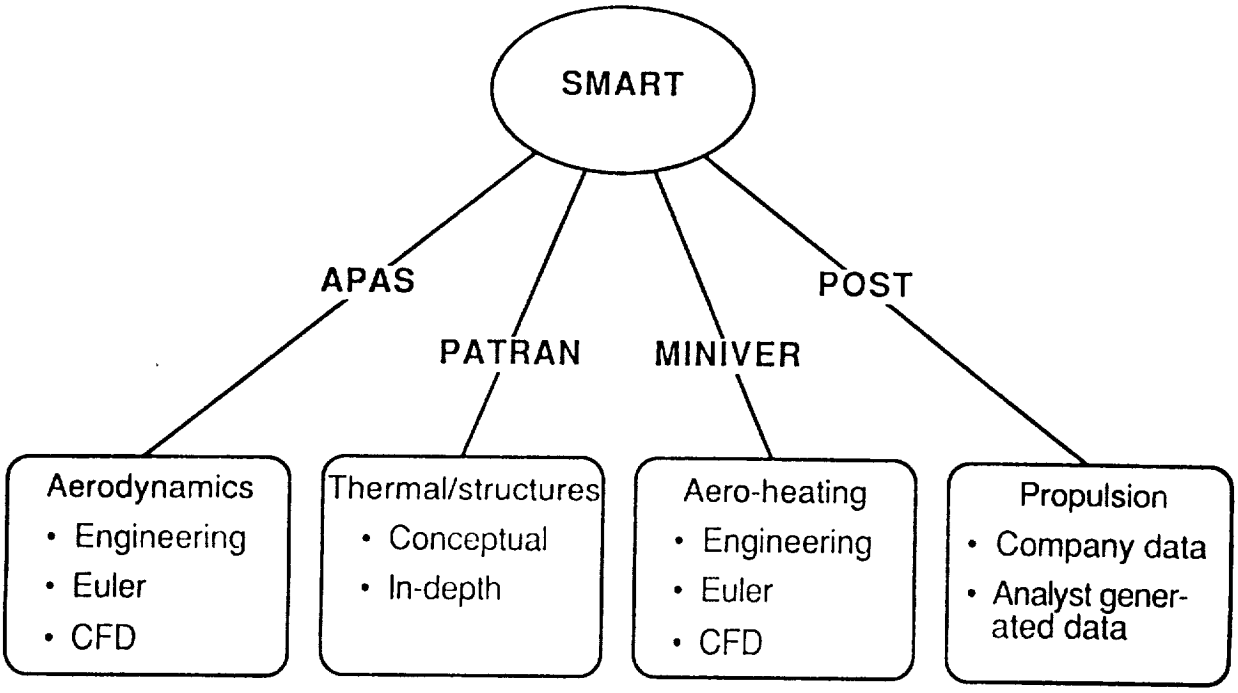


NASA IDEAS/SDRC I-DEAS INTEGRATED CAPABILITY



ENHANCED CONCEPTUAL ANALYSIS CAPABILITY

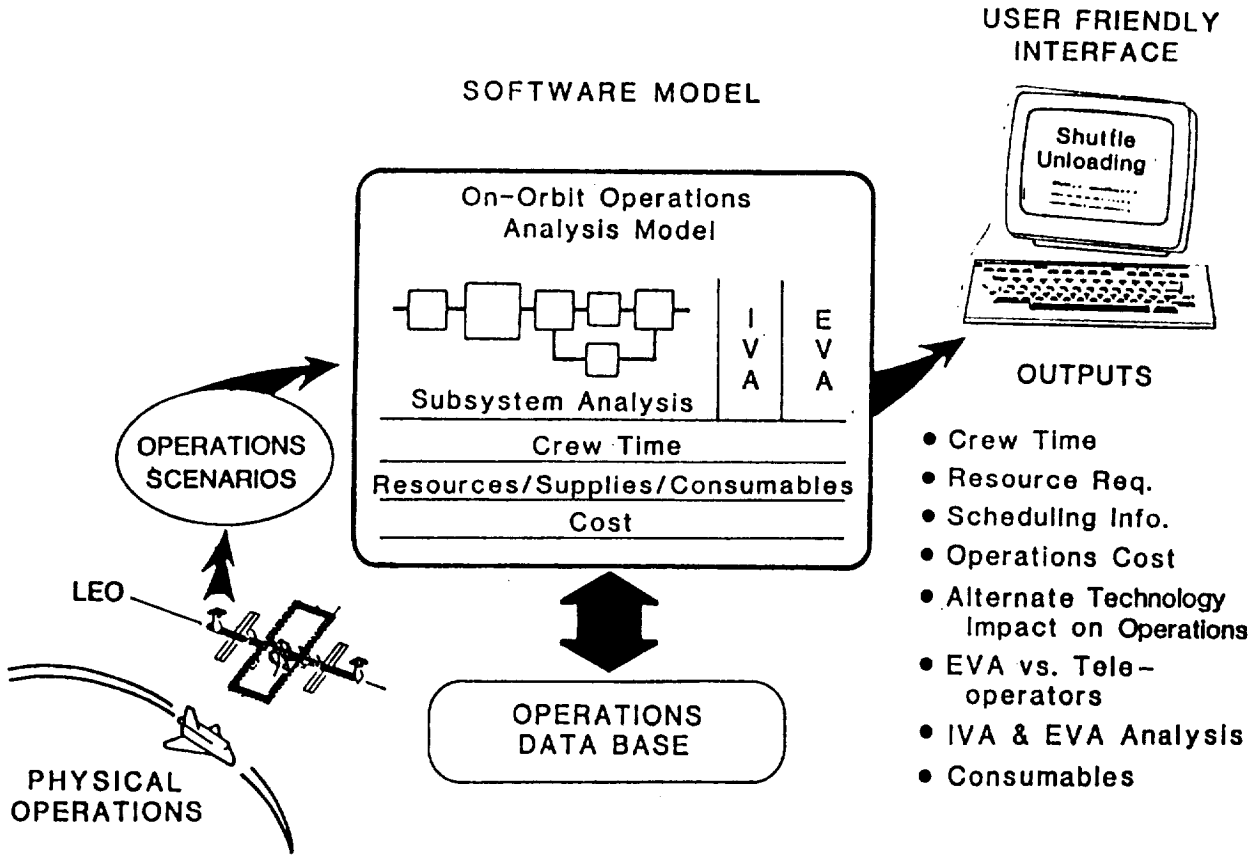


SOFTWARE FOR ORBITAL NODES IA

b) Under Development at LaRC

Category	Software Under Development at LaRC
Mission Design/Trajectory Programs	HIPOST, Planetary Orbital Determination
Orbital Mechanics	
Spacecraft Design	SDCM Upgrades
Subsystem Assessment	GN&C Subsystem
Disciplines Analysis	SHIELD (Galactic Cosmic Radiation)
Operations Simulation	On-Orbit Operations Simulation
Planetary Models Data Base	
Integrated Engineering and Analysis*	

ON-ORBIT OPERATIONS ANALYSES



SOFTWARE FOR ORBITAL NODES IA

c) Needed

Category	Needed
Mission Design/Trajectory Programs	Trajectory/Orbital Phasing Programs (E,L,M)
Orbital Mechanics	Orbital Analysis Including Stability (L,M) Sun/Planet/Spacecraft Geometry (L,M)
Spacecraft Design	Integrated Spacecraft Synthesis's Design
Subsystem Assessment	Power, Propulsion, Communications/Tracking Data Management
Disciplines Analysis	
Operations Simulation	EVA/IVA and Automation and Robotics Assessments
Planetary Models Data Base	Atmospheric (M) Gravity (M,L) Thermal (M,L)
Integrated Engineering and Analysis*	

NASA

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John T. Findlay: Flight Mechanics & Control, Inc., Hampton, Virginia.

16. Abstract
This publication summarizes the software needs and available analysis tools presented at the OEXP Analysis Tools Workshop held at the NASA Langley Research Center, Hampton, Virginia on June 21-22, 1988. The objective of the workshop was to identify available spacecraft system (and subsystem) analysis and engineering design tools, and mission planning and analysis software that could be used for various NASA Office of Exploration (code Z) studies, specifically lunar and Mars missions.

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