This document is guaranteed to be current only to issue date.

Some Mars Global Surveyor documents that relate to flight operations are under revision to accommodate the recently modified mission plan.

Documents that describe the attributes of the MGS spacecraft are generally up-to-date.

542-409, Volume 7

Mars Global Surveyor

Mission Operations Specifications

Volume 7: Training

March 21, 1996

Jet Propulsion Laboratory
California Institute of Technology

JPL D-12369, Volume 7

542-409, Vol. 7

Mars Global Surveyor

Mission Operations Specification

Volume 7: Training

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21 Mar 96

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CONTENTS

SECTION 1

1.0 INTRODUCTION

Mars Global Surveyor (MGS) operations training is developed in accordance with JPL D-10604 and "Specification for Operations System Training Development." Satisfaction of the applicable requirements of JPL D-10604 and the requirements of this document will yield a training program which can be relied upon to provide the Mars Global Surveyor project with personnel adequately trained and properly certified to successfully conduct MGS mission operations. The training program, developed following a systems methodology, provides traceability from the identification of specific needs or requirements, implementation of appropriate approaches to satisfy those needs, and to validate an individual's or a system's ability to properly execute operations. Validation of operational abilities and thus success of the training is achieved through a certification process for individuals and teams and through Mission Operations System (MOS) Operations Readiness Tests (ORT).

JPL D-10604, Section 4, contains a description of operations training at JPL. This provides an introduction for individuals who are unfamiliar with operations training and for those who have never developed a training program. Paragraph 4.2.3 of that description has been updated to reflect improvements in the cost effectiveness of operations at JPL. These improvements are reflected in operations certification as discussed in paragraph 1.3 below.

1.1 PURPOSE

The purpose of this specification is threefold:

1) Formally designate JPL D-10604 and MGS specific supplementary material contained in this document as the controlling document for development of plans for Mars Global Surveyor training programs.
2) Tailor JPL D-10604 to meet the unique needs of the Mars Global Surveyor project.
3) Define the MOS training for the Mars Global Surveyor project.

1.2 SCOPE

This specification addresses the plan for system level training of members of the MGS Mission Operations System. It is applicable to **all** individuals who will be actively involved in the conduct of Mars Global Surveyor mission operations including pre-launch, launch, initial acquisition, and TCM 1. Beyond the identification of MGS specific requirements which team training plans and programs must satisfy, this specification does not address the training and certification of individuals to fulfill their assigned operations roles.

1.3 CERTIFICATION UPDATE (4.3.2 of D-10604)

Formal acknowledgment of an individual's or team's demonstrated capability to function properly in an operational role without supervision is referred to as certification. Although not actually training, certification is so closely associated with operations training that it is convenient to consider it as a phase of the training process. It is in fact a validation of the training and of the readiness for operations. As flight and ground systems become more sophisticated and more tasks are automated, the focus of many operational roles has changed. Operations personnel devote a greater portion of their time to development related activities while monitoring and analyzing "system" performance as the operations tools become faster and more capable. This increased cognitive effort makes it particularly important to assess an individual's ability to correctly perform "crucial" tasks where an undetected error could result in loss of data, flight system damage, or mission degradation. This is due to the fact that in addition to traditional operations positions where a person's assigned tasks were almost exclusively operational and the majority of these were "crucial" in nature, there are now other situations which need to be addressed within the scope of operational certification.

- **Operational Roles**: An individual's assignment includes a mixture of operational and non operational tasks. Within the set of operational tasks assigned to the individual, some may fall within the "crucial" category. (**NOTE**: the terms operation role and operational position are used interchangeably in this document with the understanding that they refer to a significant level of support of operations by an individual)
- **Crucial Operational Tasks**: An individual's assignment includes only a few "crucial" operational tasks **OR** an individual is assigned to perform a limited number of process specific "crucial" tasks as a virtual member of another team.

The consequences of our changing situation is that the term certification for MGS really addresses the performance of "crucial" tasks and will be used as a blanket term for the following:

- **Individual Certification:**
  - For specific "crucial" tasks where these tasks represent an individual's primary involvement in a specific process outside the scope of his/her team's operational role or these few tasks represent a small percentage of an individual's work assignment.
  - In a role which consists of operational tasks, not all of which are necessarily "crucial", and which are not the individual's sole set of responsibilities.

- In a position which is primarily operational tasks with some amount of these being “crucial” in nature.

- **Team Certification**:
  When a Team Chief finds it meaningful to certify the team to support a particular activity such as launch or to execute a specific process such as sequence development and generation.

1.4 APPLICABLE DOCUMENTS

Operations Training Development (JPL D-10604)

Mission Operations Specification, Vol. 1, System (542-409 V.1)

Mission Operations Specification, Vol. 2, Data systems (542-409 V.2)

Mission Operations Specification, Vol 3, Operations (542-409 V.3)

Mission Operations Specification, Vol 4, Procedures (542-409 V.4)

Mission Operations Specification, Vol 5, Interfaces (542-409 V.5)

Mission Operations Specification, Vol. 6, Test (542-409 V.6)

Operational and Organizational Plan for the Mission Control Team (JPL D-8003)

1.5 CHANGE CONTROL

This document is planned to be used during the entire project. All changes to it shall be made in accordance with the project controls defined in 542-15, Mars Global Surveyor Documentation Plan. Revisions will be by pages and revised issues, as appropriate.

All changes to this document shall be approved by the Mars Global Surveyor Mission Manager.

SECTION 2

2.0 MISSION OPERATIONS SYSTEM TRAINING OVERVIEW

2.1 OVERVIEW

Mission Operations System training emphasizes the proper execution of procedures and implementation of interfaces to successfully complete an operational scenario. MOS training will include lectures or seminars on mission scenarios or scenario related subjects including the mission plan, maneuvers, launch, routine operations, and initial acquisition as well as subsystem design and operation for the MGS mission. Walkthroughs or paper (no actual data) simulations of mission scenarios normally follow related seminars/lectures. Following walkthroughs which serve to iron out or refine and verify procedures and interfaces, rehearsals of key mission scenarios are conducted. Rehearsals will typically involve several MOS teams and frequently involve the MOS. Individuals participating in rehearsals are expected to be proficient in their assigned roles and knowledgeable of the procedures and interfaces associated with the scenario to be rehearsed. Prior to critical operational activities such as initial acquisition or orbit insertion activities, the Mission Operations System will conduct an Operations Readiness Test to demonstrate (validate) the MOS's competency to execute the critical event. Personnel participating in ORTs will either be certified in their operational role or have a certified backup to oversee their performance.

Training will be conducted prior to launch. The training will concentrate on launch, initial acquisition, and TCM 1. The Training Plan serves a dual function both as the standards and requirements document for individual team training (Intrateam training) and as the plan for training to be conducted by the Flight Team (Interteam training) as an entity. As the analysis of training needs and development of the training program for the Flight Team progress, the results are documented and maintained by the Training Engineer.

2.1.1 Pre-launch Training

Training conducted during the period prior to the MGS Launch will prepare the Flight Team to support the MGS Mission with emphasis on Launch, Initial Acquisition and TCM 1 Phases of operations. Flight Team training activities will include launch exercises covering the activities of countdown, launch, ascent, spacecraft deployment, initial acquisition, initial assessment, and TCM 1 operations. The training activities will include participation in simulation activities with the Deep Space Network (DSN), Lockheed Martin at Denver (LMA), and the Kennedy Space Center (KSC). Certification of the Flight Team will be conducted prior to launch to verify the success of the training exercises in preparing the Team to support launch and initial assessment activities. For this purpose there will be, as a minimum, a Dress Rehearsal/ORT scheduled for launch/initial acquisition and TCM 1.

2.2 PROGRAM OBJECTIVES AND REQUIREMENTS

The prime objective of the MGS Training Program is to ensure MOS personnel are adequately trained to successfully support the MGS Mission through proper execution of established procedures and proper response to anomalous situations. Supporting objectives to be achieved by the Training Program include:

1) Providing individuals with training needed to accomplish their job tasks.
2) Validating and certifying each individual's ability to perform the specific tasks associated with his/her position
3) Verifying through exercises that the MGS Flight Team possess the requisite knowledge and skills to conduct the mission.

The specific training activities defined in this document include orientation lectures, OJT, intrateam training, interteam training (including anomaly training,), MOS training and ORT's. Where possible, personnel training will be done concurrently with other activities, thus allowing the Project to take advantage of shared resources.

Individual exercise scripts will define support required for each training exercise; provide the means for verifying MOS requirements and team interfaces; and describe training responsibilities, scenarios, and acceptance criteria.

2.2.1 Approach

The method used for developing the MGS Training Plan and training materials is a systematic approach. This approach will integrate the processes of analysis, design, development, implementation, and evaluation. The systems approach used by the Project proceeds from an analysis of responsibilities and duties to the selection of those tasks requiring training, the identification of capabilities necessary to perform these tasks, the development of training objectives, the design and development of training materials, the conduct of training, and the evaluation of the training. This process is described in detail in Section 4.

It is the responsibility of each individual team to train and certify all personnel so that they fully understand their duties and responsibilities in the MGS Project, regardless of how long personnel have worked on the project.

The principal focus of the Training Plan is to develop and exercise the ability of the constituent teams of the MGS Flight Team to work together as an integrated whole and to execute mission sequences using Flight Team procedures and hardware/software as specified in the MOS Functional Requirements.

The MGS Project has a dynamic Spacecraft simulator located at the Spacecraft Test Laboratory (STL) in Denver, Colorado. Operations personnel will monitor and react to simulated spacecraft data including anomalies. Anomalies can include corrupted spacecraft data or be declared by a “paper simulation”. In the case of a “paper simulation”, these anomalies will be passed to the appropriate flight teams for resolution. Flight Teams will be able to recognize the anomaly, respond accordingly, and identify corrective measures.

The Spacecraft Team (SCT) will initiate anomaly analysis activities, and the RTOT and Mission Operations Assurance Team (MOAT) will exercise their procedures to process downlink data in support of the analysis effort. The purpose is to provide the SCT with the data it requires to thoroughly analyze and resolve the problem as quickly as possible. The RTOT and MOAT will also respond to special data requests by the SCT for data that might not routinely be provided but which provide additional insight into the anomaly. The exercise will be terminated by the Training Engineer or by a Mission Manager status meeting.

In addition to Spacecraft anomalies, recovery from simulated failures within the GDS will be included in these training exercises. This will exercise procedures to reestablish and/or reroute data and voice circuits and to utilize alternate GDS configurations.

Interteam training exercises will not be repeated solely because they were incomplete or not completed correctly. If the failure was such that training requirements were not met and cannot be accomplished in a subsequent exercise, the MM may require that the exercise be repeated to ensure that the training requirements can be met.

ORT’s for a mission phase must be successfully completed prior to beginning Mission Operations for that phase; therefore, any ORT that is failed or not completed will be rescheduled and rerun.

2.3 ORGANIZATIONAL RESPONSIBILITIES

Members of the MGS Flight Team have special responsibilities in defining and executing the Training Plan as described in the following subsections.

2.3.1 Mission Manager

The MGS Mission Manager has overall responsibility for Flight Team readiness. The MM is responsible for assessing the effectiveness of the MGS Flight Team Training and determining the readiness of all elements of the MOS to support Mission Operations.

2.3.2 Team Chiefs

The individual Team Chief has overall responsibility for the readiness of their team to support launch through TCM 1. The Team Chief is responsible for developing and documenting intrateam training plans and conducting training exercises. The Team Chief will participate as required in the interteam training and ORT's.

The Team Chief is also responsible for assessing the success of the training exercises, evaluating team personnel and certifying to the Mission Manager that the team and its individual members are capable of supporting Mission Operations. The Team Chief will maintain a training file on each individual. The file will contain records on all training activities including completion verifications of orientation and OJT requirements. Past MGS experience for each team member will be defined/documented and will be available for review as part of the certification process.

2.3.3 Training Engineer

The MGS Training Engineer (TE) is responsible for defining the overall Flight Team Training Plan. The TE will arrange for interteam orientation lectures and plan and conduct the interteam training exercises and ORT's. The TE is also responsible for providing the data that will be used during anomaly training and ensuring the confidentiality of the data. The TE will define those GDS resources that are necessary to support MGS Training. The RTOT and Mission Planning Resource Scheduling will schedule GDS resources.

2.3.4 Network Operations Project Engineer

The MGS Network Operations Project Engineer (NOPE) is responsible for ensuring that all MGS Project unique requirements have been accounted for in the DSN training activities. The NOPE is also responsible for assessing the readiness of DSN personnel and advising the TE of any DSN problems that could affect the Training Plan.

The NOPE will arrange for special DSN technical support if necessary to support MGS training activities and will be the Project's interface for troubleshooting problems within the DSN.

2.3.5 Ground Data System Engineer

The MGS Ground Data System Engineer (GDSE) is responsible for ensuring that any GDS tests that are a prerequisite for Flight Team Training activities have been completed successfully. The GDSE will certify to the TE that the GDS is capable of supporting those Flight Team training activities that require GDS support, that is KSC/MOS, DSN/MOS, interteam training exercises and ORT's.

2.4 FLIGHT TEAM READINESS CERTIFICATION

All members of each team will be certified as ready to participate in each phase of the mission.

The Team Chief has overall responsibility for the readiness of his team to support mission operations. The Team Chief will develop a training plan and program that defines requirements for personnel certification. The program and plan will include orientation lectures, OJT requirements, and intrateam and interteam exercise participation.

The Team Chief will maintain a record for each flight team member that documents participation in each exercise (intrateam/interteam), lecture, completed OJT requirements, and identify previous MGS experience (this includes the length of time the person served in the designated MGS capacity). Personnel who are unable to perform as required will be replaced or retrained. Such action must involve the Team Chief and the Mission Manager. Prior to the Launch Readiness Review, the Mission Manager will review the certification form prepared by each Team Chief and will/will not concur with the Team Chief's assessment.

2.5 FLIGHT TEAM TRAINING PLAN SCHEDULE

Figure 2-1 provides the Flight Team training schedule through launch. Exercises are described in Subsection 6.2. In summary, the intrateam training must be completed by June 1, 1996. The interteam training will occur from June 1996 until shortly before launch.

The key interteam training exercises are as follows:

1) Launch and initial acquisition
2) Sequence Generation, uploading, and real-time command process exercises.
3) TCM 1

One or more of these training exercises will have anomalies or a process handicap injected into the exercise to determine how well the teams can cope with the simulated problem.

JPL JET PROPULSION LABORATORY

APPROVAL: J.G. BEERER

ACHIEVEMENT: JAN WILSON

MARS GLOBAL SURVEYOR
MOS TRAINING SCHEDULE

REV G, DATE: May 2,1996
CREATION DATE: Nov 7,1995

FY96: 1995 (NOV, DEC); 1996 (JAN, FEB, MAR, APR, MAY, JUN, JUL, AUG, SEP) — FY97: OCT, NOV

	ACTIVITY	Schedule
1	MILESTONES	
2	LAUNCH	11/6
3	REVIEWS	
4	FLIGHT READINESS REVIEW (NASA)	11/1
5	TRAINING READINESS-LAUNCH	7/10
6	ORR	8/19-20
7	DOCUMENTATION	
8	TEAM TRAINING PLANS	P 1/15; F 5/15
9	MOS TRAINING PLAN VOL 7	P 3\15; F 5\30
10	TRAINING ACTIVITIES	
11	INTRA-TEAM TRAINING	
12	ORIENTATION LECTURES	
13	MOSC TESTING	7/10-15
14	MOS TRAINING	
15	JPL PFOC & ECMS TRAINING	6/4-6
16	DENVER PFOC & ECMS TRAINING	6/11-13
17	PI PFOC & ECMS TRAINING	6/25-27
18	NIPC/EC TRAINING	6/28
19	ACT TRAINING	7/2
20	WALKTHROUGHS	
21	TCM-1 & MNVR DESIGN/IMPLEM	6/20
22	LAUNCH & INITIAL ACQUISITION	7/9
23	INSTRUMENT CHECKOUT	7/12
24	MOS REHEARSALS	
25	INSTRUMENT CHECKOUT	7/17
26	LAUNCH AND INITIAL ACQ.	8/8; 8/20
27	TCM 1 & MNVR DESIGN/IMPLEM.	9\12
28	OPERATIONAL READINESS TESTS	
29	INSTRUMENT CHECKOUT	10/2
30	LAUNCH & INITIAL ACQUISITION	10/8
31	TCM 1 & MNVR DESIGN/IMPLEM.	10/15
32	TCDT	10/31
33	CONTINGENCY	10/22

Contingency used, if needed, as backup date for additional rehearsal/ORT.

MOS1.PRN/May 3,1996

SECTION 3

3.0 TRAINING WORKING GROUP

The Training Working Group (TWG) is a critical element in developing a training program that will ensure an adequate number of qualified personnel to conduct flight operations. The TWG, chaired by the TE, will be the focal point for policy, requirements, and standards of the training program. The policies and membership responsibilities are specified below.

3.1 TRAINING WORKING GROUP POLICIES

1. Evaluate each team's analysis of their training requirements, specifically by:

    a) Identification of those team positions that require training.

    b) Analysis of the tasks that must be performed to successfully perform at each position.

    c) Selection of those tasks that require training to be performed properly.

    d) Use of training tools.

    e) Schedule and resource limitation.

2. Advise the TE and Team Chiefs regarding the analysis in the specific areas of:

    a) Weaknesses or deficient elements of the analysis.

    b) Opportunities of common or closely related tasks to be taught through common courses.

    c) Requirements for establishing unique courses or other means of acquiring specific training.

    d) Resolution of resource and schedule problems.

3. Provide the TE with information required in developing training activities, specifically:

a) Descriptions, specifications, characteristics, and similar information of the Spacecraft and DSN and their interfaces for use in producing simulation telemetry, courses, lectures, and training material.

b) Descriptions of potential and credible system faults, including symptoms and causes and effects, for inclusion in training and in exercises to exercise MOS contingency responses.

c) Mission descriptions, requirements, and constraints for use in developing scenarios and scripts for training exercises. Specific objectives to be achieved by the training program to verify readiness to support MGS.

4. Advise the TE in tailoring mission scenarios to support objectives of specific exercises.

5. Critique team training plans prior to their review and approval by the TE and the MM for publication as an annex to the MOS Training Plan

6. Specify MOS performance evaluation criteria.

7. Evaluate the performance of the MOS Teams during exercises and rehearsals.

3.2 ATTENDEES AND RESPONSIBILITIES

The following individuals, or designated representatives, constitute the regular attendence of the TWG:

1. TE(Chairman).

2. GDS Engineer

3. Team Chiefs.

3.2.1 Training Engineer

Responsible for developing and implementing the MGS Training Program. Specific functional responsibilities include:

1. Developing a plan for the MGS Training Program which is achievable and which will ensure that personnel required to support the MGS Mission are properly trained to do so.

2. Reporting the status of project training to project management on a regular basis.

3. Chairing the Training Working Group.

4. Producing and maintaining project training schedules that are attainable and that support mission requirements.

5. Managing development and presentation of training material for MOS training activities.

6. Assisting teams in developing training plans, acquiring required individual and team training, and establishing individual certification requirements.

7. Monitoring and critiquing of team training activities.

8. Conducting MOS exercises and rehearsals.

9. Managing MOS participation in training activities involving other organizations.

10. Providing assessments of MOS personnel readiness to project management.

11. Ensuring documentation of MGS training plans and activities.

3.2.2 MGS Ground System Engineer

Responsible for validating that the MOS is capable of supporting the MGS Mission. Specific functional responsibilities within the MGS Training Program include:

1. Participation in the TWG.

2. Assisting the TE in obtaining resources essential to implementation of the MGS Training Program.

3. Assisting the TE in configuring and conducting large system level training exercises.

3.2.3 Team Chiefs

Responsible for the training and certification of their individual team members. Specific functional responsibilities include:

1. Supporting the TE as a member of the TWG.

2. Developing team training plans in accordance with Appendix A of this plan

3. Managing team training and individual certification in accordance with the Team Training Plan.

4. Providing schedule inputs to the TE.

5. Identifying to the TE those training requirements that exceed individual team capabilities.

6. Evaluating the performance of the individuals on their respective teams.

7. Providing training documentation as requested by the TE.

SECTION 4

4.0 TRAINING DEVELOPMENT METHOD

This section provides a five-step model for the training development process. It is adaptable to all training situations and can be modified to account for schedule and budget constraints. The process can be used by each team to ensure that current team members are adequately trained and to ensure adequate training for future team members. The process includes:

1. Determining precisely what the skilled team member does or must know when doing the job, how well he or she must perform, and under what conditions.

2. Determining if training is needed and, if so, determining what kind of instruction to give the personnel so that they can do the job well.

3. Expressing the instructional needs in terms of specific measurable objectives and developing a means of determining when team members have achieved the objectives.

4. Designing appropriate training to assist team members in achieving the objectives.

5. Conducting and evaluating the training and evaluating the team members as to their ability to do the job.

The following subsections provide more detailed discussions of each step of the model to assist team chiefs in implementing this process.

4.1 SYSTEM REQUIREMENTS ANALYSIS

The purpose of this analysis is to identify the nature and scope of the team members' expected role in the operational setting. By collecting data on the system's purpose, personnel's functional responsibilities, how the system works, and how it is used, it is possible to begin to formulate appropriate training to prepare the individual to fulfill a specific operational role.

The team's training may be directed toward the performance of specific tasks or toward the transfer of knowledge to the team members or both. For that instruction that will be task-oriented, the product of the analysis is a list of the tasks each job entails as well as equipment or materials involved, performance frequency and complexity, the conditions under which the job is performed, and the standards which must be met. Because knowledge is in the mind and cannot be observed like the performance of a task, the analysis for what knowledge must be possessed is based on broad goals. This starts with identification of system needs, such as the need for analysts who understand how a specific spacecraft module functions.

The need must be translated into specific goals, such as the need for an analyst who can recognize system malfunctions. The goals are then analyzed to identify measurable behavior that indicates goal accomplishment. Recognizing that the voltage, current, or temperature output is outside an acceptable range, might be such a behavior. The product of the analysis for knowledge training is a set of educational goals and behaviors that can indicate goal attainment.

4.2 TRAINING REQUIREMENTS DEFINITION

4.2.1 Task-Oriented Training

The purpose of Task-Oriented Training is to analyze and compare tasks with skills, knowledge and abilities of team members or future team members. This delta tells what instruction is needed or will be needed as formal instruction or through OJT.

4.2.2 Knowledge Training

Knowledge Training is an analysis of a behavior. The analysis provides information to the trainer on what must be learned, so that the student can exhibit that behavior. The trainer can then develop the course content and learning techniques such as problem solving, rule using or comprehension.

4.3 OBJECTIVE TRAINING DEVELOPMENT

4.3.1 Performance Training

Specific objectives for a particuliar behavior or task must be identified in the training development. Once the objectives have been identified, the next step is to develop a means of verification to measure if the objectives have been met. Whether the verification takes a written form, oral form, or an actual demonstration of capabilities, the important factor is that it provides a clear indication of whether or not the objective has been achieved.

4.3.2 Knowledge Training

There is an added element in the development of objectives for knowledge training. That is, in addition to using the learning requirements, one must also consider the type of learning required for the task (such as problem solving, rule using, or comprehension, and including certain conditions in the objective and in controlling the verification design). As with performance (task) training, verification of knowledge may take a variety of forms.

4.4 TRAINING PLANNING, DEVELOPMENT, AND VALIDATION

Careful planning of instruction to satisfy the objectives is required in this step. This involves placing learning activities in an order that produces the required learning in the shortest time. Further, selecting and planning methods and media that most effectively support the objectives is involved. The planning provides the information needed to identify the resources which will be required for training activities. This step also includes developing the instructional materials and validating the materials by testing team members to determine if learning objectives must be modified or supplemented to provide the instruction necessary to enable the individuals to meet the learning objectives.

4.5 TRAINING CONDUCT AND EVALUATION

Once the training which a team has developed has been validated, it is ready for use through formal activities, OJT, or other means that are appropriate to the particular situation. To ensure continued effectiveness, it is necessary to evaluate how training is conducted as well as how team members perform their jobs. As the operational environment changes, it is not unusual that the training program must be modified to keep pace.

This process described in Subsection 4.5 may require compromises (such as combining validation with the conduct and evaluation of training) to meet the constraints of budget, schedule, etc. The goal is to develop for each team a program that allows clear identification of job requirements and traceability of each team member's capability to meet those requirements. Such a program allows a definite determination of whether or not an individual is trained. The program for training the Flight Team will address an additional factor: Flight Team readiness to support operations.

4.6 TEAM TRAINING PLANS

The training plan, which the team chief develops, will document the results of the job analysis, the identification of training objectives, and the training chosen to accomplish these objectives. Included in the development of the training will be the prioritization to ensure that the most critical training is accomplished even though schedule constraints may preclude conducting as much training as desirable. The plan will include the means by which the team chief will document that team members can perform the tasks identified in the analysis, that is, that they are trained in their specific job and in team processes and procedures. The requirements that must be met by team members prior to the team chief certifying that they are ready to support flight operations will be specified in the plan.

Appendix A contains an outline to be used by Team Chiefs in developing their training plan. To avoid duplicate documentation, it is acceptable for items such as position descriptions or task lists that are completely documented elsewhere to be included in the training plan by specific reference to the source document. Team training plans will be critiqued by the TWG prior to review and approval by the TE and MM. Approved training plans will be published as annexes to this document using the Following Annex numbers:

Annex 1 - Real - Time Operations Team
Annex 2 - Spacecraft Team
Annex 3 - Navigation Team
Annex 4 - Sequence Team
Annex 5 - Mission Operations Assurance Team
Annex 6 - Science Operations Team

4.7 CERTIFICATION

All members of each team will be certified as ready to participate in each phase of the mission. Certification is the process through which a team member's ability to support flight operations is documented by the Team Chief.

The Team Chief has overall responsibility for the readiness of the team to support mission operations and will develop a training plan and program that defines requirements for personnel certification. The program and plan will include orientation lectures, OJT requirements, and intrateam and interteam exercise participation. Criteria for certification will be developed by the Team Chief and documented in the team's training plan, which is approved by the MM.

Certification may be by mission phase if there are distinct training requirements associated with each phase. Completion of forms similar to those in Figures 4-1 and 4-2 for each team member is essential for providing traceability from the team member's job to his/her demonstration of their ability to perform the job. Each team member must meet all certification criteria and be certified prior to supporting the MGS flight unless a waiver is granted by the Mission Manager as specified in Subsection 4.7.1.

4.7.1 Individual Waivers

When an individual is unable to satisfy specific certification criteria due to non-availability of required course, etc., a waiver may be granted by the Mission Manager under the following circumstances. The Team Chief must request the waiver in writing explaining the reason the criteria could not be met and specifying that the individual has demonstrated an ability to accomplish their duties satisfactorily. The request will be reviewed by the TE and the MM will approve or disapprove the request.

4.7.2 Team Waivers

Upon completing the job analysis, it may become clear that resources do not exist to support further development of specific training required by the team in accordance with the requirements of the MOS Training Plan. In this event, elements that cannot be supported will be documented by assembling the Position Descriptions, applicable tasks from the task list, and instructional objectives under cover of a waiver request prepared by the Team Chief. The request will include:

1) Team Training Plan identification.

2) Date of Request.

3) List of positions affected.

4) Name of Team Chief.

5) A concise summary of the training development resource shortfall, including estimated impact on team readiness.

The TE will review the waiver request and recommend to the Mission Manager on the following actions:

1) The Mission Manager approves the request and waives specific requirements of the MOS Training Plan if training can be facilitated without a loss of traceability by granting the waiver, or

2) The Mission Manager attempts to obtain the required resources utilizing the waiver request to support pursuit of these resources.

MARS GLOBAL SURVEYOR PROJECT POSITION TRAINING RECORD

TEAM: ________________________________

POSITION: ________________________________

NAME: ________________________________

Task Description	Verified (X)	Team Chief Initials

Figure 4-1. MGS Project Position Training Record (Task Description).

MARS GLOBAL SURVEYOR PROJECT TRAINING RECORD

CERTIFICATION

________________________________ has demonstrated his/her ability to perform the

tasks required for the ________________________________ positions.

Acknowledgment:

________________________________	__________________________
Team Member Signature	Date

Certification:

________________________________	__________________________
Team Chief Signature	Date

Approval:

________________________________	__________________________
Mission Manager	Date

Figure 4-2. MGS Project Position Training Record (Certification).

SECTION 5

5.0 TEAM TRAINING

The fundamental element in the MOS Training Plan is the training provided within every team. It is in team processes and procedures that the foundation of mission operations is cast. Each Team Chief is responsible for the training of his/her team members in accordance with the specifications described in Section 4. This procedure includes determining which tasks must be performed to accomplish duties and what the training should entail. The cornerstone of this effort is the analysis of the jobs that must be performed by the team. Once the job has been analyzed, it is possible to plan how to train for each position as well as team processes and procedures.

Personnel training is conducted to verify the capability of the MOS personnel to perform assigned operations activities on a defined timeline. The training validates that:

1) These personnel have been adequately trained and are sufficiently knowledgeable to interact with the Ground Data System.

2) The personnel are aware of the defined team procedures and can implement them properly in the time allocated.

3) The procedures are complete and correct.

5.1 TRAINING TYPES

Five types of MOS training will be conducted:

1) Orientation Lectures and Documentation Review.

2) On-the-Job-Training.

3) Intrateam Training.

4) Interteam/MOS Training.

5) Operational Readiness Test Training.

The training will use portions of the GDS to permit a "realistic" simulation of the actual flight environment. Spacecraft telemetry will be provided by the STL.

At completion of Interteam/MOS training and ORT's, all Flight Team personnel will be certified as being flight-ready. The following is a list of activities that each Flight Team member must accomplish before being certified as flight-ready.

1) Orientation Lectures - specific lectures identified by Team Chief in Intrateam Training Plan.

2) Documentation - Specific documents to be read by each team member. Identified by Team Chief in Intrateam Training Plan.

3) OJT - Specific activities identified by Team Chief for each position in the Intrateam Training Plan.

4) Intrateam exercises developed by Team Chief and identified in the Intrateam Training Plan.

5) Interteam exercises developed by Training Engineer and identified in the MOS Training Plan.

6) MOS exercises developed by Training Engineer and identified in the MOS Training Plan.

7) Participate in ORT's.

5.1.1 Orientation Lectures and Documentation Review

Orientation lectures and documentation review are conducted for the purpose of briefing Flight Team personnel, especially new assignees, on the MGS Project, Spacecraft, and MOS design.

Orientation Training will be provided on the MGS Spacecraft including selected subsystems and experiments, the GDS, the Flight Team organization, and the uplink and downlink processes. Those subjects that are tailored to an individual team will be incorporated as a part of the intrateam training, while more general topics will be presented as orientation lectures.

Unless specifically excused by their Team Chief, each team member will attend each of the following orientation lectures. Teams identified in the following table are responsible for preparing and presenting the indicated lecture.

<u>LECTURE</u>	<u>PRESENTER</u>
Mission Design	Mission Design Manager
Spacecraft	Spacecraft Team
Science	Science Manager
Uplink Process	Sequencing Team
Downlink Process	Real-Time Operations Team
Organization	Mission Manager
Ground System	Ground Data System Engineer
Real-Time Command Process	Sequencing Team

The TE is responsible for planning, scheduling, and arranging for the presentation of these lectures, which will be videotaped and be made available for later viewing by Team personnel. Selected video tapes may be sent to flight operations personnel who are located at other facilities. Video tape recordings will be available in VHS format.

5.1.2 On-the-Job-Training

On-the-Job-Training (OJT) provides an opportunity for Team members to practice their operations in a supervised environment. In general, interactions with other elements of the Flight Team are not included as part of OJT. Exceptions to this practice include uplink exercises, sequence generation and system test support.

It is expected that the majority of individual team training will be conducted as OJT to qualify an individual who is already skilled to perform in a particular job position. The use of a systematic approach to designing OJT is just as important as in more formalized training to insure that training is efficient and effective.

Applying the systems process to the design of OJT is basically the same as any other application. The job performance requirements and then the training requirements must be identified. For MGS, OJT will be position qualification training - training to increase knowledge and skill for a specific job. The Team Chief will identify the job performance requirements, make certain that there is a valid need for training, and identify the specific training tasks. They can establish objectives, choose instructional methods and media, and obtain or develop instructional materials.

The training development model can be applied to OJT much the same as with other training efforts. By its nature, OJT must be flexible, and some of the process will be less formal than for other applications of the process. OJT is designed and conducted to meet behaviorally described needs and the effectiveness of that training is verified.

5.1.3 Intrateam Training

Intrateam Training is conducted for the purpose of verifying that each member of the team is capable of performing his/her required functions independently of interactions with other flight teams.

The Team Chief has responsibility for planning, preparing, performing, and assessing the success of intrateam personnel training. The Team Chiefs should ensure that the intrateam exercises concentrate on verifying that the team's operating plans and procedures are correct and that the team can satisfy the functional and performance requirements allocated to it. Furthermore, the team members should demonstrate a capability to operate the tools (hardware and software) in the Mission Support Area (MSA). Interface testing will not be done as part of the intrateam training.

Some elements of the Flight Team have been operating in a Flight Team mode for many months in support of Spacecraft System Test and Integrated System Tests (ISTs). Participation in these activities may satisfy many intrateam training objectives in accordance with the Team Chief developed training plan.

Each team will define a series of training exercises that will, when taken together, meet the intrateam personnel training objectives. These training exercises, in addition to any orientation lecture material, will be included in the team training plan and will be issued as an annex to this document. It will be the responsibility of the Team Chiefs to ensure that the team training plan is prepared, maintained, and executed.

Each Team Chief will maintain a training participation matrix that will indicate in which training activities each individual on the team has participated. Background experience, that is, participation in system tests, will also be included in training documentation. This Documentation of participation will provide the Team Chief with a basis for determining when an individual should be certified to support flight operations.

Intrateam personnel training can be divided into three phases:

1) Orientation.

2) On-the-Job-Training.

3) Training exercises based on specifically developed scenarios.

5.1.3.1 Orientation

Orientation training, as part of the intrateam personnel training, is the responsibility of the individual Team Chief. In addition to the general orientation lectures defined in subsection 5.1, each Team chief will define orientation briefings/programs and document review relevant to their respective team. The Team Chief will identify who is responsible for preparing/presenting the material. This material should be limited to information pertaining to the intrateam team procedures and functions for launch through Cruise.

5.1.3.2 On-the-Job-Training

For the Team member, OJT is a key factor in achieving mission readiness. Each Team member will be required to accomplish specific activities in their job position. An example of these activities include full understanding of procedures applicable to their positions and possible writing/review of the procedures. Specific activities will be identified by the Team Chiefs and reflected in each Teams' Training Plan.

5.1.3.3 Training Exercises

Training exercises require team personnel to exercise internal team procedures and the tools (hardware/software) used by the team. Training exercises will be designed to exercise the internal functional and performance requirements of the individual teams.

These training exercises will be divided into two processes: uplink and downlink. Separate exercise scenarios will be developed for each exercise. The uplink and downlink processes and the specific responsibility for each team as it relates to the defined process are specified in the Flight Operations Plan.

The Team Chief will be the training conductor but may delegate the responsibility to the group leaders on their teams for exercises dealing only with functions within that group.

5.1.4 Interteam Training

Interteam training is conducted to verify interfaces (products) between the individual teams, correctness of procedures that involve multiple teams, and the ability of the Flight Team as an integrated unit to accomplish combined uplink and downlink functions in an operational environment. Two configurations (Interteam and MOS) will be included in Interteam training exercises.

Deep Space Network(DSN)/MOS training will verify that the DSN and MGS Flight Team personnel are able to operate effectively together and that they can execute the procedures and interfaces in a timely and coordinated manner. Descriptions of this training will be included as an integral part of the launch and TCM1 training exercise scenarios described in detail later in the document. The goals of interteam training are to ensure that:

1) The Flight Team personnel are adequately trained and sufficiently knowledgeable to interact effectively with the GDS and the rest of the Flight Team in a flight-like environment.

2) The Flight Team personnel are aware of and able to implement the defined Flight Team procedures.

3) The Flight Team procedures are complete and correct.

4) Flight Team personnel will be trained with exercises that address both nominal activities and anomaly conditions.

Specific objectives for interteam training ensure that the Flight Team:

a) Is cognizant of GDS support capabilities and limitations.

b) Has sufficient in-depth knowledge of Spacecraft systems and subsystems to successfully operate the Spacecraft and to detect and properly assess off-nominal Spacecraft performance.

c) Is knowledgeable about science instrument constraints as they apply to the early phase of the Mission.

d) Understands the nominal launch sequence and the launch-specific configurations of the GDS.

e) Exercises interteam and MOS interfaces effectively (develops all required products in the correct form, with proper content when required).

f) Demonstrates ability to execute all required launch and initial assessment activities.

g) Responds to anomaly conditions in accordance with prepared contingency plans.

5.3 MOS EXERCISES

MOS training exercises will develop the MGS Flight Team understanding of other agencies supporting the MGS Mission. This includes procedures, interfaces, and developing expertise in activating, maintaining, and troubleshooting interface configuration.

5.4 OPERATIONAL READINESS TESTS

Operational Readiness Tests(ORTs) are conducted to demonstrate the readiness of the Mission Operations System to support flight operations. These tests will verify that all elements of the MOS can function together in accomplishing selected mission activities in a nominal environment.

SECTION 6

6.0 FLIGHT TEAM TRAINING

MGS Flight Team Training encompasses all training for MOS Flight Team personnel as an aggregate group to support the MGS Mission. The training will be developed using the process described in section 4. Training required for individuals to perform specific tasks that define their duties in supporting MGS is the responsibility of the individual Team Chief as specified in Section 5. Training of general interest and for relational operations among teams and external agencies is addressed in this section.

In developing Flight Team level training, it is assumed that an individual can perform his/her particular job. This section will therefore concentrate on the tasks and knowledge requirements reflected in the decision making and interaction essential to successful MGS Flight Operations. The emphasis will be on practicing operations rather than on lecture or class-type presentations. Ideally, all activities should be practiced prior to actual operations, but the constraints of time dictate that the most critical and unique activities receive priority.

6.1 NEEDS ANALYSIS

An analysis of the MGS MOS requirements has identified system needs and measurable objectives that form the basis of the planned MOS training.

6.1.1 System Needs

System needs are those which, if satisfied, are expected to result in successful accomplishment of MGS operations.

Three primary needs have been identified. They are:

1) MOS Teams to act in a coordinated manner to maintain the spacecraft in an operable condition.

2) MOS Teams to conduct the uplink process to control spacecraft activity.

3) MOS Teams to execute the downlink strategy to collect and process spacecraft engineering and scientific data and produce required data products.

6.1.2 Task Identification

Based on the system needs, it is possible to identify the tasks that the Flight Team must accomplish as well as the knowledge requirements for successful operational support. The tasks are the execution of the interfaces specified in the MOS Functional Requirements. The knowledge requirements include an understanding of the following:

1) MGS mission.

2) MGS organization.

3) MGS ground system.

4) MGS spacecraft.

5) Procedures and interfaces required to identify, monitor, analyze, document, and correct spacecraft problems.

6) Processes and coordination required to plan, generate, and transmit the proper command sequences to the spacecraft.

7) Mechanisms and links required to collect, prepare, and distribute the data associated with spacecraft operation.

6.1.3 Measurable Objectives

To determine the success of the training it is necessary to establish measurable objectives which indicate that the Flight Team has the knowledge and skills to successfully accomplish the required tasks. These objectives provide the basis for developing the actual training activities for the Flight Team.

The training activities described in 6.2 are designed to impart the knowledge required for the individual to act in concert and exhibit the appropriate responses to support operations under nominal and contingency conditions as well as provide opportunities for the behavior to be demonstrated and measured. For MOS training, these objectives will be identified in the training script for each specific exercise. The training script will be provided to the project approximately 2 weeks prior to the exercise.

6.2 TRAINING EXERCISES

Exercises replicating the operational environment have been selected as the most effective media for training the Flight Team. These exercises are planned to train in the interactive procedures that must be followed to successfully support mission operations. They also provide an opportunity for reinforcement of the skills and knowledge acquired during individual team training activities.

Personnel are placed in a simulated operational environment where the teams validate and demonstrate the procedures that are used during the Mission. Exercises will be conducted according to scripts based on specific scenarios and may include agencies external to JPL. Ideally, every possible combination of functions and events that could occur during a mission would be covered in the training program; however, this is impractical from both schedule and capability perspectives.

Therefore, as many exercises as possible will be planned with consideration being given to the criticality of activities, difficulty and complexity of events, alternative training opportunities, and resources in selecting the category and quantity of exercises to be conducted. Exercise scenarios will typically emphasize either the execution of a process or the conduct of realtime operations, but may certainly include elements of both.

6.2.1 Processes

Process exercises will emphasize the non-realtime activities involved in the preparations for contact with the spacecraft and in the processing, distribution and archiving of data after contact with the spacecraft. Product planning, product development, adherence to timelines, and transfer of products will receive the most attention. Analysis of non-catastrophic problems and their resolution will be included as well. Activities that would be incorporated in these scenarios include:

1) Navigation processing.

2) Maneuver sequence development.

3) Checkout sequence development.

4) Engineering data analysis.

5) Spacecraft failure response.

6) Ground failure response.

7) Spacecraft reconfiguration sequence development.

8) Data archiving and retrieval.

9) Engineering data processing

10) Determination of proper command execution by the spacecraft.

11) Resolution of anomalies.

12) Command file generation.

13) Navigation Ephemeris Command Load .

14) Sequence of Events (SOE), Space flight Operations Schedule (SFOS), and keyword file generation.

6.2.2 Real-Time Operations

The events that transpire during the actual reception of telemetry, transmission of commands, and tracking the spacecraft are the subjects of interest for realtime exercises.

1) Countdown

2) Launch.

3) DSN Acquisition.

4) Monitoring of spacecraft status.

5) Hand-over of the spacecraft from one DSN site to another.

6) Identification of spacecraft anomalies.

7) Verification of command execution by the spacecraft.

8) Selection and transmission of real-time commands to the spacecraft.

9) Execution of appropriate procedures in response to system anamolies.

10) Performance of specific mission events.

This list of activities is not all-inclusive, nor may every activity be included in the scenarios. They are merely representative of the activities that would be considered for realtime scenarios.

NOTE: Agencies outside of JPL will be supporting MGS launch activities, which means that there will be opportunities for launch procedure training in addition to exercises conducted solely by JPL.

6.2.3 Scenarios

The following scenarios have been developed to address training objectives. Additional scenarios may be added or existing scenarios modified to accommodate changes in training requirements and objectives. Exercise scripts that implement the scenarios for specific exercises will be prepared and delivered prior to activities per schedule. The scripts will identify the scenario with any planned modifications, the training objectives of the exercise, the exercise participants, the configuration including data sources, and a timeline for the exercise. The scenarios may be combined or repeated for various exercises, depending upon the progress of the Flight Team within the training program.

NOTE: The following are brief descriptions of types of exercises that could be used during training. Specific scenarios will be developed at a later time.

6.2.3.1 Launch Training

Interteam training exercises will be planned to cover the time period from approximately 1.5 hours prior to launch through DSN acquisition. If the situation warrants, the same time period will be scheduled for simulations with outside agencies.

Nominal Launch/Initial Acquisition Training Exercise

A. Objectives

Nominal training activities are intended to familiarize the Flight Team members with the procedures, activities, timelines, and data products that will come into play during a nominal MGS launch. They are also intended to provide an opportunity for the team to practice a nominal sequence as a complete team.

Specifically, Flight Team members will be expected to achieve the following objectives:

1) Execute voice procedures.

2) Perform operational procedures to support launch/initial acquisition activities.

3) Generate all required interface products in concert with the planned timeline.

4) Utilize and interact with ground-based hardware and software.

5) Monitor and analyze output of ground based data systems.

6) Exercise interteam interfaces.

B. Description

This exercise will be scheduled for 8 hours to approximately coincide with anticipated actual times for the launch, that is , the schedule will be based on a nominal launch time with exercise start time approximately 1.5 hours earlier. The times contained in this scenario are nominal for training purposes; more accurate/updated times will be found in the script issued prior to the exercise. The GDS will begin activity to configure the Ground System to allow checkout of the systems prior to beginning the exercise.

The TE will have provided direction via a pre-exercise briefing and the exercise script to configure the system for launch support, including identifying data tapes for the STL containing satellite launch telemetry data. Communications voice nets should be configured to accommodate comm verifications/ops briefing by the RTOT and TE prior to the exercise to verify system configuration.

The exercise will begin with verification of the launch state. This will be a coordinated activity by the RTOT and SCT. The TE will act as KSC, as appropriate, when any of these agencies are not participating in the exercise. Go/no go decisions for the spacecraft to launch will be made by the MM, based on recommendations from RTOT and SCT, at approximately L-TBD minutes. The RTOT/SCT recommendation must be given to the MM no later than L-TBD minutes. The MM will transmit the go/no go decision to the Project Manager (PM). This "go" for the spacecraft will be the final input expected by the PM from the MGS Flight Team prior to launch. Should the spacecraft condition change such that it becomes no-go for launch after L-TBD minutes, the status change must be transmitted by the MM to the PM not later than L-TBD minutes to allow for normal human response time and propagation delays. Beyond that time, there will be insufficient time to ensure that the launch sequence can be halted, and the PM must consider the spacecraft committed to launch if there are no Delta problems.

C. Prerequisites

The following activities are expected to have been successfully completed prior to the beginning of this exercise:

1) GDS testing.

2) Intrateam training, including DSN Operations Teams in MGS specific requirements such as initial acquisition.

3) Orientation Training.

4) Required commands, contingency sequences are built and tested.

5) DSN Sequence of Events generated by SEQ.

6) Flight procedures and plans completed.

D. Resource Requirements

This exercise will require the following resources and the configuration indicated.

1) Mission Support Area (MSA) in launch configuration.

2) GDS in launch configuration.

3) DSN station configured to support MGS.

4) Realistic spacecraft data in the format(s) that will be available during the launch and assessment phase.

5) Appropriate state vectors are required for input to the DSN/NAVT for initial acquisition pointing angles.

6) Command and telemetry processing software is available and loaded in the proper configuration and equipment to support launch-phase activities.

The preceding requirements are intended to include appropriate support personnel as well as hardware and software.

E. Manning of Teams

This exercise will involve the RTOT, SCT, NAVT, MOA, SEQ, GDS and DSN Operations Team. The Team chiefs are responsible for determining the appropriate manning for their team.

F. Evaluation Criteria

Accurate and timely execution of procedures and smooth interaction of team interfaces will be the primary criteria by which the success or failure of this exercise is judged. Specific items of interest include:

1) Correct interpretation of spacecraft data by the RTOT/SCT and proper and timely inputs to the RTOT.

2) Accurate and timely command transmission by the RTOT.

3) Timely go/no go decisions for launch.

4) Correct data products to users in timely manner.

5) Appropriate trajectory information to DSN to generate initial acquisition pointing angles.

6) Successful scheduling to GDS/DSN/KSC resources for the exercise.

7) Proper information flow between SCT and RTOT regarding monitoring of spacecraft event execution.

8) Successful data flow to and from the DSN with proper response to any unplanned data systems anomalies.

6.2.3.2 Anomaly Launch/Initial Acquisition Training Exercise

A. Objectives

Anomaly training activities, like nominal exercises, are intended to familiarize the Flight Team members with the procedures, interfaces, activities, timelines, and data products that are anticipated during a MGS launch. In addition, anomaly training will expose flight team members to situations where GDS and flight systems do not perform in the manner expected. Under these circumstances, it is the team's responsibility to ascertain if the observed performance is such that corrective action should be taken and what that action should be. The exercises also provide an opportunity for the team to practice a sequence as a flight team.

The exercises may be conducted as part of or concurrent with MOS activity. The exact nature of interplay will be dependent upon the nature and purpose of the MOS exercise and will be defined in the exercise script.

Specific objectives for the exercises are for Flight Team members to successfully:

1) Execute proper voice procedures.

2) Perform operational procedures to support launch/assessment phase activities.

3) Generate required interface products in concert with the planned timeline.

4) Utilize and interact with ground based hardware and software.

5) Monitor/analyze output of ground-based data systems.

6) Exercise interteam interfaces.

7) Assess anomalies and initiate corrective action as appropriate using mission and flight rules.

8) Execute contingency plans when required.

B. Description

The exercises will be scheduled to cover the period from L-1.5 hrs through initial acquisition. The exercises will basically follow the nominal scenario and continue until terminated by the TE. The Flight Team may encounter anomalous performance by the GDS and/or spacecraft hardware/software.

C. Prerequisites

The following activities are expected to have been successfully completed prior to the beginning of this exercise:

1) GDS testing.

2) MGS MSA testing.

3) Intrateam training.

4) Orientation training.

5) Required commands and contingency sequences built and tested.

6) Nominal launch training exercises.

7) Launch-related contingency plans.

D. Resource Requirements

These exercises will require the following resources in the configuration indicated. The time requirements will be for the duration of the exercise as indicated in the script, plus normal setup:

1) MSA in launch configuration.

2) GDS in launch configuration.

3) DSN station configured to MGS.

4) Appropriate state vectors may be required, depending on the exercise scenario, and will be specified in the exercise script.

5) Command and telemetry processing software is available and loaded in the proper configuration and equipment to support launch/initial assessment phase.

These requirements are intended to include appropriate support personnel as well as hardware and software.

E. Participation Requirements.

This exercise will involve the RTOT, SCT, NAVT, SEQ, MOA, GDS and DSN. The Team Chiefs are responsible for determining the appropriate manning for their team.

6.2.3.3 Uplink/Downlink Exercises

A. Objectives

Uplink/downlink exercises are intended to familiarize the Flight Team members with the procedures, interfaces, activities, timelines, and data products that would come into play during nominal MGS uplink/downlink operations and can execute the procedures and interfaces in a timely and coordinated manner. They are also intended to provide an opportunity for the team to practice nominal/anomalous sequences as a complete team.

Specific objectives are for Flight Team members to successfully:

1) Execute proper voice procedures.

2) Perform operational procedures to support activities in concert with the planned command generation timeline.

3) Utilize and interact with mission support equipment.

4) Monitor and analyze output of flight support data systems.

5) Exercise interteam interfaces.

6) Exercise data access by remote science users.

F. Description

The exercise will simulate the tape recorder playback at Canberra DSN Station. Tape recorder SSR1A and SSR2A will be played back at the Canberra DSN station at approximatley L+2 days. The view period lasts for approximately 3 hrs. The recorded data will require about 2 hrs. to download, and allowing for launch delays, and lock-up and commanding time, there should be ample time to perform the playback sequence. The flight Team will have worked through the command generation template timeline, procedures, meeting, and approval cycles. The command will then be transmitted through the DSN for transmission to the spacecraft. Simulated data from the tape recorder playback will be transmitted from the DSN back to the MGS MSA for review. In at least one of the exercises no anomalies will be intentionally inserted so that the practice of proper standard procedures can be exercised.

C. Prerequisites

The following activities are expected to have been successfully completed prior to the beginning of this exercise:

1) GDS testing.

2) DSN testing.

3) MGS MSA testing.

4) Intrateam training.

5) Orientation training.

D. Resource requirements

These exercises will require the following resources in the configuration indicated. The time requirements will be for the duration of the exercise as indicated in the script, plus normal setup.

1) MSA in launch configuration.

2) GDS in launch configuration.

3) Canberra Configured to support MGS.

E. Manning of Teams

This exercise requires support from RTOT, SCT, NAVT, MOA, GDS, and DSN. It is the responsibility of each Team Chief to identify participants on their team.

SECTION 7

7.0 PROJECT FAMILIARIZATION

The more an individual understands about a project, its purpose, and how their job relates to and fits into the project, the better motivated that individual normally becomes to support the project successfully. To promote this understanding, project familiarization presentations on topics of general interest to the Flight Team will be made available to all personnel supporting the MGS Project.

The presentations will not be detailed technical diatribes but rather will focus on introducing individuals to the various aspects of project key subsystem elements. The presentations will be divided into modules addressing the spacecraft and its mission, the operational organization, the ground data system, uplink and downlink processes, and launch operations. The Team Chiefs will identify the presentations that their members will attend in order to meet intrateam training requirements. It is recommended, however, that all MGS personnel attend the presentations. The presentations will be made available for use at remote locations and for later viewing in a videotape format.

Summaries of anticipated lecture content are provided in the following paragraphs along with the name of the office responsible for the development and presentation of each lecture. Outlines of the presentation should be provided to the TE and MM for review and comment prior to the commencement of presentations. Dry runs will be scheduled if the TE or MM deem necessary. Formal presentations and taping are scheduled to commence in April 1996. To minimize the number of taping sessions, and thus cost, several presentations will be scheduled in a single day. In general, lectures should be prepared in segments no longer than two hours.

1) The Mission Design presentation will address such topics as the factors involved in trajectory and orbit selection, launch windows, and mission strategy. The Mission Design Manager has responsibility for this presentation.

2) The Spacecraft lecture will cover the basic assembly. The functions and interactions of the primary subsystems will be the key topics for this talk. Some of the spacecraft subsystems will need to be presented in separate lectures due to their complexities. Responsibility for development of the lecture rests with the Spacecraft Team Chief.

3) The Uplink and Downlink Process will be presented by the Sequencing and Real-Time Operatins Teams. Timelines for the support of various events and the interchange of information to support each process will form the basis for these presentations.

4) The MOS Organization presentation will address the overall organizational structure and the primary functions of the individual teams within the MOS. The Mission Manager has responsibility for this presentation.

5) The MGS Science lecture will cover science goals, the types of data to be collected, and how the information collected will be utilized. The Science Manager has responsibility for this discourse.

6) The MGS Ground Data System presentation will concentrate on the flight configuration of the uplink and downlink hardware and data paths which will support MGS. This discourse will be the responsibility of the Ground Data System Engineer.

7) The real-time command process will be generated and presented by the Sequence Team Chief.

APPENDIX A: TEAM TRAINING PLAN OUTLINE

1. Purpose

The Purpose section of the Team Training plan shall describe the broad goal of the plan.

2. Scope

The Scope section of the Team training plan shall describe the extent of the plan's applicability in terms of personnel and time (phases).

3. Assumptions and Prerequisites

This section of the team training plan shall document all of the assumptions made during the development of the plan and list all prerequisite training for each team position addressed by the plan.

4. Team Positions

This section will identify each team position by title and will include a position description..

5. Training Development

This section of the plan shall describe the development of the team's training, the details of the training which the team will conduct, and the team's position certification process.

5.1 Needs Analysis

This section of the plan shall be based on a detailed analysis of the functions of each position on the team (identified in the Team Positions sections). The Position descriptions form the foundation for the analysis and therefore need to be validated by the Team Chief during Needs Analysis. Each major task on each position description shall be sufficiently overlaid with job particulars (Operations Scenarios) to create a detailed list of tasks to be performed by the position (these tasks may need to be revised when new capabilities are delivered to Operations). Each item of this detailed task list shall identify a single task. The Team chief shall document the detailed task list in this section.

NOTE: To ensure appropriate training design, presentation media shall not be selected until the instructional objectives have been fully developed and topically/logically grouped (See 5.3)

5.2 Training Design

This section of the plan is founded on the Position Task List prepared during the Needs Analysis. An instructional objective shall be prepared for each of the tasks of each Team Position. An instructional objective shall be expressed as a single behavioral statement, the satisfaction of which shall be measurable. For example: “Participant shall be able to specify the file from which a data set to be manipulated is to be retrieved.” Instruction objectives that can be satisfied through existing interteam resources or activities shall be identified. All instructional objectives should be grouped into topical/logical lessons to facilitate administration.

The lessons associated with each position shall be validated by the Team Chief as to whether or not they are required for the individuals filling the positions and documented here. The plan shall include descriptions of any required job-training aids. Certification criteria and verification design will also be included in specific criteria an individual must accomplish to be certified in their position. The manner in which an individual will be evaluated for his/her ability to meet the criteria and the method of documenting this evaluation will also be specified in this section.

5.3 Instruction Development

This section of the plan develops and describes the training activities for each lesson. Activities for lessons where objectives will be satisfied through existing/interteam resources or activities need not be described in detail. They will be identified in association with the appropriate lesson. For team activities such elements as resources, personnel, maximum number of participants per iteration, lesson sequencing, selected media, equipment, facilities, and external dependencies required to conduct the training for each lesson will be identified. Media selection shall be based upon the most appropriate media for the lesson within the resources available.

6. Dependencies

All supporting elements on which the implementation of the training plans depend will be identified in terms consistent with level 4 and 5 schedules and be documented in the training plan.

7. Schedules

A training schedule, including project’s need dates for certification, will be developed as a section of the plan. Detailed personnel and module training schedules will be developed and maintained by the Team Chief during the conduct of training.

MARS GLOBAL SURVEYOR

MISSION OPERATIONS SPECIFICATION

VOLUME 7, TRAINING

ANNEX 1, REAL-TIME OPERATIONS TEAM

TRAINING PLAN

FINAL

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MARCH, 1996

TABLE OF CONTENTS

1.0 Purpose

The purpose of this document is to define the Mars Global Surveyor (MGS) Real-Time Operations Team (RTOT) Training Plan as required by the MGS Mission Operations System (MOS) Training Plan, 542-409 Volume 7, Training. This plan has been developed and will be implemented to insure the readiness of RTOT personnel to support the launch and flight operations of the MGS spacecraft.

2.0 Scope

This document will address the training required for individual team member operating positions, intra-team training and inter-team training. The RTOT is the focal point for real time operations in support of the MGS Project and therefore this plan will concentrate primarily on the training required for real time console operations personnel listed herein.

Formal certification will be required and documented for all Real-Time team members.

3.0 Assumptions and Prerequisites

This intra-team plan will not address training in terms of the individual mission phases. (launch, cruise, , MOI, aerobraking, mapping). The nature of the RTOT task responsibilities is common to all mission phases and RTOT participation in MOS inter-team mission phase specific orientations and training exercises will provide necessary mission phase specific training.

In the development of this plan it is assumed that the non-real time members of the RTOT are considered qualified through their individual selection to the team and through the performance of their daily duties during operations development and pre-mission operations planning. They will, however, receive additional MGS training through participation in training lectures / orientations, training exercises and tests / simulations. This plan shall therefore address only those object positions shown in section 4.0 below. Non-real time positions not shown as object positions of this plan are the RTOT Lead and the Flight Operations Engineers.

Prerequisite to training under the provisions of this plan are a basic understanding of the organization/structure of the RTOT by each trainee, together with a basic understanding of the role and responsibilities of each team member. (The team chief and flight engineers will provide the necessary instruction to insure that this prerequisite is met by each team member.)

It is the responsibility of the RTOT Lead to staff the team with personnel who understand the technical discipline which they represent. This plan therefore assumes that each team member has the necessary background knowledge to understand the training material which will be presented.

4.0 Object Positions

The following RTOT positions are defined as those which constitute the objects of this training plan:

4.1 The Mission Controller (MC)

The Mission Controller position on the RTOT will be occupied by five individuals who collectively will provide real-time operational support 24 hours/day 7 days/week. A position description and task list for the Mission Controller is provided in the "RTOT Requirements document".

5.0 Development Methodology

The following paragraphs describe development of the Mission Control training activities.

5.1 Needs Analysis

A needs analysis indicates that personnel in the object positions must have the ability to effectively and efficiently perform the operations support tasks listed below:

5.1.1 General Mission Operations Tasks:

1. Direct and coordinate the real-time operational activities of the Project.

2. Monitor real-time spacecraft performance and verify sequence execution only during specified periods of time. These periods are defined below:

   a. Launch to Launch plus 30 days for all MSP Spacecraft and Landers.
   b. Minus 3 days and plus 3 days around all TCMs for all MSP S/C and Landers.
   c. MOI -48 hours until the ABX maneuver for all MSP S/C (~ 5 months).
   d. EDL minus 5 days until EDL plus 3 days for all MSP Landers.
   e. Other times as specified by the Flight Operations Manager.

3. Monitor the real-time operations of theAMMOS/MGDS, Ground Data System (GDS) and Deep Space Network and coordinate corrective action in the event of anomalies. Only during the times specified in # 2 above.

4. Provide operational direction and coordination to ensure information flow between all real-time elements of the Mission Operation System (MOS) and with the operational interfaces of the Data System Operations Team (DSOT) and DSN Operations Teams. Only during the times specified in # 2 above.

5. Direct the utilization and configuration of scheduled GDS resources, conduct real-time rescheduling negotiations when required, and ensure that GDS anomaly resolution and failure reporting are satisfactorily performed. Only during the times specified in # 2 above.

6. Coordinate, via the DSN Link Controller, all DSN uplink operations to the spacecraft.

7. Monitor and verify receipt of spacecraft down-link data (telemetry, radiometric) and note received data quality. Only during the times specified in # 2 above

5.1.2 S/C Command Tasks:

1. Maintain a general working knowledge, at least to the block diagram level, of the location, function and nomenclature of the components of the end to end command system including those elements of the S/C, the DSN, MGDS and the AMMOS CMD_SYS. <u>The following tasks are performed only when the Mission Controller is scheduled to be on console.</u>

2. Activate, connect and check-out the project MGDS workstation.

3. Request, display and print command files/elements from GCMD.

4. Operate and control the AMMOS CMD_SYS to transmit approved command files to the spacecraft.

5. Using information from a command form on Automated Command Tracker (ACT), operate the AMMOS CMD_SYS to retrieve and verify a command(s) from the project database (PDB) and ready the file for transmission to the S/C.

6. Determine by observing S/C Command verification information that transmitted command messages were received by the S/C.

7. ACT will maintain an administrative accounting of approved command requests, verification of proper transmission and spacecraft receipt of all commands.

5.1.3 Telemetry Monitoring and Control Tasks:

1. Maintain a general working knowledge, at least to the block diagram level, of the location, function and nomenclature of the components of the end to end telemetry system including those elements of the S/C, the DSN and the AMMOS GDS. <u>The following tasks are only performed during the times specified in section 5.1.1 # 2 above.</u>

2. Activate, check-out and operate an AMMOS MGDS DMD workstation.

3. Display S/C engineering data, DSN monitor data and other systems monitor and status data in any of several different page formats on an AMMOS MGDS DMD workstation

4. Monitor displays of S/C engineering data alarms together with other display data to assess the status and health of the S/C.

5. Interpret, translate as appropriate, install and maintain on the AMMOS system S/C engineering data and DSN monitor data decommutation maps and Channel Parameter Tables (CPTs).

5.1.4 Tracking Data Operation Tasks:

1. Maintain a general working knowledge, at least to the block diagram level, of the location, function and nomenclature of the components of the DSN systems which produce the tracking data.

2. Monitor displays to insure that appropriate tracking data are being collected in accordance with the published SOE.

5.2 Training Design

Approach

The training of RTOT Mission Control members is defined in the following phases:

Self Study
Orientation Lectures
Individual Instruction
S/C Command and Telemetry Operation Tasks
Real-time Operations Familiarization
Training Lectures
RTOT Intra-Team Training Exercises
On The Job Training (OJT)
MOS Inter-Team Training Exercises/Simulations
Launch Specific Joint Exercises
Dress Rehearsals and Operational Readiness

5.2.1 Self Study:

To prepare for and as prerequisite to RTOT position specific training, each team member trainee, through individual self study, shall:

1. Become familiar with the MGS Mission and its purpose by studying the "Mars Global Surveyor Mission Plan" (542-405).

2. Become familiar with the MGS MOS, its teams and its responsibilities by studying the "MGS MOS Specification, Volume 3, Operations " (542-409 V3)

3. Become familiar with the MGS RTOT Mission Control, its structure, its functional responsibilities and its operational interfaces by studying the "RTOT Requirements Document"

4. Develop a basic introductory level knowledge of the "UNIX" computer operating system.

5. Become familiar with the basic AMMOS MGDS system configuration.

The RTOT Lead is responsible to provide study material for this training phase.

5.2.2 Orientation Lectures:

Each RTOT member shall attend the MOS Orientation Lecture series provided by the MOS Training Engineer. It is intended that this series of lectures will provide the attendee with a background understanding and overview knowledge of:

1. MGS Mission Design
2. MGS Science Mission
3. MGS MOS Organization
4. MGS Spacecraft
5. MGS Ground Data System
6. MGS Uplink Process
7. MGS Downlink Process
8. MGS Launch Operations

5.2.3 Individual Instruction:

Individual instruction shall be provided to each trainee, where appropriate, in the following areas:

5.2.3.1 General Real-Time Mission Operations Training:

The skills of general real-time mission operation are learned primarily through participation in training exercises and test activity. Each team member will be scheduled, in turn, to support such activities. The RTOT Lead will designate the appropriate person to provide individual instruction to the team members as necessary to develop these skills.

The proficiency of each operator will be assessed by the Team Chief through personal observation and post activity critiques.

5.2.3.2 S/C Command Task Training:

Introduction to the AMMOS Command System (CMD_SYS) and individual command workstation hands-on instruction will be provided by experienced team members.

Each trainee will receive instruction on the functions and configuration of the CMD_SYS as well as hands-on instruction in the operation of the MGS workstation portion of the system.

This instruction shall include but shall not be limited to:

1. A working knowledge of the functions, configuration and location of the components of theAMMOS Command System.

2. Workstation turn-on, activation and connection to the system.

3. Generation of command transmit files (GCMDs) from project PDB.

4. Operation of the workstation to display, read, print and verify command files.

5. Operator retrieval of command(s) from the MGS PDB for transmission to the S/C.

6. Operation of the workstation to queue command files at a DSS and effect transmission of these files to the S/C.

During this instruction, each trainee shall prepare and maintain a personal note book of step by step instructions necessary to perform the required command system operations. These notebooks will provide valuable individual reference material during later training exercises and may also be use to update RTOT command operating procedures where appropriate.

5.2.3.3 Telemetry Monitoring and Control Training:

Introduction to the Space Flight Operations Center system and individual MGDS workstation hands-on instruction will be provided by members of the Section 391 Operations Training Group.

Each mission control trainee will be given individual instruction on the functions and configuration of the AMMOS data system as well as hands-on instruction in the operation of the SUN (DMD) user workstation.

This instruction shall include but shall not be limited to:

1. A working knowledge of the functions, configuration and location of the components of the AMMOS system.

2. Turn on, activation, check-out and operation of a MGDS DMD workstation.

3. How to load software.

4. Generation and use of data displays.

5. How to enter display processes.

6. Process telemetry data and monitor alarm limits.

7. Translate and control decom maps and channel parameter tables.

8. How to query the PDB and process recalled data.

During this instruction, each trainee shall prepare and maintain a personal note book of step by step instructions necessary to perform the required workstation operations. These notebooks will provide valuable individual reference material during later training exercises and may also be used to update RTOT operating procedures where appropriate.

5.2.3.4 Tracking Data Tasks

While the RTOT does not actually monitor tracking data it is necessary to monitor the operation of the DSN during collection of these data to insure that they are in fact being collected in accordance with the requirements of the SOE. No specific individual training in this area is planned, however, each trainee will attend training lectures which will prepare them with sufficient knowledge of the DSN tracking system to allow monitoring of the data collection process.

The training lecture series is identified in paragraph 5.2.4 below.

5.2.4 Training Lectures

The RTOT requires a level of technical understanding in some areas that cannot be obtained through attendance of the MGS MOS Orientation Lecture series. Therefore the RTOT Lead, together with the MOS Training Engineer, shall arrange for an additional Training Lecture series specifically designed for the mission control portion of the RTOT.

These lectures shall be provided by experts in each topic and shall be accompanied by a suitable "hand-out" which can be retained by the students for future reference. Each lecture shall cover detail at least to the block diagram level. The RTOT Lead shall be responsible for coordinating the mission control personnel schedule to insure attendance at these lectures. The following is a list of training lecture topics required for this lecture series.

Spacecraft:

All S/C subsystems and an overall look at the S/C system.

Deep Space Network:

A session on the new Link Controller interfaces.

Ground Communications Facility and Interfaces toMGDS:

An Overall look at the GDS equipment and block diagrams as well as the version of software that will be used on MGS.

Each lecture shall be of sufficient detail to provide the student with the knowledge necessary to, by monitoring system data, assess the status and health of the each system and to determine if the S/C and GDS are operating properly and if the required data are being collected in accordance with the published SOE.

5.2.5 Intra-Team Training Exercises

To develop proficiency in the S/C command tasks and the telemetry monitoring and control tasks a series of intra-team training exercises will be scheduled.

5.2.5.1 S/C Command Exercises

The AMMOS command system (CMD) together with the MGDS data system will be utilized to provide realistic S/C commanding exercises for the operators during GDS testing.

During these exercises each operator will be required to operate the command workstation in exactly the same manner as when commanding the actual S/C.GCMDs will be retrieved from the PDBand all actions required by the command procedure to verify the commands, transmit command files to a simulated MGS spacecraft, verify transmission and perform all command accounting functions. **When ACT becomes available, all members will require a training class and further testing using the ACT system.**

Anomaly conditions will be periodically introduced into ORT exercises by the project training engineer to develop operator reaction and corrective action proficiency.

Each operator will be scheduled to perform as many of these exercises as is necessary to build command operation proficiency. Subsequent to initial operator training additional exercises will be periodically scheduled to maintain command proficiency.

The proficiency of each operator will be assessed by the Team Lead through personal observation and post activity critiques and all operator participation will be entered in the training record.

5.2.5.2 Telemetry Monitoring Exercises

The AMMOS telemetry system will be utilized to provide realistic S/C engineering data to the operators for training exercises in S/C health and status monitoring.

During these exercises each operator will be required to operate the AMMOS workstation (SUN terminal and DMD software) in exactly the same manner as when monitoring the actual S/C. S/C engineering telemetry generated by the STL and the actual S/C data will be routed into the AMMOS system and the operator will perform all actions required by procedure to monitor health and safety of the S/C and to insure data flow through the system. S/C data will be displayed for viewing and will be alarm checked in the same manner as will S/C data in actual flight. The operators will perform all same functions, such as data selection, data display and specific data print out for real time broadcast data as well as non-real time data queried from the CDB.

As with the commanding exercises, each trainee will prepare and maintain a personal note book of step by step instructions necessary to perform the required S/C data display and monitoring operations. These notebooks will provide valuable individual reference material during later training exercises and may also be use to update RTOT operating procedures where appropriate.

Each operator will be scheduled to perform as many of these exercise as is necessary to develop S/C monitoring proficiency.

5.2.6 OJT During Integration and Test Activities

The majority of operational training for the mission control portion of the RTOT will be achieved through participation in exercises and tests where each operator will be required to perform those tasks and functions associated with individual positions. Ground Data System (GDS) integration and test activities provide an ideal opportunity for this "On the Job Training" (OJT). These activities are developed and conducted by the MGS Integration and Test Engineer. The RTOT will participate in these activities not only to provide required support to the Integration and Test Engineer but also to derive the maximum possible benefit from the "OJT". To the extent possible, scheduling of real-time (on console) RTOT operators to support these activities will be planned to provide an even distribution of training benefit across the team. Following each activity the RTOT will conduct an internal post test critique to assess the team's performance and to identify any areas where additional training emphasis should applied.

5.2.7 MOS Inter-Team Training Exercises/Simulations

The MOS training engineer will develop, schedule and coordinate a series of inter-team training exercises which replicate the operational environment of the several MGS mission phases.

Together with all other teams of the MGS MOS, the RTOT (both real-time and development elements) will fully participate in all training exercises. Participation in these exercises will provide the RTOT personnel with required training in mission phase specific operations and will develop inter-team interface coordination skills. These exercises will also provide a means for testing of operator specific task proficiency and over all flight team operations. To the maximum extent possible, scheduling of real-time (on console) RTOT operators to support the exercises will be planned to provide an even distribution of training benefit across the team. Following each exercise the RTOT will conduct an internal post test critique to assess the teams performance and to identify any areas where additional training emphasis should applied.

5.2.8 Launch Specific Joint Exercises

Joint exercises are defined as those launch specific exercises which involve not only the MGS MOS but also the external centers and agencies with which the MOS interfaces during the launch phase. Specifically these external elements are:

Lockheed / Martin Astronautics (LMA)
Kennedy Space Center (KSC)
Delta Launch Vehicle (Delta II)

These exercises will be scheduled by the JPL ATLO Manager in conjunction with the MGS Training Engineer.

5.2.9 Dress Rehearsals and Operational Readiness Tests

To demonstrate readiness to support the MGS mission, the RTOT will participate in the planned Dress Rehearsals and Operational Readiness Tests as an integral part of the MGS MOS Flight Team.

6.0 Training Records and Certification

Prior to launch of the MGS mission, it is the responsibility of the Team Lead to certify, Flight Operations Manager, that the RTOT is trained and ready to support flight operations. The RTOT Lead will maintain a training record for each team member. Participation in orientation and training lectures, training exercises and test/training simulations as well as other experience, i.e., participation in system tests, will be included the training record. This documentation of participation together with a first hand assessment of operator performance during on-line test and training activities will provide the RTOT Lead with a basis for determining when an individual should be certified. All training requirements for RTOT personnel must be met and each member must be certified prior to the member's support of Operational Readiness Tests (ORT's). To be considered certified, the individual team member must meet the certification criteria shown in paragraph 6.1 below.

The RTOT Lead's operator certifications will be reviewed with Flight Operations Mananger for concurrence.

6.1 Operator Certification Criteria

6.1.1 Mission Controller

An RTOT Mission Controller is considered certified to support MGS flight operations when he/she has demonstrated a basic knowledge of the following topics and the ability to effectively and efficiently perform the following specific tasks:

General:

1. Use proper voice net procedure with operational interfaces
2. General knowledge of the MGS spacecraft and its mission
3. General knowledge of the DSN and its support to MGS
4. Basic understanding of launch and deploy operations
5. Basic understanding of AMMOS and MGDS systems supporting MGS
6. Basic understanding of the MGN MOS organization and interfaces
7. Monitor S/C, DSS and AMMOS performance data to determine proper S/C and GDS operation

AMMOS Specific:
1. Login to workstation and bring up windowing system
2. Check AMMOS and RTOT file configurations on the workstation
3. Start AMMOS software
4. Review data sources
5. Initiate data processing
6. Invoke RTOT standard displays
7. Change displays and data within a display
8. Dump information to a file and print the file
9. Make a hardcopy of a screen and a window
10. Capture data to a file
11. Create and interpret a minor telemetry frame dump
12. Effect auto update of CPTs to subscribed DMDs
13. Manipulate MGS CPT information
14. Manipulate MGS Decom map information
15. Alter CPT information
16. Query PDB
17. Review PDB catalog
18. Set-up/invoke macros and scripts
19. Perform functions on a remote workstation
20. Isolate and recover from workstation anomalies
21. Shut down and sign off workstation

AAMOS CMD Specific:
1. Connect CMD to a DSS for command operation
2. Assign CMD to a Spacecraft ID (MGS)
3. Verify and understand CPA modes
4. Verify correct MGS command database
5. Read and manage RTOT command directory
6. Read GCMD files into the CMD directory
7. Rename files in the directory
8. Print and verify command files
9. Send command files to CPA directory
10. Attach command files to the CPA radiation queue
11. Manipulate CPA operations modes to effect transmission to S/C
12. Review eletronic command request form for proper information
13. Translate a command from information on command form
12. Disconnect CMD from a DSS
13. Verify S/C receipt of transmitted commands (CV)

The sheets that will be used to verify these steps are located in Appenix B & C.

6.1.2 Operational Interface Agreements to be Exercised

The OIAs for MGS are currently under revision due changes made by tyhe new MSOP requirements Guidelines. These will be included as soon as they are available. The approximate due date is May 1, 1996

6.1.3 Operational Procedures to be Exercised

RTOT.MC-0001	Mission Controller Daily Operations
RTOT.MC-0002	Voice Net Communications
RTOT.MC-0003	SOE and SFOS Generation (DELETED)
RTOT.MC-0004	Critical Operations
RTOT.MC-0005	Real-Time Problem Detection, Notification, and Analysis
RTOT.MC-0006	AMMOS Workstation Configuration
RTOT.MC-0007	AMMOS Workstation Operations
RTOT.MC-0008	Workstation Problem Isolation and Recovery
RTOT.MC-0009	Updating and Re-configuring RTOT.MC Files
RTOT.MC-0010	Processing Commands
RTOT.MC-0011	Product Archiving
RTOT.MC-0012	Verification Procedure for Real-Time Commanding

PROCEDURES FOR DSN PERSONELL ARE IN THE NETWORK OPERATIONS PLAN (NOP) 870-333

PROCEDURES FOR DSOT PERSONNEL ARE DIFINED IN THE MULTIMISSION GROUND DATA SYSTEM OPERATIONS DOCUMENT (2000-5-3050, REV. D.

7.0 Training Schedule

The RTOT training schedule is a compilation of the GDS testing schedule, the IST tesing schedule, the MOSC testing schedule, and all walkthroughs and OTRs scheduled by the MGS Training Engineer. Other individual tests will be held within the RTOT as required. Appendix A & B provide a look at the sheets that will be required to be completed by the RTO Team Lead on each individual.

APPENDIX "A"

MARS GLOBAL SURVEYOR PROJECT POSITION TRAINING RECORD

TEAM: ____

POSITION: ____

NAME: ____

Task Description	Verified (X)	Team Chief Initials

APPENDIX "B"

MARS GLOBAL SURVEYOR PROJECT TRAINING RECORD

CERTIFICATION

______________________________ has demonstrated his/her ability to perform the tasks

required for the ____________________________________ positions.

Acknowledgment:

______________________________________ ______________________________________
Team Member Signature Date

Certification:

______________________________________ ______________________________________
Team Chief Signature Date

Approval:

______________________________________ ______________________________________
Flight Operations Manager Date

Appendix "C"

ACRONYMS AND ABBREVIATIONS

AAMOS	Advanced Multi-mission Operations System
CPT	Channel Parameter Table
DMD	Data Monitor and Display
DSOT	Data Systems Operations Team
DSN	Deep Space Network
DSS	Deep Space Station
FOE	Flight Operations Engineer
FOM	Flight Operations Manager
GCMD	Ground Command File
GDS	Ground Data System
CMD	AMMOS Command System
MC	Mission Controller
MGDS	Multi-mission Ground Data System
MGS	Mars Global Surveyor
MOI	Mars Orbit Insersion
MOS	Mission Operations System
MSP	Mars Surveyor Progam
OJT	On The Job Training
OPSCON	DSOT Operations Controller
S/C	Spacecraft
SCMD	S/C Command File
SCT	Spacecraft Team
SOE	Sequence Of Events
SFOF	Space Flight Operations Center
SFOS	Space Flight Operations Schedule
TCM	Trajectory Correction Maneuver

MARS GLOBAL SURVEYOR
(MGS)

SPACECRAFT TEAM TRAINING PLAN

ANNEX 2
to
MOS SPECIFICATION VOLUME 7

4 APRIL 1996

REVISION: FINAL

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SPACECRAFT TEAM TRAINING PLAN

ANNEX 2
to
MOS SPECIFICATION VOLUME 7

FOR THE
MARS GLOBAL SURVEYOR

4 APRIL 1996
Revision: FINAL

Prepared by: ________________________
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TABLE OF CONTENTS

1. INTRODUCTION

1.1 Purpose

This document provides the plan for the conduct of the Mars Global Surveyor (MGS) Spacecraft Team (SCT) training intended to demonstrate flight operations readiness. This document constitutes Annex 2 to 542-409, Vol. 7.

1.2 Scope

Training of the SCT includes SCT internal operations, interactions with other MGS mission operations elements, and interactions with the MGS spacecraft. Most of the SCT training is obtained through team member on-the-job training (OJT) in the design, integration, test and operation of the MGS spacecraft subsystem, support equipment, workstations, and operations procedure development during Assembly, Test and Launch Operations (ATLO). The remainder of training is via videos and simulations. The aerobraking phase operations training will occur after launch.

Each SCT member's readiness for flight operations will be judged by the SCT Chief or his/her designate, based on specified criteria documented in 542-409, Vol. 4.

Formal SCT training is scheduled to begin in 1996 per the schedule contained in 542-409, Vol. 7.

1.3 Applicable Documents

Number	Title
542-409 Vol. 3	MGS Mission Operations Specification: Operations
542-409 Vol. 4	MGS Mission Operations Specification: Procedures
542-409 Vol. 7	MGS Mission Operations Specification: Training

2. ASSUMPTIONS AND PREREQUISITES

2.1 Assumptions

This section lists the assumptions made during the development of the plan.

a. Most of the SCT training is obtained through OJT.

b. The majority of SCT members have transitioned from other parts of the Lockheed Martin Aeronautics (LMA) MGS project.

c. The SCT tasks contained in this document are from 542-409, Vol. 3. This training plan will not be updated specifically to reflect changes in task or job descriptions in future versions of Vol. 3. The training defined in this plan will be applied appropriately to accommodate any task description changes.

2.2 Prerequisites

This section lists the prerequisite training required for each position addressed in this plan.

a. All SCT member are required to attend the following JPL provided orientation lectures:
- Mission Design
- Science
- Uplink Process
- Downlink Process
- Organization
- Ground System
- Realtime Command Process

In addition, all SCT members are required to attend the Spacecraft orientation lectures, and in some cases, prepare and present these lectures.

b. All SCT members are required to review the following documents:

Number	Title
542-110	Project Policies
542-140	Configuration Management Plan
542-170	Launch/Hold Criteria
542-400	Mission Requirements Document
542-404	Mission Security Plan
542-405	Mission Plan
542-407	Mission Sequence Plan
542-409	Mission Operations Specifications
Volume 1	System
Volume 2	Data System
Volume 3	Operations
Volume 4	Procedures
Volume 5	Interfaces
Volume 7	Training
Volume 8	Facilities
Volume 9	Operations Handbooks (Block, Command and Telemetry Dictionaries and Telemetry Calibration Handbook)
Volume 10	Flight and Mission Rules
Volume 11	Contingency Plans
542-423	Mission Operations Policies
542-SE-001	Spacecraft Performance and Interface Specification
542-SE-002	Spacecraft Fault Protection Design Specification
542-MO-003	MOS Spacecraft Performance and Analysis Software User's Guide

3. TEAM POSITIONS

This section identifies and briefly describes each position of the SCT requiring training to conduct MGS mission operations. These positions are summarized in the following paragraphs.

3.1 Control Element

The team control element coordinates and directs the operations of the team to ensure that the necessary team functions are performed and the products are generated consistent with Flight Team schedules. The team control element reports to the Flight Operations Manager.

3.2 Systems Group

This element of the SCT is responsible for System Engineering support, maintaining ground software, performing contingency planning, conducting on-line operations support and planning, operating the System Test Lab (STL), and maintaining MSA (including STL) hardware and configuration. It will consist primarily of systems and software engineers.

3.3 Subsystems Group

This element of the SCT is responsible for analysis and maintenance of spacecraft subsystems' health and performance. Six major spacecraft subsystems require Mission Operations System (MOS) support: Attitude and Articulation Control Subsystem (AACS), Command and Data Handling (C&DH), Power, Propulsion, Telecommunication, and Thermal. This element will operate the telemetry analysis and subsystems' performance prediction software modules. This software constitutes the Spacecraft Performance and Analysis Software (SPAS), which forms the Ground Data System (GDS) Engineering Analysis Subsystem (EAS). This element will consist primarily of spacecraft subsystem engineers who have transitioned from the MGS Spacecraft development and ATLO phases to MOS.

3.4 Staffing Description

The SCT will exist as an operational entity from the beginning of formal Flight Team Training activities to the end of the mission. During the launch operations phase, the SCT will coordinate with the LMA ATLO team at the launch site and respond to requests for command generation and telemetry analysis.

During cruise and planetary operations (after aerobraking) the SCT will be nominally staffed 8 hours per day, 5 days a week. The specific number of personnel assigned to each group and their work hours will vary over the duration of the mission according to the level of spacecraft activities. For high activity periods, such as launch, Mars Orbit Insertion (MOI), and aerobraking, the SCT will work extended shifts or weekends as required to support significant spacecraft activity.

4. TRAINING DEVELOPMENT

This section describes the development of the SCT's training needs, the details of the training the SCT member will receive, and the SCT certification process to verify mission readiness.

4.1 Needs Analysis

The list of tasks to be performed by each SCT position for all mission phases is contained in Appendix A.

4.2 Training Design

Participation in training activities by each SCT member will be recorded on the verification / certification form shown in Appendix A. Each SCT member's name, his/her organizational position, the tasks for which training is required, the applicable activities to accomplish this training, and the supervisor's and management's approval are contained on this form. Separate forms exist for each SCT position.

Each SCT member's readiness for mission support and the degree of training accomplished will be evaluated by the SCT Chief and the Systems and Subsystems lead engineers based on the following general criteria:

- Amount and type of OJT from program participation, especially ATLO support
- Demonstrated documentation understanding
- Procedures understanding via authorship and/or use during exercises
- Workstation familiarization via participation in SFOC-developed training
- Simulations (primarily Operational Readiness Tests [ORT]) participation and responsiveness
- Formal training lecture attendance

4.3 Instructional Development

There are four basic training activities required for the SCT: documentation review, orientation lectures (or videos), OJT in spacecraft design and/or ATLO, and simulations, as described in 542-409, Vol. 7.

5. DEPENDENCIES

The supporting elements on which the implementation of this training plan depends are:

- Orientation lectures from Flight Team members
- Workstation training from the JPL Multimission Ground Support Office (MGSO)
- Integrated System Tests (IST) and MOS Compatibility testing from ATLO
- Simulations from JPL training engineer.

6. SCHEDULE

The training schedule is dynamic and changes occur frequently as the MGS program progresses. Therefore, a specific SCT training schedule is not included in this document, but is included within the Flight Team training schedule contained in 542-409, Vol. 7.

APPENDIX A

Training Verification / Certification Forms:

- **Control Unit**
- **Systems Unit**
- **Subsystems Unit**

SCT Training Verification / Certification **Control Unit**

Name: James C. Neuman

Position: Spacecraft Team Chief

Task	***Training Activity***	***Verification***	***Date***	***Comments***
Assimilate MGS Spacecraft Design	Lectures, MOS Docs			
Assimilate MGS Mission Plans	Lectures, MOS Docs			
Assimilate MGS MOS Processes	OJT, Simulation, Lectures, MOS Docs			
Operate DMD Workstation	OJT, W/S Training			
Coordinate SCT Activities with Mission Manager & Flight Team Elements	Simulation			
Perform Functions of Assistant Mission Manager	Simulation			
Report Status to JPL Mgmt (Reviews, HQ Quarterly Inputs)	Simulation			
Maintain Staffing Plans & Schedules	Simulation			
Provide Technical Direction	Simulation			
Resolve Intrateam Issues	Simulation			
Conduct SCT Meetings and Support Flight Team Meetings	Simulation			
Plan Future Spacecraft Activities, Develop Engineering Objectives	Simulation			
Coordinate with Mission Planning and Sequencing Team	OJT, Simulation			
Support Realtime Operations	OJT, Simulation			
Lead the Spacecraft Team During Anomalous Conditions & Recovery	Simulation			
Gather S/S Input & Report Health and Status of Spacecraft	Simulation			
Review Selected Team Products	Simulation			
Review Mission Planning Products	Simulation			
Review Sequencing Products	OJT, Simulation			
Review Non-Stored Command Products	OJT, Simulation			

Certification: ______________________

Flight Operations Manager

SCT Training Verification / Certification **Control Unit**

Name: Eileen M. Dukes

Position: Subsystems Lead Engineer

Task	***Training Activity***	***Verification***	***Date***	***Comments***
Assimilate MGS Spacecraft Design	Lectures, MOS Docs			
Assimilate MGS Mission Plans	Lectures, MOS Docs			
Assimilate MGS MOS Processes	OJT, Simulation, Lectures, MOS Docs			
Operate DMD Workstation	OJT, W/S Training			
Coordinate SCT Activities with Mission Manager & Flight Team Elements	Simulation			
Perform Functions of Assistant Mission Manager	Simulation			
Report Status to JPL Mgmt (Reviews, HQ Quarterly Inputs)	Simulation			
Maintain Staffing Plans & Schedules	Simulation			
Provide Technical Direction	Simulation			
Resolve Intrateam Issues	Simulation			
Conduct SCT Meetings and Support Flight Team Meetings	Simulation			
Plan Future Spacecraft Activities, Develop Engineering Objectives	Simulation			
Coordinate with Mission Planning and Sequencing Team	OJT, Simulation			
Support Realtime Operations	OJT, Simulation			
Lead the Spacecraft Team During Anomalous Conditions & Recovery	Simulation			
Gather S/S Input & Report Health and Status of Spacecraft	Simulation			
Review Selected Team Products	Simulation			
Review Mission Planning Products	Simulation			
Review Sequencing Products	OJT, Simulation			
Review Non-Stored Command Products	OJT, Simulation			

Certification: ____________________
Spacecraft Team Chief

Concurrence: ____________________
Flight Operations Manager

SCT Training Verification / Certification **Control Unit**

Name: Kenny R. Starnes

Position: Systems Lead Engineer

Task	***Training Activity***	***Verification***	***Date***	***Comments***
Assimilate MGS Spacecraft Design	Lectures, MOS Docs			
Assimilate MGS Mission Plans	Lectures, MOS Docs			
Assimilate MGS MOS Processes	OJT, Simulation, Lectures, MOS Docs			
Operate DMD Workstation	OJT, W/S Training			
Coordinate SCT Activities with Mission Manager & Flight Team Elements	Simulation			
Perform Functions of Assistant Mission Manager	Simulation			
Report Status to JPL Mgmt (Reviews, HQ Quarterly Inputs)	Simulation			
Maintain Staffing Plans & Schedules	Simulation			
Provide Technical Direction	Simulation			
Resolve Intrateam Issues	Simulation			
Conduct SCT Meetings and Support Flight Team Meetings	Simulation			
Plan Future Spacecraft Activities, Develop Engineering Objectives	Simulation			
Coordinate with Mission Planning and Sequencing Team	OJT, Simulation			
Support Realtime Operations	OJT, Simulation			
Lead the Spacecraft Team During Anomalous Conditions & Recovery	Simulation			
Gather S/S Input & Report Health and Status of Spacecraft	Simulation			
Review Selected Team Products	Simulation			
Review Mission Planning Products	Simulation			
Review Sequencing Products	OJT, Simulation			
Review Non-Stored Command Products	OJT, Simulation			

Certification: ______________________
Spacecraft Team Chief

Concurrence: ______________________
Flight Operations Manager

SCT Training Verification / Certification **Systems Unit**

Name: ______________________________

Position: ______________________________

Task	*Training Activity*	*Verification*	*Date*	*Comments*
Assimilate MGS Spacecraft Design	Lectures, MOS Docs			
Assimilate MGS Mission Plans	Lectures, MOS Docs			
Assimilate MGS MOS Processes	OJT, Simulation, Lectures, MOS Docs			
Operate DMD Workstation	OJT, W/S Training			
Plan Future Spacecraft Activities, Develop Engineering Objectives	Simulation			
Coordinate with Mission Planning and Sequencing Team	OJT, Simulation			
Support Realtime Operations	OJT, Simulation			
Operate the Spacecraft During Anomalous Conditions & Recovery	Simulation			
Gather S/S Input & Report Health and Status of Spacecraft	Simulation			
Maintain the Ground Software Supporting Spacecraft Operations	OJT			
Define & Maintain Appropriate Procedures for Systems Operations	OJT			
Define and Maintain Telemetry Reqmts for System Performance Assessment	OJT			
Define, Maintain, & Deliver Appropriate Workstation Display Configurations	OJT			
Review Mission Planning Products	Simulation			
Produce Input to Sequence Processes	OJT, Simulation			
Review Sequencing Products	OJT, Simulation			
Produce Input to Non-Stored Commanding Processes (Excl SASFs)	OJT, Simulation			
Review Non-Stored Command Products	OJT, Simulation			
Define Constraint Checking Requirements for Systems and Ensure Implementation of Adequate, Appropriate Constraint Checks in Software or Procedure Checklists	OJT			
Monitor System Performance Via Evaluation of Selected Spacecraft Telemetry to Assess Current Status	OJT, Simulation			
Analyze Selected Spacecraft Telemetry to Establish Performance Trends	OJT, Simulation			
Operate the Systems Analysis Programs & Maintain the Systems Databases of EAS	OJT, Simulation			
Generate and Track System-Related Engineering Command and S/C Activity Sequence Requests	OJT, Simulation			
Archive Processed Engineering Data	OJT			
Support APG Meetings	Simulation			
Support Systems-Level STL Test Planning, Conduct, and Analysis	OJT, Simulation			
Provide STL Test Conduct	OJT, Simulation			
Provide STL Test Analysis & Report	OJT, Simulation			
Manage MSA, Perform System Admin Functions & CM, Maintain Library	OJT			

Certification: ______________________________
Systems Lead Engineer

Concurrence: ______________________________
Spacecraft Team Chief

SCT Training Verification / Certification **Subsystems Unit**

Name: ____________________

Position: ____________________

Task	***Training Activity***	***Verification***	***Date***	***Comments***
Assimilate MGS Spacecraft Design	Lectures, MOS Docs			
Assimilate MGS Mission Plans	Lectures, MOS Docs			
Assimilate MGS MOS Processes	OJT, Simulation, Lectures, MOS Docs			
Operate DMD Workstation	OJT, W/S Training			
Define & Maintain Appropriate Procedures for Subsystem Operations, Including Maintenance and Calibrations	OJT			
Define and Maintain Telemetry Requirements for Subsystem Performance Analysis	OJT			
Define & Maintain Red & Yellow Alarm Limits for All Mission Phases	OJT			
Define & Maintain Appropriate Workstation Display Configurations	OJT			
Review Mission Planning Products	Simulation			
Define Proper Operation and Maintenance Reqmts for Subsystems	OJT, Simulation			
Perform Periodic Performance Predicts	OJT, Simulation			
Perform Subsystem Perform. Analysis	OJT, Simulation			
Analyze Selected Spacecraft Telemetry to Establish Performance Trends	OJT, Simulation			
Maintain Database Containing Current and Historical Performance and Configuration Status of Subsystems	OJT, Simulation			
Provide Engineering Support for Reloading Flight Software Updates	OJT, Simulation			
Produce Input to Sequence Processes	OJT, Simulation			
Review Sequencing Products	OJT, Simulation			
Produce Input to Non-Stored Commanding Processes (Excl SASFs)	OJT, Simulation			
Review Non-Stored Command Products	OJT, Simulation			
Support Realtime Operations	OJT, Simulation			
Define Constraint Checking Requirements for Subsystems and Ensure Implementation of Adequate, Appropriate Constraint Checks in Software or Procedure Checklists	OJT			
Monitor Subsystem Performance Via Evaluation of Selected Spacecraft Telemetry to Assess Current Status	OJT, Simulation			
Report on Subsystem Health and Status, Including Consumable Status & Predicted Subsystem Life	Simulation			
Operate the Appropriate Subsystem Analysis Programs & Maintain the Models and Databases of the EAS	OJT, Simulation			
Generate and Track Subsystem-Related Engineering Command and Sequence Activity Requests	OJT, Simulation			
Archive Processed Engineering Data	OJT			
Support S/S-Level STL Test Planning, Conduct, and Analysis	OJT, Simulation			

Certification: ____________________
Subsystems Lead Engineer

Concurrence: ____________________
Spacecraft Team Chief

542 - 409 ANNEX 3

MARS GLOBAL SURVEYOR

NAVIGATION TEAM TRAINING PLAN

Prepared by:

E. Graat, P. Esposito
Navigation Analysts

Approved by:

P. Esposito
Navigation Team Chief

PRELIMINARY VERSION: April 22, 1996

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

MARS GLOBAL SURVEYOR

Table of Contents

MARS GLOBAL SURVEYOR

Table of Contents

ACKNOWLEDGMENT

This plan evolved from the Mars Observer Navigation Team Training Plan whose lead author was E. Graat. S. Demcak provided updates to our directory structure and organization on the NCF computers, Ares and Tharsis.

1.0 Navigation Training Plan Overview

1.1 Navigation Training Plan

1.1.1 Purpose

This document defines the training plan for the Mars Global Surveyor Navigation Team (NAV) which shall insure the readiness of NAV personnel to carry out flight operations. It is in response to requirements levied by the Project through the MOS Training Engineer, Jan Wilson.

1.1.2 Scope

This plan identifies navigator training requirements and a plan for each person to achieve flight operations readiness. The training period actually began once the MGS Project was formed. It continued throughout the period of analysis leading to the Final Navigation Plan (published 9/15/95) and intensified with the Ground Data System (GDS) and AMMOS formal test periods. It shall culminate with special Sequence (MOSC, etc) and Operational Readiness Tests (ORTs) and internal NAV testing.

1.1.3 Navigation Team

Navigation has six flight operations positions; these are given and followed with a brief description of work tasks (based in part on the Mars Observer experience):

Navigation Team Chief: P. Esposito

Orbit Determination Analysts: J. Giorgini and E. Graat

Propulsive Maneuver Analyst: V. Alwar

Trajectory and Aerobraking Design Analyst: M. D. Johnston

Navigation Analyst and Workstation Engineer : S. Demcak

TABLE 1. NAVIGATION FUNCTIONAL OVERVIEW - INTERPLANETARY PHASE

- TEAM MANAGEMENT, PROJECT AND OPERATIONS COORDINATION
    - COORDINATE ACTIVITIES WITH FLIGHT TEAMS
        - MANEUVER IMPLEMENTATION WORKING GROUP
        - EPHEMERIS WORKING GROUP
        - SEQUENCE REVIEWS
        - ENCOUNTER GDS DELIVERY
        - MOC IMAGE PLANNING AND IMPLEMENTATION
    - ESTABLISH WORK SCHEDULES, ASSIGNMENTS AND BUDGETS
    - PREPARE FOR PROJECT REVIEWS AND PRESENTATIONS
        - POST-INJECTION REPORT
        - POST-TCM REPORT
        - FORMAL PROJECT REVIEWS (LAUNCH READINESS REVIEW, ENCOUNTER READINESS REVIEW, ...)
    - WEEKLY STATUS REPORTS TO PROJECT AND NASA
    - CONDUCT NAVIGATION TEAM MEETINGS
        - CURRENT RESULTS, DISCUSS OPERATIONAL PROBLEMS, LECTURES, EXPLANATION OF NEW MODELS AND ALGORITHMS,...
    - ESTABLISH TEST AND TRAINING SESSIONS - CERTIFY NAVIGATORS
        - NAV SOFTWARE USAGE, WORKSTATION PROFICIENCY, PDB FILE TRANSFER, COTS SOFTWARE, ...
    - ASSIST IN PLANNING AND PARTICIPATE IN OPERATIONAL READINESS TESTS (ORTs)
    - PROVIDE TECHNICAL DIRECTION AND CROSS-CHECKING OF NAV RESULTS
    - ASSESS ECRs FOR NAVIGATION IMPACT
    - PREPARE PROJECT / MISSION PRESENTATION TO JPL COMMUNITY
        - “ON THE ROAD TO MARS”
        - “INTERPLANETARY AND ORBITAL NAVIGATION”
    - PREPARE FOR AND COORDINATE THE SECTION 312 LAUNCH AND ENCOUNTER READINESS REVIEWS (NAVIGATOR REVIEW)
    - MAINTAIN CROSS-TRAINING FOR OD AND ANALYSIS, ...
    - CONFERENCE PAPER PREPARATION
        - “NAVIGATING MARS OBSERVER: LAUNCH THROUGH ENCOUNTER AND RESPONSE TO THE PRE-ENCOUNTER ...”
        - “MARS OBSERVER INTERPLANETARY ORBIT DETERMINATION”
    - CONFERENCE TRAVEL AND PRESENTATION

TABLE 1. NAVIGATION FUNCTIONAL OVERVIEW - INTERPLANETARY PHASE

- TRAVEL TO LMA FOR CONSULTATION
- MARSGRAM: MONITOR AND UPDATES
- INTERFACE WITH PUBLIC INFORMATION OFFICE
- MISCELLANEOUS ACTIVITIES

PRESENTATIONS TO RADIO SCIENCE TEAM, SECTION MANAGER UPDATES AND QUIET HOUR, INTERVIEWS WITH REPORTERS, PROJECT AND SECTION “ALL HANDS MEETINGS”, PREPARATION FOR ECAP, EMPLOYEE INPUT TO GROUP SUPERVISORS, JPL TRAINING (TQM, “ THE CHANGING JPL”, ETC), MOI NEWS CONFERENCE (PRESENTATION AND PANEL MEMBER), ...

TABLE 2. NAVIGATION FUNCTIONAL OVERVIEW - INTERPLANETARY PHASE

- ORBIT DETERMINATION AND ANALYSIS (OD&A)
    - PREPARE FOR INITIAL ACQUISITION AND ESTABLISH INJECTION ORBIT
        - INITIAL CONDITIONS: LAUNCH PROFILE DATA FILE AND ICVs; INITIAL OD : ANGLES AND DOPPLER; MULTIPLE OD ACTIVITY; ASSESS INJECTION ACCURACY; MAP TO ENCOUNTER
    - CONTINUAL OD FOR MODEL AND TARGETING ACCURACY AND CROSS-CHECKING
        - ORBIT DETERMINATION SOLUTIONS AND ANALYSIS (DOPPLER ONLY, RANGE ONLY, DOPPLER AND RANGE)
        - DETERMINE MODEL UPDATES AND ASSESS ACCURACY (SRP, AMDs, NG ACCELERATIONS, ...)
        - DETERMINE POST-TCM PARAMETERS - PROVIDE RESULTS TO SCT
        - DETERMINE AND MONITOR S/C LOCATION AND ACCURACY IN THE TARGET PLANE (B-PLANE)
        - CORRECT TRACKING DATA FOR S/C SPIN SIGNATURE
    - NAVIGATION RESULTS, FILE GENERATION AND DISTRIBUTION
        - PERIODIC SPK FILES FOR S/C EPHEMERIS UPLINK
        - PERIODIC P-FILES FOR DSN OPERATIONS FOR ANGULAR POINTING AND FREQUENCY PREDICTIONS
        - PERIODIC LT FILES FOR TIME COORDINATION AND COMMANDING
        - PERIODIC STATRJ FILES FOR SCT LINK ANALYSIS
        - LONG-TERM P-FILE GENERATION FOR MISSION PLANNING AND DSN VIEW PERIODS AND STATION ALLOCATION
        - PDB TRANSFER, VERIFICATION AND NOTIFICATION (FILE RELEASE FORMS)
    - GENERAL TRAJECTORY / ORBIT INFORMATION FOR PUBLIC INFORMATION / RELATIONS
    - PREPARE OD RESULTS FOR MANEUVER DESIGN (TCMs, MOI, ETC)
    - ASSESS TRACKING DATA ACCURACY, MONITOR AND FEEDBACK TO THE TMOD (FRs)
        - ASSESS DATA QUALITY AND BIAS FOR ONE-WAY DOPPLER
        - ASSESS DATA QUALITY AND BIAS FOR DIFFERENCED DOPPLER
    - PROVIDE RANGING PARAMETERS TO DSN OPERATIONS
    - DOCUMENT RESULTS AND PROVIDE SYSTEMATIC FILE STORAGE
    - GDS ENCOUNTER DELIVERY (4/1/97)

        PLAN FOR AND CHECK RECONFIGURATION OF WORKSTATIONS

TABLE 2. NAVIGATION FUNCTIONAL OVERVIEW - INTERPLANETARY PHASE

  - UNDERGO TEST AND TRAINING WITH NEW DATA SYSTEM
- ATTEND WORKING GROUP MEETINGS AS REQUIRED
- PARTICIPATE IN CONFERENCE PAPER PREPARATION
- UNIX WORKSTATIONS: H/W AND S/W TRAINING, TRACKING PROBLEMS AND INTERFACE WITH SAs FOR RESOLUTION
- SCRIPT / ROUTINE DEVELOPMENT FOR TASK AUTOMATION (COTS, GNUPLOT, ...)
  - DATA CORRECTION FOR S/C ROTATION, B-PLANE TARGETING PLOTS, AMD SYSTEMATIC TRENDS, ...
- INTRA-TEAM AND CROSS-TRAINING
- LOCKFILE DEVELOPMENT, REVIEW AND VERIFICATION (LAUNCH AND ENCOUNTER)
- MISCELLANEOUS

TABLE 3. NAVIGATION FUNCTIONAL OVERVIEW - INTERPLANETARY PHASE

- PROPULSIVE MANEUVER AND AEROBRAKING DESIGN AND IMPLEMENTATION
    - INJECTION ASSESSMENT
    - MANEUVER TARGET UPDATES
    - DESIGN TCM-1,2,3,4, BACK-UP MOI AND MOI PROPULSIVE MANEUVERS; ALSO TCM-1C AND TCM-4C
    - MANEUVER VERIFICATION
    - DESIGN ALL "ROUTINE " AEROBRAKING MANEUVERS (AB-2,3,4, ABMs, AND ABX) ; (NOMINAL UP AND DOWN, 1/2 X UP AND DOWN, 2X UP AND DOWN)
    - REVIEW SEQUENCES FOR MANEUVER SPECIFICATION CROSS-CHECK
    - ANALYSIS TO SUPPORT THE TCM-4 GO/NO GO DECISION
    - UPDATE THE MISSION DELTA-V BUDGET
    - DEVELOP MISSION TRADES BASED ON THE DELTA-V ASSESSMENT
        - CAPTURE ORBIT PERIOD REDUCTION
        - EARLY TERMINATION OF AEROBRAKING

- AEROBRAKING DESIGN AND UPDATE
    - RE-DESIGN BASELINE AEROBRAKING PLAN BASED ON LAUNCH DATE, TCM-1 DELTA-V, REVISED ATMOSPHERIC DENSITY INFORMATION (GROUND BASED AND MPF MEASUREMENTS) AND LIKELIHOOD OF A GLOBAL DUST STORM
    - REFINE THE AEROBRAKING OPERATIONS DECISION PROCESS

- OTHER ACTIVITIES
    - ENCOUNTER GDS TEST AND TRAINING
    - ENCOUNTER ORT PARTICIPATION
    - MEETING ATTENDANCE AND PRESENTATION PREPARATION AS REQUIRED (NAV TEAM, MANEUVER WG, PROJECT MANEUVER REVIEWS, ...)
    - CROSS-TRAINING FOR OD&A
    - CROSS-TRAINING FOR MANEUVER DESIGN
    - OFF-LINE INTERFACE WITH PROPULSION ENGINEER (LMA)
    - MISCELLANEOUS (INCLIN BIAS AT MOI, PITCH-OVER SIMULATION, ...)

1.1.4 Navigation Plan Document

This plan provides detailed guidelines concerning navigation flight operations. It gives expected spacecraft location accuracy, propulsive maneuver design capability (i.e. velocity changes or delta-velocities), a tracking data analysis strategy, a summary of operational procedures and operational interface agreements throughout the mission. It also provides an overview of NAV deliveries during the critical aerobraking period. It is required reading for each member of the NAV Team.

1.1.5 Mars Observer Navigation Publications

Two previous documents are required reading as an important source of preparation for MGS interplanetary flight operations:

1) Mars Observer Interplanetary Cruise Orbit Determination, L. A. Cangahuala et al, AAS/AIAA Conference paper AAS 94-133, 2/14/94.

2) Navigating Mars Observer: Launch Through Encounter and Response To The Spacecraft's Pre-Encounter Anomaly, P. B. Esposito et al, AAS/AIAA Conference paper AAS 94-119, 2/14/94.

1.2 Navigation Functions and Responsibilities

The trajectory, orbit determination, maneuver, and navigation planning functions of the Mars Global Surveyor (MGS) Navigation Team (NAV) are described in the following sections.

1.2.1 Trajectory and Orbit Analysis

Purpose:
To describe the functions and responsibilities of trajectory and orbital analysis .

Prerequisites:
The navigator must have a solid understanding of orbital and celestial mechanics.
During and prior to the Mars Global Surveyor mission, trajectory and orbit analysis will involve the following activities:

1) The generation of predicted and reconstructed S and P kernels from spacecraft ephemeris files (P- files).
2) The generation of light time (LT) files, orbit propagation and timing geometry (OPTG) files, orbit number and station polynomial (STATRJ) files.
3) The maintenance of a data base on the navigation computer for the products listed in items 1 and 2.
4) The delivery of the navigation products listed in items 1 and 2 to the Project Data Base (PDB).
5) The generation of spacecraft trajectories for the design and verification of maneuvers.
6) Prior to the actual mission operations, the generation of a nominal set of navigation products (such as above) for planning and test and training purposes.
7) Throughout AB, maintain and update the navigation databases.

1.2.2 Orbit Determination and Analysis

Purpose:
To describe the functions and responsibilities of orbit determination and analysis .

Prerequisites:
The navigator must have a solid understanding of orbital and celestial mechanics, matrix algebra, estimation theory, and navigation tracking data and analysis.
During the Mars Global Surveyor mission, orbit determination and analysis will involve the following activities:

1) The determination and prediction of MGS's orbit from radiometric tracking data. MGS's orbit will be determined by estimating the spacecraft state and other dynamic parameters based on the information content of the radiometric tracking data. This data includes one-way X-band (8.4 GHz) Doppler (F1), two-way coherent X-band Doppler (F2), X-band range (SRA), and two-way minus three-way X-band Doppler (F2MF3). Also, some angle data will be used immediately after launch. The updated estimated parameters will be used in the prediction of the trajectory and orbit.
2) The monitoring and assessment of tracking data quality and biases.
3) The improvement of various dynamical models such as solar radiation pressure, Mars atmospheric density, and Mars gravity as well as others.
4) The generation of orbit solutions for the design and reconstruction of maneuvers. For all mission phases, maneuvers will be designed from the best orbit solution available. Note that aerobraking (AB) represents a special case for maneuver design. From the analysis of tracking data, the velocity-change due to an executed maneuver or its direction and magnitude can be estimated.
5) The generation of a highly accurate Mars gravity model during the Gravity Calibration (GC) sub-phase of the mission.
6) The generation of navigation products. This activity includes maintenance of the product database on the navigation computer and delivery of the products to the PDB.

1.2.3 Maneuver Analysis

Purpose:
To describe the functions and responsibilities of maneuver analysis .

Prerequisites:
The navigator must have a solid understanding of orbital and celestial mechanics, matrix algebra, and control theory.
During the Mars Global Surveyor mission, maneuver analysis will involve the following activities:

1) The design of maneuvers based on the best available orbit determination solution and the mission requirements levied on the Navigation Team. This applies to all phases of the mission: Interplanetary, Orbit Insertion, and Mapping.

1a) Note that during the aerobraking (AB) subphase, propulsive maneuvers shall have been previously designed during the interplanetary phase. Thus these maneuvers shall be used off-the-shelf and will not be designed during AB.

2) The generation of the Maneuver Profile File (MPF) for the spacecraft team and the evaluation of the spacecraft team's Maneuver Implementation File (MIF).
3) The assessment of maneuver execution in real-time and their reconstruction. The nominal maneuver values and their uncertainties will also be provided to assist their reconstruction efforts.
4) For all maneuvers, provide a verification that the maneuver does not violate the Sun-constraint.

1.2.4 Aerobraking Design and Decision Process

Purpose:
To describe the functions and responsibilities of aerobraking design.

Prerequisites:
The navigator must have a solid understanding of orbital and celestial mechanics, matrix algebra, estimation theory, navigation tracking data and analysis, and all procedures associated with the planning and acquisition of navigation tracking data.
During the MGS interplanetary and orbit insertion phases, AB design will involve the following activities:

1) Redesign of the baseline AB plan based upon a) launch date and b) fuel consumption (delta-v) actuals for TCM-1 and TCM-2. Also updated atmospheric density and indications of global dust storm activity shall affect this AB redesign.

2) Implement the AB Operations Decision Process and update as necessary.

1.2.5 Cross Training

It is the goal of this plan that every member of the Navigation Team be cross-trained to carry out multiple functions. This can be achieved by intra-team training and by training within Section 312 using that section’s resources. This capability shall be especially important during aerobraking. During this interval, each team member must be capable of exercising the orbit determination and analysis function and accessing the NCF, PDB and OSCAR for file transfers.

2.0 The Navigation Computer Environment

The computer environment of the Mars Global Surveyor Navigation Team is described in the following sections. The topics covered include the computer system configuration, the UNIX operating system, and the NAV directory structure.

2.1 The Navigation Computer System Configuration

Purpose:
To acquaint the navigator with the hardware, software, and system configuration of the Navigation Team's computer system.

Prerequisities:
None.

At present the Navigation Team's computer hardware consists of six Sun SPARC workstations, two HP 720 workstations, and two HP 750 workstations. The physical location of the Sun SPARC and HP 720 workstations are within the Mission Support Area (MSA) on the second floor of building 264. The two HP 750 workstations are located at the Multi Mission Navigation Computing Facility (NCF) , in room 267 of building 301. The individual NAV machines are designated as follows (the assigned-to person is shown in parenthesis) :

Sun SPARC:	mgnav1 (Esposito), mgnav2 (Johnston), mgnav3 (Demcak), mgnav4 (Alwar), mgnav5 (Giorgini) and mgnav6 (Graat)
HP 720:	mgnavhp1, mgnavhp2
HP 750:	ares, tharsis

Each workstation is able to access several other workstations simultaneously. This connectivity between workstations is provided by the MGS Operations LAN and the Multi-Mission Navigation LAN both of which go through the Multi-Mission Ground Data System (MGDS) backbone via restricted routers (RR). Access between the Navigation machines on the same LAN is facilitated by the remote login command rlogin. To access a machine on a different LAN, the telnet command must be used.

The exchange of information between NAV and the outside world is facilitated through the Project Data Base (PDB) and the DSN/Navigation Interface VAX (OSCAR). Access to the PDB and OSCAR from the individual workstations is as follows:

PDB:	mgnav1, mgnav2, mgnav3, mgnav4, mgnav5, mgnav6
OSCAR:	ares, tharsis (also the mgnav workstations, through the firewall)

Access to OSCAR is provided by the File Transfer Program, ftp, while access to the PDB uses the Advanced Multi-Mission Operations System (AMMOS) programs such as cdb_wotu, cdb_fti, and dbq. The NAV workstation configuration and connectivity are illustrated in Figure 2.1.

The Navigation Software System is installed on ares and tharsis. The Navigation Software System consists of the Double Precision Trajectory Program (DPTRAJ), the Orbit Determination Program (ODP), the Maneuver Operations Program Set (MOPS), the DPTRAJ-ODP Utilities, the Navigation Library Software and some gravity analysis tools. With respect to the HP 750s, ares comprises the primary navigation computer with tharsis serving as the backup in the NCF. One HP-720 (mgnavhp1) serves as another backup workstation, located in Bldg 264, 2nd floor, with a subset of the Navigation software installed. This machine shall also be used in a development role for Mars '98 analysis.

Installed on each Sun SPARC workstation is the Advanced Multi-Mission Operations System software. AMMOS includes the PDB access software, the Navigation Ancillary Information Facility (NAIF) software, the Standard Formatted Data Unit (SFDU) software, and the Data Monitoring & Display (DMD) software. At present mgnav1 through mgnav5 support the PDB, NAIF, SFDU, and DMD software while the mgnav6 workstation supports only the PDB, NAIF, and SFDU software. Currently no AMMOS software has been installed on any HP workstation.

The operating system on each of the NAV workstations is some version or "flavor" of UNIX. The Sun SPARCs use Sun OS 4.1.3 which is basically the Berkeley Standard Delivery (BSD 4.3) version of UNIX. The HPs use HP-UX which is the System V UNIX with BSD extensions. The NAV workstations also support window software. Both the Sun SPARC and HP workstations support X windows and Motif while only the HP workstations support HP VUE. A short introduction to the UNIX operating system is given in the next section.

2.2 The UNIX Operating System

Purpose:

To provide the navigator with a brief introduction to the UNIX operating system.

Prerequisites:

The navigator must have access to a NAV workstation. The System Administrator (SA) should have already provided this. Presently, the SAs for the MM Navigation LAN are J. Mantel (x 4-8124) and C. Rhoades (x 4-7162) and the Lead SA for the MGS Operations LAN is Mike Fitzpatrick (x 3-0756); (S. Taylor (x 3-0756) is the supervisor).

The UNIX operating system is composed of three core software components: the kernel, the file system, and the Shell. In brief, the kernel manages the resources of the computer, the file system organizes the data on the computer, and the Shell is a program which interfaces between the user and the kernel. The kernel holds little interest for the needs of navigation, but the file system and Shell merit some discussion.

The UNIX file system is hierarchical. A hierarchical file system has a unique file type called a directory which may contain both data files and other directories (subdirectories). Also, the hierarchical file system branches from a single place known as the root, denoted by /. The root contains directories which may also contain many other directories and files. Since the root is listed at the "top" (placed first), this hierarchical file system is called an inverted tree structure.

A sequence of directories is called a path. A specific directory or file may be uniquely identified by its absolute or relative pathname. The absolute pathname of a directory always starts from the root directory while a relative pathname starts from the current working directory.

When one logs onto a UNIX machine, one is placed at a node within the file system. This node is the home directory and one owns all files and directories contained therein. The elements of the hierarchical file structure are illustrated in Figure 2.2. Here, the relations between the root directory, its subdirectories, and the user's home directory can be seen.

To manipulate the files and directories on a UNIX system, familiarity with the following short list of commands is essential:

pwd	present working directory or print working directory. This command will print the absolute pathname of the current directory.
cd	change directory. cd followed by a directory name will place one in that directory. cd with no arguments places one back in the home directory.
ls	lists the contents of a directory.
mkdir	make directory. mkdir allows one to create new directories.
rmdir	remove directory. rmdir removes directories from the system.
chmod	change mode. chmod will change the mode or protection on files and directories.
cp	copy a file. To copy file1 to file2: cp file1 file2
mv	moves a file or directory. mv allows one to move files from one directory to another or whole directories to another directory. mv also can be used to rename files or directories.
rm	removes or deletes files.
more	scans through a text file allowing one to read its contents.
vi	visual editor. vi is a standard full screen text editor.
tar	tape file archiver. tar can save/extract multiple files and directories to/from magnetic tape, disk, or file (tarfile).
man	manual information. man is an on-line UNIX reference manual. man describes the command's function, its options, and its syntax. All of the above listed commands have man entries including the man command.

The Shell

The Shell serves as the interface between UNIX and the user. Automatically started with each login, it is an interactive program which reads commands, checks syntax, executes UNIX or other built-in system commands, and assumes control when those commands have terminated. The Shell can maintain a history of executed commands which may be recalled, allows file-matching by use of meta characters (wild-cards), and provides customizing of the working environment. Also, Shell scripts or programs may be written which are able to read multiple arguments, perform loops, execute a sequence of commands, make logical decisions, query for input, and require no compilation or linking.

The Shell is an ordinary C program and there may be several versions available on a single machine. Two common Shells are the Bourne Shell and the C-Shell. The Bourne Shell is available on all UNIX machines. It is compact and fast but has less interactive features than the C-Shell. A man entry may be called up for the Bourne Shell by man sh.

The Shell version often used on the NAV machines is the C-Shell, which has a C-like syntax. A man entry exists for the C-Shell and it may be called up as follows: man csh. The files .login and .cshrc in the home directory contain parameters which control the working environment and may be edited to suit the user's needs. For each login, the .login file brings up the C-Shell which then executes the .cshrc file. The .cshrc file defines abbreviations for commands or command sequences (alias) and sets the size of the history list (history) maintained. Also, .cshrc is processed when one starts a subshell (e.g. opening a new window). The .login file sets terminal characteristics, defines pathnames to important programs (search paths), and displays messages.

2.3 The Navigation Directory Structure

Purpose:
To acquaint the navigator with the common directory structure on ares created by the Navigation Team to manage its input files and output products.

Prerequisites:
The navigator must have access to a NAV workstation and knowledge of the UNIX operating system.

Navigation personnel have created a set of common directories to manage all their input files and output products. The major aims of the common directory structure are to save disk space by eliminating the need for each navigator to track and store his own input files, to reduce analysis errors caused by using outdated or inappropriate inputs, to ease any desired reexamination of data and products, and to simplify archiving.

The NAV directories exist on ares and tharsis at the node (a subset of these files shall also exist in the same directory on mgnavhp1):

/home/mgs

Below this directory are several subdirectories intended to serve the orbit determination, trajectory and orbit analysis, and maneuver analysis functions of the Navigation Team. The following subdirectories of /home/mgs will mainly serve the trajectory and orbit analysis and orbit determination functions:

od/dat/amd The latest and all previously delivered files describing the angular momentum desaturation events are to be stored here.

od/dat/atmos Mars atmospheric density and related information shall be stored here.

od/dat/eop The latest and all previously delivered earth orientation parameter files collected from OSCAR are to be placed here. This is a new file interface that is currently being negotiated with TMOD.

od/dat/ginlock The current and all previously used Lockfiles are stored here. Also, the inputs used in the creation of each Lockfile will be preserved as references.

od/dat/ion The latest ionospheric calibration inputs are to be stored here along with the final monthly files from TSAC.

od/dat/lpoly The launch polynomial files have been placed here. Note that for MGS, this file has been replaced with the Launch Profile Data File which shall be received from MDAC.

od/dat/namelists Examples of specific namelist inputs for the DPTRAJ-ODP programs and utilities are placed here.

od/dat/neif The navigation engineering information files are to be placed here.

od/dat/odf The latest and all previously delivered tracking data files collected from the OSCAR are to be placed here. Also, tracking data files that have been merged to cover various spans are to be stored here. Note that a backup tracking data delivery procedure exists in which ODF files are placed on the PDB.

od/dat/tp The latest and all previously delivered timing and polar motion arrays are to be stored here.

od/dat/trop The inputs needed to model the Earth's troposphere are to be placed here.

od/solns/cruise The final orbit determination solution files for the cruise phase are to be stored here.

od/solns/gravcal The final orbit determination solution files for the gravity calibration phase are to be stored here.

od/solns/insertion The final orbit determination solution files for the insertion phase (MOI to start of mapping) are to be stored here.

od/solns/mapping The final orbit determination solution files for the mapping phase are to be stored here.

The next several subdirectories of /home/mgs will serve the maneuver analysis:

mnvr/dat	Input files for the maneuver analysis software are placed here.
mnvr/dat/namelists	Maneuver namelist inputs for maneuver programs and utilities are stored here.
mnvr/misc	Miscellaneous files useful to maneuver analysis are placed here.
mnvr/solns/cruise	Maneuvers designed for the cruise phase are to be stored here.
mnvr/solns/gravcal	Maneuvers designed for the gravity calibration phase are to be stored here.
mnvr/solns/insertion	Maneuvers designed for and during the insertion phase are to be stored here.
mnvr/solns/mapping	Maneuvers designed for the mapping phase are to be stored here.

For all phases of the MGS misssion, the products generated by NAV are stored under the directories (as well as some related information):

/home/mgs/Nav_Products/cruise

/home/mgs/Nav_Products/gravcal

/home/mgs/Nav_Products/insertion

/home/mgs/Nav_Products/mapping.

Other directories under /home/mgs include:

/home/mgs/Documentation	Miscellaneous documentation.
/home/mgs/bin	Contains programs or scripts written by Nav personnel.
/home/mgs/ammos	Contains files related to the AMMOS software on the Sun workstations.

For each of the above listed directories, subdirectories have been created for each product type:

litime	Geocentric and topocentric one-way light time files are to be stored here.
mpf	The maneuver profile files are to be stored here.
mrf	The maneuver reconstruction files are to be stored here.
pfiles	The NAVIO format spacecraft ephemeris files are to be stored here.
optg	The orbit propagation and timing geometry files are to be stored here.

orbnum The orbit number files are to be stored here.

spk The SPK files are to be stored here. The SPK is a uniquely formatted file which contains spacecraft and planetary ephemeris information.

statrj The station polynomial coefficients files are to be stored here.

Although not maintained by the Navigation Team, the following directories on ares are important:

/usr/mmnav/dat/gen Contains the planetary ephemeris file, the satellite ephemeris file, the planetary partials file, and the satellite partials file. It also contains various navigation data files used throughout the mission.

/usr/mmnav/bin Contains the DPTRAJ, ODP, MOPS, and Utility executables.

/usr/mmnav/csh Contains the DPTRAJ, ODP, MOPS, and Utility scripts.

/usr/mmnav/lib Contains the Navigation Library Software.

2.4 AMMOS and NAV Software Electronic Documentation

Purpose:

To aquaint the navigator with the availability and locations of electronic versions of the AMMOS and NAV software documentation.

Prerequisities:

The navigator must have knowledge of the UNIX operating system. In addition, he must have access to at least two computers with World Wide Web (WWW) browsers: ares and a computer outside of a restricted LAN. These computers must be able to display X widgets to the console of the computer at which the user is sitting. He must also be familiar with using WWW browsers.

Much of the AMMOS and NAV software documentation is available electronically. Up-to-date documentation on the development versions of DPTRAJ, ODP, MOPS, MASL and other section software may be accessed through the section 312 home page. The NAV software documentation is available on ares and tharsis . Most of the AMMOS software documentation may be accessed from the MMNAV LAN. It may also be accessed using certain WWW browsers (e. g. Netscape) on the MGS OPS LAN provided certain configurations are made to the browsers.

2.4.1 NAV Software Electronic Documentation

The NAV software documentation is electronically available in two forms. The older form uses the NAV delivered program `xdoc` to view most of the DPTRAJ-ODP User's Reference Manuals, Volumes 1-4. This electronic documentation will not be actively supported in the future. The documentation has recently been converted to HTML form for use with World Wide Web (WWW) browsers. This documentation is included with the NAV software delivery. It contains more complete versions of the DPTRAJ-ODP User's Reference Manuals, plus many other related NAV software documents not available with `xdoc`. The latest documentation on multi-mission development versions of the navigation software may be accessed from the section 312 home page.

The WWW browsers currently available on ares and tharsis are `Mosaic and Netscape`. For example, to view the NAV software, execute `Mosaic`. Then choose "Open Local..." from the "File" menu. Choose one of the following files. (Both files are essentially identical.)

/usr/mmnav/doc/html/index.html
/usr/mmnav/doc/html/navigation_documentation.html

Then click on the highlighted text for the documentation that is desired. The highlighted text "Documentation" will get the user to another page, from which he can view NAV software related documentation.

If desired, the user can setup `Mosaic` to display the NAV software documentation page as its start-up home page. This is done via the environment variable WWW_HOME for `Mosaic`. In the C-shell, this would be done as:

```
setenv WWW_HOME /usr/mmnav/doc/html/index.html
```

2.4.2 AMMOS Software Electronic Documentation

The AMMOS documentation is available in two formats: HTML and PDF. A WWW browser should be used to view both types of formats. (In order to view PDF files, the Adobe Acrobat reader program, `acroread`, is also required.). Most of the AMMOS software documentation may be accessed from the MMNAV LAN. It may also be accessed using certain WWW browsers (e. g. Netscape) on the MGS OPS LAN provided certain configurations are made to the browsers. This documentation can be accessed using the URL:

http://div390-www.jpl.nasa.gov/usrguide/ughome.htm

The NAIF documentation is not presently available via a WWW browser. It is delivered with the NAIF distribution, though. On NAV workstations with the NAIF software installed, the documentation is available as plain text files in the directory:

/SFOC/naif_V42/doc

2.4.3 Other NAV Related Electronic Documentation

DSN related documentation may be found under its WWW home page:
http://dsn-www.jpl.nasa.gov/dsn/

MGS information may be found under the MGS WWW home page:
http://mgs-www.jpl.nasa.gov/

Some miscellaneous, navigation documentation is located on ares in:
/home/mgs/Documentation

Unofficial notes related to NAV work are contained in:
/home/mgs/Documentation/Procedures/Work

There are both HTML and text versions of many of these unofficial “procedures “.

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"DPTRAJ-ODP INTERFACES AND FILE FORMAT DESCRIPTIONS, Volume 3", Mars Global Surveyor Project Document 642-3405-DPTRAJ/ODP, 4/12/96.

"MANEUVER OPERATIONS PROGRAM SET (MOPS) UTILITY USER GUIDE", 3/29/96.

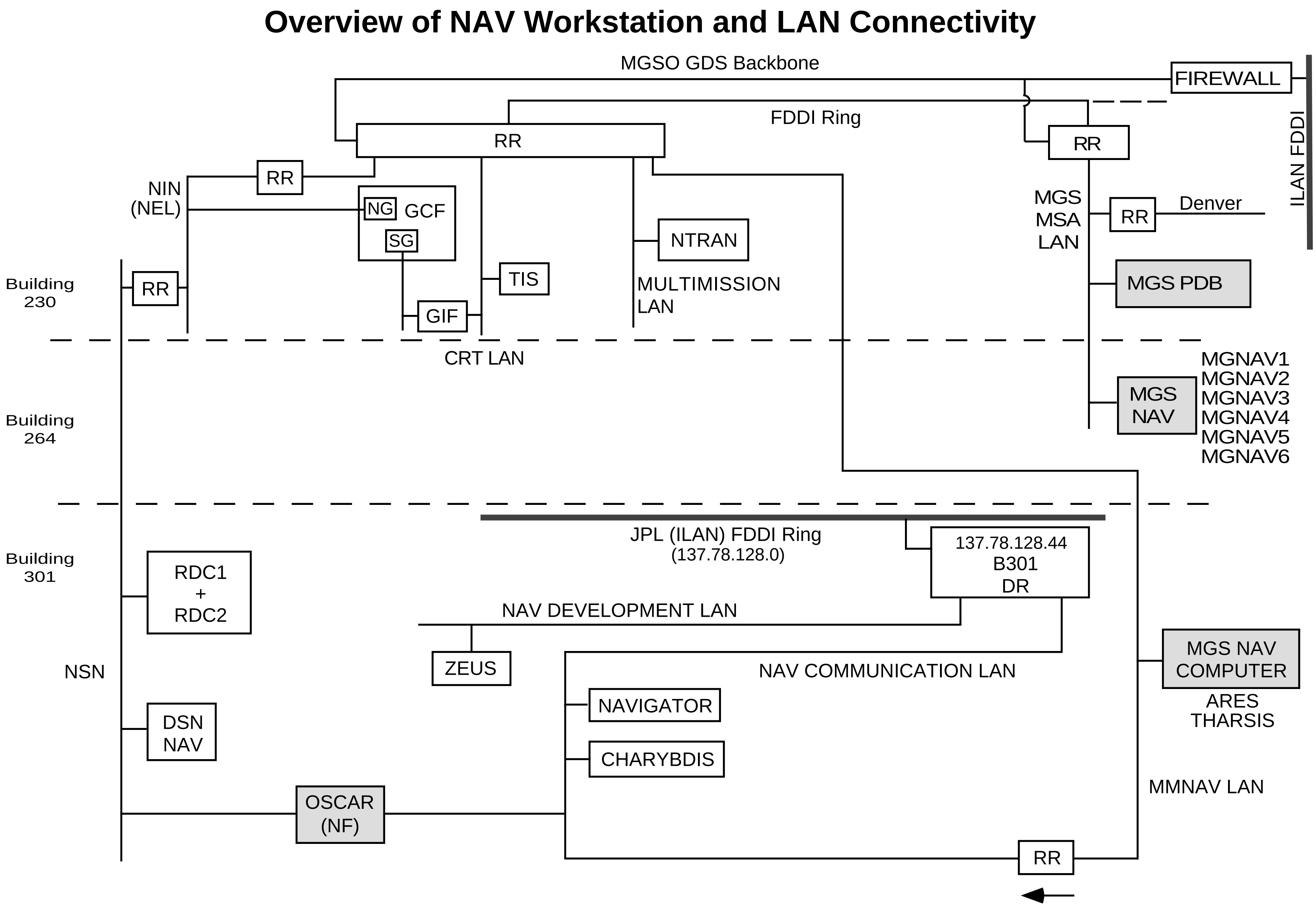

Fig. 2.1 Overview of Navigation workstations and network connectivity

```
/              root directory
|
|
net/           a subdirectory of root
|
|
ares/
|
|
home/
|
|
ejg/           home directory
```

/net/ares/home/ejg is the pathname for ejg's home directory.

Fig. 2.2 Hierarchical File structure

3.0 The Trajectory and Orbit Determination Software

The functions, inputs, and products of the trajectory and orbit determination software are described in the following sections. The topics discussed in this section include the function and execution of each DPTRAJ-ODP program, the sequences in which the DPTRAJ-ODP programs may be executed to generate solutions and products, and the contents of the MGS Lockfile.

3.1 The DPTRAJ-ODP

Purpose:
To acquaint the navigator with the function and execution of each program in the DPTRAJ and the ODP.

Prerequisites:
The navigator must have access to a NAV workstation and must be familiar with the NAV computer system configuration, the UNIX operating system, and the NAV directory structure.

At present, the Navigation Software System is mounted on the two HP 750 workstations, ares and tharsis. Ares comprises the primary NAV computer with Tharsis serving as the backup machine. The Navigation Software System consists of the Double Precision Trajectory Program (DPTRAJ), the Orbit Determination Program (ODP), the Maneuver Operations Set (MOPS), the DPTRAJ-ODP Utilities, and the Navigation Library Software. On Ares, the following directories have been created to store the Navigation Software System:

/usr/mmnav/bin	Contains the DPTRAJ, ODP, MOPS, and Utility executables.
/usr/mmnav/csh	Contains the DPTRAJ, ODP, MOPS, and Utility scripts.
/usr/mmnav/lib	Contains the Navigation Library Software.

Each program of the DPTRAJ, ODP, MOPS, and Utilities have an on-line help page. By typing the program name on the command line, followed by the word “help”, and hitting return, a brief program description appears which includes information on the required input files, the type of output generated, and how execution is invoked.

The DPTRAJ programs are concerned with the generation of precision spacecraft trajectories and the information derived from those trajectories. Many of the products NAV delivers to the Project are produced using the DPTRAJ programs: one-way light time (LT) files, orbit propagation and timing geometry (OPTG) files, station polynomial coefficient (STATRJ) files, spacecraft ephemeris files and orbit number files.. A brief description of each DPTRAJ program used by MGS NAV follows:

gindrive — serves as the input processor for all the programs in the DPTRAJ, the ODP, and MOPS. gindrive can be executed in two distinct modes: create and update. In the create mode, gindrive reads an ASCII file of namelist inputs and generates a NAVIO (i.e. binary) file called the GINFILE. This GINFILE is often called the Lockfile and contains the baseline navigation models needed for a particular mission (Section 3.2 describes the MGS Lockfile). In the update mode, gindrive again reads an ASCII file of namelist inputs but updates an existing GINFILE (often a Lockfile copy) specified by the user. The GINFILE, either created or updated by gindrive, functions as the contol file for the DPTRAJ, the ODP, and MOPS.

gindump — reads a GINFILE and prints its contents. Several options are available which determine the form and content of the dump including an user interactive option. Since the GINFILE controls the execution of the DPTRAJ, the ODP, and MOPS, gindump should always be executed as a means of validating the contents of the GINFILE.

icprep — generates an ASCII file of namelist inputs describing launch initial conditions. Icprep reads the launch polynomial coefficients file to create its output file. The namelist inputs generated by icprep can be used as input to gindrive. Note that this program was required for Mars Observer launch operations. For MGS launch operations, it will not be used because the Launch Polynomial File has been replaced by the Launch Profile Data File.

pvdrive — generates an integrated spacecraft ephemeris NAVIO file based on the initial conditions, astrodynamic models, and force models on the GINFILE and the information from the planetary ephemeris file. Pvdrive may be executed in three modes: generate trajectory information only (P-FILE), generate trajectory and variational partial information (PV-FILE), and perform a search on specific burn parameters.

twist — generates print of the spacecraft ephemeris relative to various coordinate systems. twist requires the P-FILE (or PV-FILE), the planetary ephemeris file, and the GINFILE. The GINFILE specifies which central bodies and in what coordinate systems the spacecraft ephemeris should be printed. Twist also generates the orbit propagation and timing geometry file (OPTG) which contains spacecraft ephemeris data for specific events (e.g. periapsis times).

litime — generates a one-way light time file as a function of spacecraft event time. litime can generate geocentric and topocentric files.

statrj — generates a station polynomial coefficients file. The STATRJ file may contain spacecraft rise/set times as seen from various tracking stations, the spacecraft azimuth/elevation information, spacecraft to station range information, and other range and angular data between the spacecraft, the Sun, the Earth, and Mars (or other planet).

The programs of the ODP are concerned with the generation of computed observables and observable partials based on spacecraft trajectories generated in DPTRAJ, forming data residuals between the computed observables and the measured observables on tracking data files, using those residuals to estimate corrections to the initial trajectories, and mapping the new solutions and their covariances to useful coordinate systems and times. The programs of the ODP are summarized below.

translate — reads an ASCII file of Control Statement Processor (CSP) commands and generates a NAVIO file whose instructions are subsequently executed in regres and/or edit1. Basically, CSP commands direct the ODP on how it handles radiometric tracking data. Via the CSP commands, the navigator can assign data weights, apply media calibrations, and remove suspect data.

regres — generates a NAVIO file, called the REGRES file, of computed data observables, data residuals (observed - computed), and partial derivatives of those observables with respect to various parameters (e.g. spacecraft state) for each data point on a tracking data file. Regres requires information from the GINFILE, the PV-FILE, the planetary ephemeris file, and the NAVIO CSP command file from translate.

edit1 — reads the NAVIO CSP command file output from translate and modifies tracking data or REGRES files accordingly.

accume — processes the data on the REGRES file and generate information arrays and residual vectors. When all the REGRES data is used to form a single information array and residual vector, the filter is said to be operating in the single batch mode. If the REGRES data is formed into several information arrays and residual vectors, the filter is said to be operating in the sequential batch mode. In the single batch mode, the NAVIO ACCUME file is the only output from accume; however, in the sequential batch mode and if stochastic parameters are specified, accume writes a SMOOTH file and an ACCUME file. The SMOOTH file contains knowledge on the evolution of the stochastic parameters for later use in solve and smooth.

solve — reads the information arrays and residual vectors from accume and generates corrections to the estimated parameters so as to minimize the weighted sum-of-squares of the data residuals. Solve also generates covariance and sensitivity matrices. Solve can execute using either of two numerical algorithms: square-root information filter (SRIF) or singular value decomposition (SVD). If the information array is singular, the SVD method must be used. For well-conditioned, large parameter (> 50) solutions, it is better to use SRIF. Like accume, solve operates in either the single or sequential batch modes. In the single batch mode, solve produces two NAVIO files: SOLVE and SALIENT. The SOLVE file contains the corrections to the estimated parameters while the SALIENT file contains the updated parameters, data and a priori summaries, and the square root of the solution covariance. In the sequential batch mode with stochastic parameters specified, solve generates one additional NAVIO file, SMOOTHINFO, which holds estimated parameter information on each batch for processing in smooth.

smooth — calculates "smoothed" estimates for each data batch using the batch estimates and covariances calculated in solve (SMOOTHINFO) and the stochastic parameter evolution information generated in accume (SMOOTH). Since all the available data is used in their calculation, the "smoothed" estimates for each batch are more accurate than corresponding solve estimates which only use data from a single batch. Obviously, to execute smooth, both accume and solve must have been executed in the sequential batch mode.

output generates a printed display as well as a NAVIO file of the current and predicted data residuals. Data residual plots can be generated from the NAVIO file by several Utility programs (e.g. xide).

mapgen produces mapping matrices for use by mapsem.

mapsem uses the mapping matrices generated by mapgen to map the solution estimates and covariances to a variety of coordinate systems and times. The mapped quantities can also be written to the SALIENT file.

The generation of orbit solutions and navigation products requires the execution of several DPTRAJ-ODP programs in a fixed sequence. Navigation products such as OPTG files, orbit number files, light-time files, and STATRJ files only involve the execution of DPTRAJ programs. Typically, the parameters controlling the product characteristics are first input to the GINFILE via gindrive. The information on the updated GINFILE is then used by pvdrive to create a P-FILE. Lastly, the data on the GINFILE and P-FILE are used by twist, litime, and statrj to generate their respective output. Figure 3.1 illustrates the basic execution sequence of the DPTRAJ.

Unlike product generation, the orbit determination process requires the execution of programs from both the DPTRAJ and ODP. Once again, a GINFILE is made ready with all the desired navigation models. Next, a PV-FILE is generated for input to regres and later to mapgen. translate creates the NAVIO CSP file for regres which in turn generates the REGRES file used in the filter programs accume, solve, and smooth. The mapping programs, mapgen and mapsem, and residual display program, output, are executed last. The execution sequences for the filter and mapping functions of the ODP are shown in Figures 3.2 and 3.3 respectively.

On ares, the programs of the DPTRAJ and ODP (also MOPS and the Utilities) may be executed most efficiently by two methods: xodp, and scripts. xodp organizes the programs of the DPTRAJ, ODP, MOPS, and Utilities under a windows environment. xodp allows the navigator to prepare input files, build program sequences, execute those sequences, and examine program output by making selections from various menu windows. The programs of the DPTRAJ, ODP, MOPS, and Utilities may also be executed by scripts. Though less general and user friendly than xodp, scripts can be written for the specific needs of the user. A sample C-Shell script used for orbit determination is presented in section 3.4.

Lastly, the following DPTRAJ-ODP Utilities are often used in navigation analysis:

difwsq This program forms DDOR data.

difdop This program forms differenced Doppler data.

fast A trajectory integration program.

navinfo A program which plots a variety navigation data.

niocomp This program compares the contents of two NAVIO files.

odfconvrt This program converts the format of the ODF file transferred from OSCAR before being read by the ODP software.

orbitnumber   This program generates an orbit number file from an OPTG or P-file.

ftpnio; nioftp   Programs to convert between NAVIO and binary formats.

nio2text ; text2nio   Programs to convert between NAVIO and ASCII formats.

oddump   Dumps the contents of tracking data or REGRES files.

odmerge   This program merges two tracking data or REGRES files.

odmodify   This program modifies the contents of a REGRES file.

salsol   Reads solution vectors and covariances from a SALIENT file.

salsum   Generates an orbit solution summary.

str   A program which interpolates a S/C state from a P/PV-FILE.

3.2 The Mars Global Surveyor Lockfile

Purpose:
To acquaint the navigator with the contents of the MGS Lockfile and how those contents effect the execution of the DPTRAJ-ODP program set.

Prerequisites:
The navigator should be familiar with the function and execution of the DPTRAJ-ODP programs.

As mentioned in section 3.1, the manner of execution of the DPTRAJ, ODP, and MOPS programs is controlled by the information on the GINFILE. The data on the GINFILE describes the spacecraft mass, area, and orientation, the forces acting on the spacecraft such as gravity and solar radiation pressure, the locations of the tracking stations, the astrodynamic constants and models, and the filter's estimation and mapping characteristics. To ensure that the trajectory, orbit determination, and maneuver functions use a consistent set of navigation models, a single GINFILE has been created based on the best available data. This GINFILE is usually referred to as the Lockfile. The MGS Lockfile is stored on ares as:

/home/mgs/od/dat/ginlock/lockfiles/mgslock_cruise_V1.0.nio

Before generating orbit solutions or navigation products using the MGS Lockfile, the navigator must first copy (cp) the Lockfile to his working directory and then change its protection (chmod) from read-only to read-write. This Lockfile copy may now be updated as needed by executing gindrive.

As a reference, the ASCII namelist file from which the Lockfile was created is stored on ares as:

/home/mgs/od/dat/ginlock/lockfiles/mgslock_cruise_V1.0.txt

The following briefly describes the Lockfile by DPTRAJ-ODP program.

pvdrive

A nominal set of Earth centered Cartesian ICs in the EME2000 coordinate system were provided by Dan Johnston. These ICs were taken at the TIP for November 6, 1996 and are intended chiefly as an example. Some other integration control parameters are:

The integration start time is 06-NOV-1996 18:05:15.4060 UTC.

The integration stop time is 01-NOV-1997 00:00:00.0000 UTC.

The local integration error tolerance (EPS) is set to 1.0D-10 km/s.

Astrodynamic constants such as planetary radii and flatness, the precession, obliquity, and sidereal values, North pole and prime meridian directions come from twelve sources which are listed as comments among the Lockfile inputs.

The GM values for the planets, Sun, and Moon were provided by the planetary ephemeris DE403.

The spacecraft mass is approximately 1060.0 kg and was taken from the Performance Assessment Report.

Newtonian point mass gravitational influences from the Sun, Moon, and planets are turned on. Also, the relativistic influences are turned on for the Sun and Jupiter.

Oblateness models are used for the Earth (8x8), Moon (8x8), and Mars (JPL Mars 50C model; the original model is 50 x 50).

The acceleration due to solar radiation pressure is turned on. The solar radiation pressure model uses the ODP's spacecraft coordinate system (X*, Y*, Z*) and models MGS as a collection of eight components (a parabolic antenna and seven flat plates) which undergo several attitude changes during the interplanetary cruise.

The timing and polar motion array . Its time span is valid to 2010.

Start and stop times are specified for both quadratic and exponential gas leak models but with all accelerations set to zero.

Both impulsive and finite burn maneuver model inputs are listed as comments. The reference coordinate system for the impulsive burn model defaults to the spacecraft coordinate system.

The variational partials for the spacecraft Cartesian state are generated.

twist

10 print lists are specified in the Lockfile. The lists are composed of ANGLE,

BODY, and CONIC groups for the Earth, Sun, Mars, Phobos and Deimos as central bodies and referenced to several coordinate systems.

Trajectory print will occur for the following events: phase starts, body-spacecraft closest approach, entering and exiting Sun occultations, entering oblateness sphere, geocentric occultations, finite and impulsive burns.

There are currently no default parameter values for the generation of OPTG files.

litime
The light time convergence tolerance, TOL, is set to 1.0D-6 seconds. There are no other default parameter values for the generation of LITIME files.

statrj
Print and numerical control parameters are set in the Lockfile.

The station location set used is from W. Folkner and is consistent with DE-403.
The station masks come from R. F. Sunseri and the Voyager Neptune era data-base.

translate and edit1
Data names and numbers have been set for 35 data types in the Lockfile. These include VLBI data types, Doppler data types, range data types, and angle data types.

EDFLAG has been set to TRUE so that once the CSP commands have been translated, those commands will be executed in regres.

regres
The frequency constants have all been set in the Lockfile. Also, inputs to specify range biases, one-way Doppler drift, and station clock offsets are listed.

The station location set used is from W. Folkner and is consistent with DE-403.

The litime solution convergence criterion and iteration number are set.

The troposphere refraction corrections have been turned on. The coefficients used to map the zenith range delay to lower elevations have been set in arrays TABWET and TABDRY.

accume, solve, and smooth
accume is set to run in a single batch mode. No stochastic parameters are listed and the SMOOTH file will not be written.

solve is set to run in the square-root infomation filter (SRIF) mode with only the spacecraft state to be estimated. solve will display its output as a 132 column page and the SALIENT file will be written.

The array DIAGQ contains the spacecraft state a priori uncertainty (sigmas squared).

The array DIAGQ1 contains the solar radiation parameters a priori uncertainty (sigmas squared).

The array DIAGQ2 holds the Earth, Moon, and Mars GM uncertainties as well as the Earth and Mars J2 uncertainties (sigmas squared).

The array DIAGQ3 contains the media and SRA a priori uncertainty (sigmas squared).

APQ4 holds the station location covariance.

APQ5 contains the planetary ephemeris covariance consistent with DE-403.

mapgen and mapsem
There are four map cases set in the Lockfile. These cases include: the Mars Orbit Insertion (MOI) B-Plane referenced to the Mars Mean Equator (MME) of Date, the MOI classical elements in MME of Date, the MOI B-Plane in EME2000, and the MOI B-Plane in Earth Ecliptic of 2000.

output
output will display the before fit residuals for 13 data types.

3.3 Bibliography

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Graat, E., "Mars Global Surveyor Launch Lockfile Version 1.0", JPL IOM MOS-96-DRAFT, April, 1996.

3.4 Sample C-shell Script

The C-Shell script presented on the following pages will execute the programs of the DPTRAJ and ODP to generate orbit determination solutions in either the single batch mode or in the sequential batch mode.

The script is called odfit and its execution requires the navigator to have a working directory with two subdirectories called inputs/ and output/. The inputs/ subdirectory contains the namelist inputs and ASCII CSP commands the navigator intends to use in the orbit determination solution. The output/ subdirectory will store the DPTRAJ-ODP files generated by odfit. The script itself may reside in the working directory or in a special script directory which is defined in a search path.

odfit uses four arguments in its execution:

odfit argument-1 argument-2 argument-3 argument-4

where:

argument-1 defines the mission phase such as "cru" for cruise.
argument-2 defines the solution ID such as "F2Only" for a Doppler solution.
argument-3 is used only for iterating and should be the name of the SOLVE file.
argument-4 defines which filter mode the script will execute.

An auxiliary file referenced by odfit, called odprep, allows the navigator to specify which namelist files, ASCII CSP command files, and tracking data files will be used in the orbit determination solution. odprep resides in the working directory and should be updated by the navigator before the execution of odfit.

A sample of the contents of odprep are shown on the next page followed by the contents of odfit .

Table 3.4.1 User Setup For odfit Script

```
##################################################################
#  The following list should have all the namelist inputs needed for a data fit.

  set gin_inputs = (      "$INPUTS/ics.nl"       \
          "$INPUTS/dynamics.nl"        \
          "$INPUTS/filter.nl"    \
          "/home/mgs/od/dat/tp/tp_ld920525-pt920622"           \
          )


##################################################################
#  The following specifies that the lockfile will be copied and updated.

  set ginfile = "/home/mgs/od/dat/ginlock/lockfiles/gin_mgslock_cruise_V1.0.nio"

##################################################################
#  The following list should include:
#
#  Inputs for the weighting and deletion of data and for media calibrations.
#

  set csp_inputs = (      "$INPUTS/csp.data.weights" \
          "/home/mgs/od/dat/trop/refrac_Fourier"         \
          "/home/mgs/od/dat/ion/ioncal_MGS"  \
          )


##################################################################
#  The following specifies the tracking data file to be input to regres.

  set odfile = "/home/mgs/od/dat/astdf/od92260-92265.nio"

##################################################################
```

Table 3.4.2 C-Shell script, odfit, For Generating Orbit Determination Solutions

```
#! /bin/csh -f
#
setenv PHASE	$argv[1]
setenv CASEID		$argv[2]

set odw = `pwd`
setenv DIRECTORY	$odw

setenv INPUTS		"$DIRECTORY"/inputs
setenv OUTPUT		"$DIRECTORY"/output
setenv NAVDATA		/usr/mmnav/dat/gen
setenv PPFILE		/usr/mmnav/dat/gen/pp_de403_em_9620-0307.nio

source $DIRECTORY/odprep
rm -f  $OUTPUT/"$CASEID"

if ("$argv[3]" == " " ) then

	rm -f  $INPUTS/update.nl
	echo "  IDPXIT=0, SOLNO=0, ITNO=1, " > $INPUTS/update.nl
	foreach i  ( $gin_inputs )
		cat $i  >> $INPUTS/update.nl
	end

	rm -f	$OUTPUT/gin_"$PHASE"_"$CASEID"
	cp $ginfile	$OUTPUT/gin_"$PHASE"_"$CASEID"
	chmod 644	$OUTPUT/gin_"$PHASE"_"$CASEID"

	unset  SAT4
	unsetenv  SAT4

	gindupdate	\
		$INPUTS/update.nl	\
		$OUTPUT/gin_"$PHASE"_"$CASEID"	\
		200	\
	>  $OUTPUT/"$CASEID"

else

	ginupdtf	\
		$OUTPUT/sol_"$PHASE"_"$CASEID"	\
		$OUTPUT/gin_"$PHASE"_"$CASEID"	\
	>  $OUTPUT/"$CASEID"

endif
```

```
gindump         \
        $OUTPUT/gin_"$PHASE"_"$CASEID"  m           \
 >>  $OUTPUT/"$CASEID"

##########################################################################

unset  SAT4
unsetenv  SAT4

rm -f    $OUTPUT/pv_"$PHASE"_"$CASEID"

pvdrive         \
        $OUTPUT/pv_"$PHASE"_"$CASEID"       \
        $OUTPUT/gin_"$PHASE"_"$CASEID"      \
        $NAVDATA/de403_1996-2004.nio        \
>>  $OUTPUT/"$CASEID"

twist    \
        $OUTPUT/pv_"$PHASE"_"$CASEID"       \
        ""
        $OUTPUT/gin_"$PHASE"_"$CASEID"      \
        $NAVDATA/de403_1996-2004.nio        \
 >>  $OUTPUT/"$CASEID"

##########################################################################

rm -f    $INPUTS/csp.text

foreach i ( $csp_inputs )
        cat $i  >> $INPUTS/csp.text
end

rm -f    $OUTPUT/csp_"$PHASE"_"$CASEID"
rm -f    $OUTPUT/rg_"$PHASE"_"$CASEID"

translate       \
        $OUTPUT/gin_"$PHASE"_"$CASEID"      \
        $OUTPUT/csp_"$PHASE"_"$CASEID"      \
        $INPUTS/csp.text      \
 >>  $OUTPUT/"$CASEID"

regres  \
        $odfile \
        $OUTPUT/rg_"$PHASE"_"$CASEID"       \
        $OUTPUT/pv_"$PHASE"_"$CASEID"       \
        $OUTPUT/csp_"$PHASE"_"$CASEID"      \
        $OUTPUT/gin_"$PHASE"_"$CASEID"      \
        $NAVDATA/de403_1996-2004.nio   \
        $NAVDATA/pp_de403_em_9610-0307.nio  \
 >> $OUTPUT/"$CASEID"
```

```
#########################################################################

rm -f    $OUTPUT/ac_"$PHASE"_"$CASEID"
rm -f    $OUTPUT/sal_"$PHASE"_"$CASEID"
rm -f    $OUTPUT/sol_"$PHASE"_"$CASEID"
rm -f    $OUTPUT/smo_"$PHASE"_"$CASEID"
rm -f    $OUTPUT/smoin_"$PHASE"_"$CASEID"

if ("$argv[4]" == "" ) then

        accume\
                $OUTPUT/rg_"$PHASE"_"$CASEID"        \
                $OUTPUT/ac_"$PHASE"_"$CASEID"        \
                $OUTPUT/pv_"$PHASE"_"$CASEID"        \
                ' '        \
                $OUTPUT/gin_"$PHASE"_"$CASEID"       \
         >>  $OUTPUT/"$CASEID"

        solve    \
                $OUTPUT/ac_"$PHASE"_"$CASEID"        \
                $OUTPUT/sol_"$PHASE"_"$CASEID"       \
                $OUTPUT/sal_"$PHASE"_"$CASEID"       \
                ' '        \
                $OUTPUT/gin_"$PHASE"_"$CASEID"       \
         >>  $OUTPUT/"$CASEID"

else

        accume\
                $OUTPUT/rg_"$PHASE"_"$CASEID"        \
                $OUTPUT/ac_"$PHASE"_"$CASEID"        \
                $OUTPUT/pv_"$PHASE"_"$CASEID"        \
                $OUTPUT/smo_"$PHASE"_"$CASEID"       \
                $OUTPUT/gin_"$PHASE"_"$CASEID"       \
         >>  $OUTPUT/"$CASEID"

        solve    \
                $OUTPUT/ac_"$PHASE"_"$CASEID"        \
                $OUTPUT/sol_"$PHASE"_"$CASEID"       \
                $OUTPUT/sal_"$PHASE"_"$CASEID"       \
                $OUTPUT/smoin_"$PHASE"_"$CASEID"  \
                $OUTPUT/gin_"$PHASE"_"$CASEID"       \
         >>  $OUTPUT/"$CASEID"

        smooth\
                $OUTPUT/sol_"$PHASE"_"$CASEID"       \
                $OUTPUT/smo_"$PHASE"_"$CASEID"       \
                $OUTPUT/smoin_"$PHASE"_"$CASEID"  \
                $OUTPUT/sal_"$PHASE"_"$CASEID"       \
                $OUTPUT/gin_"$PHASE"_"$CASEID"       \
         >>  $OUTPUT/"$CASEID"
```

```
endif

######################################################################

rm -f    $OUTPUT/prs_"$PHASE"_"$CASEID"

output  \
        $OUTPUT/rg_"$PHASE"_"$CASEID"        \
        $OUTPUT/ac_"$PHASE"_"$CASEID"        \
        $OUTPUT/sol_"$PHASE"_"$CASEID"       \
        $OUTPUT/prs_"$PHASE"_"$CASEID"       \
        $OUTPUT/gin_"$PHASE"_"$CASEID"       \
        $NAVDATA/de403_1996-2004.nio         \
        $OUTPUT/pv_"$PHASE"_"$CASEID"        \
 >> $OUTPUT/"$CASEID"

######################################################################

rm -f    $OUTPUT/map_"$PHASE"_"$CASEID"

mapgen          \
        $OUTPUT/pv_"$PHASE"_"$CASEID"        \
        $OUTPUT/map_"$PHASE"_"$CASEID"       \
        $OUTPUT/gin_"$PHASE"_"$CASEID"       \
        $NAVDATA/de403_1996-2004.nio         \
        $NAVDATA/pp_de403_em_9610-0307.nio   \
 >>  $OUTPUT/"$CASEID"

mapsem          \
        $OUTPUT/map_"$PHASE"_"$CASEID"       \
        $OUTPUT/sal_"$PHASE"_"$CASEID"       \
        $OUTPUT/gin_"$PHASE"_"$CASEID"       \
 >>  $OUTPUT/"$CASEID"

######################################################################

rm -f $INPUTS/csp.nl
rm -f $INPUTS/update.nl
rm -f $OUTPUT/csp_"$PHASE"_"$CASEID"
rm -f $OUTPUT/map_"$PHASE"_"$CASEID"
```

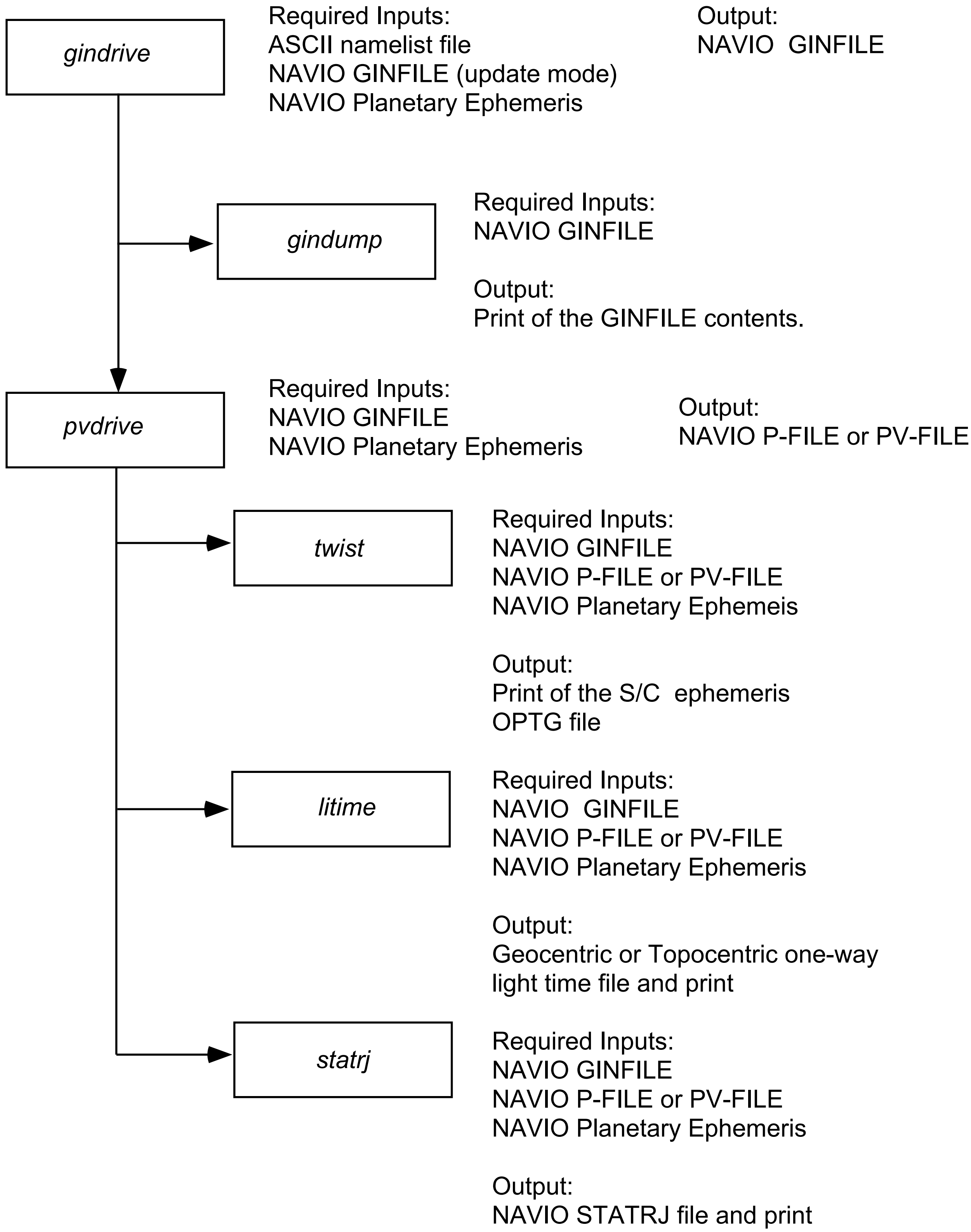

Figure 3.1 DPTRAJ Flowchart

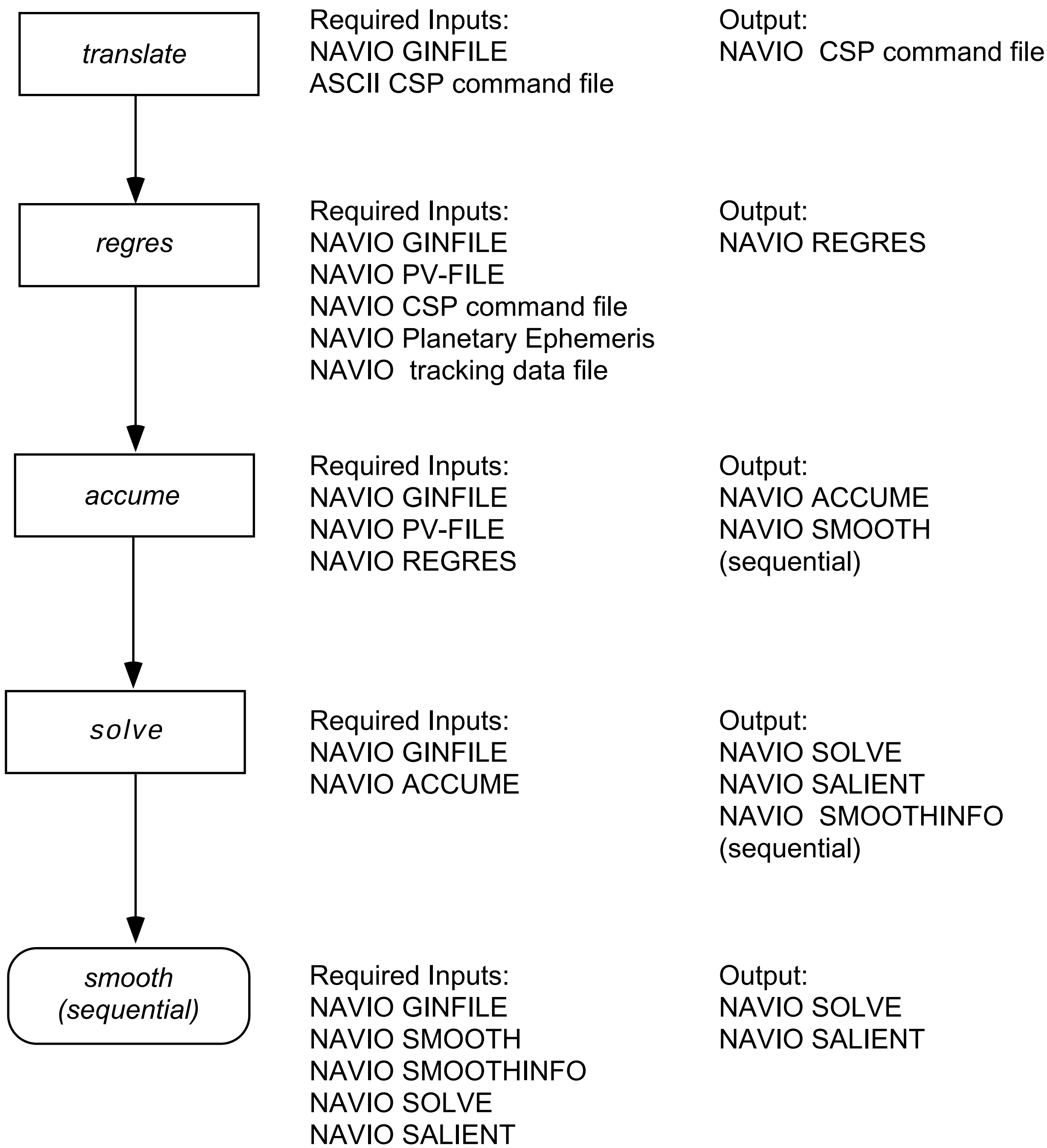

Figure 3.2 ODP Filter Flowchart

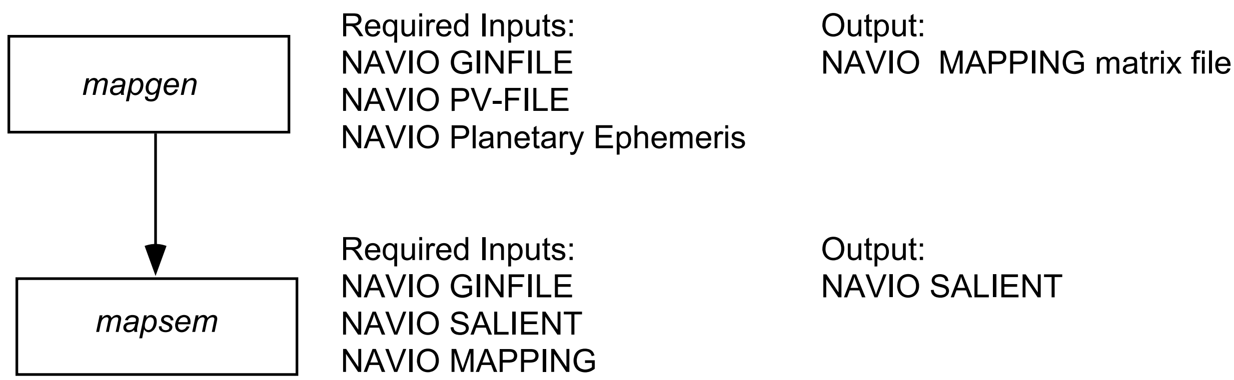

Figure 3.3 ODP Mapping Flowchart

4.0 The Trajectory and Orbit Analysis Process

The trajectory and orbit analysis process is described in this section. The topics covered include an overview of the trajectory and orbit analysis activities, the interaction of the trajectory and orbit analysts with the orbit determination and maneuver analysts, and the knowledge of relevant operational procedures.

4.1 The Trajectory and Orbit Analysis Activities

Purpose:
To review the activities of the trajectory and orbit analysts and their interaction with the orbit determination and maneuver analysts.

Prerequisites:
The navigator must be familiar with the function and execution of the DPTRAJ programs.

During and prior to the MGS mission, trajectory and orbit analysis will involve the following activities:

1) The generation of predict and reconstructed S and P kernels from spacecraft ephemeris files.
2) The generation of light time (LT) files, orbit propagation and timing geometry (OPTG) files, orbit number files, and station polynomial (STATRJ) files.
3) The maintenance of a data base on the navigation computer for the products listed in items 1 and 2.
4) The delivery of the navigation products listed in items 1 and 2 to the Project Data Base (PDB).
5) The generation of spacecraft trajectories for the design and verification of maneuvers.
6) Prior to the actual mission operations, the generation of a nominal set of navigation products (such as above) for planning and test and training purposes.
7) Maintain and update aerobraking databases.

For the cruise, orbit insertion, and mapping phases of the MGS mission, the trajectory and orbit analysts will generate the navigation products based on the best available orbit determination solution. These navigation products include spacecraft ephemeris, light time (LT), orbit propagation and timing geometry (OPTG), orbit number and station polynomial (STATRJ) files.

The trajectory and orbit analysts will work with the maneuver analyst in the design and verification of maneuvers throughout the mission. First, the trajectory and orbit analysts will verify the spacecraft trajectory generated from the best available orbit determination solution before the maneuver design process begins. Next, once the maneuver design has been generated, the trajectory and orbit analysts will implement that maneuver and confirm that the trajectory achieves the desired targets.

4.2 Navigation Operational Procedures

Purpose:

To review those operational procedures which are the responsibility of the trajectory analysts .

Prerequisities:
The navigator should be familiar with the NAV computer environment and the programs of the DPTRAJ.

The trajectory and orbit analysts are responsible for the following operational procedures:

NAV-0001 ICPREP EXECUTION - TARGET INTERFACE POINT (TIP) INITIAL CONDITIONS

NAV-0002 INTER-CENTER VECTOR (ICV) FILE TRANSFER FROM THE DSN / NAVIGATION INTERFACE (OSCAR) AND INPUT TO DPTRAJ

NAV-0003 ORBIT TRACKING DATA FILE (ODF) TRANSFER FROM THE DSN TO THE NAV TEAM

NAV-0004 TRANSFER OF MEDIA CALIBRATION AND TIME AND POLAR MOTION FILES FROM THE PDB TO THE NAV COMPUTER

NAV-0005 ANGULAR MOMENTUM DESATURATION (AMD) FILE TRANSFER AND INPUT TO DPTRAJ

NAV-0006 NAVIGATION PROCESS: ORBIT DETERMINATION AND PROPULSIVE MANEUVER ASSESSMENT
- UPDATE STATE (GIN FILE)
- ANALYZE RADIOMETRIC DATA
- UPDATE MODEL PARAMETERS
- PROPAGATE STATE AND UNCERTAINTIES

NAV-0007 NAVIGATION PROCESS: DESIGN AND VERIFICATION OF PROPULSIVE MANEUVERS
- MANEUVER PERFORMANCE DATA FILE TRANSFER
- MANEUVER PROFILE FILE GENERATION
- MANEUVER IMPLEMENTATION FILE ASSESSMENT

NAV-0008 SPACECRAFT EPHEMERIS (P-FILE) GENERATION AND TRANSFER TO THE DSN/NAV INTERFACE (OSCAR)

NAV-0009 SPK FILE GENERATION AND TRANSFER TO THE PDB

NAV-0010 LIGHT TIME FILE GENERATION AND TRANSFER TO THE PDB

NAV-0011 STATION POLYNOMIAL (STATRJ) FILE GENERATION AND TRANSFER TO THE PDB

NAV-0012 ORBIT PROPAGATION AND TIMING GEOMETRY FILE (OPTG) GENERATION AND TRANSFER TO THE PDB

NAV-0013 REAL-TIME RADIOMETRIC DATA DISPLAY

NAV-0014 GENERATE AND ANALYZE DIFFERENCED DOPPLER DATA

NAV-0015 DETERMINE ATMOSPHERIC DENSITY MODEL PARAMETERS ESTABLISH DATABASE FOR PREDICTION AND SHORT-TERM VARIATION

NAV-0016 DETERMINE MARS GRAVITY FIELD MODEL COEFFICIENTS

NAV-0017 GUIDELINES FOR PROPULSIVE MANEUVER SELECTION (OFF-THE-SHELF) THROUGHOUT AEROBRAKING

NAV-0018 MAINTAIN AND UPDATE NAVIGATION AEROBRAKING DATABASE
MONITOR AND PREDICT AEROBRAKING PROGRESS

NAV-0019 SFDU WRAP / UNWRAP AND PDB ACCESS FOR FILE TRANSFER

4.3 Bibliography

"Mars Global Surveyor Navigation Plan", MGS Project Document 542-406, Rev. A, JPL Document D-12002, Sept 15, 1995.

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"DPTRAJ-ODP Users Reference Manual, Volume 2", Mars Global Surveyor Project Document 642-3405-DPTRAJ/ODP, 1/25/96.

"DPTRAJ-ODP INTERFACES AND FILE FORMAT DESCRIPTIONS, Volume 3", Mars Global Surveyor Project Document 642-3405-DPTRAJ/ODP, 4/12/96.

"MANEUVER OPERATIONS PROGRAM SET (MOPS) UTILITY USER GUIDE", 3/29/96.

5.0 The Orbit Determination And Analysis Process

The MGS orbit determination process is described in this section. The topics covered include the tracking data types available and their information content, the signatures in data residuals caused by dynamic and media errors, the standard orbit determination cases to be generated, the criteria of a valid orbit solution, and knowledge of operational procedures required by orbit determination analysts.

5.1 Radiometric Tracking Data

Purpose:
To review the information content of the tracking data types available to the orbit determination process.

Prerequisites:
The navigator must be familiar with the function and execution of the DPTRAJ-ODP programs.

During the MGS mission, there will be several tracking data types available for orbit determination purposes. These data types include two-way coherent X-band (8.4 GHz) Doppler (F2), X-band range (SRA), and two-way minus three-way X-band Doppler (F2MF3). The tracking data will be collected by the 34m HEF stations of the Deep Space Network (DSN) and then sent on to the Radiometric Data Conditioning Team (RMDCT). The RMDCT will then format the tracking data for use by NAV. Each data type is briefly discussed below.

Doppler

MGS can provide X-band two-way coherent Doppler (F2) from either its low or high gain antennas. F2 measurements are generated when a single tracking station radiates a signal to the spacecraft which in turn multiplies the received signal frequency, f, by a constant and sends the signal back to the transmitting station. The Doppler frequency shift calculated at the transmitting station is multiplied by c/2f, c being light speed, to render the spacecraft's line-of-sight velocity component. The diurnal motion of the tracking station provides a Doppler tracking pass with information on the spacecraft's right ascension, by observing the null in the diurnal harmonic modulation, and with information on the spacecraft's declination from the amplitude of the diurnal modulation. The expected measurement accuracy is 0.1 mm/s for 60 second averages.

Range
Range data is obtained at a single tracking station by measuring the time delay between the transmission and reception of a ranging signal. It is collected through the sequential ranging assembly (SRA). The expected measurement accuracy is 15 meters.

Differenced Doppler
Three-way Doppler (F3) measurements are formed when one station uplinks to the spacecraft which then downlinks to a second station. The uplink station can also receive the spacecraft's downlink to form F2 measurements. By differencing the F2 and F3 measurements, a new data type, F2MF3, is formed which contains information on the spacecraft's velocity in the plane-of-sky. The plane-of-sky velocity component measured will be parallel to the baseline joining the two tracking stations.

The expected measurement accuracy is 0.1 mm/s for 60 second averages.

Although VLBI data are not required by the MGS mission, we briefly describe these data types:

DDOR

Delta differential one-way range (DDOR) measurements are composed of the simultaneouus viewing of the spacecraft by two tracking stations and the observation of a natural radio source (quasar) angularly near the spacecraft using the same stations. For both the spacecraft and radio source, the difference in signal arrival time between the tracking stations is measured. This time delay, coupled with the knowledge of the baseline between the stations, provides a direct geometric determination of the angle between the baseline and the signal source. By differencing the spacecraft and quasar time delays, DDOR is formed. This differencing reduces the effects due to common error sources such as media, timekeeping, station locations, and station instruments. The expected measurement accuracy is 0.8 nanoseconds.

DDOD

Delta differential one-way Doppler (DDOD) measurements are composed of the simultaneous viewing of the spacecraft by two tracking stations and the observation of a quasar angularly near the spacecraft using the same stations. For both the spacecraft and radio source, the time delay-rate of the signal is measured. This time delay-rate, coupled with the knowledge of the baseline between the stations, determines the angular velocity of the signal source with respect to the baseline. This is equivalent to the information content of F2MF3 data. By differencing the spacecraft and quasar time delays, DDOD is formed. Again, the differencing reduces the common error sources. The expected measurement accuracy is 0.0577 mm/s.

In the orbit determination process, computed tracking data measurements or observables are generated from a nominal set of dynamic and media models. These computed observables are differenced from the actual observables to form data residuals which indicate the defects in the dynamic and media models. In many instances, dynamic or media modelling errors produce unique patterns or signatures in the data residuals. By visual inspection of these residual signatures, the orbit determination analyst can often identify the source of the mismodelling. Using this information, the analyst can either modify the deficient model or adjust the filter configuration to remove the signature. In section 5.5, simulated data residual plots of F2 and SRA data are shown for various dynamic and media model errors.

5.2 Standard Orbit Determination Cases

Purpose:

To acquaint the navigator with the standard set of orbit determination solutions to be examined during the mission.

Prerequisites:

The navigator must be familiar with the function and execution of the DPTRAJ-ODP programs.

During the interplanetary phase of the mission, the following set of orbit determination solutions should be examined:

1) Estimate the spacecraft state in the single batch mode using a short arc (< 21 days) of the most recent F2 data.
2) Estimate the spacecraft state in the single batch mode using a short arc of the most recent F2 and SRA data.
3) Estimate the spacecraft state and other dynamic parameters in the single batch mode for a long arc (> 35 days) of the most recent F2 data.
4) Estimate the spacecraft state and other dynamic parameters in the single batch mode for a long arc of the most recent F2 and SRA data.
5) Estimate the spacecraft state and other dynamic or media parameters in the sequential batch mode over a long arc of the most recent F2, SRA, data.

For each of the above solutions, the F2 data should be weighted at its anticipated measurement accuracy of 0.1 mm/s. Based on the operational experiences of the Mars Observer Navigation Team, the SRA data weight may range from 5 to 25 meters.

The selection of estimated dynamic parameters should be based on the signatures observed in the data residuals and on the known spacecraft activities. Also, the corrections made by the filter to these parameters should be scrutinized.

During the orbit insertion and mapping phases of the mission, the following set of orbit solutions should be examined:

1) Estimate the spacecraft state using F2 data only.
2) Estimate the spacecraft state and the atmospheric drag using F2 data only.
3) Estimate the spacecraft state and the atmospheric drag using F2 and SRA data (if available).
4) Estimate the spacecraft state and the atmospheric drag using F2, SRA, and F2MF3 data.
5) Estimate the spacecraft state, atmospheric drag, and the coefficients of a 5x5 gravity field using F2 and SRA (if available) data.
6) Estimate the spacecraft state, atmospheric drag, and the coefficients of a 5x5 gravity field using F2, SRA, and F2MF3 data.

Before the Gravity Calibration and mapping phases of the mission, the F2 data may be weighted at 10 mm/s. The SRA data weight will be determined from the cruise experience. Since the Mars gravity field modelling will be greatly improved during the Gravity Calibration phase, the F2, F2MF3 data should be weighted at their expected measurement accuracy during the mapping phase.

For the cruise, insertion, and mapping phases of the mission, each solution examined must be iterated upon until convergence is achieved. A converged orbit solution must meet the following criteria:

1) The actual weighted sum of squares of the data residuals (S) should equal the predicted weighted sum of squares of the data residuals (SL). That is, | S - SL | < some small number. The ODP program solve displays this information with every iteration.
2) No signature or bias should be apparent in the data residuals. The ODP program output generates the statistics and printed display of the data residuals.
3) The corrections to the estimated parameters should make physical sense.

5.3 Navigation Operational Procedures

Purpose:
To review those operational procedures which are the responsibility of the orbit determination analysts.

Prerequisities:
The navigator should be familiar with the NAV computer environment and the programs of the DPTRAJ-ODP.

The orbit determination analysts are responsible for the following operational procedures:

NAV-0001 ICPREP EXECUTION - TARGET INTERFACE POINT (TIP) INITIAL CONDITIONS

NAV-0002 INTER-CENTER VECTOR (ICV) FILE TRANSFER FROM THE DSN / NAVIGATION INTERFACE (OSCAR) AND INPUT TO DPTRAJ

NAV-0003 ORBIT TRACKING DATA FILE (ODF) TRANSFER FROM THE DSN TO THE NAV TEAM

NAV-0004 TRANSFER OF MEDIA CALIBRATION AND TIME AND POLAR MOTION FILES FROM THE PDB TO THE NAV COMPUTER

NAV-0005 ANGULAR MOMENTUM DESATURATION (AMD) FILE TRANSFER AND INPUT TO DPTRAJ

NAV-0006 NAVIGATION PROCESS: ORBIT DETERMINATION AND PROPULSIVE MANEUVER ASSESSMENT
- UPDATE STATE (GIN FILE)
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NAV-0010 LIGHT TIME FILE GENERATION AND TRANSFER TO THE PDB

NAV-0011 STATION POLYNOMIAL (STATRJ) FILE GENERATION AND TRANSFER TO THE PDB

NAV-0012 ORBIT PROPAGATION, TIMING AND GEOMETRY FILE (OPTG) GENERATION AND TRANSFER TO THE PDB

NAV-0013 REAL TIME RADIOMETRIC DATA DISPLAY

NAV-0014 GENERATE AND ANALYZE DIFFERENCED DOPPLER DATA

NAV-0015 DETERMINE ATMOSPHERIC DENSITY MODEL PARAMETERS ESTABLISH DATABASE FOR PREDICTION AND SHORT-TERM VARIATION

NAV-0016 DETERMINE MARS GRAVITY FIELD MODEL COEFFICIENTS

NAV-0017 GUIDELINES FOR PROPULSIVE MANEUVER SELECTION (OFF-THE-SHELF) THROUGHOUT AEROBRAKING

NAV-0018 MAINTAIN AND UPDATE NAVIGATION AEROBRAKINGDATABASE MONITOR AND PREDICT AEROBRAKING PROGRESS

NAV-0019 SFDU WRAP / UNWRAP AND PDB ACCESS FOR FILE TRANSFER

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"DPTRAJ-ODP Users Reference Manual, Volume 2", Mars Global Surveyor Project Document 642-3405-DPTRAJ/ODP, 1/25/96.

"DPTRAJ-ODP INTERFACES AND FILE FORMAT DESCRIPTIONS, Volume 3", Mars Global Surveyor Project Document 642-3405-DPTRAJ/ODP, 4/12/96.

"MANEUVER OPERATIONS PROGRAM SET (MOPS) UTILITY USER GUIDE", 3/29/96.

5.5 Simulated F2 and SRA Residual Plots

Dynamic and media modelling errors often produce unique signatures in the data residuals. To acquaint the orbit determination analyst with the signatures produced by various dynamic and media errors, simulated F2 and SRA data residuals are presented on the following pages.

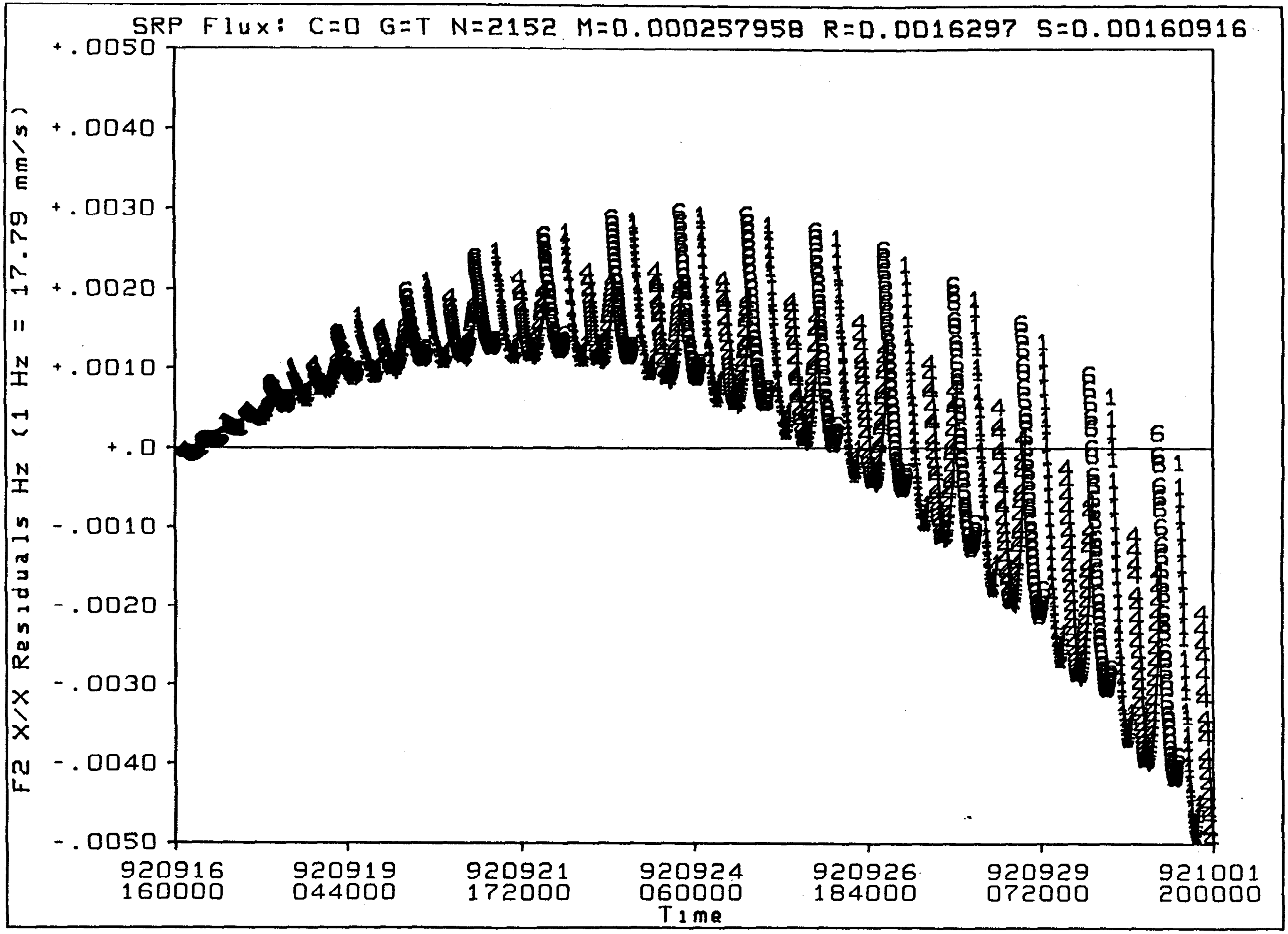


Figure 1: 5% increase in the solar radiation flux.

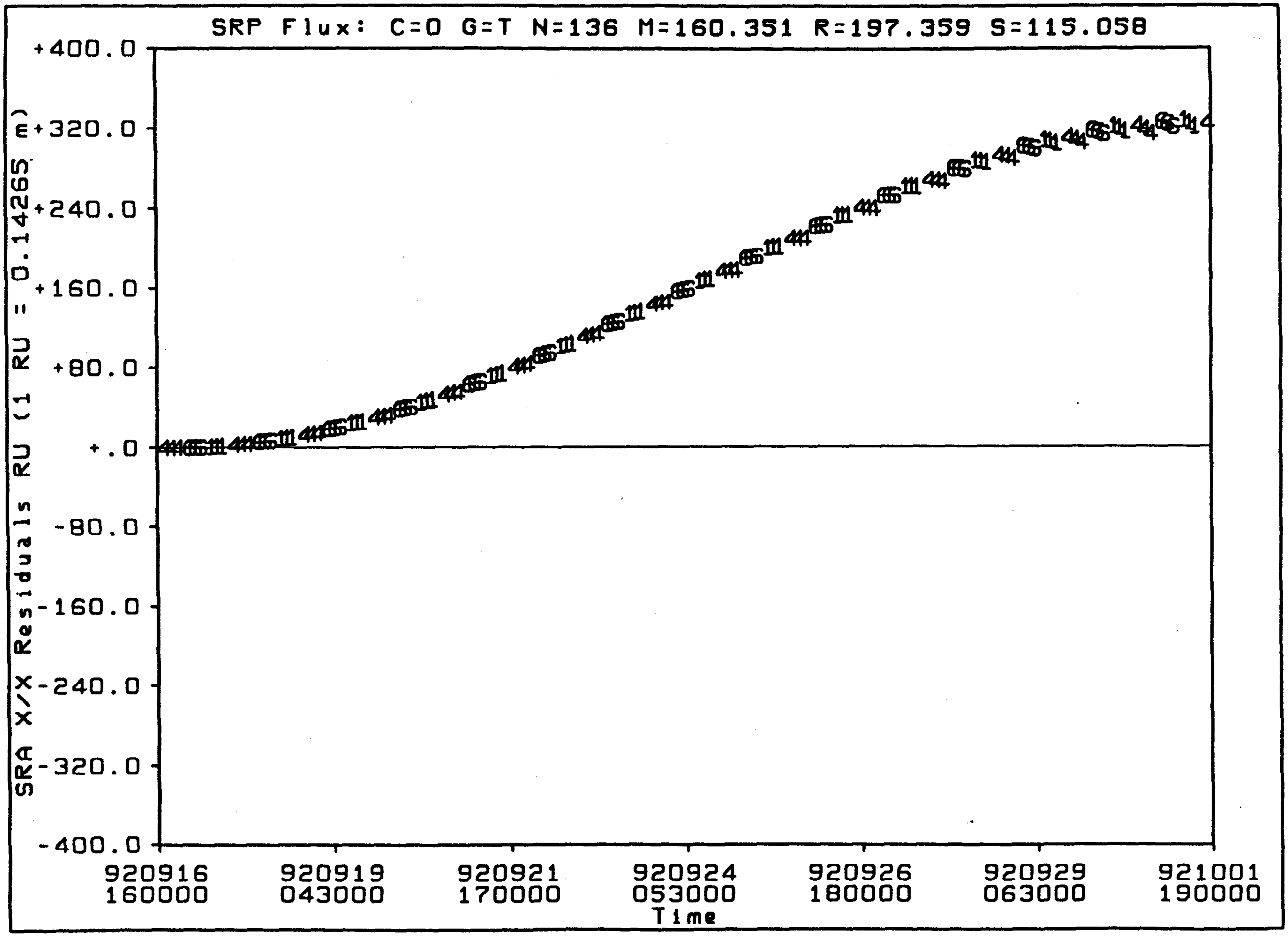


Figure 2: 5% increase in the solar radiation flux.

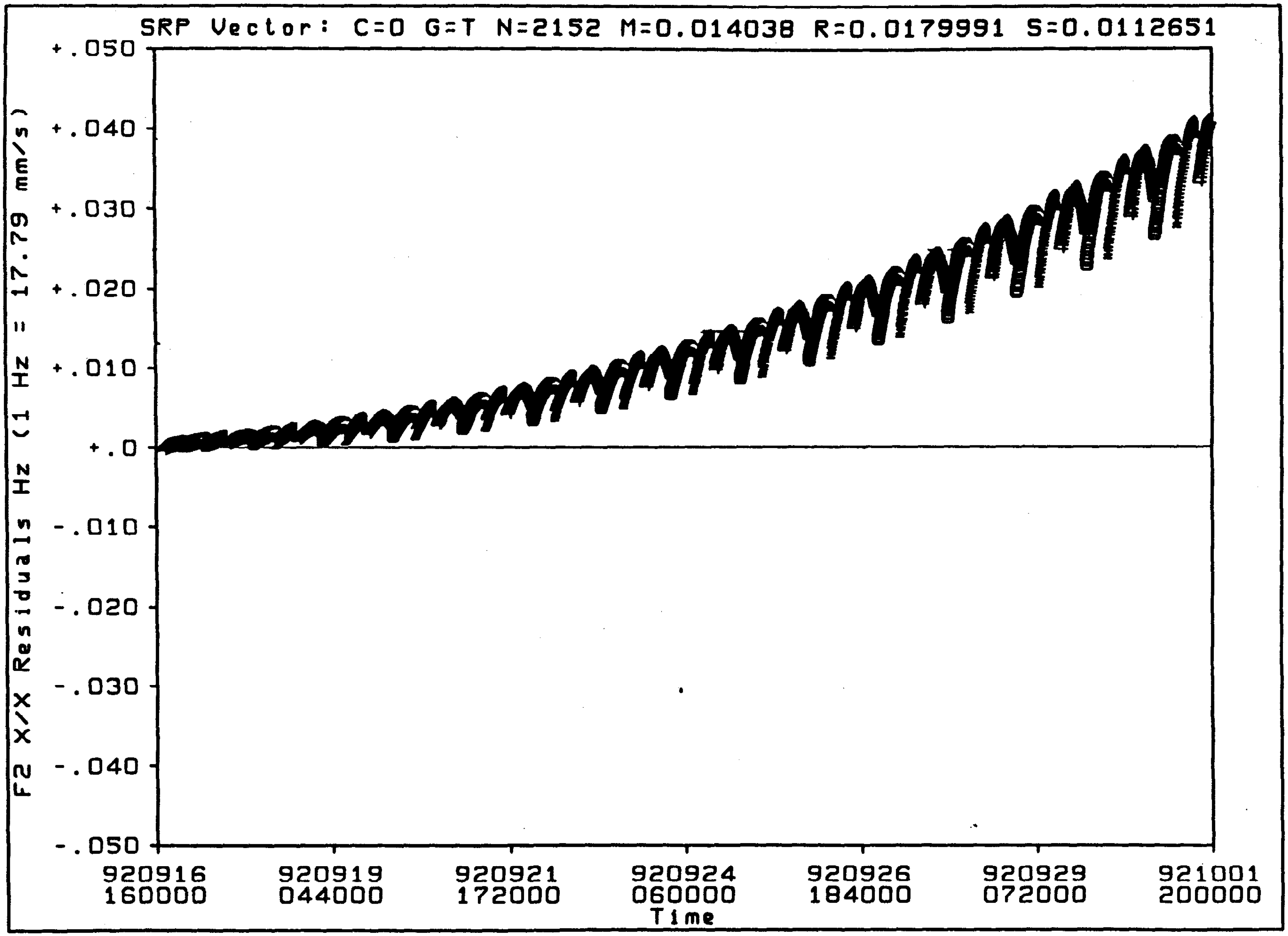


Figure 3: 5 degree offset in the spacecraft attitude.

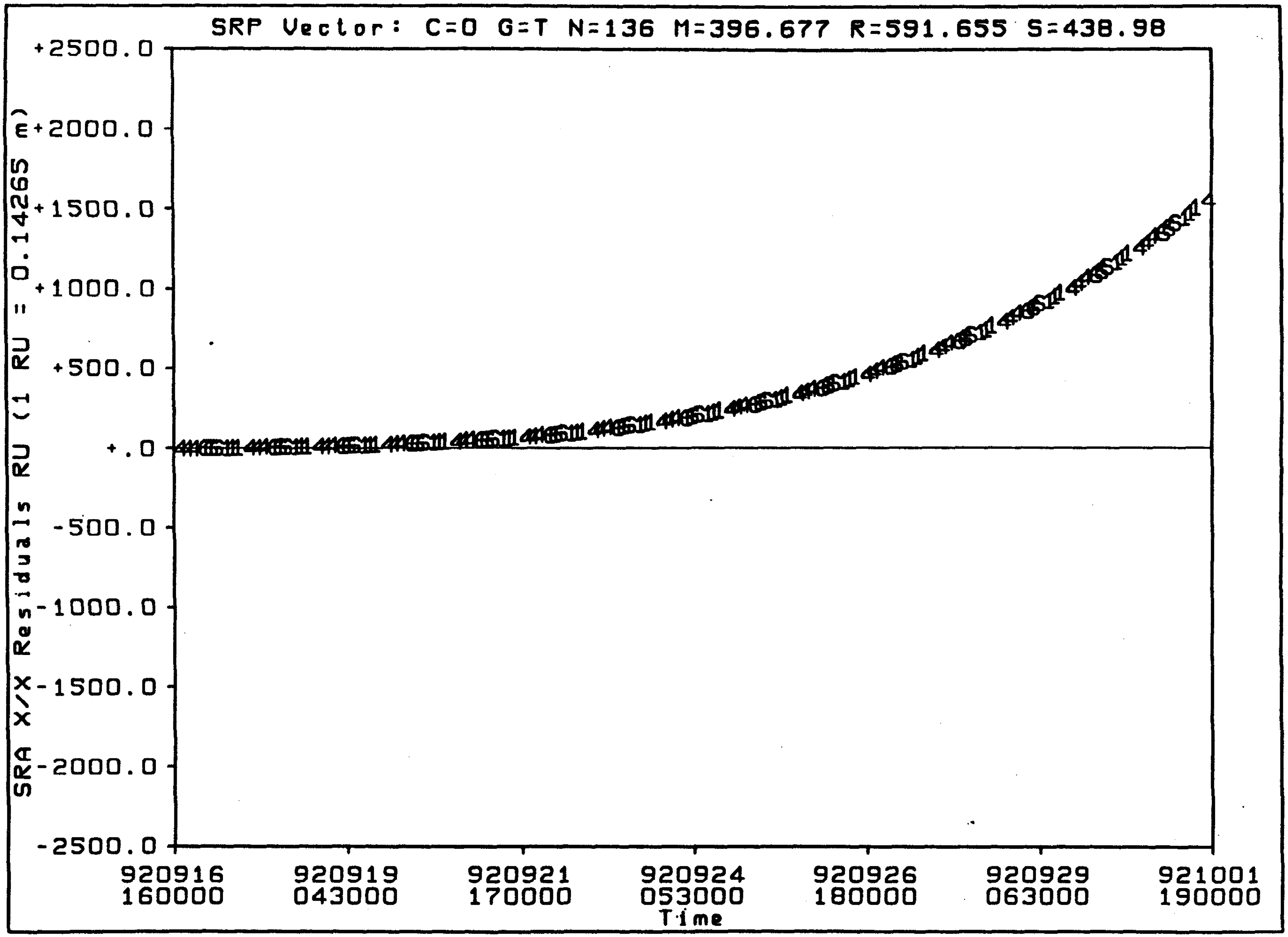


Figure 4: 5 degree offset in the spacecraft attitude.

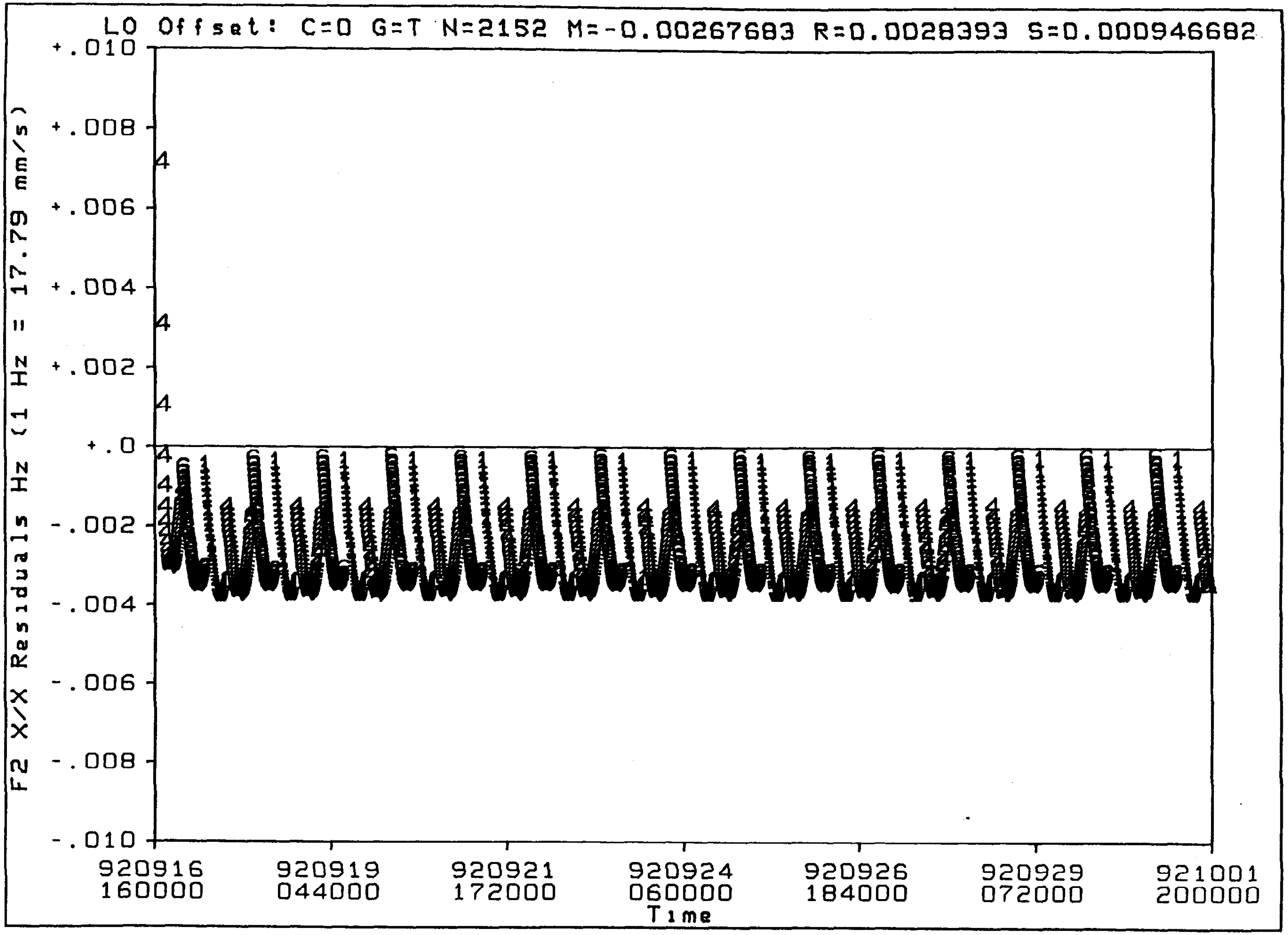


Figure 5: 10^{-5} degree offset in the longitude of the tracking stations.

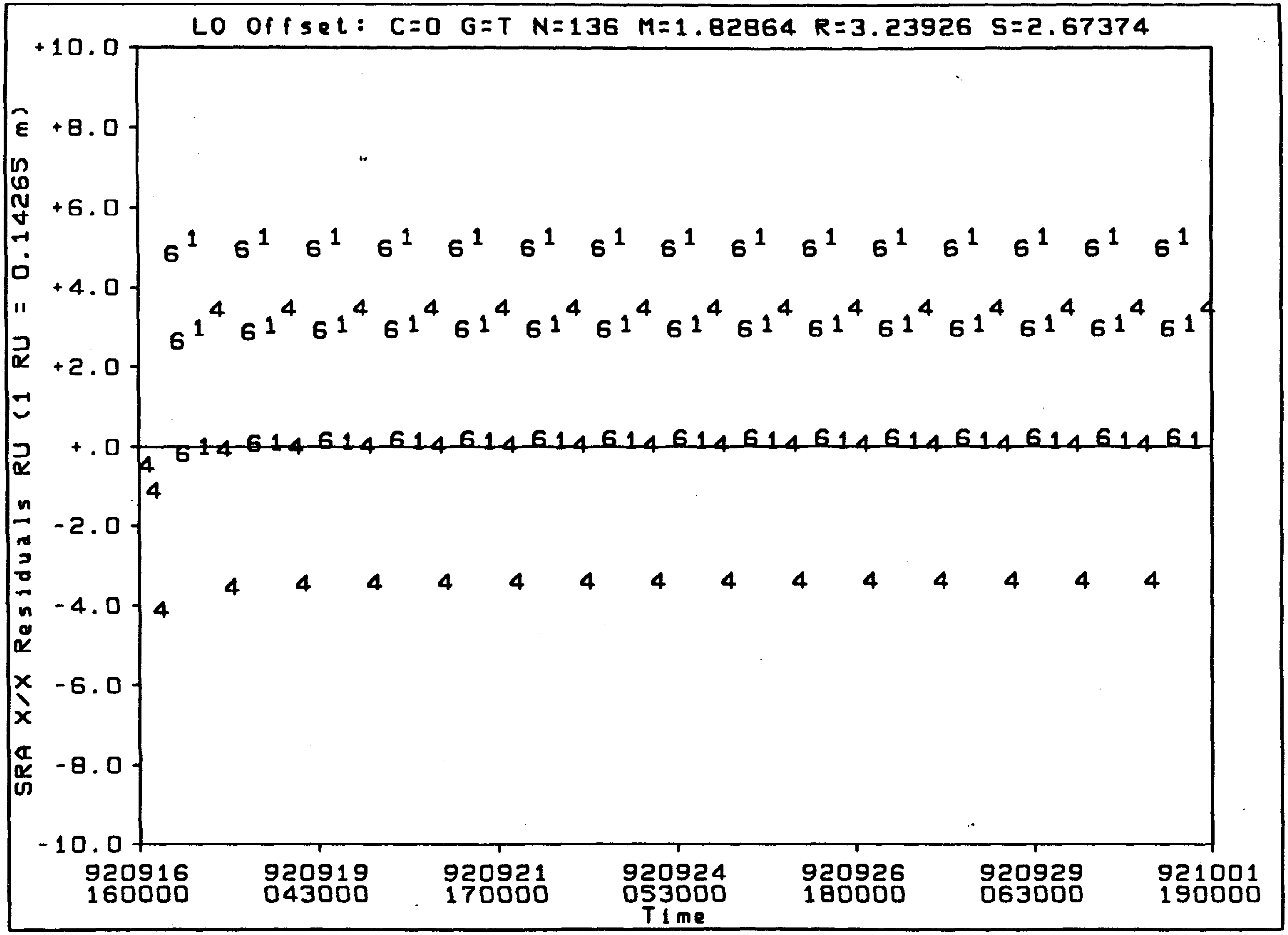


Figure 6: 10^{-5} degree offset in the longitude of the tracking stations.

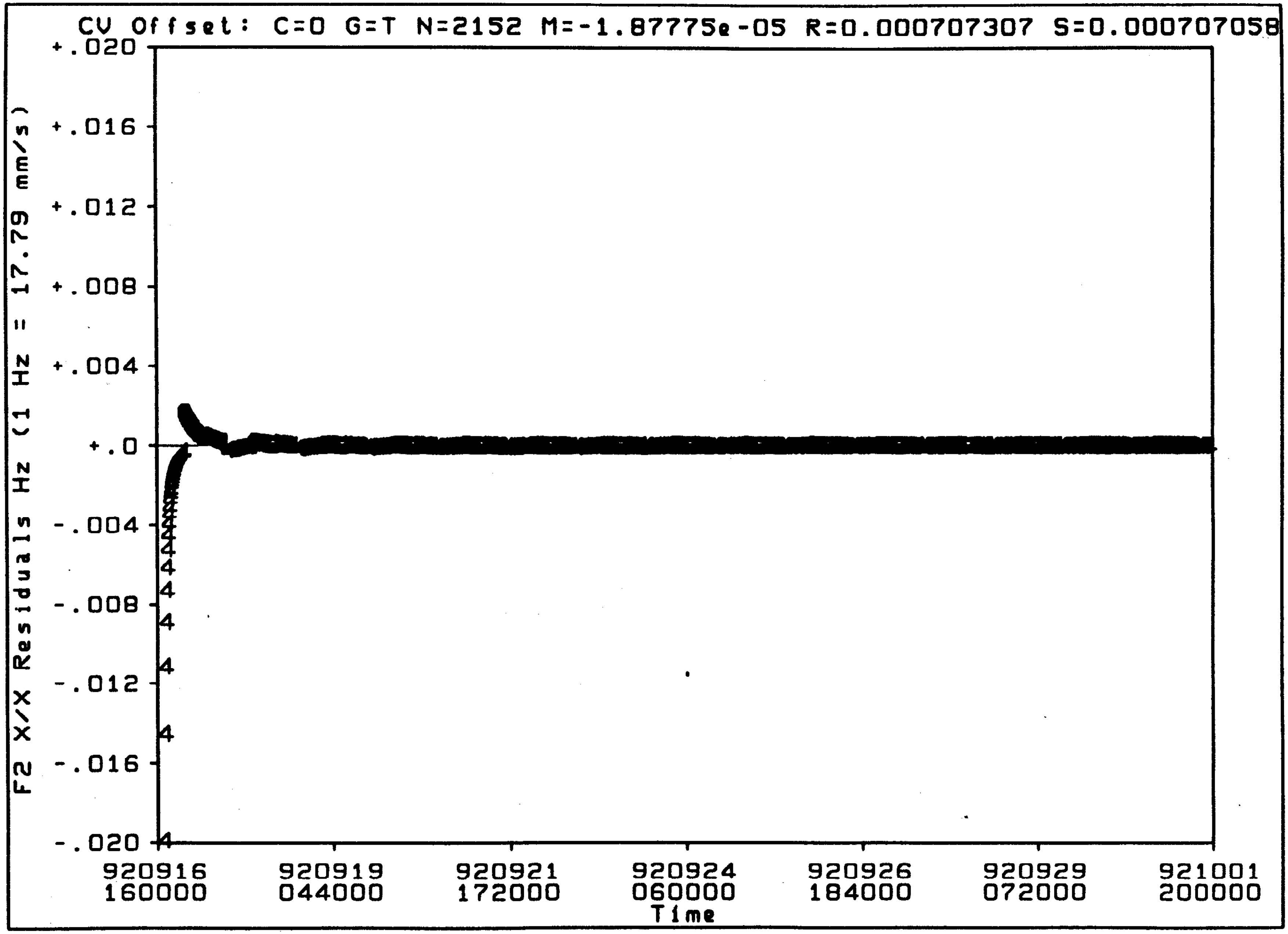


Figure 7: 10 meter offset in the z-height of the tracking stations.

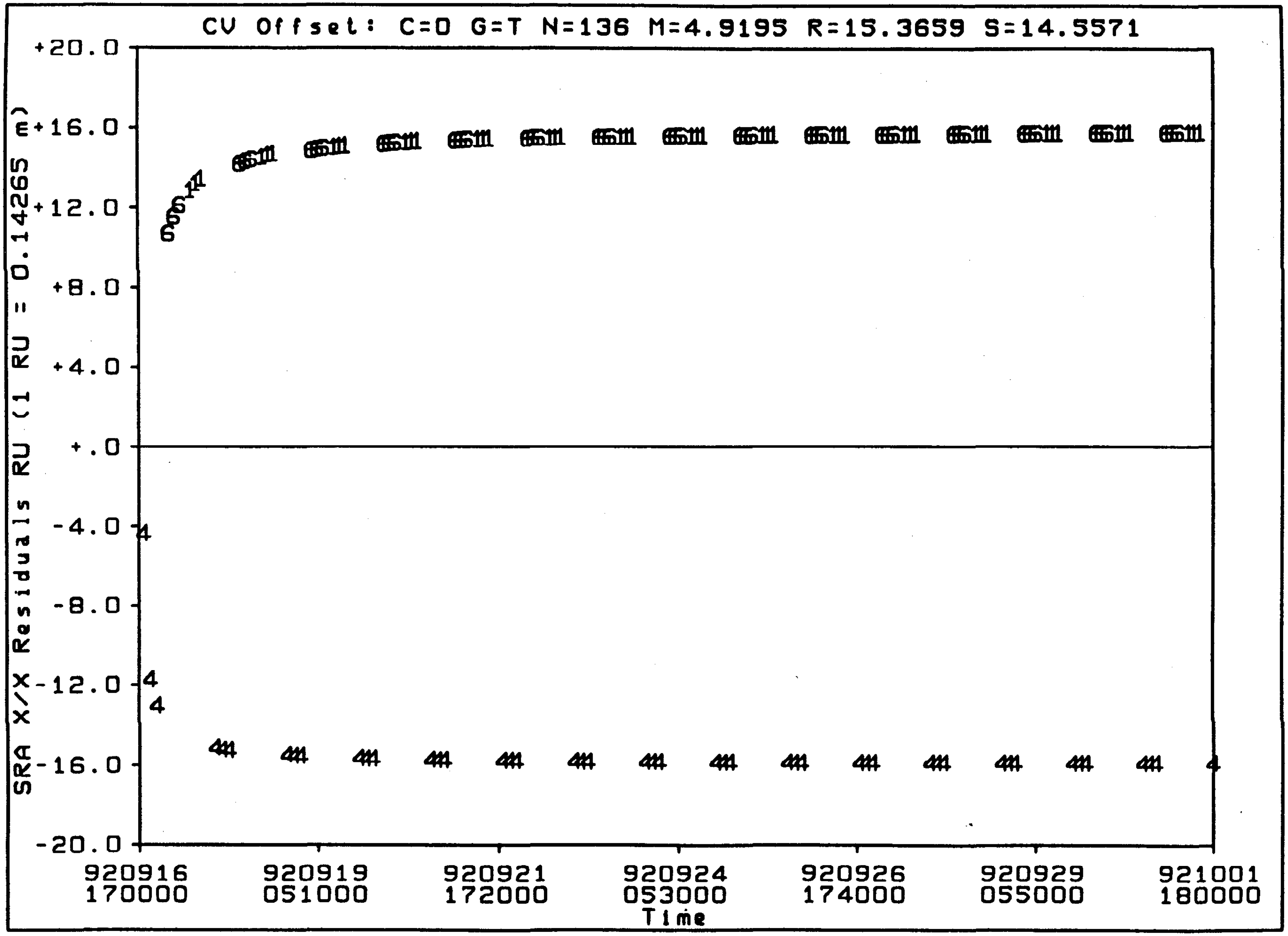


Figure 8: 10 meter offset in the z-height of the tracking stations.

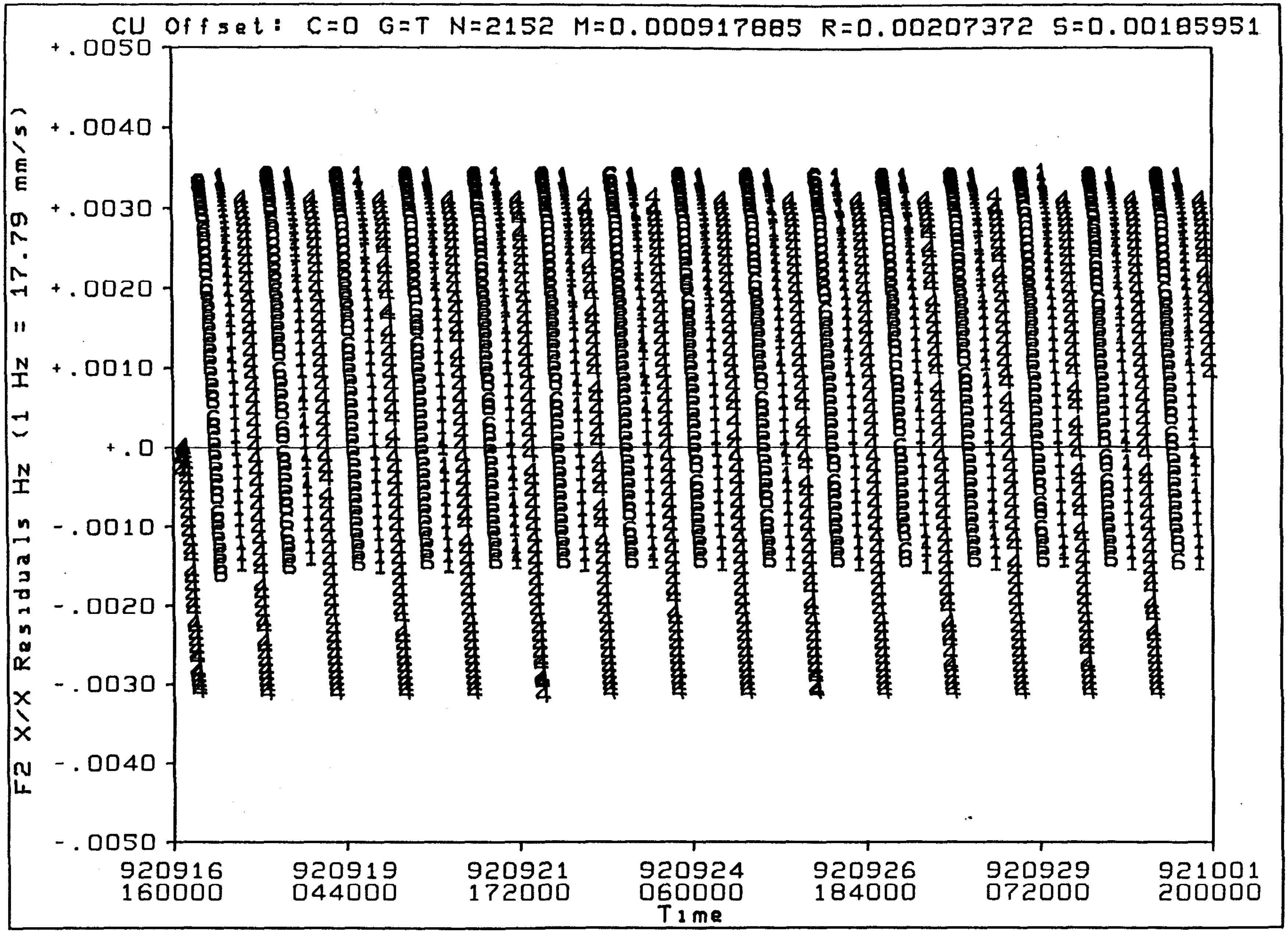


Figure 9: 0.85 meter offset in the spin axis radius of the tracking stations.

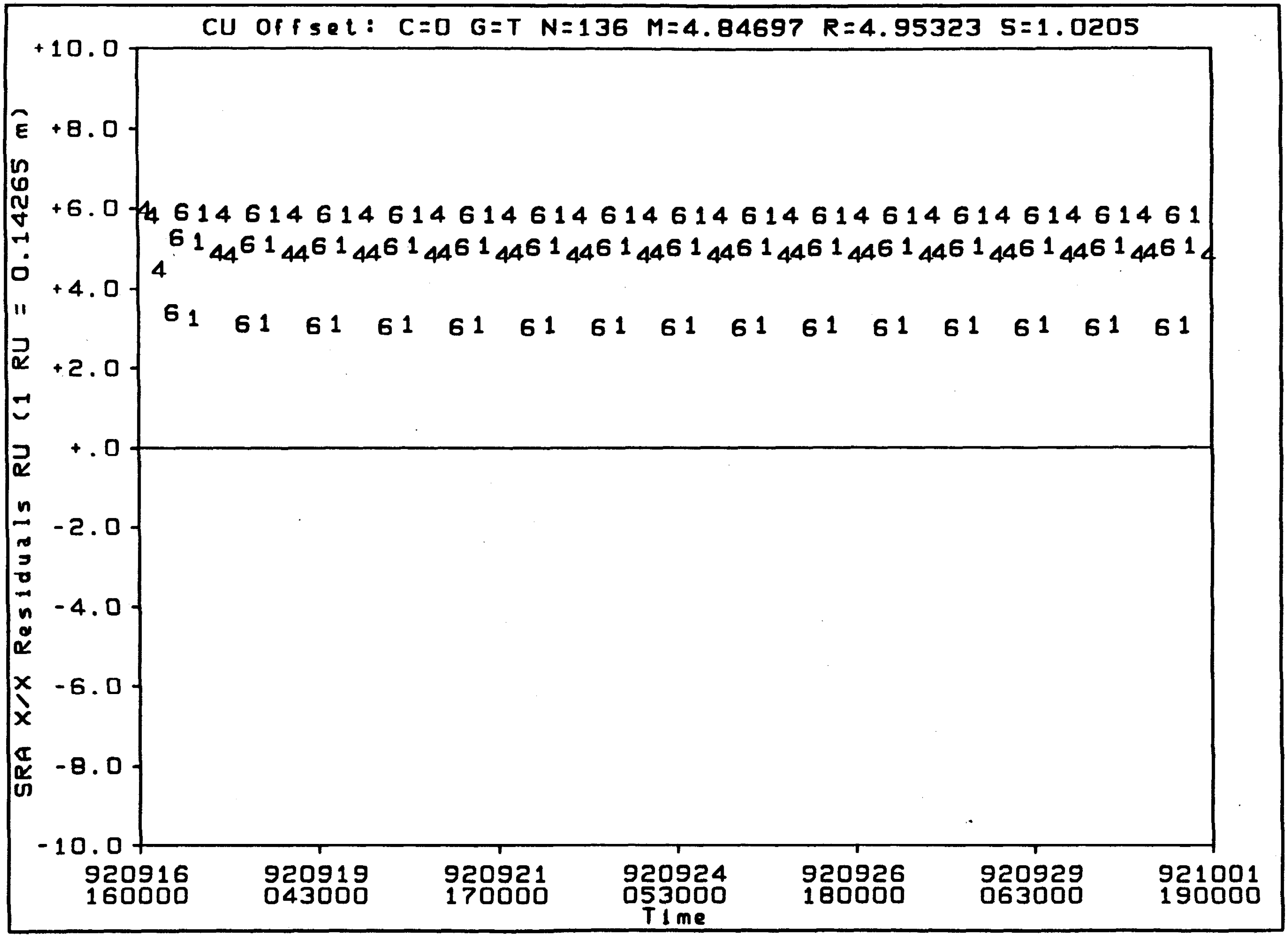


Figure 10: 0.85 meter offset in the spin axis radius of the tracking stations.

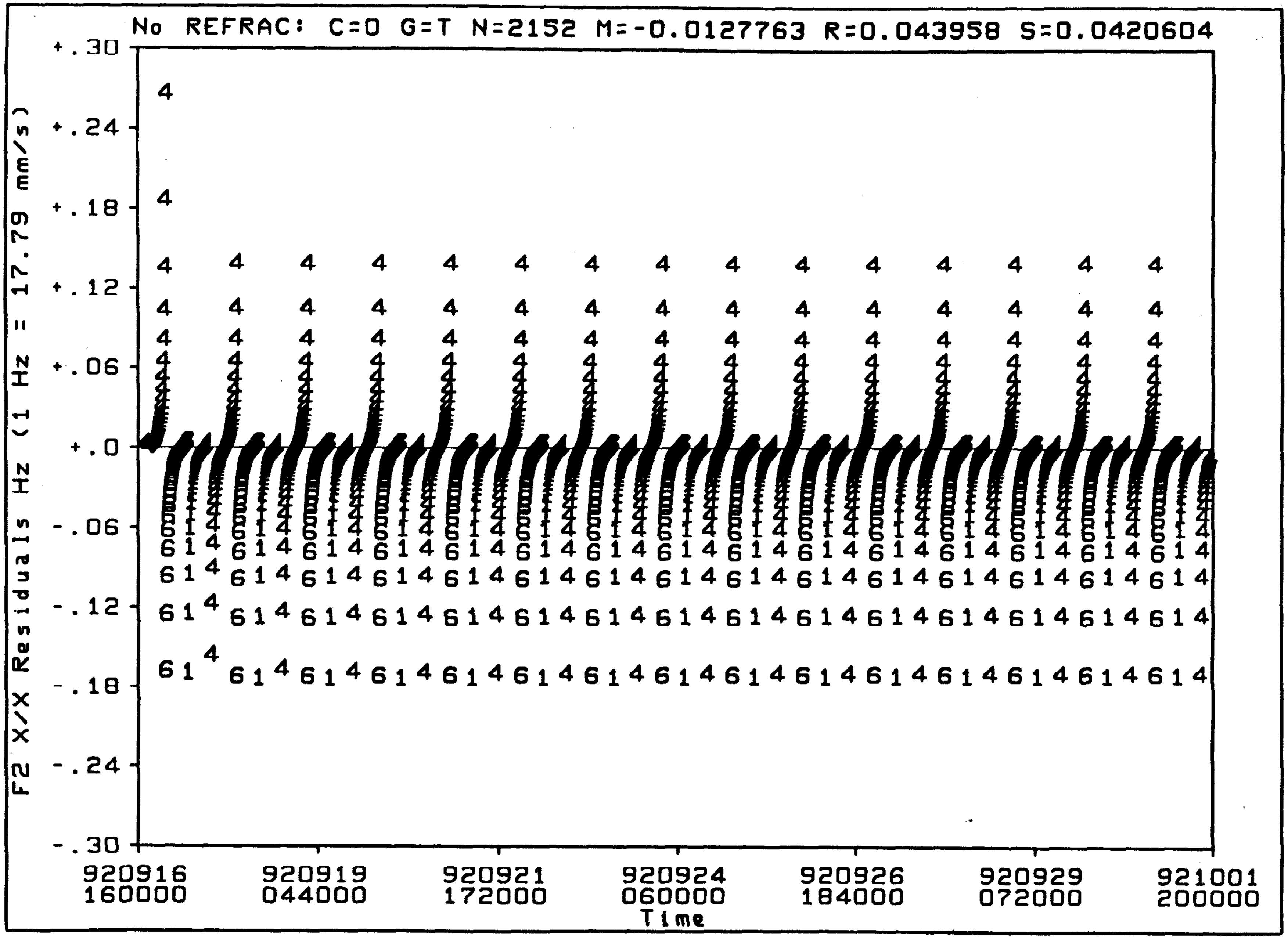


Figure 11: No Earth troposphere modelling.

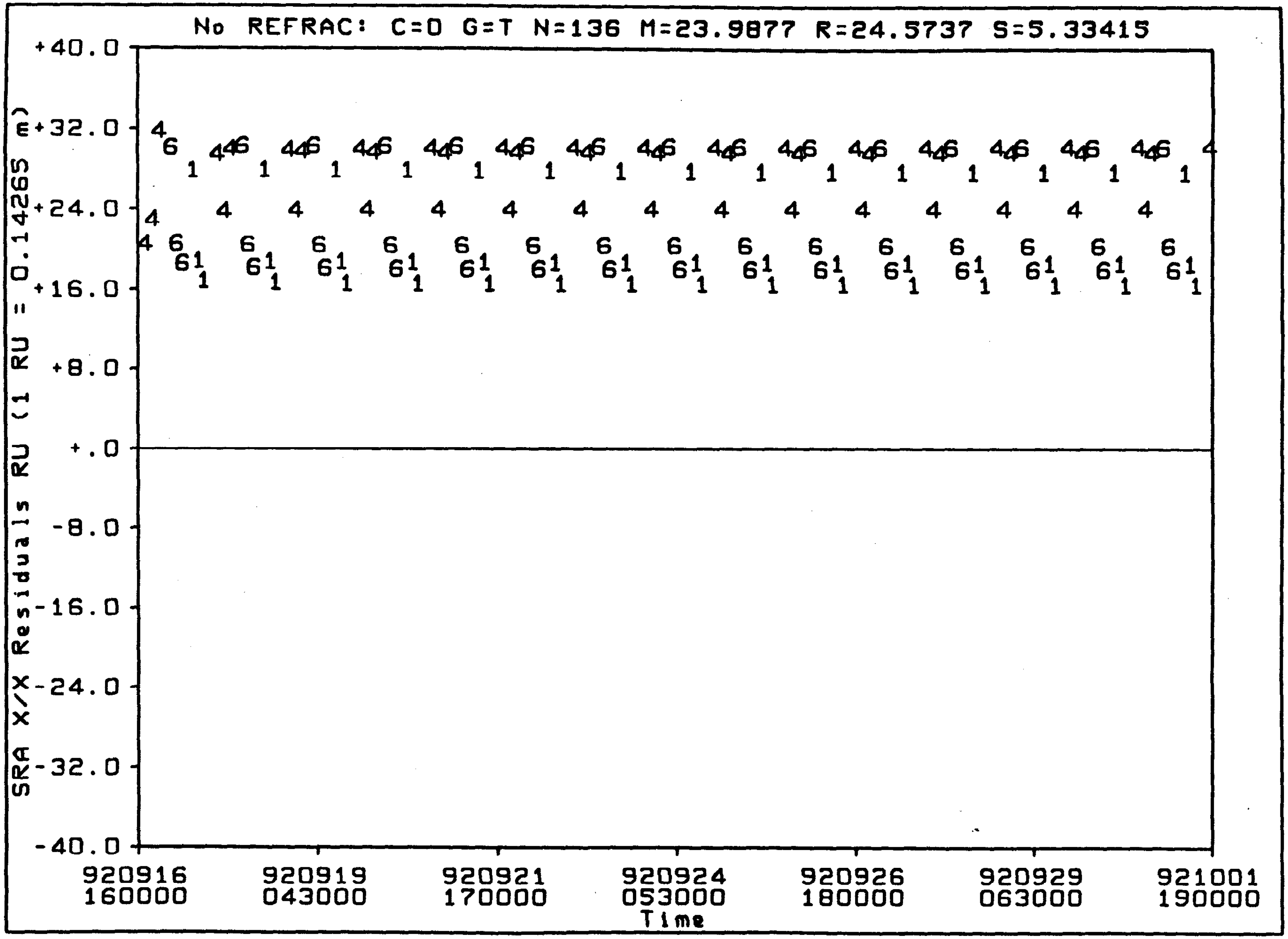


Figure 12: No Earth troposphere modelling.

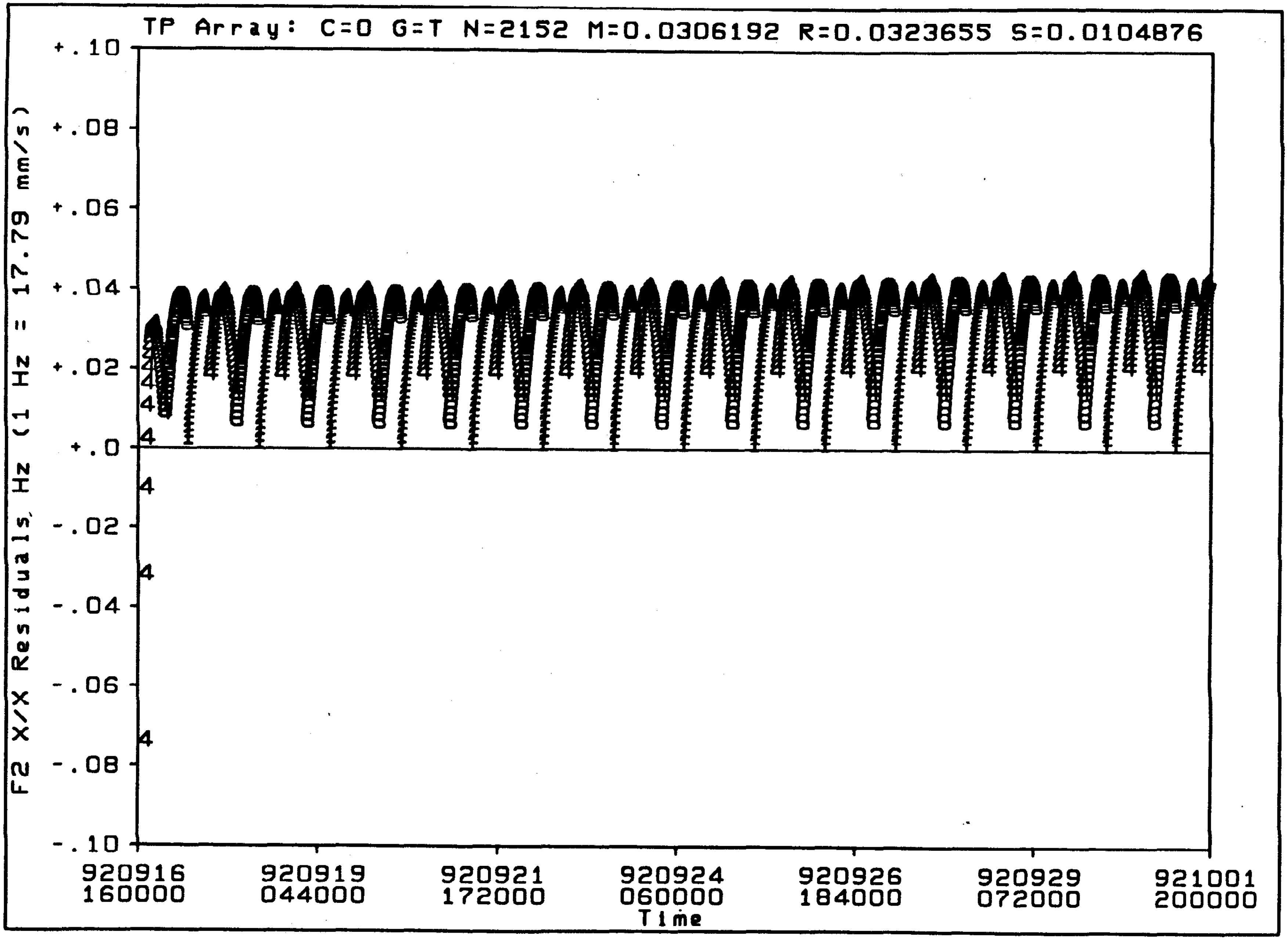


Figure 13: 7 day old timing and polar motion array.

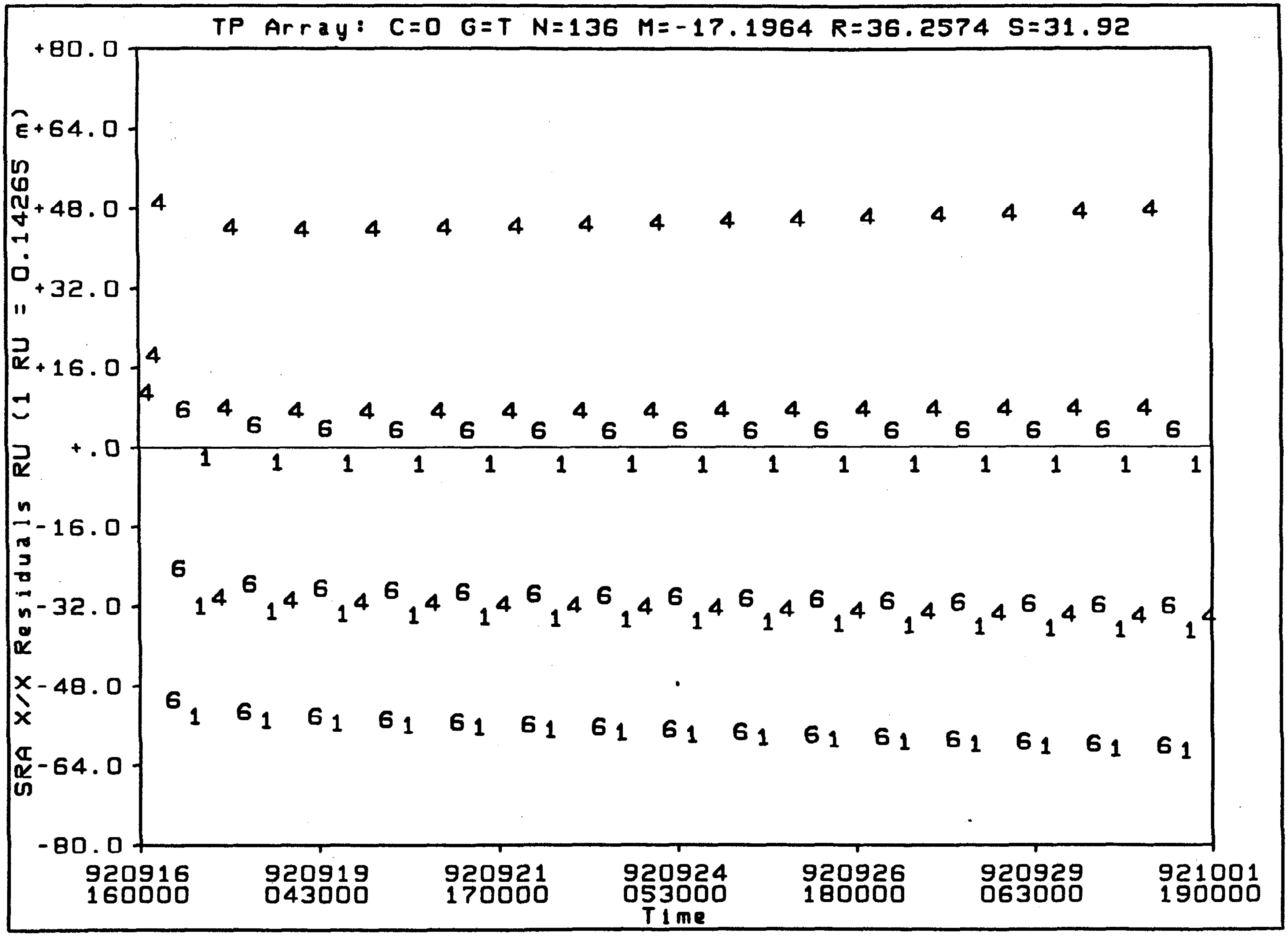


Figure 14: 7 day old timing and polar motion array.

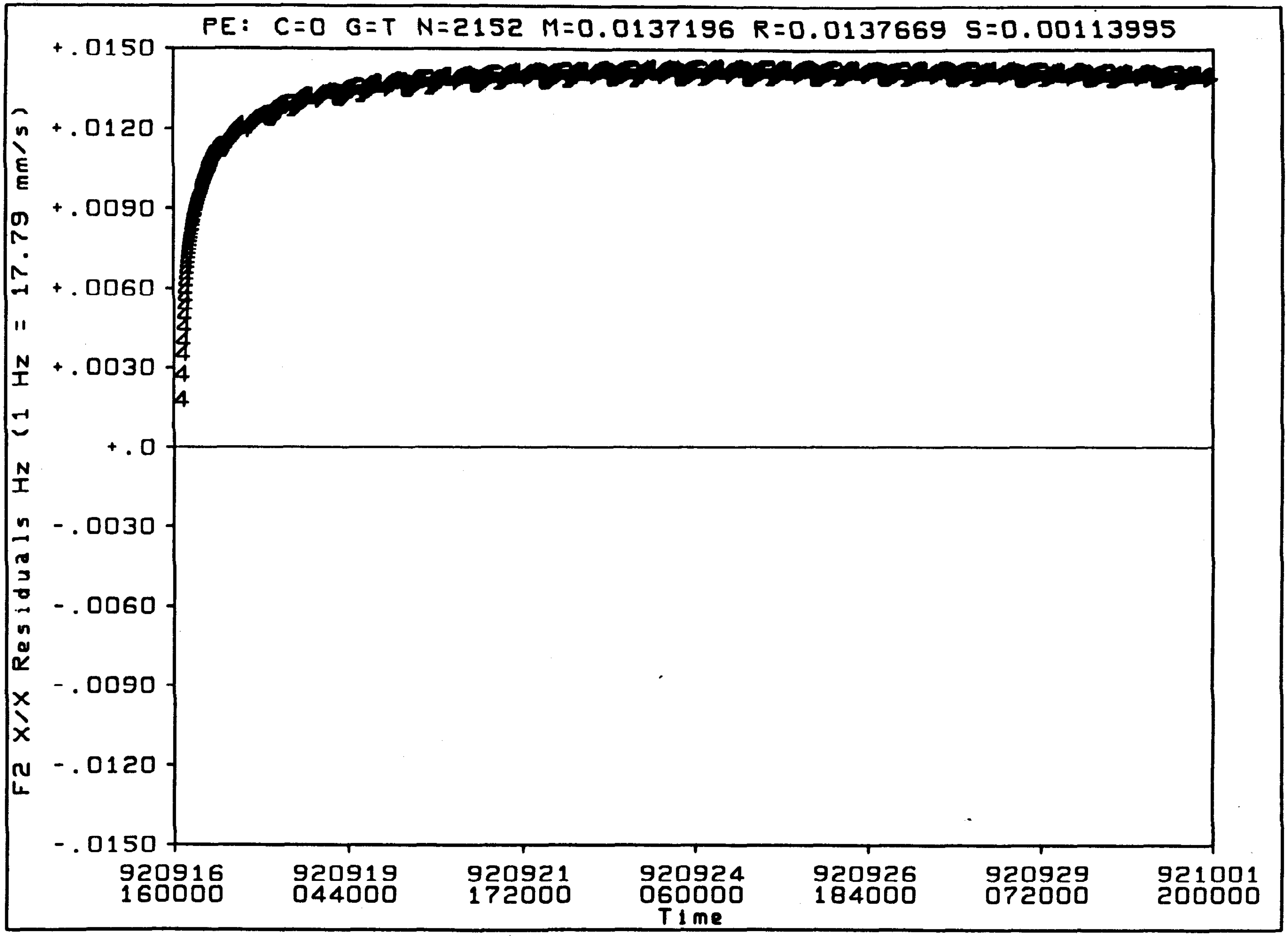


Figure 15: Planetary ephemeris offset.

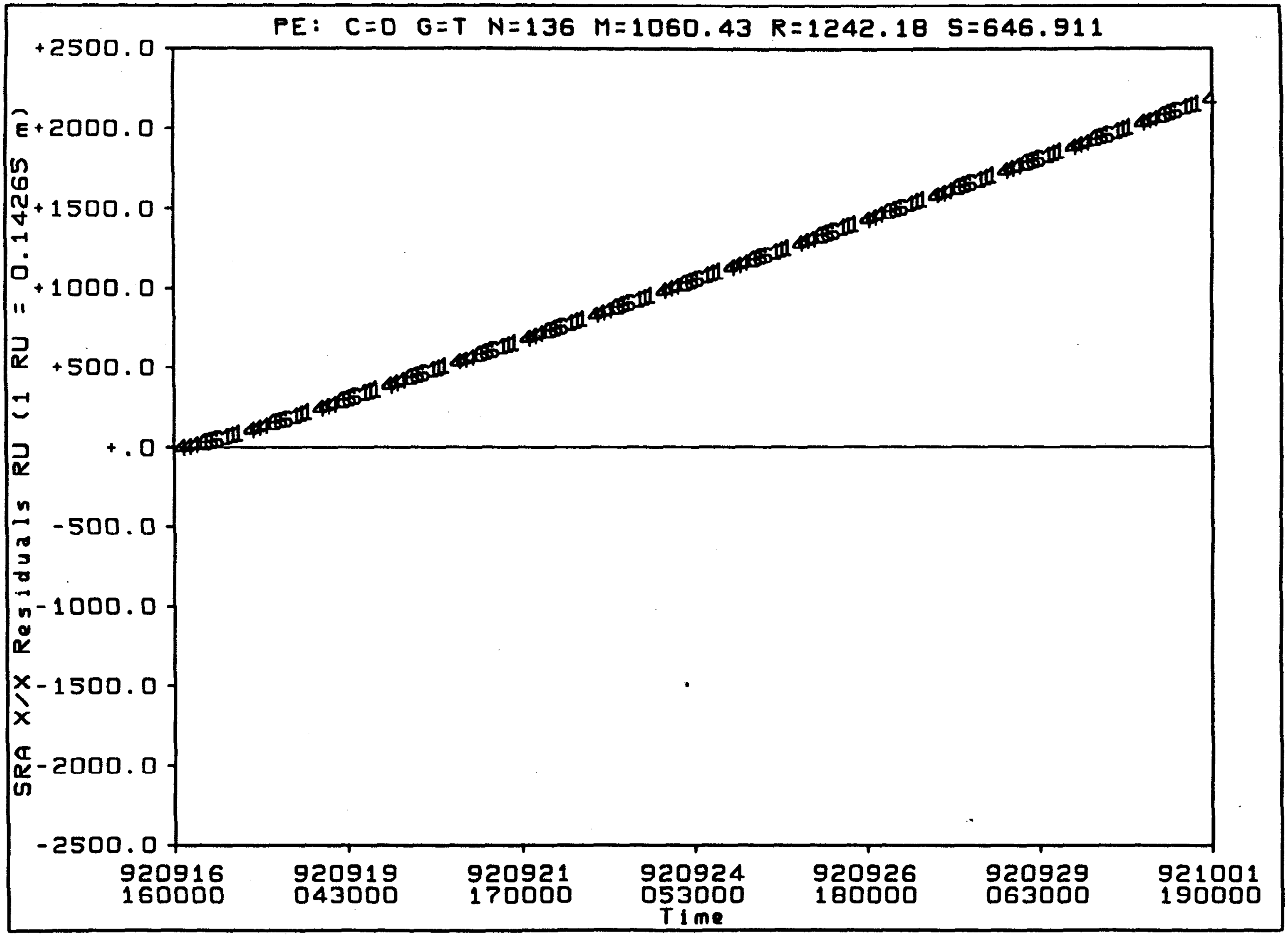


Figure 16: Planetary ephemeris offset.

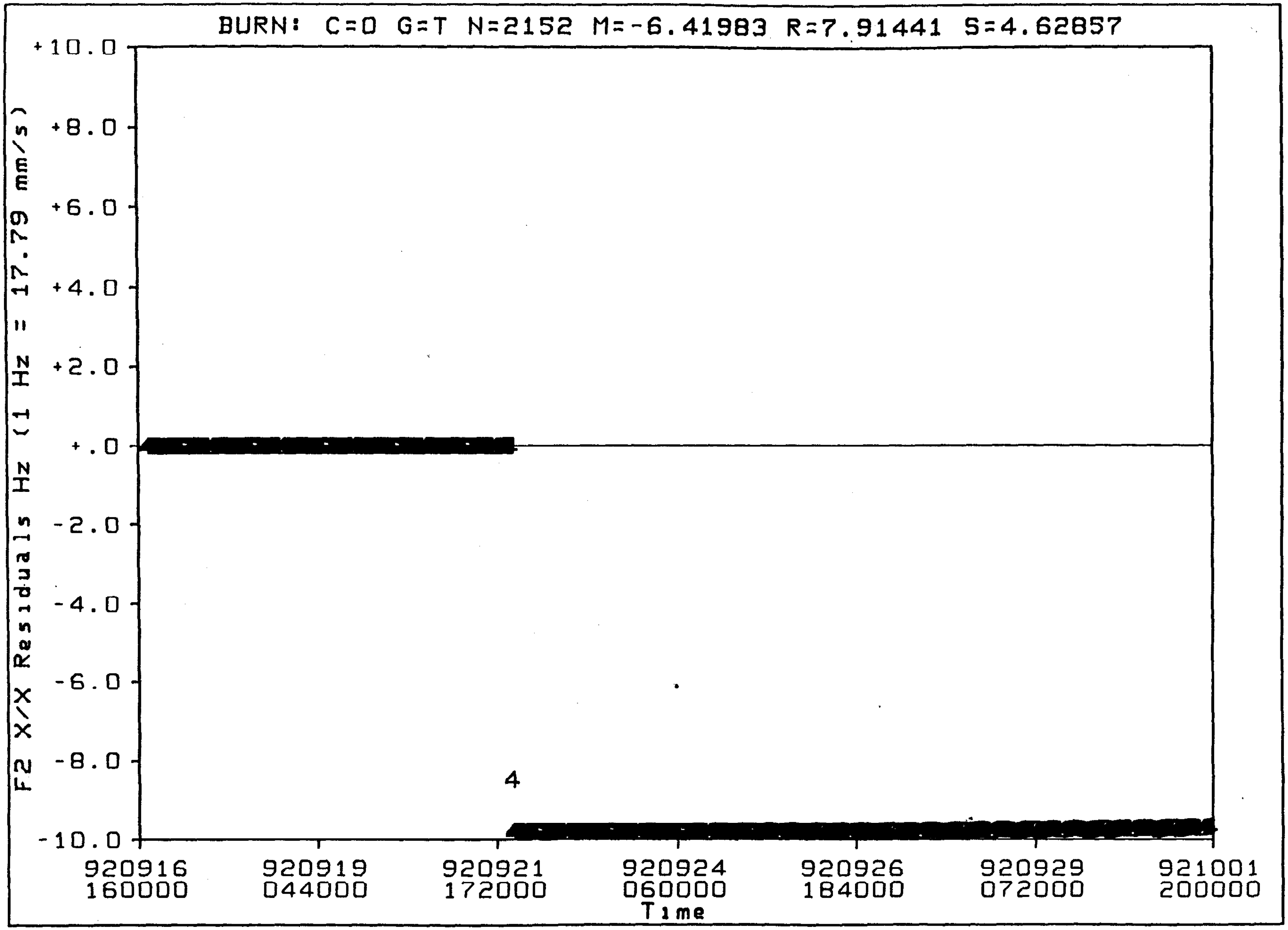


Figure 17: The F2 data residuals due to a 1% ΔV underburn in a maneuver.

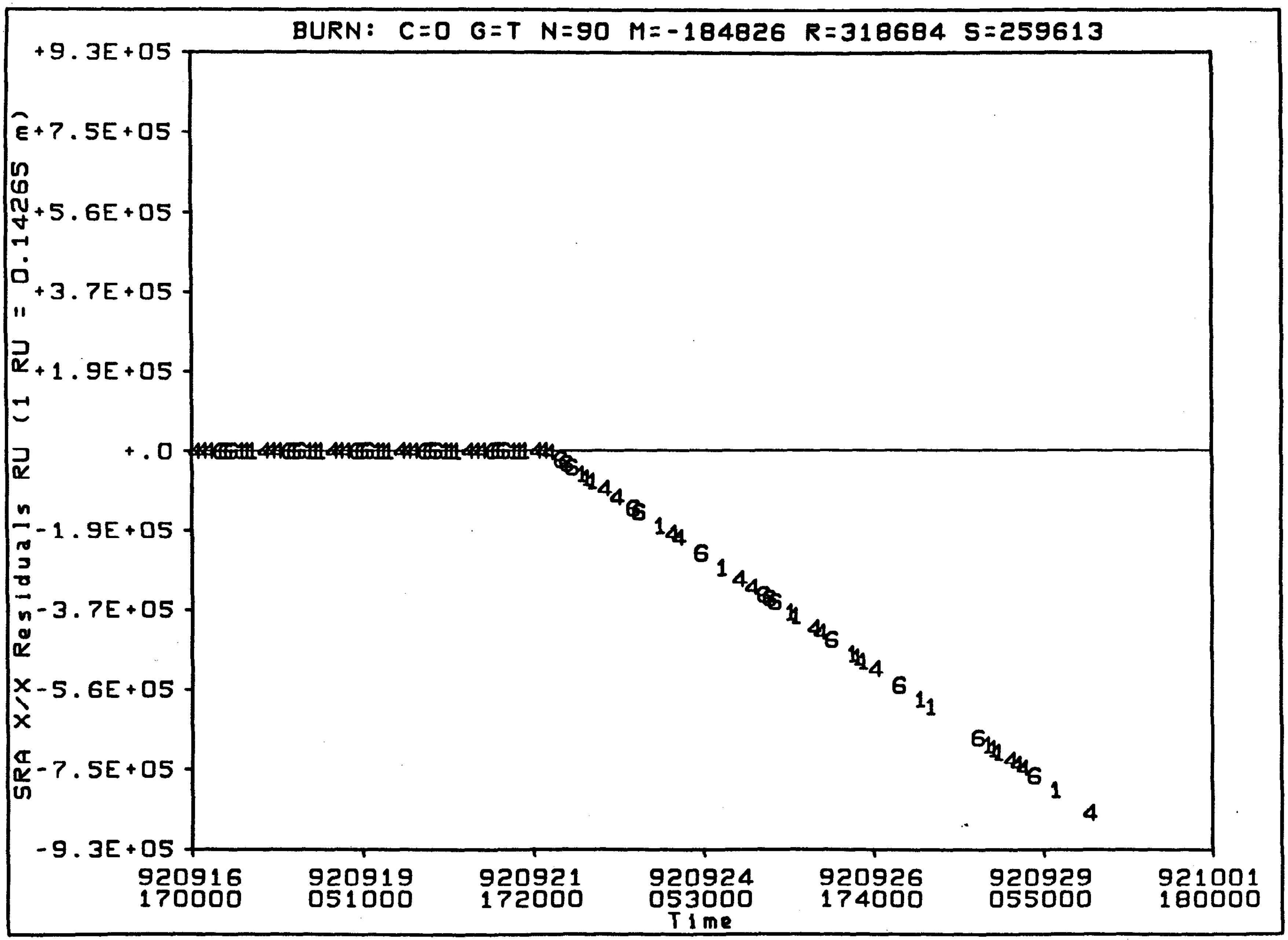


Figure 18: The SRA data residuals due to a 1% ΔV underburn in a maneuver.

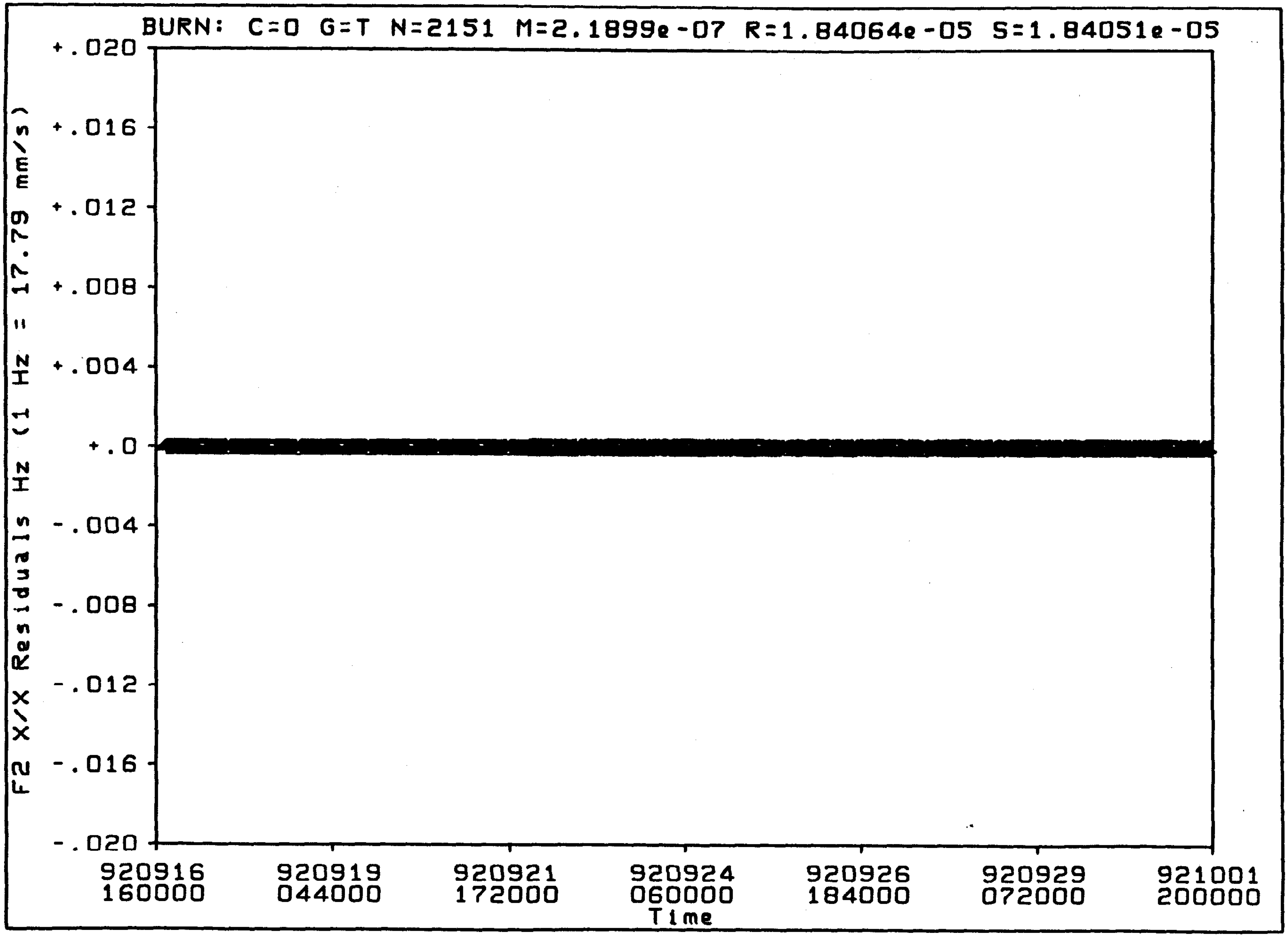


Figure 19: The F2 data residuals due to a maneuver which started 0.1 second late.

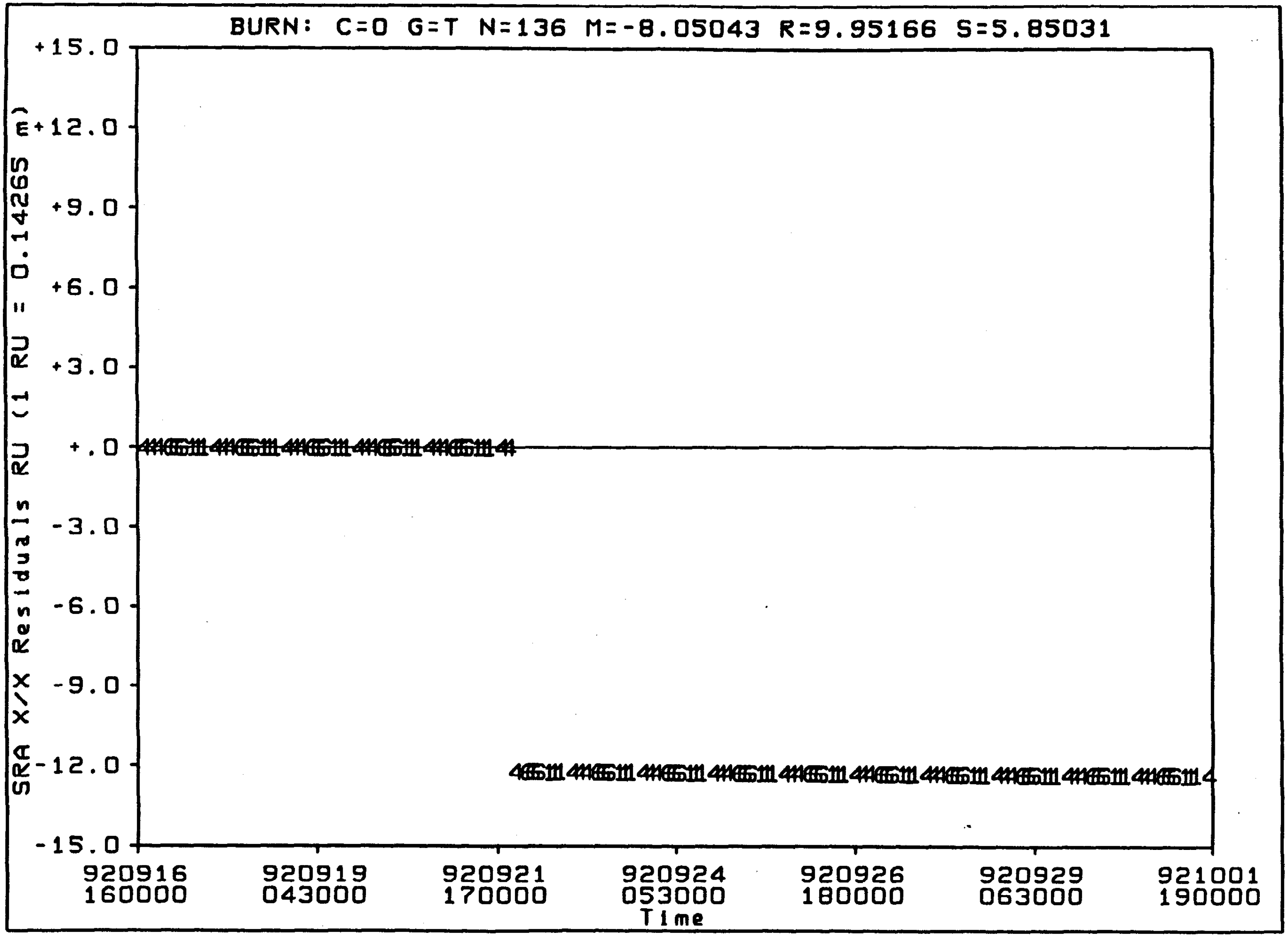


Figure 20: The SRA data residuals due to a maneuver which started 0.1 second late.

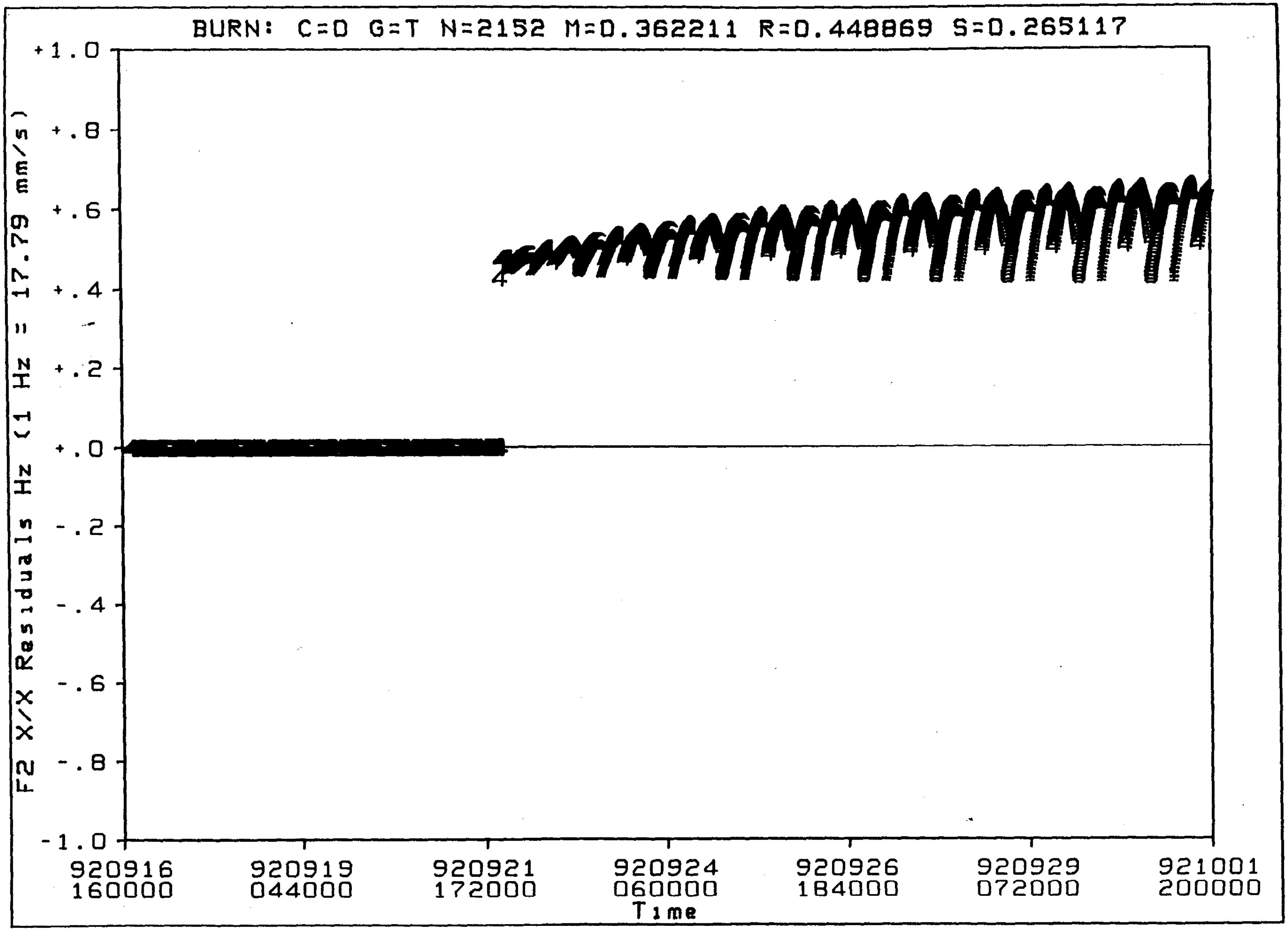


Figure 21: The F2 data residuals due to a -0.2 degree offset in a maneuver's right ascension.

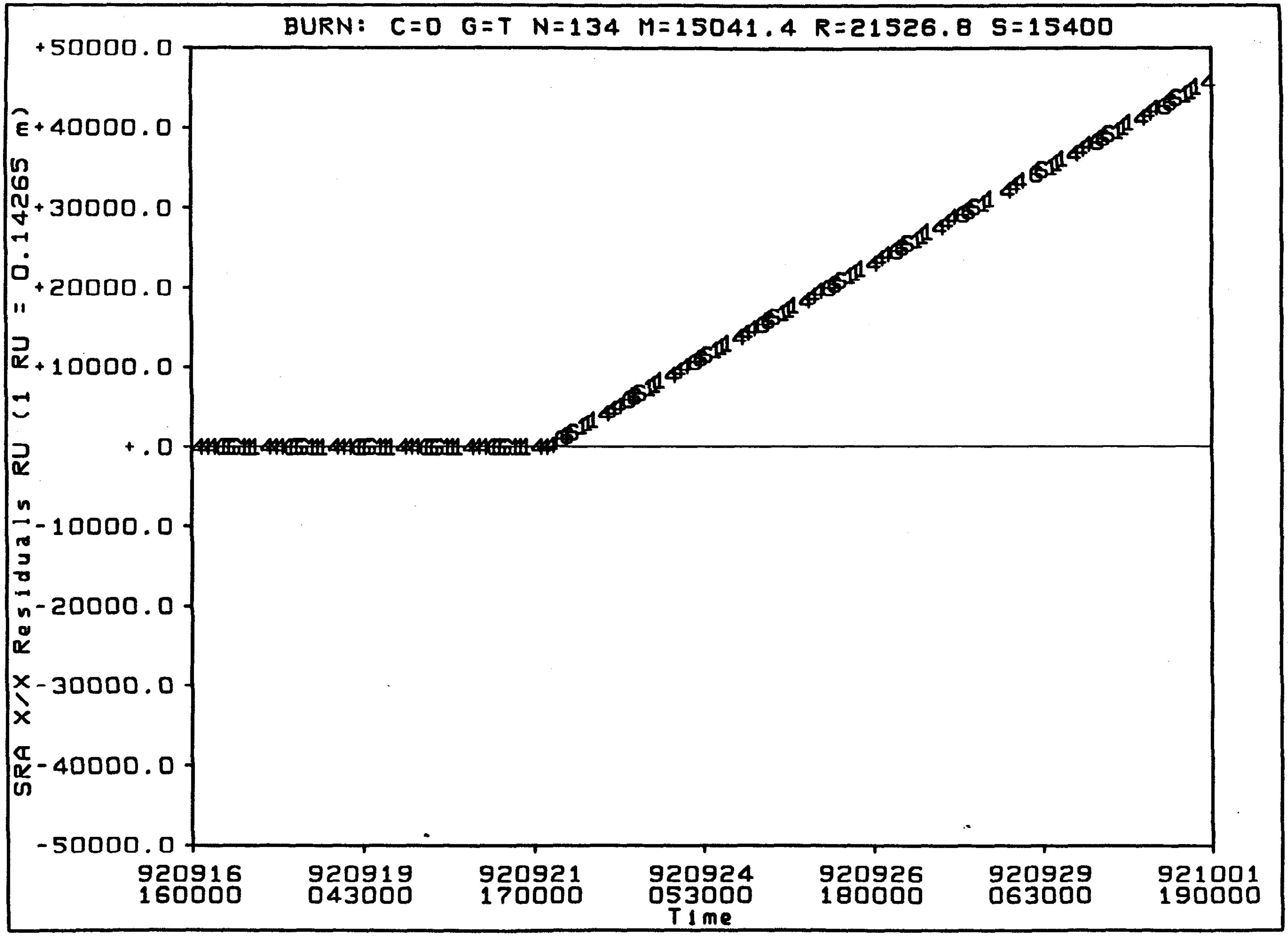


Figure 22: The SRA data residuals due to a -0.2 degree offset in a maneuver's right ascension.

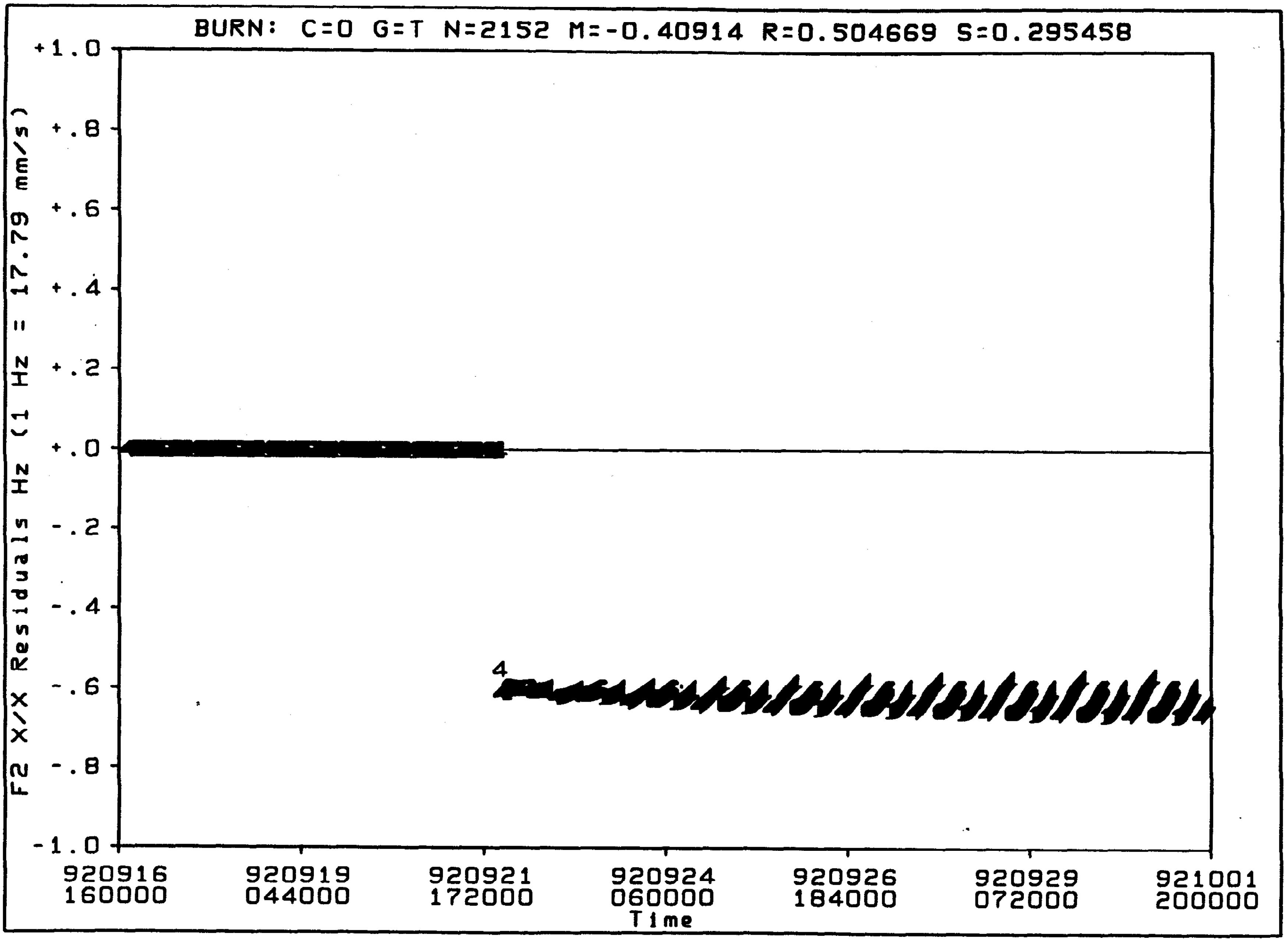


Figure 23: The F2 data residuals due to a -0.2 degree offset in a maneuver's declination.

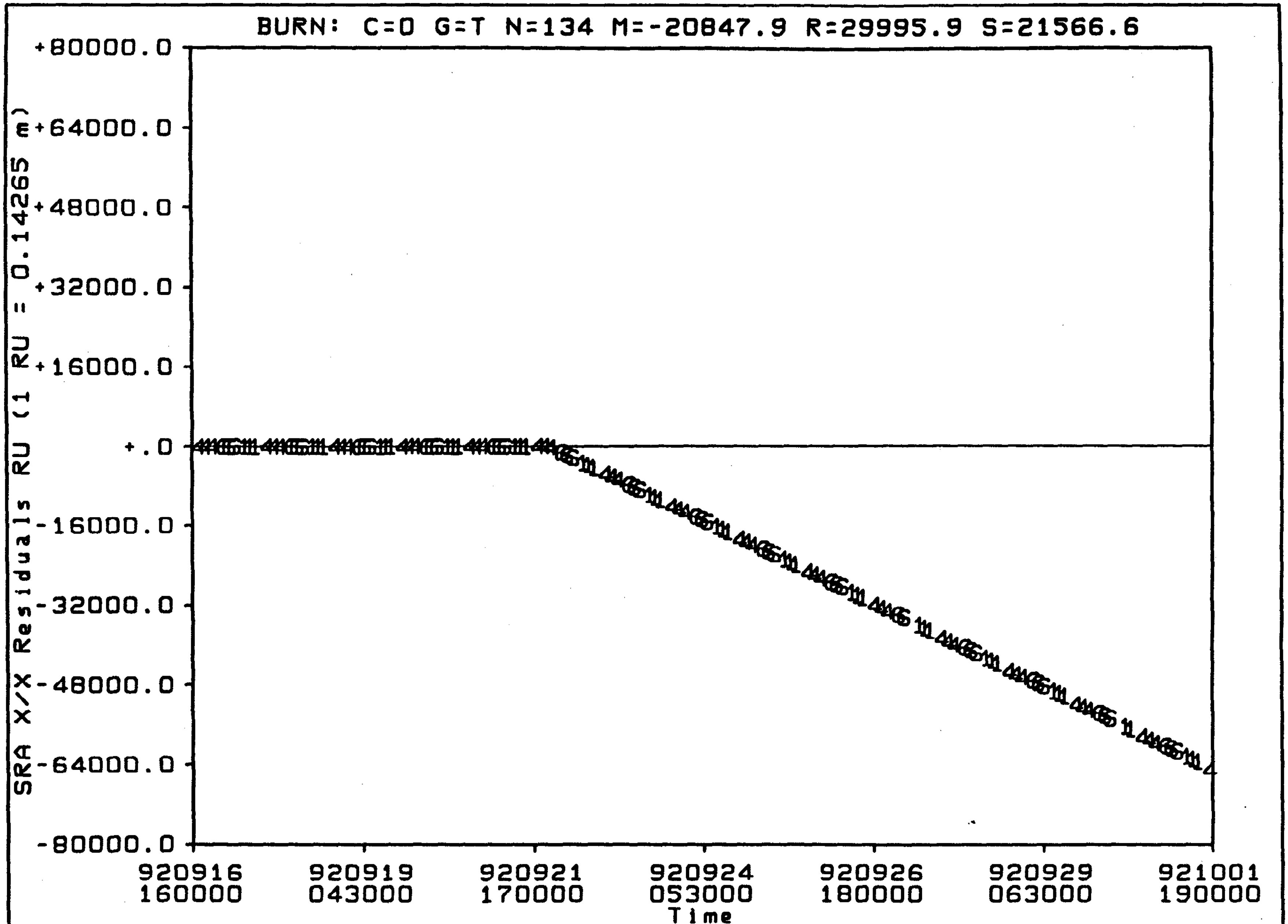


Figure 24: The SRA data residuals due to a -0.2 degree offset in a maneuver's declination.

6.0 The Maneuver Analysis Process

The MGS maneuver analysis process is described in this section. The topics covered include the function and execution of the maneuver software (MOPS) and the knowledge of operational procedures required by the maneuver analysts.

6.1 The Maneuver Software

Purpose:
To acquaint the navigator with the function and execution of each program in the MOPS.

Prerequisites:
The navigator must have access to a NAV workstation and must be familiar with the NAV computer system configuration, the UNIX operating system, and the NAV directory structure.

The following programs compose the Maneuver Operations Program Set, MOPS:

sapp reads the Maneuver Implementation File (MIF) and the SALIENT file to produce various sensitivity and probability data for a particular maneuver design. These data include velocity covariances and delivery error plots. sapp can also create a State Estimates File. In addition to the MIF and SALIENT input files, sapp requires an ASCII namelist file and a K-matrix file.

verify calculates maneuver parameters from the Maneuver Implementation File. verify generates the Maneuver Verification Data File which is used to update the GINFILE. Along with the MIF, an ASCII namelist file is required as input to verify.

rtmon produces real-time monitoring plots from the Maneuver Implementation File and an ASCII namelist input file.

btrack determines the spacecraft aimpoint during a finite burn. btrack requires a K-matrix file and a Maneuver Profile File (MPF), Maneuver Implementation File, or Maneuver Verification Data File for maneuver data.

pq/pqplot is a group of programs which calculate and plot the probabilities of impact with the encounter body (i.e. Mars). Input is through an ASCII namelist file. pq and pqplot are important in monitoring the planetary protection guidelines.

pitch is used to design a finite burn with a constant spacecraft pitch rate. It will be used for Mars Orbit Insertion (MOI) maneuver. Given an ASCII namelist file of initial conditions, pitch generates a family of finite burns starting at different epochs. The target parameters in the fixed orbit are the semi-major axis, eccentricity, and argument of periapsis.

power is identical to pitch except that the orbit inclination may also be changed.

The following Utility programs are often used in maneuver analysis:

calcaew	A program which generates initial estimates for pitch-over maneuvers to facilitate convergence of the program pitch.
fast	A trajectory integration program.
ftpnio & nioftp	Programs to convert between NAVIO and binary formats.
lambic	An interplanetary Monte-Carlo simulation program.
mpfgen	A program which generates the Maneuver Profile File (MPF) from pvdrive (in search mode, i.e. sepv) output.
niocomp	This program compares the contents of two NAVIO files.
nio2text & text2nio	Programs to convert between NAVIO and ASCII formats.
otmcalc	A program which generates initial estimates for Longitude Grid Control (LGC) maneuvers to facilitate convergence of sepv.
salsol	Reads solution vectors and covariances from a SALIENT file.
str	A program which interpolates a spacecraft state from a P-FILE or PV-FILE.
sunang	A program which checks the angle between the spacecraft's +Z-axis (where the instruments are located) and the Sun.

The maneuver process for TCM-1 has been summarized in flowchart form and is presented in Section 6.4.

6.2 Navigation Operational Procedures

Purpose:
To review those operational procedures which are the responsibility of the maneuver analyst.

Prerequisites:
The navigator should be familar with the NAV computer environment and the programs of the DPTRAJ and MOPS.

The maneuver analyst is responsible for the following operational procedures:

NAV-0007 NAVIGATION PROCESS: DESIGN AND VERIFICATION OF PROPULSIVE MANEUVERS
MANEUVER PERFORMANCE DATA FILE TRANSFER
MANEUVER PROFILE FILE GENERATION

MANEUVER IMPLEMENTATION FILE ASSESSMENT

NAV-0017 GUIDELINES FOR PROPULSIVE MANEUVER SELECTION (OFF-THE-SHELF) THROUGHOUT AEROBRAKING

6.3 Bibliography

"Mars Global Surveyor Navigation Plan", MGS Project Document 542-406, Rev. A, JPL Document D-12002, Sept 15, 1995.

Moyer, T., "Mathematical Formulation of the Double-Precision Orbit Determination Program", Technical Report 32-1527. Jet Propulsion Laboratory, Pasadena CA, May 15, 1971.

"DPTRAJ-ODP Users Reference Manual, Volume 1", Mars Global Surveyor Project Document 642-3405-DPTRAJ/ODP, 3/22/96.

"DPTRAJ-ODP Users Reference Manual, Volume 2", Mars Global Surveyor Project Document 642-3405-DPTRAJ/ODP, 1/25/96.

"DPTRAJ-ODP INTERFACES AND FILE FORMAT DESCRIPTIONS, Volume 3", Mars Global Surveyor Project Document 642-3405-DPTRAJ/ODP, 4/12/96.

"MANEUVER OPERATIONS PROGRAM SET (MOPS) UTILITY USER GUIDE", 3/29/96.

6.4 Maneuver Design Process Flowchart

This flowchart is given as a sequence of figures under Fig. 6.1.

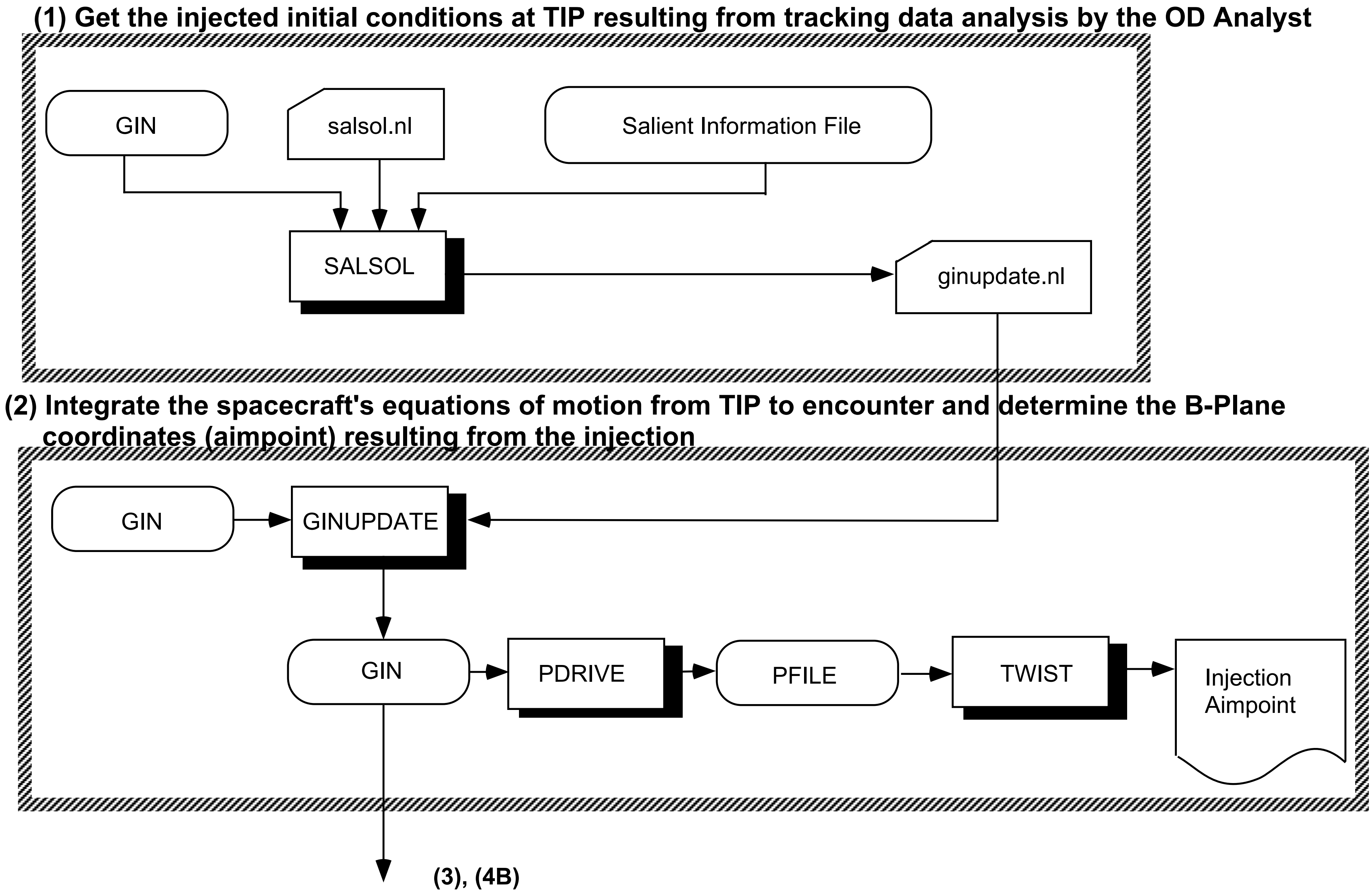
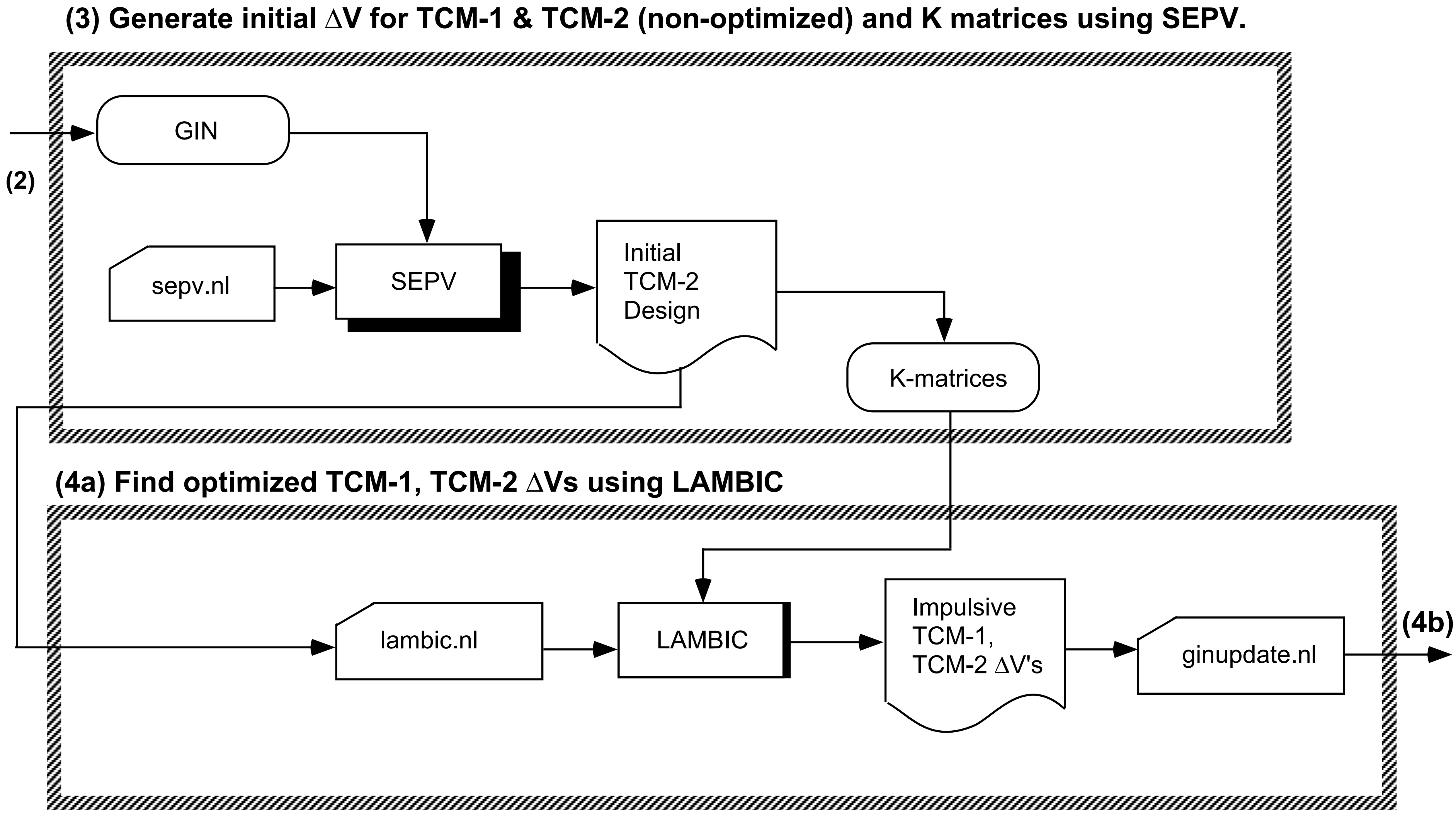
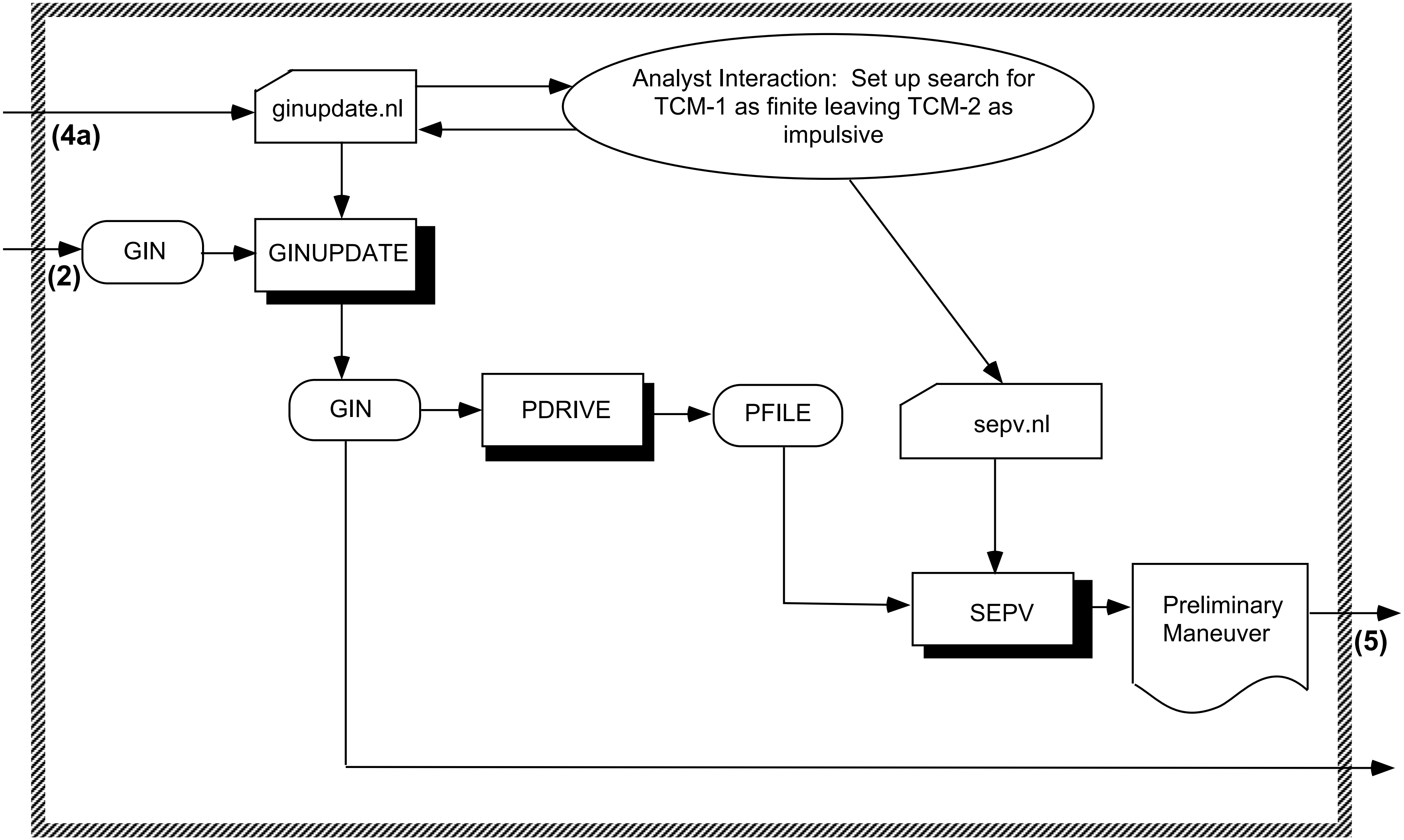


FIG 6.1 PROPULSIVE MANEUVER DESIGN FLOWCHART FOR TCM-1 & TCM-2



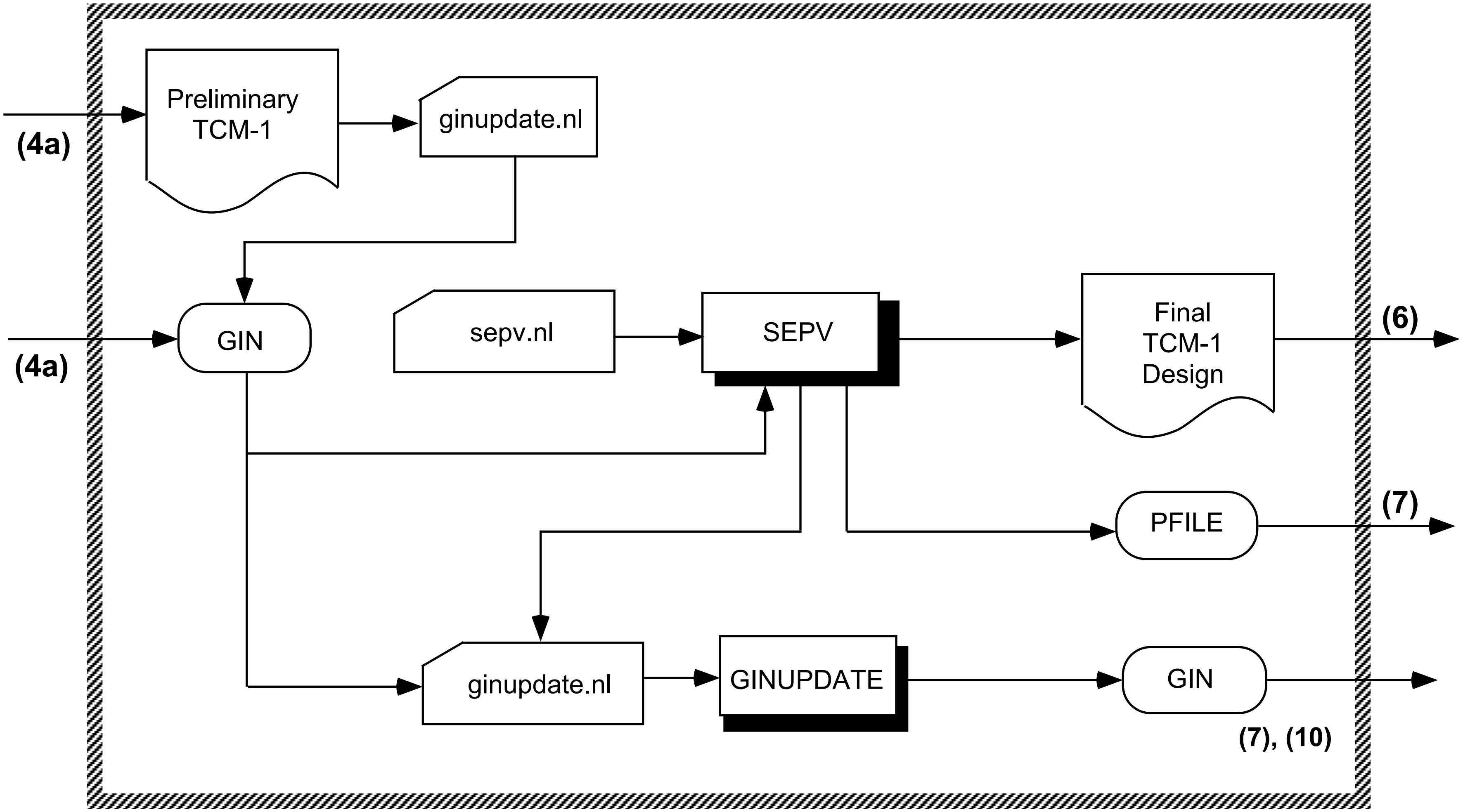
PROPULSIVE MANEUVER DESIGN FLOWCHART

(4b) Set Up TCM-1 Search

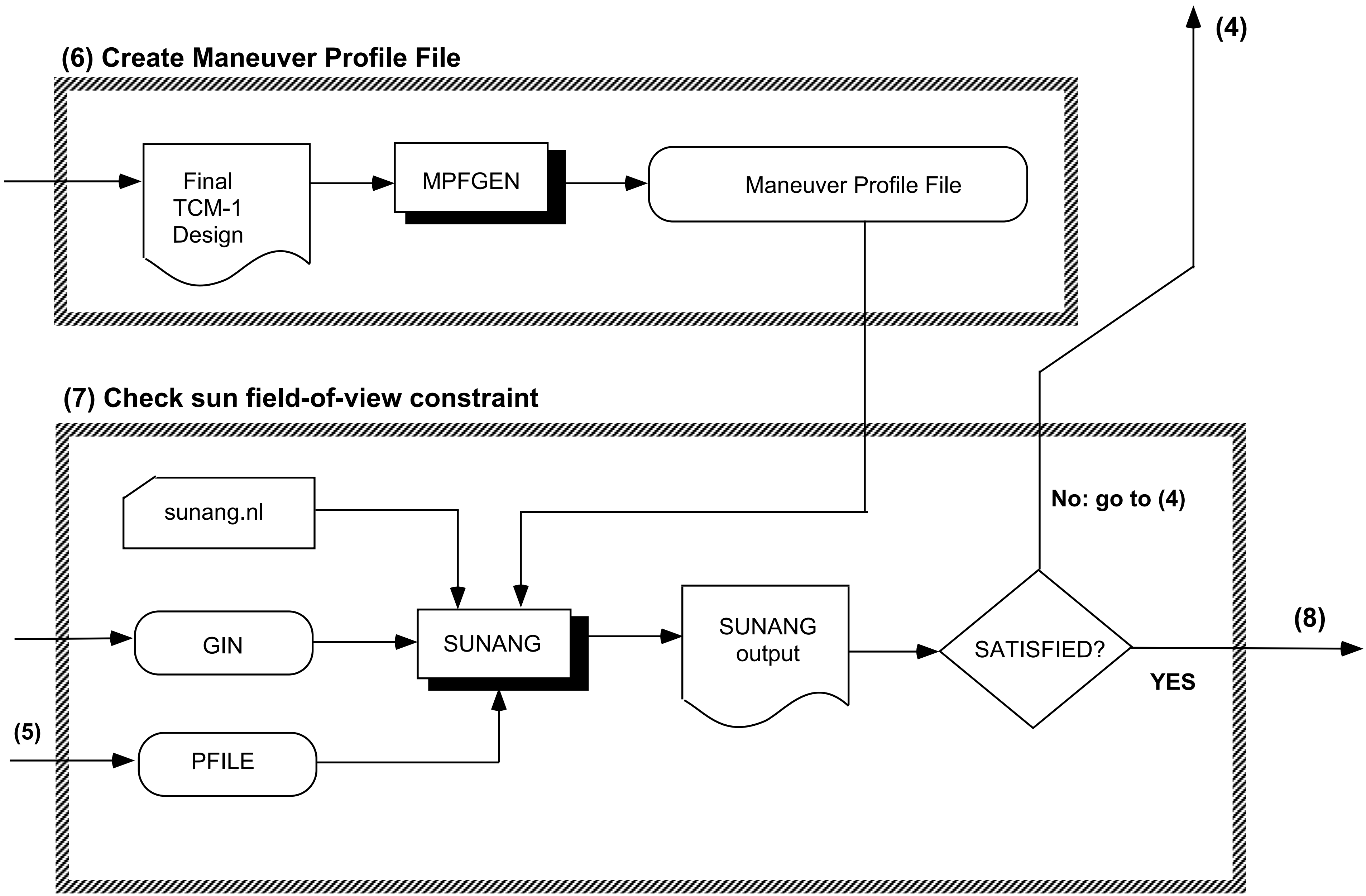


PROPULSIVE MANEUVER DESIGN FLOWCHART

(5) Design the finite burn for TCM-1

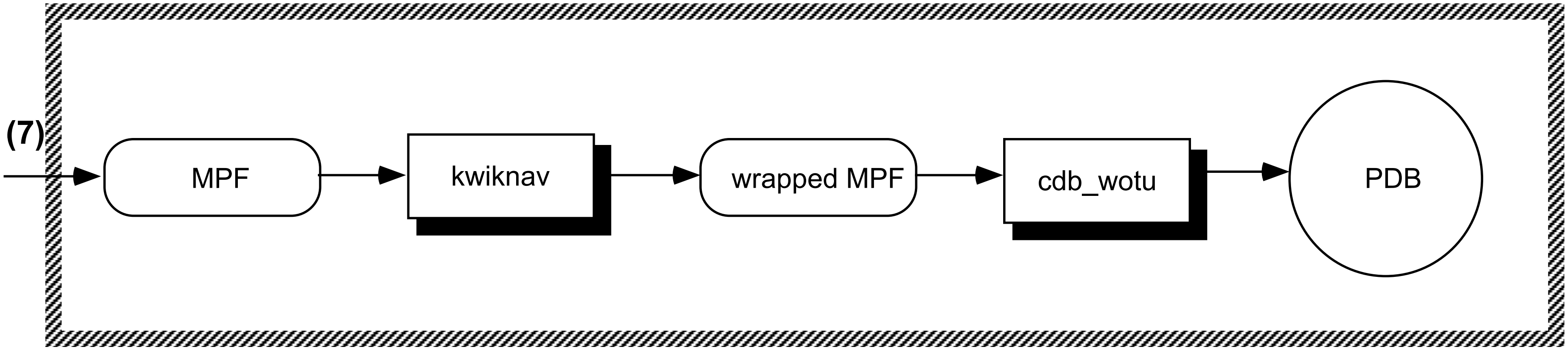


PROPULSIVE MANEUVER DESIGN FLOWCHART

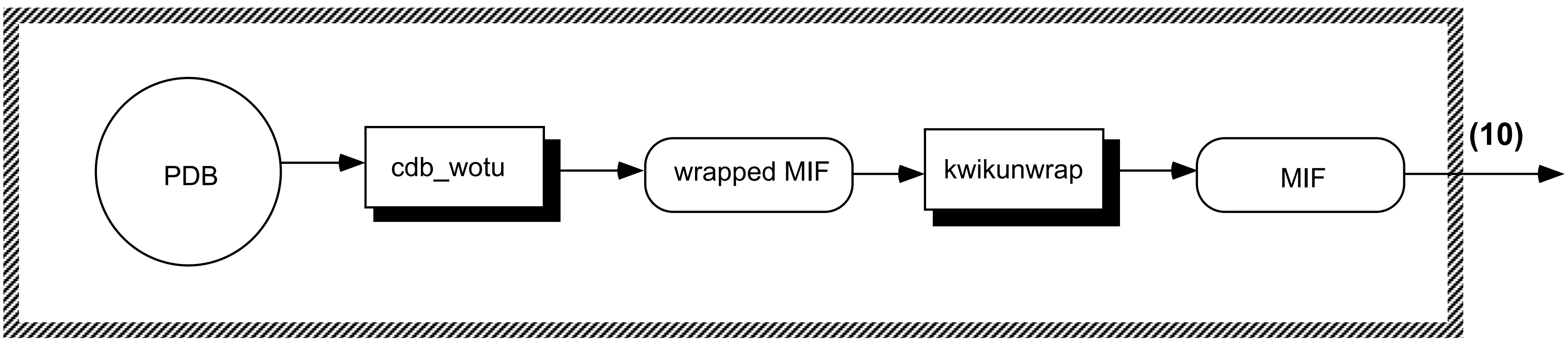


PROPULSIVE MANEUVER DESIGN FLOWCHART

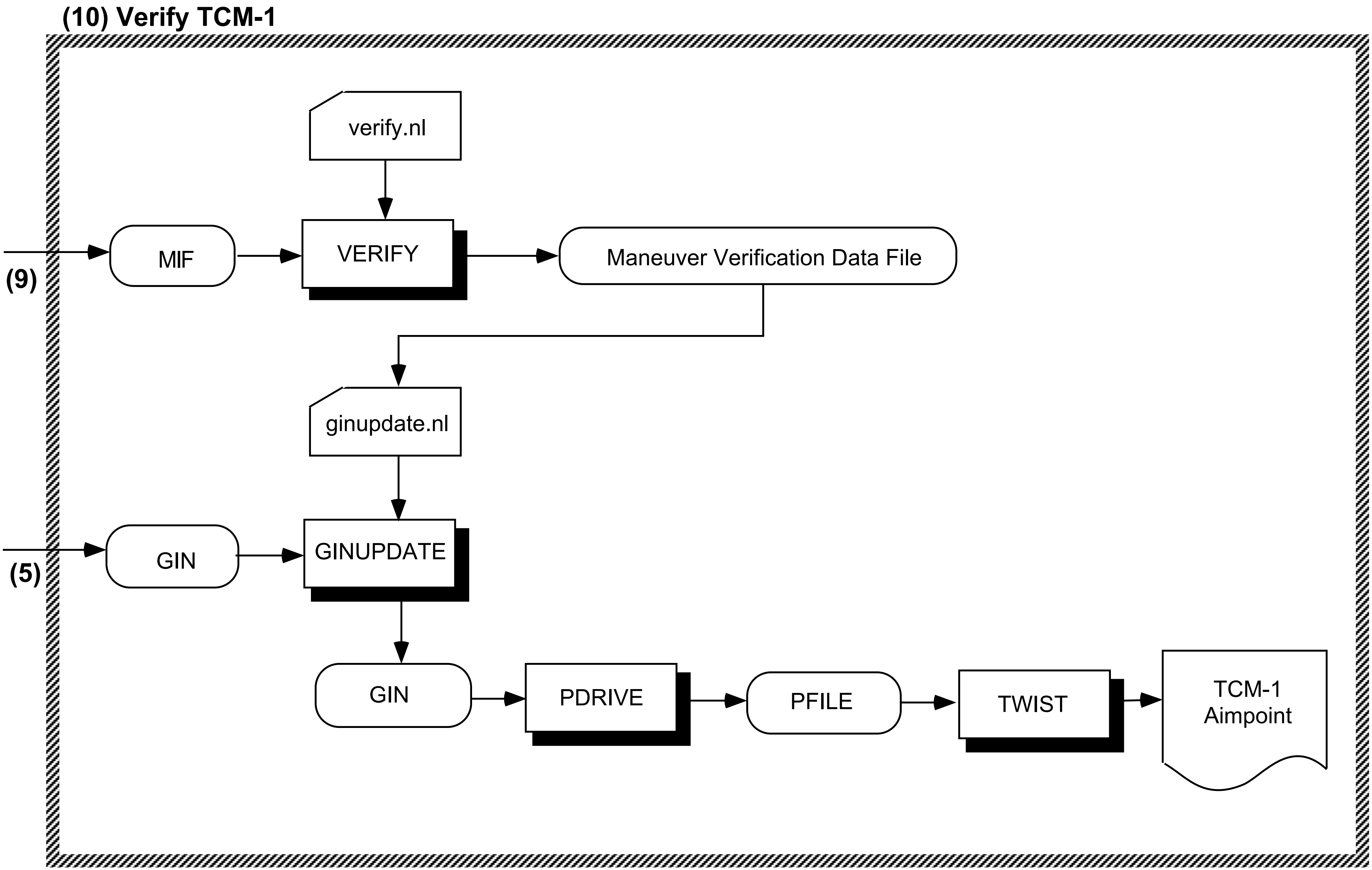
(8) Place Maneuver Profile File on PDB



(9) Retrive Maneuver Implemtation File from PDB



PROPULSIVE MANEUVER DESIGN FLOWCHART



PROPULSIVE MANEUVER DESIGN FLOWCHART

7.0 Navigation Analyst Certification

The certification of a navigation analyst will be achieved when the analyst has mastered the topics listed in the Navigation Training Record to the satisfaction of the Navigation Training Engineer, the Navigation Team Chief, and for maneuver analysts, the Maneuver Group Supervisor of Section 312.

The topics listed in the Navigation Training Record include the following:

The Navigation Computer Environment

The Navigation Software

Project Training Exercises

Intra-team Training Exercises

The Navigation Operational Procedures

Supplemental Training: lectures, classes, previous experience, etc.

The MGS Navigation Training Records for the orbit determination, maneuver and trajectory and aerobraking design functions are presented on the following pages. These forms are to be filled out by the individual analyst as each of the listed items is accomplised.

MARS GLOBAL SURVEYOR NAVIGATION TRAINING RECORD

Position: Orbit Determination Analyst

Analyst: ________________________

Function: The determination of the spacecraft orbit from radiometric tracking data during the interplanetary, orbit insertion, and mapping phases of the Mars Global Surveyor mission. Activities will include daily orbit determination solutions, product generation, and support of maneuver design and reconstruction activities.

I. Navigation Computer Environment

The analyst is proficient in the following subjects:

a) The NAV computer hardware components and their physical layout.
b) The connectivity between NAV workstations via the MGS Operations LAN and the Multi-Mission Navigation LAN.
c) The procedures to access the PDB using the AMMOS software and the DSN/ Navigation Interface VAX (OSCAR) using ftp.
d) The hierachical file structure of the UNIX operating system.
e) The use of UNIX to manipulate files and directories on the NAV workstations.
f) The use of the C-Shell to customize the working environment of the NAV work-stations.
g) The layout and contents of the NAV common directories for the management of input files and output products.

II. Navigation Software

The analyst is proficient in the following subjects:

a) The function and output product of each program in the DPTRAJ software set.
b) The specific input files and their formats required to execute each program in the DPTRAJ software set.
c) The sequence in which the DPTRAJ programs are executed to generate S/C ephemeris files and print, one-way light time information, and station polynomial coefficient files.
d) The function and output product of each program in the ODP software set.
e) The specific input files and their formats required to execute each program in the ODP software set.
f) The sequence in which the ODP programs are executed to generate computed observables for Doppler and range data types, data residuals, information arrays, state corrections, covariances, and mappings of those corrections and

covariances to important or useful coordinate systems and times.

g) The procedure to iterate on the orbit determination process through the DPTRAJ-ODP software.

h) The MGS Lockfile contents and how those contents control the manner in which the DPTRAJ-ODP programs execute.

i) The function, products, and execution of the Utility programs: difwsq, difdop, ftp-nio, niocomp, nioftp, nio2text, oddump, odmerge, odmodify, salsum, str, and text2nio.

III. Orbit Determination Procedures

The analyst is proficient in the following subjects:

a) The inspection of data residuals to remove blunder points, identify trajectory and media mismodelling, determine data weights from the apparent noise, and provide quick maneuver data.

b) The generation of orbit solutions from Doppler data only, Doppler and range data and range-only data .

c) The generation of orbit solutions which estimate for the spacecraft state, solar pressure parameters, gravitational parameters, maneuvers, and nongravitational accelerations.

d) The generation of orbit solutions using the ODP in both the single batch and sequential batch modes.

e) The evaluation of solutions based on the mean and RMS of the data residuals and the validity of corrections to estimated dynamic parameters.

f) The preparation of files and inputs to the maneuver and trajectory functions.

IV. GDS Test and Integration and Project Readiness Exercises

GDS Test: Tracking data from DSS-65
Date: November 27, 1995 Participant ________

GDS Test: Tracking data from DSS-45
Date: December 1, 1995 Participant ________

GDS Test: Tracking data from DSS-15
Date: December 5, 1995 Participant ________

GDS Test: Navigation Data Flow Test
Date: December 5, 1995 Participant ________

GDS Test: Tracking data from DSS-43
Date: December 18, 1995 Participant ________

GDS Test: Tracking data from DSS-63
Date: December 20, 1995 Participant ________

GDS Test: Navigation Data Flow Backup Test
Date: January 9, 1996 Participant ________

GDS Test: Tracking data from DSS-24

Date: January 16, 1996 Participant ________

GDS Test: Tracking data from DSS-65
Date: January 23, 1996 Participant ________

GDS Test: Tracking data from DSS-45
Date: February 14, 1996 Participant ________

GDS Test: Downlink Process Data Flow
Date: January 19, 1996 Participant ________

Rehearsal 1; Launch
Date: TBD Participant ________

Rehearsal 2; C2 (TCM-1) Operations
Date: TBD Participant ________

Rehearsal 3; Launch Anomaly
Date: TBD Participant ________

ORT1; C2 (TCM-1) Operations
Date: TBD Participant ________

ORT2; Launch Operations
Date: TBD Participant ________

V. Intra-team Training Exercises

NAV Team Training: Injection through TCM-1
Date: TBD Participant ________

NAV Team Training: MOI
Date: TBD Participant ________

VI. Navigation Operational Procedures

Procedure	Authored/Co-authored	Exercised/Proficient
NAV-001	________	________
NAV-002	________	________
NAV-003	________	________
NAV-004	________	________
NAV-005	________	________
NAV-006	________	________
NAV-007	________	________
NAV-008	________	________
NAV-009	________	________

NAV-010	________	________
NAV-011	________	________
NAV-012	________	________
NAV-013	________	________
NAV-014	________	________
NAV-015	________	________
NAV-016	________	________
NAV-017	________	________
NAV-018	________	________
NAV-019	________	________
NAV-020	________	________

VII. Supplemental Training

Session 1 Overview of NAV Operations Software Delivered with GDS L1.0
Date: TBD ________

Session 2 Techniques of Maneuver Design
Date: TBD ________

2. Navigation Team Tutorials

Solar Radiation Pressure Model: Inputs to the DPTRAJ, model implementation, estimation inputs, and B-Plane dispersions. Presented by E. Graat
Presentation Date: 01/18/96 ________

Navigation Directory Structure: Organization of common directories on ares and the location of important files and data. Presented by S. Demcak.
Presentation Date: 02/06/96 ________

MSOP Core Capabilities Review Overview and Question/Answer Session.
Presented by P. Esposito
Presentation Date: 03/07/96 ________

Review of the Navigation Astrodynamic Parameters and Constants for the MGS Launch and Interplanetary Phase: L1.0 Lockfile. Presented by E. Graat (Team Review)
Presentation Date: 03/21/96 ________

Overview of the MGS Launch and Injection Strategy and Timeline.
Presented by D. Johnston.
Presentation Date: 04/18/96 ________

Angular Momentum Desaturation Model: Inputs to the DPTRAJ, model implementation, size and frequency, and file format. Presented by E. Graat.

Presentation Date: TBD ________

End-To-End Review of the Propulsive Maneuver Design, Verification and Implementation Process. Presented by V. Alwar (Team Review)
Presentation Date: TBD ________

Review and Preparation for Flight Operations During Aerobraking
Presented by P. Esposito
Presentation Date: TBD ________

3. Previous Operations or Other Training Experience:

Approved by: ______________________ Date: ___________

E. Graat
Navigation Training Engineer

Approved by: ______________________ Date: ___________
P. Esposito
Navigation Team Chief

MARS GLOBAL SURVEYOR NAVIGATION TRAINING RECORD

Position: Maneuver Analyst

Analyst: ________________________

Function: The design and evaluation of maneuvers to meet the objectives of the Mars Global Surveyor mission during the cruise, orbit insertion, and mapping phases. Activities will include the design of maneuvers based on the best available orbit determination solutions, generation of the Maneuver Profile Files, and real-time maneuver reconstruction activities.

I. Navigation Computer Environment

The analyst is proficient in the following subjects:

a) The NAV computer hardware components and their physical layout.
b) The connectivity between NAV workstations via the MGS Operations LAN and the Multi-Mission Navigation LAN.
c) The procedures to access the PDB using the AMMOS software and the DSN/ Navigation Interface VAX (OSCAR) using ftp.
d) The hierachical file structure of the UNIX operating system.
e) The use of UNIX to manipulate files and directories on the NAV workstations.
f) The use of the C-Shell to customize the working environment of the NAV work-stations.
g) The layout and contents of the NAV common directories for the management of input files and output products.

II. Navigation Software

The analyst is proficient in the following subjects:

a) The function and output product the DPTRAJ programs gindrive, gindump, pvdrive, and twist.
b) The specific input files and their formats required to execute the above listed programs in the DPTRAJ software set.
c) The sequence in which the DPTRAJ programs are executed to generate S/C ephemeris files and print.
d) The function and output product of each program in the MOPS software set.
e) The specific input files and their formats required to execute each program in the MOPS software set.
f) The sequence in which the DPTRAJ and MOPS programs are executed to gen-erate and verify maneuver designs.
g) The MGS Lockfile contents and how those contents control the manner in which the DPTRAJ and MOPS programs execute.

h) The function, products, and execution of the Utility programs: calcaew, ftpnio, lambo, mpfgen, niocomp, nioftp, nio2text, otmcalc, salsol, sepvmd, str, sunang, and text2nio.

III. Maneuver Procedures

The analyst is proficient in the following subjects:

a) The ability to evaluate whether a given maneuver design meets the navigation constraints and perform trade-offs based on the flight rules if it does not.
b) The ability to interogate and understand the information on the Maneuver Performance File.
c) The generation of Maneuver Profile Files (MPF) for all mission phases.
d) The verification of Maneuver Implementation Files (MIF).
e) The knowledge of timelines associated with maneuver design and with orbit determination solution generation.
f) The intra-team procedures concerning maneuver design, verification, and reconstruction.

IV. Project Test and Training Exercises

GDS Test: Tracking data from DSS-65
Date: November 27, 1995 Participant ________

GDS Test: Tracking data from DSS-45
Date: December 1, 1995 Participant ________

GDS Test: Tracking data from DSS-15
Date: December 5, 1995 Participant ________

GDS Test: Navigation Data Flow Test
Date: December 5, 1995 Participant ________

GDS Test: Tracking data from DSS-43
Date: December 18, 1995 Participant ________

GDS Test: Tracking data from DSS-63
Date: December 20, 1995 Participant ________

GDS Test: Navigation Data Flow Backup Test
Date: January 9, 1996 Participant ________

Rehearsal 1; Launch
Date: TBD Participant ________

Rehearsal 2; C2 (TCM-1) Operations
Date: TBD Participant ________

Rehearsal 3; Launch Anomaly
Date: TBD Participant ________

ORT1; C2 (TCM-1) Operations
Date: TBD Participant ________

ORT2; Launch Operations
Date: TBD Participant ________

V. Intra-team Training Exercises

NAV Team Training: Injection through TCM-1
Date: TBD Participant ________

NAV Team Training: MOI
Date: TBD Participant ________

VI. Navigation Operational Procedures

Procedure	Authored/Co-authored	Exercised/Proficient
NAV-001	________	________
NAV-002	________	________
NAV-003	________	________
NAV-004	________	________
NAV-005	________	________
NAV-006	________	________
NAV-007	________	________
NAV-008	________	________
NAV-009	________	________
NAV-010	________	________
NAV-011	________	________
NAV-012	________	________
NAV-013	________	________
NAV-014	________	________
NAV-015	________	________
NAV-016	________	________
NAV-017	________	________
NAV-018	________	________
NAV-019	________	________
NAV-020	________	________

VII. Supplemental Training

Session 1 Overview of NAV Operations Software Delivered with GDS L1.0
Date: TBD ________

Session 2 Techniques of Maneuver Design
Date: TBD ________

2. Navigation Team Tutorials

Solar Radiation Pressure Model: Inputs to the DPTRAJ, model implementation, estimation inputs, and B-Plane dispersions. Presented by E. Graat
Presentation Date: 01/18/96 ________

Navigation Directory Structure: Organization of common directories on ares and the location of important files and data. Presented by S. Demcak.
Presentation Date: 02/06/96 ________

MSOP Core Capabilities Review Overview and Question/Answer Session.
Presented by P. Esposito
Presentation Date: 03/07/96 ________

Review of the Navigation Astrodynamic Parameters and Constants for the MGS Launch and Interplanetary Phase: L1.0 Lockfile. Presented by E. Graat (Team Review)
Presentation Date: 03/21/96 ________

Overview of the MGS Launch and Injection Strategy and Timeline.
Presented by D. Johnston.
Presentation Date: 04/18/96 ________

Angular Momentum Desaturation Model: Inputs to the DPTRAJ, model implementation, size and frequency, and file format. Presented by E. Graat.
Presentation Date: TBD ________

End-To-End Review of the Propulsive Maneuver Design, Verification and Implementation Process. Presented by V. Alwar (Team Review)
Presentation Date: TBD ________

Review and Preparation for Flight Operations During Aerobraking
Presented by P. Esposito
Presentation Date: TBD ________

3. Previous Operations or Other Training Experience:

Approved by: ____________________ Date: __________
E. Graat

Navigation Training Engineer

Approved by: ______________________ Date: ___________
G. Bollman
Maneuver Group Supervisor

Approved by: ______________________ Date: ___________
P. Esposito
Navigation Team Chief

MARS GLOBAL SURVEYOR NAVIGATION TRAINING RECORD

Position: Trajectory Analyst
Analyst: ________________________

Function: The generation and analysis of trajectories and associated products during the cruise, orbit insertion, and mapping phases of the Mars Global Surveyor mission. Activities will include navigation product generation, trajectory verification, and support of maneuver design and reconstruction activities.

I. Navigation Computer Environment

The analyst is proficient in the following subjects:

a) The NAV computer hardware components and their physical layout.
b) The connectivity between NAV workstations via the MGS Operations LAN and the Multi-Mission Navigation LAN.
c) The procedures to access the PDB using the AMMOS software and the DSN/ Navigation Interface VAX (OSCAR) using ftp.
d) The hierachical file structure of the UNIX operating system.
e) The use of UNIX to manipulate files and directories on the NAV workstations.
f) The use of the C-Shell to customize the working environment of the NAV workstations.
g) The layout and contents of the NAV common directories for the management of input files and output products.

____

II. Navigation Software

The analyst is proficient in the following subjects:

a) The function and output product of each program in the DPTRAJ software set.
b) The specific input files and their formats required to execute each program in the DPTRAJ software set.
c) The sequence in which the DPTRAJ programs are executed to generate S/C ephemeris files and print, one-way light time information, and station polynomial coefficient files.
d) The generation of predict and actual S and P kernels from spacecraft ephemeris.
e) The verification of trajectories for maneuver design and reconstruction.
f) The function, products, and execution of the Utility programs: fast, ftpnio, niocomp, nioftp, nio2text, str, and text2nio.

____

III. Project Test and Training Exercises

GDS Test: Tracking data from DSS-65
Date: November 27, 1995 Participant ________

GDS Test: Tracking data from DSS-45
Date: December 1, 1995 Participant ________

GDS Test: Tracking data from DSS-15
Date: December 5, 1995 Participant ________

GDS Test: Navigation Data Flow Test
Date: December 5, 1995 Participant ________

GDS Test: Tracking data from DSS-43
Date: December 18, 1995 Participant ________

GDS Test: Tracking data from DSS-63
Date: December 20, 1995 Participant ________

GDS Test: Navigation Data Flow Backup Test
Date: January 9, 1996 Participant ________

Rehearsal 1; Launch
Date: TBD Participant ________

Rehearsal 2; C2 (TCM-1) Operations
Date: TBD Participant ________

Rehearsal 3; Launch Anomaly
Date: TBD Participant ________

ORT1; C2 (TCM-1) Operations
Date: TBD Participant ________

ORT2; Launch Operations
Date: TBD Participant ________

IV. Intra-team Training Exercises

NAV Team Training: Injection through TCM-1
Date: TBD Participant ________

NAV Team Training: MOI
Date: TBD Participant ________

V. Navigation Operational Procedures

Procedure	Authored/Co-authored	Exercised/Proficient

NAV-001	________	________
NAV-002	________	________
NAV-003	________	________
NAV-004	________	________
NAV-005	________	________
NAV-006	________	________
NAV-007	________	________
NAV-008	________	________
NAV-009	________	________
NAV-010	________	________
NAV-011	________	________
NAV-012	________	________
NAV-013	________	________
NAV-014	________	________
NAV-015	________	________
NAV-016	________	________
NAV-017	________	________
NAV-018	________	________
NAV-019	________	________
NAV-020	________	________

VI. Supplemental Training

Session 1 Overview of NAV Operations Software Delivered with GDS L1.0
Date: TBD ________

Session 2 Techniques of Maneuver Design
Date: TBD ________

2. Navigation Team Tutorials

Solar Radiation Pressure Model: Inputs to the DPTRAJ, model implementation, estimation inputs, and B-Plane dispersions. Presented by E. Graat
Presentation Date: 01/18/96 ________

Navigation Directory Structure: Organization of common directories on ares and the location of important files and data. Presented by S. Demcak.
Presentation Date: 02/06/96 ________

MSOP Core Capabilities Review Overview and Question/Answer Session.
Presented by P. Esposito
Presentation Date: 03/07/96 ________

Review of the Navigation Astrodynamic Parameters and Constants for the MGS Launch and Interplanetary Phase: L1.0 Lockfile.   Presented by E. Graat (Team Review)
Presentation Date: 03/21/96 ________

Overview of the MGS Launch and Injection Strategy and Timeline.
Presented by D. Johnston.
Presentation Date: 04/18/96 ________

Angular Momentum Desaturation Model: Inputs to the DPTRAJ, model implementation, size and frequency, and file format. Presented by E. Graat.
Presentation Date: TBD ________

End-To-End Review of the Propulsive Maneuver Design, Verification and Implementation Process.   Presented by V. Alwar (Team Review)
Presentation Date: TBD ________

Review and Preparation for Flight Operations During Aerobraking
Presented by P. Esposito
Presentation Date: TBD ________

3. Previous Operations or Other Training Experience:

Approved by: ____________________ Date: __________
E. Graat
Navigation Training Engineer

Approved by: ____________________ Date: __________
P. Esposito
Navigation Team Chief

542-409 ANNEX 4

MARS GLOBAL SURVEYOR

MISSION PLANNING AND SEQUENCING TRAINING PLAN

Prepared by:

____

Bruce Waggoner

Approved by:

____

R. Brooks
Mission Planning and Sequencing Team Chief

June 1996

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

JET PROPULSION LABORATORY INTEROFFICE MEMORANDUM

01 May 1996

To: J. Wilson

From: R. Brooks

Subject: MP&S Team Training Plan

The MP&S Team training strategy will progress in the following manner.

- Each team member has been provided with access to the following documents. They are required reading for each member.

    - Mission Plan
    - Mission Sequence Plan
    - Block Dictionary
    - Flight Rules
    - MP&S Team Procedures (consisting of MP&S Checklist and NIPC/EC Flow Charts)
    - MOS Spec Vol-3
    - Planning & Sequencing Subsystem Users Guide

- Each team member has and will continue to participate in lectures given by the MP&S Team Chief or by other members of the team who are expert in some specific field.

- Each team member has and will continue to participate in MP&S Team internal training activities (task execution exercises and role-playing exercises).

- Each team member has and will continue to participate in actual MOSC and ATLO Sequence Development. This provides each member direct experience in the following.

    - MP&S command and sequence development process in action
    - Interaction with other team members
    - Familiarization with actual flight sequences and MGS sequencing strategies
    - Familiarization with sequence review products
    - Direct application of knowledge attained through above learned lessons
    - Use of Operational Interface Agreements SEQ-001 through SEQ-010

- Each team member has or will participate in the various Test and Training exercises, rehearsals and Operational Readiness Tests taking place between early June, 1996 and the end of October, 1996.

- Participate in GDS testing, using MP&S S/W tools in various capacities to validate said tools.

All current MP&S members are currently participating in or have successfully completed all of the above described training activities. New members to the MP&S will be required to train in the same manner as described above and also perform their tasks while under the supervision of team members already certified in performing their tasks. This

"Mentor" training technique assures that all new members receive a quick and thorough training program.

The following pages indicate, in tabular format, each current SEQ member's qualifications for being certified to perform their respective functions on the team.

TABLE 1.1 - MP&S Team Member Certification Qualifications

Team Member	Brooks	Waggoner	Morris	Carberry	Bunker	Sidney	Arroyo
Team Position	**TC**	**SIE**	**SIE**	**SIE**	**SIE**	**Mission Planner**	**DSN Scheduler**
Time with MO/MGS	**7yr/6yr**	**1.5yr/9mo**	**2yr/9m o**	**1yr/1.25yr**	**0/6mo**	**3yr/2yr**	**6mo/1.5yr**
Previous Exp	**VGR MO**	**SME VGR GLL MO CAS**	**VGR MO GLL**	**MO SIR-C**	**VGR HST**	**MO CAS**	**PNR MO PBS MGN GLL**
On-the-Job	✔	✔	✔	✔	✔	✔	✔
Test & Training	✔	✔	✔	✔	✔	✔	✔
Proj Doc Study Team Lectures & Videos	✔	✔	✔	✔	✔	✔	✔
Certification Required	✔	✔	✔	✔	✔	✔	✔
Test & Training Participation							
Walkthroughs							
• **Voice Net Protocol**	✔						
• **Mnvr Des & Imple**	✔	✔	✔	✔	✔		✔
MOS Rehearsals							
• **Mnvr Des & Imple**	✔			✔	✔		✔
• **Launch & Init Acquisition**	✔	✔	✔				
• **TCM-1**	✔		✔	✔			✔
ORTs							
• **Launch & Init Acquisition**	✔	✔	✔				
• **TCM-1**	✔		✔	✔			✔

LEGEND:
TC = Team Chief, SIE = Sequence Integration Engineer, VGR = Voyager, PBS =Phobos, MGN = Magellan, GLL = Galileo, CAS = Cassini, SME = Solar Mesosphere Explorer, SIR-C = Shuttle Imaging Radar-C Instrument, HST = Hubble Space Telescope, MO = Mars Observer.

The following task descriptions for each team position will be used on the training verification form and for developing training activities. All MP&S Team members will be cross-trained to provide contingency staffing as required.

The following tasks are expected to be performed by the MP&S Team Chief.

- Manage the MP&S Team
- Perform budgetting and scheduling tasks
- Perform the tasks of an SIE in a backup role

- Represent MP&S Team at MSOP meetings

The following tasks are expected to be performed by an MP&S Sequence Integration Engineer.

- Generate accurate sequence files per MP&S timelines and procedures
- Generate accurate command files per MP&S timelines and procedures
- Manage the people and tasks specific to the development of a sequence
- Represent MP&S Team at sequence approval meetings
- Communicate and resolve problems concerning the MP&S Team software tools

The following tasks are expected to be performed by an MP&S Sequence Integration Engineer.

- Assist the SIE in developing sequences
- Review sequences for compliance with the Mission Sequence Plan

The following tasks are expected to be performed by an MP&S DSN Scheduler.

- Assist the SIE in developing sequences
- Review sequences for compliance with DSN activities and allocations
- Represent MP&S Team at DSN scheduling meetings
- Produce DSN products as required by the flight team

Certification shall be verified for each task by the team member initialing their training verification form (attached) upon the completion of each task. The Team Chief shall also initial each form upon task completion. Final certification of each team member for flight will be verified by completing all training tasks on their training verification form.

MSOP
Mission Planning & Sequencing Team
Training Verification Form

Team Member Name: ____

Team Member Position: ____

Task	Team Member Initials	Team Chief Initials	Date Completed

ANNEX 5 DELETED

542-409 ANNEX 6

MARS GLOBAL SURVEYOR

SCIENCE OPERATIONS SITE TRAINING PLAN

Prepared by:

R. Springer

Approved by:

T. Thorpe
Science Office Manager

FINAL VERSION: June 4, 1996

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

1.0 INTRODUCTION

1.1 Purpose

This document provides a description of the testing and training planned at the Science Operations Sites utilized by the eleven Mars Global Surveyor Science Investigations to support instrument operation and data product generation during the life of the mission. The purpose of this plan is to define the objectives, prerequisites, configurations, resources, acceptance criteria, schedule, conduct and reporting of site readiness testing and training activities. The objectives and configurations identified in the plan are applicable as of the start of the cruise phase.

1.2 Test Philosophy

The Mars Global Surveyor Science Operations Sites (Table 1-1) are of two types: Flight Experiment (FE) and Interdisciplinary (IDS), according to capability and operational readiness. The FE sites are responsible for command generation, electronic data return (EDR) processing, and instrument health monitoring. The IDS sites are responsible for level 1 + data record analysis and generation. The operational readiness of the FE sites is phased according to cruise data acquisition requirements versus mapping data processing configuration requisites.

Operations testing of the Science sites follows a design and implementation schedule having the following milestones:

Activity	Date
Mission Operations Review (Cruise)	8/96
Operations Readiness Testing (Launch)	11/96
Operations Readiness Testing (Encounter)	9/97
Mission Operations Review (Mapping)	12/97

Operations readiness testing will demonstrate the operations responsibilities assigned to the Science Investigative Teams described in MGS Project Document 542-409 Vol. 3 including:

- Verify correct sequence operation and health of instrument
- Provide instrument health evaluation reports, problem detection reports, and trend analyses as necessary to SCT
- Deliver data to the Planetary Data System for permanent archive (for encounter testing)
- Resolve science conflicts
- Provide non-interactive science command requests to the PST via the PDB
- Provide interactive command requests the to SCT via the PDB
- Provide security functions as specified in the MGS Security Plan

Table 1-1. MGS Investigations, PIs, IDS's, and Experiment Representatives

Investigation	Institution	Principal Investigator	Experiment Representative (Area code 818)
Magnetometer (MAG)	GSFC	Mario Acuña 301-286-7258	Daniel Winterhalter 354-3238
Mars Orbiter Camera (MOC)	Malin Space Science Systems, San Diego	Michael Malin 619-552-2650 x500	Richard Springer 393-7825
Mars Orbiter Laser Altimeter (MOLA)	GSFC	Dave Smith 301-286-8671	Bruce Banerdt 354-5413
Radio Science (RS)	Stanford University	Len Tyler (Team Leader) 415-723-3535	Mick Connally 393-1072
Thermal Emission Spectrometer (TES)	ASU	Phil Christensen 602-965-7105	John Callas 354-9088
Interdisciplinary Scientists (IDS)	Washington University	Ray Arvidson 314-935-5609	Richard Springer 393-7825
	U. S. Geological Survey, Menlo Park, CA	Mike Carr 415-329-5174	
	Caltech	Andy Ingersoll 818-395-6167	
	University of Colorado	Bruce Jakosky 303-492-8004	
	Ames Research Center	Rob Haberle 415-604-5491	
	U. S. Geological Survey, Flagstaff, AZ	Larry Soderblom 602-556-7018	

These operations activities begin with sequence planning, skeleton sequence review and instrument command generation via mini-SASF inputs to the SEQGEN programs resident on the Science Operations Planning Computers (SOPC) and submittal of these requests to the JPL MGS Project Database (PDB). The FE Science Sites will produce instrument performance reports and enable adaptive sequence planning. The site data processing will produce standard and special data products as described in the Science Data Management Plan and Archive Data Generation and Transfer Plan for all levels of processing (Levels 1-4). At JPL, Experiment Representatives using SOPC-equivalent workstations will interface with the MOS teams to coordinate science objectives; participate in MOS DSN support meetings; confirm that PI inputs are complete, consistent with planning and constraints, and conflict free; and conduct and analyze both instrument engineering and science parameters in regard to operations.

The philosophy of this plan is to exercise as comprehensively as possible all systems hardware, software, procedures, and personnel in an environment that represents the cruise and mapping phase flight operations in a timely manner. This will be accomplished using Sequence of Events, (SOE), test scripts, ATLO MOS-C data, and calibration data sets in conjunction with the JPL operations, PDB and Team (SCT, PST, and data administration) interfaces. Cruise testing will utilize SASF data formats and checkout events as described in the Mission Plan, the Science Requirements Document and the Science Site configuration given in the Operations Facility Configuration and Control Plan (PD # 542-311) as configured for cruise operations.

1.3 Applicable Documents

The Science Operations Test and Training Plan is responsive to and consistent with the following documents.

542-300	Investigation Description and Science Requirements Document
542-404	Project Security Plan
542-409	Mission Operations Specifications, Volumes 1-8
542-309	Investigation Software Users Guides for Operations
542-310	Science Data Management Plan
542-311	Operations Facility Configuration and Control Plan
542-312	Archive Data Generation and Transfer Plan

1.4 Document Control

The overall responsibility for the development and maintenance of the Mars Global Surveyor Science Site Test and Training Plan resides with the Science Office. Consistent with the Payload Policies and Requirements Document, this document is subject to the Project Configuration Management Plan and will be revised by means of change notices.

2.0 TEST DESCRIPTIONS

2.1 Responsibilities

2.1.1 Science Office

The Science Manager has the following responsibilities:

1) Assure that all required documentation is delivered to and from the science operations sites and that configuration control of these documents is in place, including SIS, OIA, Security Plan, Operations Facility Configuration and Control Plan, and MOS Specification documents as they pertain to operations testing.

2) Certify that proper training of necessary site personnel has occurred via information provided by the Principal Investigator/Team Leader/IDS.

3) Assure that facility readiness and security measures are established according to schedule and perform inspections of these capabilities.

4) Provide resources as appropriate to satisfy the science operations objectives of the investigations.

2.1.2 Principal Investigator/Team Leader/IDS

1) Identify personnel training requirements and certify their completion.

2) Provide test/training reports. Maintain facility configuration and control.

3) Ensure science site operations are consistent with the science objectives of the Mars Global Surveyor Mission.

2.1.3 Test Supervisor/Conductor

1) Provide test scheduling information.

2) Develop test scripts/SOE and data sources as appropriate.

3) Conduct pre- and post-test briefings, monitor test conduct, resolve conflicts, and prepare and distribute test reports.

4) Assure appropriate test setup, environment, requirements demonstration, and test objective compliance.

2.2 Sequence of Events

All mission readiness tests will be conducted using an SOE provided by the TS/TC. The SOEs will be designed to create a Mars Global Surveyor operational environment, which will permit evaluation of engineering capabilities, appropriate science data processing and operational performance. As such, events will be time ordered and constrained as they would be under flight conditions. A preliminary copy will be provided to each participating element (the Science Support Engineer, the PST, the data administration analyst, the Science Manager, and the ER) approximately seven working days prior to each test for review and comment. The final version will be distributed three working days prior to the test. The SOE will contain the following information:

1. Schedule
2. Facility requirements
3. Mission simulation, system configuration, and preparation information

Steps of the test sequence will provide Mars Global Surveyor-unique parameters for hardware configuration changes and operation control input parameters for software changes. Information on requirements for and disposition of test products will also be provided.

2.3 Personnel

Personnel participating in readiness tests are as follows:

2.3.1 Science Site

1. Principal Investigator/Team Leader/IDS

2. Test Supervisor/Test Conductor

3. Workstation Operators

4. Security Administrator

5. Operations Manager/Programmers (as appropriate)

6. Co-Investigators/Team Members (as appropriate)

2.3.2 JPL

1. Science Support Engineer

2. PST Representative

3. Data Administration Representative (as appropriate)

4. Experiment Representative

5. SCT Representative (as appropriate)

6. MOS/MGS Security Representative (as appropriate)

2.4 Setup

To set up the readiness tests the test conductor will prepare and distribute the SOE. Requirements to be verified and validated will also be identified and the appropriate JPL representatives notified, including the Science Office Manager. The test supervisor will verify the proper site configuration, conduct an on-line post-test critique after each test with all test participants, and provide a final report, including a determination of readiness, to the Science Manager.

2.5 Test Criteria

The objectives of the readiness tests are to demonstrate for the appropriate mission phase that the following functions can be performed at the science operations sites:

2.5.1 FE Sites

- Verify correct sequence operation and health of instrument

- Provide instrument health and performance reports as necessary to SCT

- Deliver data to the Planetary Data System (for encounter test only)

- Resolve science conflicts
- Provide non-interactive science command requests to the PST via the PDB
- Provide interactive command requests the to SCT via the PDB
- Provide security functions as specified in the MGS Security Plan

2.5.2 IDS Sites

- Retrieve processed data products from the FE sites and ancillary information from the PDB (Mapping Phase)
- Provide security functions as specified in the MGS Security Plan (Mapping Phase)

Acceptance Criteria consist of demonstrating that the objectives can be accomplished. Problems relevant to the following topics shall be documented in the final report.

1. Hardware and software failures
2. Personnel performance discrepancies
3. Procedural/document deficiencies
4. Security incompatibilities/violations
5. JPL interface problems

Any capability that cannot be demonstrated due to hardware or software constraints will constitute a lien against the associated objective and will be retested. MGS/MSOP capabilities previously demonstrated need not be retested.

2.6 Reporting

Within three working days after each test, the TS will prepare a written test report for the PI/TL/IDS. The report will include an overall assessment of test success based on the objectives, a summary of problems encountered, and explanations for waivers or liens. Within seven working days following the last test in a series, the PI/TL/IDS will submit a final test report to the Science Manager.

3.0 OPERATIONS TRAINING

3.1 Site Training

Science Site operations training will evolve in several stages. First facility hardware and software including the investigation's “host” computers will be the topic of team training for staff personnel. Prior to JPL interfacing, the appropriate personnel will become familiar with the site process designs (e.g. CDR material) as they pertain to sequence planning, instrument health monitoring, command preparation, telemetry processing and archival record preparation, including ancillary data analysis, e.g., NAIF tool applications. Co-Investigator support and data analysis participation is defined by the tasks budgeted in the Experiment Operations Plan. All activities of support personnel shall be consistent with Project approved documentation including the Mars Global Surveyor Project Security Plan, Operations Facility Configuration and Control Plan, Payload Flight Rules and Constraints, Payload Command and Telemetry Dictionary, Investigation's Software Users Guide for Operations, and the Mission System Configuration Management Plan. This activity will lead to Acceptance Test participation for all support members as defined in Section 4 and will be reviewed at the Mission Operations Readiness Review (MOR).

3.2 MOS (MGSO/MGS) Training

It is the responsibility of each Principal Investigator/Team Leader/IDS to ensure that the site personnel are adequately trained and certified to support the Mars Global Surveyor Mission consistent with the Mission Operations Specification Vol. 7: Training (PD # 542-409). Required task training, as identified by this document is listed in Table 3-1: Training Requirements Matrix. Training for workstation (SOPC) users may be obtained through classroom courses provided by the JPL Flight Projects Office. In addition to SFOC and workstation courses, Mars Global Surveyor specific information will also be available. Workstation and MOS interface difficulties are also topics of the Science Data Validation Team meetings.

3.3 Science Support Engineer Interface Training

The Science Support Engineer at JPL began interface testing in August of 1995. This testing utilizes multimission hardware provided by the Multimission Ground Support Office (MGSO) and software supplied by MGSO, the MGS Planning and Sequencing Team (PST) and the Investigations Teams. A key element in this process is the SOPC link to the PDB for the transfer of command and data files. As the delivery of the program sets which enable this process (MGSO Versions 21 and 23: BROWSER, DECOM, DMD, SFDU reader tools, NAIF toolkit, the Automated Command Tracking System, SEQGEN, SPICE files, and performance verification reports) arrive at the science sites, each team is expected to become familiar with their SIS's and operations. Interface testing, including PDB access, will proceed through July 1996 and is expected to provide training for all FE Site personnel. Readiness for encounter will be re-verified by April 1997.

Table 3-1. Training Requirements Matrix for Science Team

No.	Task Responsible participant needs to demonstrate a capability/ability to:	Participant Science Investigator	 Experiment Rep.	 Payload Engineer
1	Monitor instrument telemetry to verify health and proper operation	**x**	**x**	**x** S/C TLM only
2	Report instrument health to spacecraft team	**x**		
3	Deliver processed science data to PDS for archive	**x**		
4	Provide non-interactive payload command requests to the Planning and Sequence Team	**x**	**x**	
5	Provide interactive command requests to the spacecraft team	**x**	**x**	**x**
6	Validate science inputs to sequence generation process		**x**	
7	Analyze trends and calibration measurements for instruments	**x**	**x**	**x** S/C TLM only
8	Ensure sequences do not have unexpected or negative impact on instruments		**x**	**x**
9	Retrieve SPICE and ancillary data from PDB	**x**		
10	Run MGSO tools (DMD, ACT, etc.) that will allow for efficient operations	**x**	**x**	**x**

3.4 Ground Data System Interface Training

End-to-end data file transfers consistent with Operations Interface Agreements are expected to begin in July 1996. Participation in this process with actual SASFs and system test calibration data will provide hands on training for engaging all paths through the GDS. It is anticipated that all delivered programs will be in final form to support Cruise Phase operations at this time. Following these activities a pre-delivery facility inspection of each site will occur to verify security procedures and readiness for ORT participation as part of the Science Office Mission Operations Readiness Review (July/August 1996).

3.5 Operations Readiness Testing Training

Demonstration of the uplink and downlink sequence activity scenarios by the ORT in September-October 1996 will enable verification of the procedures and contingency operations for both the FE science site and ER support Teams. These exercises will provide training of all personnel in the operations activities described in the Experiment Operations Plans and will certify readiness to support cruise phase operations. All configuration management and control procedures are expected to be operational at this time.

3.6 IDS Training

Training of personnel located at the Interdisciplinary Science operations sites will of necessity proceed subsequent to the FE sites. While the IDS's are responsible for determining compliance with PD # 542-409 Vol. 7 as described above, and are encouraged to utilize the classroom training provided by FPO and the Project, their training will be more limited due to the lack of required operations tasks involving data acquisition or EDR processing. As described above the SOPC-PDB data link will be tested and this testing will provide training during the encounter GDS and operations readiness tests. The training certification of all site personnel and security compliance will be reviewed at the mapping Mission Operations Readiness review in December 1997.

4.0 INVESTIGATION TRAINING RESPONSIBILITIES

The PI or IDS at each investigation site is responsible for certifying his personnel are trained for operations. These responsibilities include those levied by the Mars Global Surveyor project, as well as those required to meet the science objectives of the site.

4.1 Functional Requirements

The following functions will be demonstrated at each site as specified:

FE sites (Cruise), all sites (Mapping)

- Retrieve data products and ancillary information from the PDB (IDS retrieve products from FE sites), as necessary
- Provide security functions as specified in the MGS Security Plan

Flight Experiment sites

- Verify correct sequence operation and health of instrument
- Provide instrument health and performance reports as necessary to SCT
- Deliver data to the Planetary Data System (for encounter test only)
- Resolve science conflicts
- Provide non-interactive science command requests to the PST via the PDB
- Provide interactive command requests to the SCT via the PDB
- Generate required sequences for and review each period of instrument activity

4.2 General Responsibilities List

Each person will be expected to perform the following functions as appropriate for their position.

- Preparation of preliminary uplink sequences
- Preparation of final uplink sequences
- Delivery of final uplink sequences to JPL
- Preparation and delivery of interactive commands
- Preparation and delivery of non-interactive payload commands
- Retrieval of telemetry from the PDB
- Instrument health monitoring
- Preparation and delivery of instrument health report to JPL
- Anomaly handling
- Preparation of archival products
- Delivery of archival products to PDS
- Maintenance of the operations system
- Maintenance of data security

4.3 Personnel Certification List

The following is the current list of people that are to be certified in different aspects of operations at their respective sites. Science access to the PDB is currently restricted this list.

MOC

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MAG/ER

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