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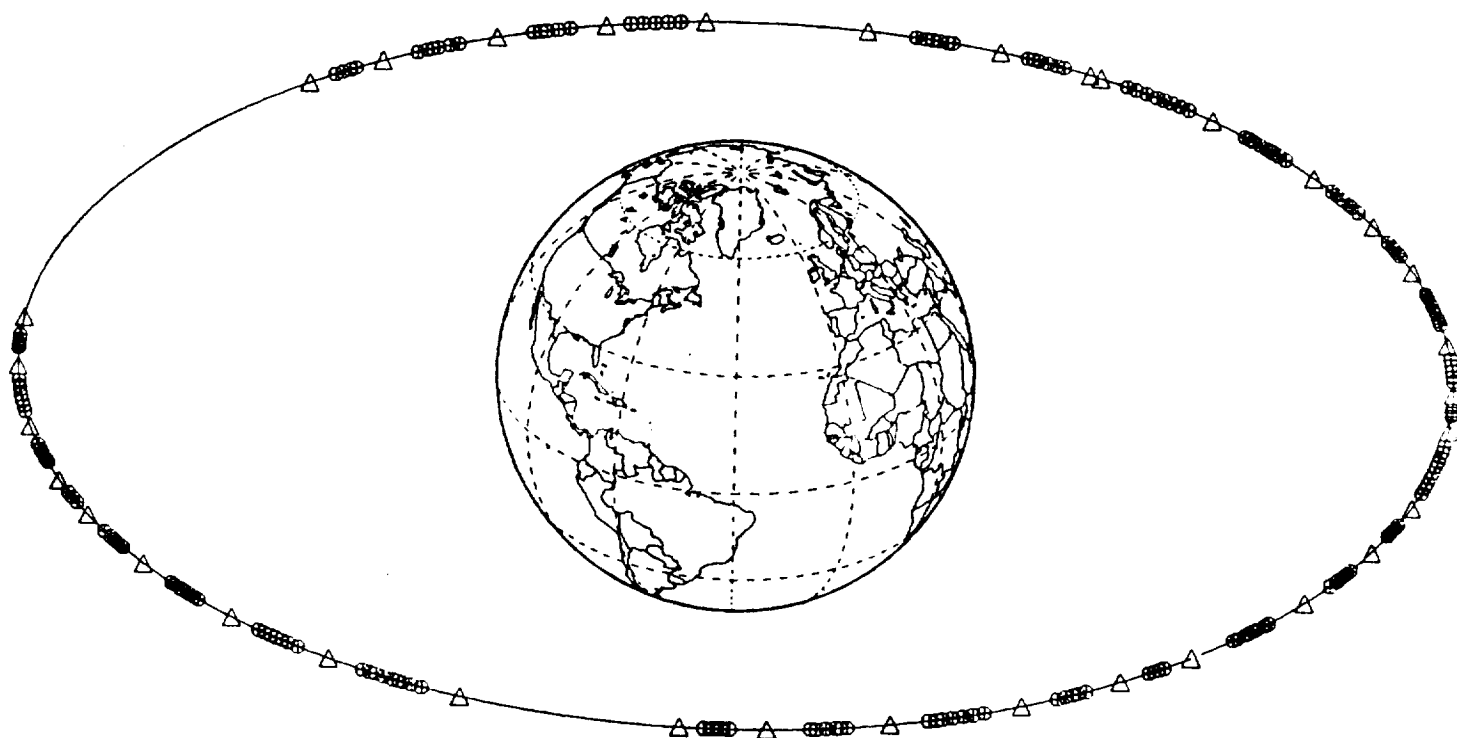
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# *Numerical Arc Segmentation Algorithm for a Radio Conference – NASARC (Version 4.0)*

## *User's Manual*

Wayne A. Whyte, Jr., Ann O. Heyward, Denise S. Ponchak,  
Rodney L. Spence, and John E. Zuzek



National Aeronautics and Space Administration  
Lewis Research Center  
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## PREFACE

The software package, Numerical Arc Segmentation Algorithm for a Radio Conference (NASARC), was developed to provide a method of generating predetermined arc segments for use in the development of an allotment planning procedure to be carried out at the 1988 World Administrative Radio Conference (WARC-88). Through careful selection of the predetermined arc (PDA) for each administration, flexibility can be increased in terms of choice of system technical characteristics and specific orbit location. The NASARC software determines pairwise compatibility between all possible systems at discrete arc locations. NASARC then exhaustively enumerates groups of administrations whose satellites can be closely located in orbit and finds the arc segment over which each such compatible group exists. From the set of all possible compatible groupings, groups and their associated arc segments are selected using a heuristic procedure such that a PDA is identified for each administration.

The information contained in the *NASARC (Version 4.0) Technical Manual* (NASA TM-101453) and *NASARC (Version 4.0) User's Manual* (NASA TM-101454) relates to the state of Numerical Arc Segmentation Algorithm for a Radio Conference (NASARC) software development through November 1, 1988. The *Technical Manual* describes the NASARC concept and the algorithms used to implement the concept. The *User's Manual* provides information on computer system considerations, installation instructions, description of input files, and program operation instructions. Significant revisions have been incorporated in the Version 4.0 software over prior versions. These revisions have further enhanced the modeling capabilities of the NASARC procedure and provide improved arrangements of predetermined arcs within the geostationary orbit. Array dimensions within the software have been structured to fit within the currently available 12-megabyte memory capacity of the International Frequency Registration Board (IFRB) computer facility. A piecewise approach to predetermined arc generation in NASARC (Version 4.0) allows worldwide planning problem scenarios to be accommodated within computer run time and memory constraints with enhanced likelihood and ease of solution.



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## 1.0 INTRODUCTION

This volume contains information on the installation and operation of the NASARC (Version 4.0) software package for the generation of predetermined arcs to aid in allotment planning procedures.

The first major section of this manual presents detailed instructions for the installation of the NASARC (Version 4.0) software package. While the specifics of the installation process may vary from site to site due to differences in computer hardware and operating systems, a sufficiently detailed procedure is provided to allow for straightforward installation.

The second major portion of this manual provides full information on the use of the NASARC package for planning exercises, including descriptions of all required input files and their preparation, directions for execution of the NASARC (Version 4.0) package, and guidelines for user-supplied technical parameter values. Information is also given on the use of the NASARC (Version 4.0) package in conjunction with the synthesis package ORBIT-II, which was developed by the Kokusai Denshin Denwa Co, Ltd., Tokyo, Japan.

Detailed information on the concepts and algorithms contained in the NASARC (Version 4.0) software package may be found in the *NASARC (Version 4.0) Technical Manual* (NASA TM-101453).

## 2.0 INSTALLATION OF THE NASARC SOFTWARE PACKAGE

In this section, full instructions are given for the installation of the NASARC software package. Information is given on the attributes of the magnetic tape that contains the NASARC package, creation of program modules from source codes, construction of appropriate commands necessary to utilize the NASARC software, and attributes of files needed for program input and output. Prior to this detailed information, a discussion of system considerations for NASARC installation is given to aid the user in determining appropriate installation procedures for his or her specific machine and operating system.

### 2.1 System Considerations for NASARC Installation

In the following sections, information is given on the language and storage requirements of the NASARC software package.

#### 2.1.1 Language/Compiler Requirements

The NASARC software package is written in the (ANSI standard) FORTRAN 77 computer language. An effort has been made to ensure that no extensions of the language that are specific to a particular system or machine have been introduced into the software package. Thus, the user should be able to compile the appropriate NASARC source codes using an (ANSI standard) FORTRAN 77 compiler suitable for the user's system.

#### 2.1.2 Storage and Memory Requirements

To aid the user in successfully installing and running the NASARC software package on his system, both file storage requirements and run-time memory requirements are now given. The user should note that these requirements concern the NASARC source code files and program modules only; storage requirements for associated input and output files are discussed in section 2.3.

Source file storage requirements:

NASINTRF source code:	36.0 kilobytes
NASARC0 source code:	48.6 kilobytes
NASSEP source code:	155.45 kilobytes
NASARC1 source code:	227.45 kilobytes

NASARC2 source code: 430.85 kilobytes  
NASARC3 source code: 135.65 kilobytes  
NASARC4 source code: 351.07 kilobytes

**Object code storage requirements:**

NASINTRF object code: 0.043280 megabyte  
NASARC0 object code: 0.047440 megabyte  
NASSEP object code: 0.120560 megabyte  
NASARC1 object code: 0.219520 megabyte  
NASARC2 object code: 0.378240 megabyte  
NASARC3 object code: 0.134720 megabyte  
NASARC4 object code: 0.326960 megabyte

**Run-time memory requirements:**

NASINTRF module: 0.080880 megabyte  
NASARC0 module: 0.036488 megabyte  
NASARC1 module: 7.061416 megabytes  
NASARC2 module: 8.574322 megabytes  
NASARC3 module: 0.791528 megabyte  
NASARC4 module: 0.941972 megabyte

### 2.1.3 Tailoring NASARC to the Operating System

The NASARC software package was developed on an Amdahl 5860 running under the IBM VM operating system. While example job control language is included in this manual, the user should note that commands needed to load and run the NASARC modules and create and define files will depend on the user's operating system. All such system commands are external to the NASARC programs; therefore, no modification to the NASARC source code is necessary to adapt the package to any particular operating system.

## 2.2 Detailed Installation Instructions for the NASARC Software Package

In this section, detailed instructions are given for the installation of the NASARC software package. As was mentioned in section 2.1.3, the specific procedure used to install the NASARC package differs for different operating systems. However, the guidelines presented in the following sections are sufficiently detailed to allow straightforward installation of the NASARC package.

### 2.2.1 Magnetic Tape Attributes

The NASARC software package is provided on a magnetic tape with the following attributes:

Number of tracks, 9	Number of files, 8
Density, 1600 bpi	Logical record length, 80 bytes
Character set, EBCDIC	Block size, 800

All files included on the tape should be unloaded; source code files should then be compiled to create the appropriate program modules. The files included, and their attributes and purposes, are listed in table 2.2-1 in the order in which they appear on the tape. The user is referred to sections 2.1.2 and 2.3 for information on file storage requirements.

TABLE 2.2-1—FILES INCLUDED ON MAGNETIC TAPE

File name	Purpose	Record length	Block size
NASINTRF	Fortran source code	80	800
NASARC0	Fortran source code	↓	↓
NASSEP	Fortran source code		
NASARC1	Fortran source code		
NASARC2	Fortran source code		
NASARC3	Fortran source code		
NASARC4	Fortran source code		
EXEC	NASARC procedure (VM system)		

### 2.2.2 Creation of NASARC Program Modules

After the files included on the magnetic tape have been unloaded and named according to the conventions of the user's system, seven compiled modules must be created from the seven source files (NASINTRF, NASARC0, NASSEP, NASARC1, NASARC2, NASARC3, and NASARC4) included on the tape. While conventions for naming load modules differ from system to system, the modules should be named to correspond as closely as possible to the designations NASINTRF, NASARC0, NASSEP, NASARC1, NASARC2, NASARC3, and NASARC4 as this will aid the user in following the directions in the remainder of this manual.

Each module has a specific purpose within the software package as a whole. NASINTRF, the interface program, creates three of the input files utilized by the remaining NASARC modules from the single data file defined by the International Frequency Registration Board (IFRB) to contain required system parameters for all systems to be considered in a plan. NASARC0, the input program, prompts the user for further input parameter values and verifies as correct all inputs supplied via input files; an additional input file is created from the interactively supplied user inputs, which will be utilized by the remaining NASARC modules. NASSEP, the satellite separation program, calculates worst-case required orbital separations for all possible pairs of satellites. The remaining NASARC modules (NASARC1, NASARC2, NASARC3, and NASARC4) are used iteratively in a piecewise approach to the orbital arc defined by the user. NASARC1, the grouping program, enumerates a list of compatible groupings of satellites and the arc segments over which each such grouping may exist. NASARC2, the arc determination program, accepts the output of NASARC1 as input and selects appropriate groupings, determines their allotted arc lengths, and arranges the arc segments in orbit. NASARC3, the group arc extension program, examines compatible groupings of systems selected by NASARC2 in order to determine possible extensions of their group arcs, should rearrangement of allotted arcs in orbit become necessary in examination of subsequent pieces of the orbital arc. NASARC4, the arc interchange program, examines the most current arrangement of allotted orbital arcs in order to determine if the arrangement may be improved through a heuristic swapping procedure.

A more detailed explanation of the purposes of NASINTRF, NASARC0, NASSEP, NASARC1, NASARC2, NASARC3, and NASARC4 may be found in the *NASARC Technical Manual*; storage and memory requirements for each program module are addressed in section 2.1.2 of this manual.

Tables 2.2-2 through 2.2-8 contain complete listings of the names of the programs and subroutines that should appear in each program module after compilation. The purpose of each subroutine is also briefly described. For further insight on the structure of the NASARC modules, the user is referred to the flowcharts presented in section 3.1.

TABLE 2.2-2.—PROGRAMS AND SUBROUTINES CONTAINED IN NASINTRF MODULE AFTER COMPILATION

Program/subprogram name	Purpose of program/subprogram
MAIN	Construct Service Area file, Affiliated Sets Code file, and Point Sets file from single requirements data file utilized by WARC-ORB (2). Files will be utilized by NASARC0, NASSEP, NASARC1, NASARC2, NASARC3, and NASARC4 modules.

TABLE 2.2-3—PROGRAMS AND SUBROUTINES CONTAINED IN NASARC0 MODULE AFTER COMPILATION

Program/subprogram name	Purpose of program/subprogram
MAIN	Prompt user for interactive inputs; assemble interactive inputs into input data file utilized by NASARC1, NASARC2, NASARC3 and NASARC4. Verify all externally created input files consistent and correct.
INTRST	Determine intersection endpoints of pair of arc segments; used to verify that arcs of affiliated service arcs intersect.

TABLE 2.2-4.—PROGRAMS AND SUBROUTINES CONTAINED IN NASSEP MODULE AFTER COMPILATION

Program/subprogram name	Purpose of program/subprogram
SEPAR	Calculate worst-case orbital separations needed to achieve target single-entry $C/I$ value for all possible pairs of satellite systems.
SETCON	Set constant values for use throughout programs.
RDPTS2	Read sets of polygon points for service areas from Point Sets file.
CREAT2	Create arrays of ellipse data needed for separation calculations.
INTRST	Determine intersection endpoints of pair of arc segments.
NEAR	Determine two nearest endpoints of two service arcs that do not intersect.
BISECT	Perform bisecting search to determine new satellite positions to be tested for achievement of target single-entry $C/I$ .
SCOFF	Calculate spacecraft antenna off-axis angle.
CICK2	Verify that current orbital separation is sufficient to achieve target $C/I$ .
ESOFF	Calculate antenna discrimination.
ANGLES	Calculate spacecraft antenna half-power beamwidth in direction of interest.
ERRS	Change initial error flag of Input Data file to Y if error encountered.

TABLE 2.2-5—PROGRAMS AND SUBROUTINES CONTAINED IN NASARC1 MODULE AFTER COMPILATION

Program/subprogram name	Purpose of program/subprogram
MAIN	Determine compatible groupings and arc segments over which they may exist, in current portion of orbit.
SETCON	Set constants used throughout programs.
INTRST	Determine intersection endpoints of pair of arc segments.
RDPTS	Read sets of polygon points for service areas from Point Sets file.
ERR	Change initial error flag of Input Data file to Y if error encountered.
CREATE	Read necessary ellipses from master Ellipse file and store in array.
CICLK	Verify that grouping criterion provides sufficient orbital separation to achieve target <i>C/I</i> value.
SCOFF	Calculate spacecraft antenna off-axis angle.
ESOFF	Calculate earth station off-axis angle.
ANGLES	Calculate half-power beamwidth for satellite antenna in direction of service area polygon point.
DISC	Calculate antenna discrimination.
ACCUM	Accumulate individual groupings, locations into list of groupings and segments.
ARCSEG	Form list of compatible groups, individual locations into list of groups, arc segments.
QUICK1	Sort list in ascending order on two fields. Primary field is compatible group string; secondary field is arc location at which group occurs.
PART1	Partition list of elements to be sorted.
QUICK2	Sort list of compatible groups, arc segments in ascending order, by compatible group and western group arc boundary.
PART2	Partition list of elements to be sorted.
CHK180	Determine if group arc span crosses 180° east longitude. (Entry within subroutine ACCUM.)
OUTLST	Output service areas, service arc longitudes, individual buffer lengths, list of groupings, arc segments.

TABLE 2.2-6—PROGRAMS AND SUBROUTINES CONTAINED IN NASARC2 MODULE AFTER COMPILATION

Program/subprogram name	Purpose of program/subprogram
MAIN	Select appropriate groups from NASARC1 output; determine allotted arc lengths in order to place all administrations into geostationary orbital arc.
INPARM	Read NASARC input parameters ( <i>C/I</i> , downlink frequency, antenna diameters, etc.) from Input Data file.
INSEGS	Read Intermediate Segments file; determine bounds of cumulative arc, bounds of current segment, and direction of allotment buildup (E-W or W-E).

TABLE 2.2-6—Continued.

Program/subprogram name	Purpose of program/subprogram
INGRPS	Read service arc information relevant to present portion of orbit (service areas, service arc longitudes, buffer arcs), along with groups, group arcs generated over present portion of orbit from current Groups file.
LSTPAR	Echo NASARC input parameters in Intermediate Selection file.
INALLT	Read groups, allotted arc bounds, group arc bounds selected in prior portions of orbit, from Intermediate Allotted Groups file.
INRMN	Read those groups that adjoin either edge of current portion of arc, from Unallotted Groups file.
JOINER	Append unallotted groups list read by INRMN to group list generated by NASARC1 for current portion of orbit; join group arcs of duplicate groups where overlapping or contiguous.
PARTIT	Partition current service areas into 3 priority classes according to service arc remaining outside cumulative arc.
CRTADM	Determine information for each service area from master group list, to find critical service area, including number of service areas remaining in groups list, remaining service areas, and frequency of occurrence of each service area. Return service area appearing in fewest number of groups, having smallest service arc, as critical service area.
MISSPI	Check if Priority 1 service areas are missing from master groups list.
LSTALT	Write current allotted arcs to Intermediate Selection file, and to Intermediate Allotted Groups file, at end of execution for present portion of orbit.
PRIOR	Evaluate service areas as priority 1 (P1), priority 2 (P2), or priority 3 (P3) for allotment.
SEGCHK	Check if remaining arc in current portion of orbit is sufficient to allot at least a 2 member group of Priority 2 or Priority 3 service areas. If not, no more arc allotments will be found and NASARC2 will stop.
OUTRMN	Scan remaining groups in master list (after arc determination process for present portion of orbit is completed); identify groups whose group arc adjoins one edge of the cumulative arc. Write groups to Unallotted Groups file.
UPDATE	Update master groups list after arc allotted, by deleting critical group members from groups in list, joining group arcs of resultant duplicate groups where overlapping or contiguous, and eliminating duplicates where appropriate.
UNPACK	Convert group from packed format (no spaces between service area codes) to unpacked format (space separating service area codes in group) to improve readability when writing groups to files.
ITUARC	Import service area; export associated visible service arc longitudes, arc length.

TABLE 2.2-6—Continued.

Program/subprogram name	Purpose of program/subprogram
GRPBUF	Determine group transitional arc by examining service area transitional arcs of member service areas, selecting largest.
PTACHK	Find prior temporary allotted arcs lying within, overlapping desired potential temporary allotted arc. For each of these, determine if contiguous arc space is available within group arc to move allotted arc to location allowing desired arc to be allotted.
ADDBOA	Add group's temporary allotted arc to binary orbital arc replica.
XTRACT	Extract critical group members from given group in master list.
PULL	Places individual service areas from group into separate elements of array.
INDEX2	Find starting column of 3-character service area code within group character string.
CHK180	Logical function subprogram; determines if given arc span straddles 180° meridian.
ADJST1	Adjust two longitudes defining arc boundaries so that westernmost edge is numerically less than easternmost edge; both in range 0° to 360°.
COMBIN	Used in subset arc extension, when forming critical groups sublist.
QUICK1	Used in groups list updating process; employs Quicksort algorithm (devised by C.A.R. Hoare). Sort groups list alphabetically; for same group, order group arcs west to east. For duplicate groups with same west longitude, places group arc extending furthest east first.
PART1	Partitioning module, used by QUICK1.
QUICK2	Used in forming the critical groups sublist; employs Quicksort algorithm. Perform compound sort on sublist; first, on number of members in group (descending order); then on group arc length (descending order); then group's total frequency of occurrence (ascending order).
PART2	Partitioning module, used by QUICK2.
QUICK3	Quicksort routine used in subset arc extension process, when forming critical groups sublist. Performs compound sort on sublist; first, on number of members in group (ascending order); then alphabetically (ascending order); then on western longitude of group arc (ascending order).
PART3	Partitioning module, used by QUICK3.
QUICK4	Quicksort routine used in subset arc extension process. Sorts group arcs in west to east order; for segments with same west longitude, places segment that extends furthest east first.
PART4	Partitioning module, used by QUICK4.
QUICK5	Quicksort routine used in formation of critical administration list. Sorts administrations in ascending order, first on frequency of occurrence of service area in master groups list, then on visible service arc length.

TABLE 2.2-6—Concluded.

Program/subprogram name	Purpose of program/subprogram
PART5	Partitioning module, used by QUICK5.
SACHK	Logical function to determine if sufficient service arc remains open to allot service area as part of critical group.
SUBLST	Create sublist of groups from current master list, containing critical service area. List is sorted in ascending order with respect to group size.
CRTGRP	Determine critical group containing critical service area from master groups list.
XTEND	Extend group arcs which are subsets of other groups, when forming critical groups sublist.
QUICK6	Quicksort routine used to sort allotments in west to east order.
PART6	Partitioning routine used by QUICK6.
ALLOT	Find allotted arc for critical group within group arc, changing previous allotted arcs if necessary.
GRPARC	Logical function indicating whether or not group's allotted arc is within group's group arc.
NEIGH	Determine, for given allotted arc, endpoints of closest neighboring allotted arcs.
MATRIX	Read entries of satellite separation matrix calculated by NASSEP.
QUICK7	Quicksort routine used to sort separation matrix entries.
PART7	Partitioning routine used by QUICK7.
BINARY	Performs binary search of list sorted in ascending order.
MAXSEP	Determine maximum orbital separation required between two satellites or groups of satellites.
PDASEP	Determine required separation between two allotted arcs.
UPDAT2	Update master groups list after arc allotted by deleting allotted group members from groups in list, joining group arcs of resultant deuplicate groups where overlapping or contiguous, and eliminating duplicates where appropriate.
PUSH	Allots arcs by moving prior allotted arcs. Relative ordering of allotted arcs to east or west of current location will not change.
ARCCHK	Identify prior allotted arc intersecting specified portion of orbital arc.
FINSEP	Determine final required separations between allotted arcs.
QUICK8	Quicksort routine used in forming critical service area list.
PART8	Partitioning routine used by QUICK8.



TABLE 2.2-7—PROGRAMS AND SUBROUTINES CONTAINED IN NASARC3 MODULE AFTER COMPILATION

Program/subprogram name	Purpose of program/subprogram
MAIN	Extend group arcs of cumulative set of groups given allotted arcs by NASARC2 module, if possible, within current portion of orbit.
SETCON	Set constants used throughout programs.
INTRST	Determine intersection endpoints of pair of arc segments.
RDPTS	Read sets of polygon points for service areas from Point Sets file.
ERR	Change initial error flag of Input Data file to Y if error encountered.
CICLK	Verify that grouping criterion provides sufficient orbital separation to achieve target $C/I$ value.
SCOFF	Calculate spacecraft antenna off-axis angle.
ANGLES	Calculate half-power beamwidth for satellite antenna in direction of service area polygon point.
ESOFF	Calculate earth station antenna off-axis angle.
DISC	Calculate antenna discrimination.

Table 2.2-8.—PROGRAMS AND SUBROUTINES CONTAINED IN NASARC4 MODULE AFTER COMPILATION

Program/subprogram name	Purpose of program/subprogram
MAIN	Improve most current arrangement of allotted arcs through heuristic swapping procedure.
INTRST	Determine intersection endpoints of pair of arc segments.
SWAP	Perform interchange of allotted arc segments after determining that interchange is feasible and improves arrangement.
FEASIN	Calculate matrix of feasible arc segment interchanges.
REPORT	Produce output report of NASARC results when all portions of orbit within Segments file are exhausted.
CNDREP	Produce condensed output report of NASARC results.
UNPACK	Convert group from packed format (no spaces between service area codes) to unpacked format (space separating service area codes in group) to improve readability when writing groups to files.
TEMPOR	Attempt to clear further arc space, if necessary, between two allotted arc segments in final improved arrangement.
ADDBOA	Add group's temporary allotted arc to binary orbital arc replica.

TABLE 2.2-8—Concluded.

Program/subprogram name	Purpose of program/subprogram
PUSH	Move prior allotted arcs laterally. Relative ordering of allotted arc segments will not change.
DENSE	Determine whether arbitrary portion of arc is occupied by prior allotted arc segments.
PTACHK	Find prior temporary allotted arcs lying within or overlapping desired portion of orbit. For each arc found, determine if contiguous arc space is available within group arc to move allotted arc to location allowing desired arc to be occupied by incoming allotted arc.
PTRBUB	Pointer bubble sort routine; sorts potential temporary allotted arcs according to number of intersections that each has with prior temporary allotted arcs.
ARCCHK	Identify prior allotted arcs intersecting specified portion or orbital arc.
BUB1	Combination pointer and bubble sort routine.
PUSH1	Determine if two allotted arcs of different lengths may be interchanged after lateral readjustment of neighboring allotted arcs.
PUSH2	Attempt to clear sufficient arc space for given allotted arc length.
ADJUST1	Adjust two longitudes defining arc boundaries so that westernmost edge is numerically less than easternmost edge; both in range 0° to 360°.
AFFINT	Determine service arc of affiliated set.
NEAR2	Determine two nearest endpoints of nonintersecting service arcs.

### 2.2.3 Creation of Commands/Job Control Language Necessary to RUN NASARC Programs—NASARC and INTRFACE Procedures

It was stated earlier that the specific set of system commands and/or job control language statements needed to exercise the NASARC package program modules differ for different operating systems. Thus, the user must issue the commands and/or job control language statements that are suitable for the system in use. While the specific commands issued by the user depend on the user's system, the general list of functions that must be performed by such commands is consistent for all systems. Many operating systems allow the user to create a single named procedure that executes a sequence of system commands; it is suggested that such a procedure be created to perform the following described operations.

To utilize the NASARC software package for allotment planning purposes, all seven of the NASARC modules (NASINTRF, NASARC0, NASSEP, NASARC1, NASARC2, NASARC3, and NASARC4) must be executed in the proper sequence. If multiple segments are being run, NASARC1, NASARC2, NASARC3, and NASARC4 must be executed consecutively in a repeated fashion for all segments specified by the user. (See fig. 2.2-1.)

The NASINTRF module is the first program module that must be executed, and it is executed only once. Its purpose is to create the Service Area file, the Affiliated Sets file, and the Point Sets file for use by the remaining NASARC modules. It reads from a file designed by the International Frequency Registration Board (IFRB) that contains the required system parameters for all systems to be considered in a planning exercise. The Requirements Data file contains parameter specifications and options that must be translated to specifications and options compatible with NASARC; NASINTRF performs this function as well. If the user does not possess, or

# The NASARC EXEC Procedure

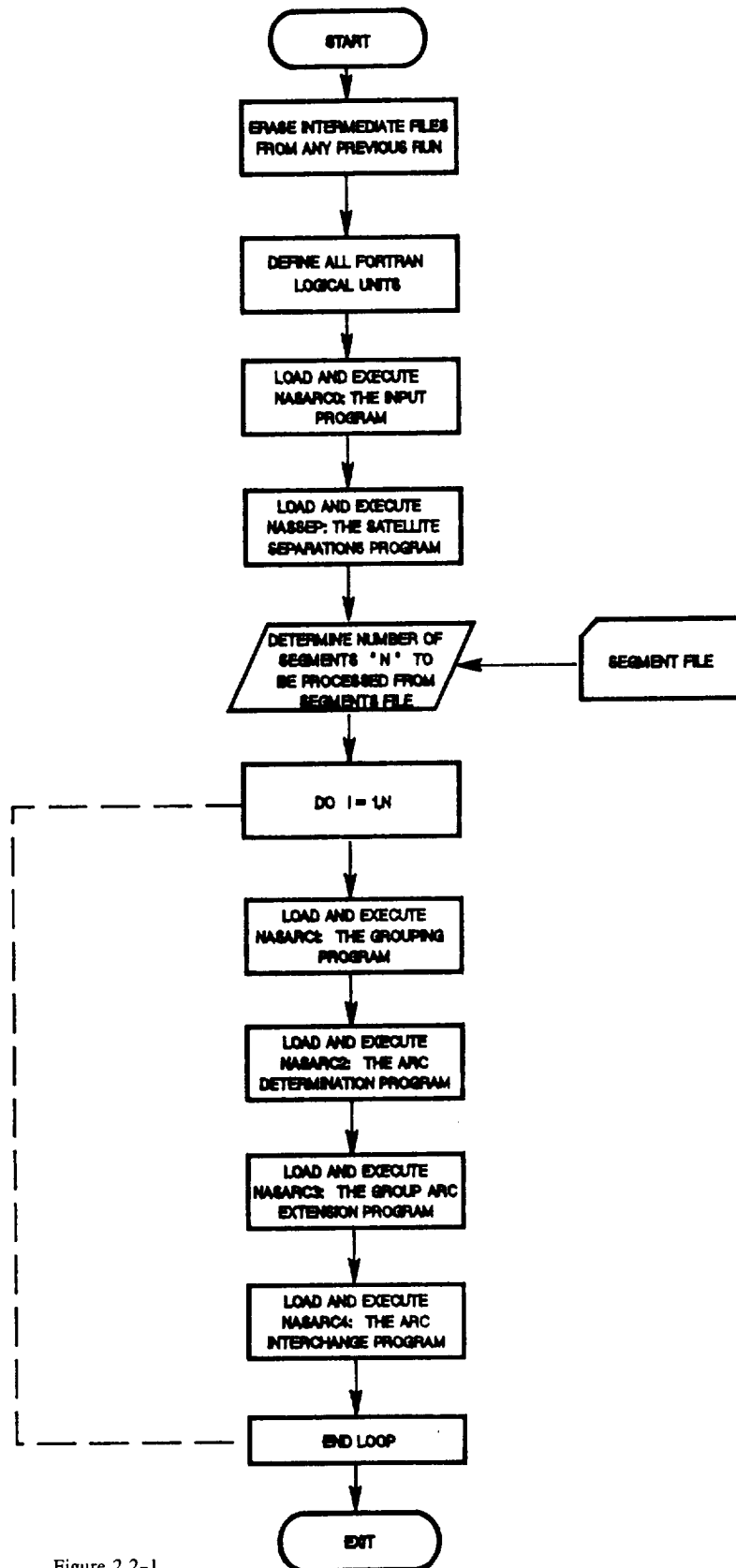


Figure 2.2-1.

wish to use, a **Requirements Data** file, it is possible to create **Service Area**, **Affiliated Sets**, and **Point Set** files directly; in this case, the **NASINTRF** module need not be used. Further details on direct creation of these files are provided in section 2.3 herein.

To perform the functions described, the **INTRFACE** procedure to execute **NASINTRF** should contain appropriate system commands and/or job control language to execute the following sequence of instructions:

- (1) For **BATCH** processing only, set and define necessary job parameters.
- (2) Define all **FORTRAN** logical units:
  - (a) Define **FORTRAN** logical unit 15 as the **Service Area** file, with appropriate file attributes.
  - (b) Define **FORTRAN** logical unit 25 as the **Requirements** file, with appropriate file attributes.
  - (c) Define **FORTRAN** logical unit 13 as the **Affiliated Sets** file, with appropriate file attributes.
  - (d) Define **FORTRAN** logical unit 14 as the **Point Sets** file, with appropriate file attributes.
- (3) Load and execute the **NASINTRF** module.
- (4) For **BATCH** processing only, submit job for processing.

Following execution of the **INTRFACE** procedure, the remaining **NASARC** modules may be run. The **NASARC0** module is the first program element that must be executed, and it is executed only once. Its purpose is to create the **Input Data** file from user prompted inputs for the remaining **NASARC** modules to use when executing. It reads from the **Service Area** file, **Point Sets** file, **Affiliated Sets** file, and **Segments** file. It prompts the user for the input parameters (date and time of run, comments describing the run, downlink and uplink frequencies, annual percent outage due to rain attenuation, rain attenuation limit flag, and maximum rain attenuation limit) and checks if they are within established limits. Also, an error checking procedure is performed to determine if all files are structured correctly. When an error is discovered, an error flag is set to **Y** (yes). This flag is read by all subsequent program elements through the **Input Data** file and if it is set to **Y**, it causes them to immediately **STOP** executing—thus preventing unnecessary erroneous runs.

The **NASSEP** program reads all files generated by the **NASINTRF** and **NASARC0** programs, and the master **Ellipse** file. **NASSEP** produces a file that is utilized by both the **NASARC2** and **NASARC4** modules—the **Satellite Separations** file. The **NASSEP** program needs to be executed only once for a given set of data contained in the **Service Area** file, the **Affiliated Sets** file, and the **Point Sets** file, and it generates a file that contains the worst-case separations for all possible pairs of satellites.

The **NASARC1** program reads all of the files read by the **NASARC0** program and, in addition, the **Input Data** file, the master **Ellipse** file, and the **Intermediate Allotted Groupings** file. **NASARC1** produces two files that are used by **NASARC2**—the **Groups** file and the **Intermediate Segments** file. Also, the **Segments** file is modified for subsequent runs of the **NASARC1** module.

The **NASARC2** program reads from the **Input Data** file, the **Intermediate Allotted Groupings** file, the **Unallotted Groups** file, and the two files created by **NASARC1**. Its updated result, after each segment is executed, is stored in the **Intermediate Allotted Groups** file. **NASARC2** also generates an **Intermediate Selection** file which provides information on the selection of the allotted groups.

The **NASARC3** program performs the group arc extension function. For this, it reads the **Service Area** file, master **Ellipse** file, **Point Sets** file, **Affiliated Sets** file, **Input Data** file, and **Intermediate Allotted Groupings** file. After execution, its results are stored in a modified **Intermediate Allotted Groupings** file. **NASARC3** extends the group arcs of allotted groupings as far as possible across the orbital arc.

The **NASARC4** program serves two purposes. Up to and including execution during the last segment specified in the **Segments** file, **NASARC4** attempts to rearrange the most current arrangement of allotted arcs via a heuristic swapping procedure designed to improve compatibility between neighboring allotted arcs. The resulting new arrangement is stored in the **Intermediate Allotted Groupings** file. When executing during the last segment, **NASARC4** also restores the original **Segments** file and produces the **NASARC Report** file, **Condensed Report** file, and **Predetermined Arc** file.

To perform the tasks described, the NASARC procedure should contain appropriate system commands and/or job control language to execute the following sequence of instructions in the following order presented (see also fig. 2.2-1):

- (1) For BATCH processing only, set and define necessary job parameters.
  - (2) Erase intermediate files from any previous run:
    - (a) Erase Intermediate Allotted Groupings file.
    - (b) Erase Intermediate Segments file.
    - (c) Erase Unallotted Groups file.
    - (d) Erase Groups file.
    - (e) Erase Error Message file.
    - (f) Erase Intermediate Selection file.
    - (g) Erase Intermediate Improvement file.
  - (3) Define all FORTRAN logical units:
    - (a) Define FORTRAN logical unit 10 as the terminal (output unit for interactive queries to user).
    - (b) Define FORTRAN logical unit 11 as the terminal (input unit for interactive queries to user).
    - (c) Define FORTRAN logical unit 12 as the Input Data file, with appropriate file attributes.
    - (d) Define FORTRAN logical unit 13 as the Service Area file, with appropriate file attributes.
    - (e) Define FORTRAN logical unit 14 as the Affiliated Sets file, with appropriate file attributes.
    - (f) Define FORTRAN logical unit 15 as the Point Sets file, with appropriate file attributes.
    - (g) Define FORTRAN logical unit 16 as the Segments file, with appropriate file attributes.
    - (h) Define FORTRAN logical unit 17 as the Intermediate Segments file, with appropriate file attributes.
    - (i) Define FORTRAN logical unit 18 as the Ellipse file, with appropriate file attributes.
    - (j) Define FORTRAN logical unit 19 as the Error Message file, with appropriate file attributes.
    - (k) Define FORTRAN logical unit 20 as the Groups file, with appropriate file attributes.
    - (l) Define FORTRAN logical unit 21 as the Intermediate Allotted Groupings file, with appropriate file attributes.
    - (m) Define FORTRAN logical unit 22 as the Unallotted Groups file, with appropriate file attributes.
    - (n) Define FORTRAN logical unit 23 as the Intermediate Selection file, with appropriate file attributes.
    - (o) Define FORTRAN logical unit 24 as the NASARC Report file, with appropriate file attributes.
    - (p) Define FORTRAN logical unit 25 as the Predetermined Arc file, with appropriate file attributes.
    - (q) Define FORTRAN logical unit 27 as the Satellite Separations file, with appropriate file attributes.
    - (r) Define FORTRAN logical unit 28 as the Intermediate Improvement file, with appropriate file attributes.
    - (s) Define FORTRAN logical unit 29 as the Condensed Report file, with appropriate file attributes.
  - (4) Load and execute the NASARC0 module.
  - (5) Load and execute the NASSEP module.
  - (6) Determine the number of segments to be run (N).
  - (7) Load and execute the NASARC1 module.
  - (8) Load and execute the NASARC2 module.
  - (9) Load and execute the NASARC3 module.
  - (10) Load and execute the NASARC4 module.
  - (11) For BATCH processing only, submit job for processing.
- } Loop through instructions (7), (8), (9), and (10) N times.

If the user's system is unable to perform the loop indicated previously, steps (7) and (10) must be repeated as many times as there are segments to be run.

### 2.3 Auxiliary File Requirements

The NASARC software package requires several auxiliary files for program input and output. Auxiliary files needed fall into one of three categories: input files, which are generally prepared prior to repeated execution of the NASARC1, NASARC2, NASARC3, and NASARC4 modules; intermediate files, which are generated by

NASARC programs for temporary use; and output files, which are produced at the end of use of the NASARC package. The contents, formats, and approximate storage requirements (where possible) of each file are described in the following sections.

### 2.3.1 Input Files

In general, input files are those required for use by one or more of the NASINTRF, NASARCO, NASSEP, NASARC1, NASARC2, NASARC3, or NASARC4 modules. In most circumstances (discussed in section 2.3.1.5), these files are generated by utilizing the NASARC modules, although the required files may also be constructed independently. The files must adhere to the file structure, format, and content described in the appropriate section.

#### 2.3.1.1 Segments File

The NASARC (Version 4.0) software package is based on an approach to developing predetermined orbital arcs that differs in a significant respect from the approach utilized in prior versions of the software. NASARC (Version 4.0) applies the general concepts and calculations utilized by earlier versions of the software in a piecewise approach to the orbital arc as a whole; that is, a segment of the orbital arc is examined for compatible groups of service areas, and the arc spans over which such groups may exist are found. These group arcs lie within the portion of the arc currently being examined. From the list of groups and group arcs, groups are selected and predetermined arcs are found for the selected groups. These arcs also lie in the portion of the arc currently being examined. The process is repeated for subsequent segments of the arc.

The Segments file contains the portions of arc that are to be sequentially examined and the grouping criteria to be applied for each segment. Each segment is listed by its western and eastern limiting longitude; each record of the file contains one segment. Up to 40 such records may be included in the file; the segments may span the entire 360° of available orbital arc, which is regarded by NASARC Version 2.0 as ranging from -179° east longitude to 180° east longitude. If a portion of the orbit under consideration crosses the 180° meridian, the western edge of the arc segment may have a positive longitude, while the eastern edge has a negative longitude. Each segment has associated with it a grouping criterion, expressed in degrees, which defines the maximum allowable orbital separation required between two satellites that will allow them to be considered compatible and eligible for grouping.

The density of systems that may share portions of the orbital arc varies across the geostationary orbit. Thus, a particular segment of the orbit to be analyzed may contain locations that are visible to many more service areas than locations in other segments. For this reason, the user may wish to vary the grouping criterion—an upper limit on the orbital separation that may be required between two systems in order for them to be considered compatible—for each segment of the orbit to be processed. A higher value would be suitable for a less dense portion of the orbit; a lower value would serve to reduce the number of groupings generated in a higher density portion of the orbit.

The portions of orbital arc listed within the Segments file must be disjoint; that is, no two segments of the orbit that are listed in the file should encompass arc locations that overlap. Two portions of arc whose western and eastern boundaries (respectively) are separated by 1° of orbital arc are considered to be adjoining portions of the arc. After the first portion of the arc listed within the segment file, each subsequent segment must adjoin either the eastern or western arc boundary of one of the prior segments.

The specific format in which each record must be constructed is (1X, F7.2, 1X, F7.2, 1X, F7.3), and can be illustrated as follows:

		±	X	X	X	.	X	X		±	X	X	X	.	X	X		X	X	X	.	X	X	X
Column no.:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

Columns 2 through 8 of each record should contain the western boundary of each portion of the orbit to be considered, expressed in degrees east longitude in the range  $-179.00$  to  $180.00$ . Similarly, columns 10 through 16 should contain the eastern boundary of each segment to be considered in the range  $-179.00$  to  $180.00$ . Columns 18 through 24 contain the grouping criterion, which may range from 0.0 to 1.0.

As each record in the file is of fixed, 80-byte length, and up to 40 such records may be included in the file, the Segments file may occupy up to 3.2 kilobytes of memory.

### 2.3.1.2 Requirements Data File

The Requirements Data file was created by the International Frequency Registration Board to contain system requirements data submitted by administrations for allotment planning of the Fixed Satellite Service at the 1988 World Administrative Radio Conference. An interface module (NASINTRF) was created for the NASARC (Version 4.0) software package that utilizes the Requirements Data file to create the Service Area file, the Affiliated Sets file, and the Point Sets file by translating data, codes, and options utilized in other IFRB planning software to formats and options required by the NASARC software. Because this file is not an integral part of the NASARC software package, and is of limited application, no further details will be provided in this part of the NASARC software package, and is of limited application, no further details will be provided in this *User's Manual*. The user is advised to create his own Service Area, Affiliated Sets, and Point Sets files to suit his own application of the NASARC software. Details on creation of these files are presented in subsequent sections.

### 2.3.1.3 Service Area File

The Service Area file may either be generated automatically from the Requirements Data file, via use of the NASINTRF (interface) module, or it may be constructed via an editor by the user. The user is reminded that, should he choose to construct his own file, the format and type of data presented in this section must be strictly adhered to.

The Service Area file is a particularly important file in several respects. First and foremost, this file is a complete listing of all service areas to be considered as candidates for an allotted arc. However, the file also contains information specific to each service area that influences outcomes and decision processes throughout each of the four NASARC program modules.

The first record of the Service Area file is a unique record. It contains information (in nine items) that is to be applied globally to the entire scenario. The first item is the rain attenuation flag, a single character code that specifies whether or not rain attenuation is to be taken into account in subsequent calculations. This is followed by the minimum half-power beamwidth, expressed in degrees, which provides the smallest realistic elliptical satellite antenna beamwidth to be considered in processing the scenario. The third, fourth, fifth, and sixth items are constants utilized in calculating the allotted arc length that is required by a particular group of systems. The seventh item is a reference noise bandwidth, expressed in megahertz (MHz). This value is followed by the minimum power level for the earth station, expressed in dBW, and, finally, the minimum power level for the satellite, also expressed in dBW.

Each subsequent record of the Service Area file may contain up to twenty-three items. The first item of each record is a three-character service area code representing an administration or service area. These codes are generally taken from the country symbols appearing in the International Frequency List. This item must be followed, in each record, by the western and eastern longitudinal limits of the service area's service arc, corresponding to a given elevation angle. As for the Segments file (see section 2.3.1.1) longitudes range from  $-179^\circ$  east longitude to  $180^\circ$  east longitude; if a service arc crosses the  $180^\circ$  meridian, its western service arc boundary is positive while the eastern arc boundary is negative.

The fourth item in each Service Area file record is an integer numeric code used to identify a single service area as a member of an affiliated set of service areas. Briefly, the concept of an affiliated set of service areas allows

the user to consider situations in which several service areas are to be served from a single orbital location—for example, a nation with widely dispersed territories. By identifying each such service with the same integer numeric code, the user signifies to the NASARC program modules that, in any compatible grouping found, either all or none of the member service areas must be included. The concept of an affiliated set of service areas is discussed in greater detail in the *NASARC (Version 4.0) Technical Manual*.

The fifth, sixth, seventh, and eighth items in each Service Area file record relate to the individual specification of space station characteristics. The fifth item is a six-character code identifying a choice of space station antenna patterns to be utilized for the particular service area in question. The user must select such a pattern for each service area. For further information on the choice of patterns available, the user is referred to section 3.1.1.2.4 of the *NASARC (Version 4.0) Technical Manual* and to section 3.2.2.3.2 herein.

The sixth, seventh, and eighth items in each Service Area file record also relate to space station characteristics for the individual service area. These items are the space station antenna parameter value, the space station antenna efficiency, and the spacecraft receiver noise temperature. The space station antenna parameter value must be specified relative to the choice of the space station antenna pattern selected. The needed space station parameter value may represent different quantities such as a sidelobe level expressed in decibels, or an antenna decay constant expressed as a real number, depending on the choice of pattern selected. A value for the seventh option, antenna efficiency, allows the user to specify a space station antenna efficiency that corresponds to the specific antenna choice and parameter value already specified in the record. The antenna efficiency is expressed as a decimal percentage (e.g., 55% = 0.55). The eighth option, spacecraft receiver noise temperature, is specified in decibels converted from degrees Kelvin (dB-K). The ninth item is the spacecraft power, expressed in decibels converted from watts (dBW). A more detailed discussion of space station antenna parameters is presented in the *NASARC (Version 4.0) Technical Manual* and in section 3.2.2.3.2 herein.

The tenth and eleventh items relate to the earth station transmit antenna. The tenth item specifies the antenna pattern code for the earth station transmit antenna; the eleventh item is an associated parameter value. Items twelve and thirteen are identical in meaning, but relate to the earth station receive antenna. Item fourteen is the earth station antenna efficiency; the same value will be applied to both transmit and receive antennas. Item fifteen is the earth station noise temperature, expressed in dB converted from degrees Kelvin. Item sixteen is the earth station power level, expressed in dBW. Further details of earth station parameters are presented in the *NASARC (Version 4.0) Technical Manual*, and in section 3.2.2.5 herein.

The seven remaining items specified for each service area determine how the service area's system will be treated in the *C/I* calculations performed by the NASARC modules.

Items seventeen and eighteen are the carrier-to-noise ratios (*C/N*'s) to be achieved on the uplink and downlink, respectively, expressed in dB. These values are utilized if spacecraft and earth station powers are to be calculated as those necessary to achieve a given *C/N* rather than those values directly supplied by the user.

Item nineteen is the target single-entry, total-link *C/I* to be achieved for the service area's system, expressed in dB.

Items twenty and twenty-one also refer to the uplink and downlink, respectively, for the service area's system. These items are single character option codes, specifying the manner in which uplink power and downlink power are to be included in calculations. As stated previously, power values may be calculated from supplied *C/N*'s or they may be directly supplied as inputs.

Item twenty-two is also a single character code; it specifies, for the purposes of allotment planning at the 1988 World Administrative Radio Conference (WARC), whether or not the service area's system is to be considered an existing system. This option impacts compatibility assessment between service areas.

The twenty-third, and final, item for each service area is also a single character flag. This flag specifies whether the system of the service area in question is to be considered as uplink only, downlink only, or an uplink/downlink system. This option also answers a specific need arising in allotment planning at the 1988 WARC.



Further details and explanations of these options may be found in the *NASARC (Version 4.0) Technical Manual*.

The Service Area file must be constructed in a manner which maintains order compatibility with the Ellipse file (see section 3.2.6 herein). Such ordering must be performed by the user as the NASARC modules do not permute the order of the input records; the records are stored and processed in the order in which they are read. The specific format in which Service Area file records must be constructed is presented in table 2.3-1.

As each record in the file is of fixed 150-byte length and up to 301 such records may be included in the file, the Service Area file may occupy up to 45 kilobytes of memory.

TABLE 2.3-1—FORMAT OF SERVICE AREA FILE

(a) First record

Item	Column	Description	Format	Item	Column	Description	Format
1	2	Rain attenuation flag	A1	6	43 to 52	Allotted arc length equation constant, C4	F10.0
2	3 to 12	Minimum half-power beamwidth, deg	F10.0	7	53 to 62	Reference noise bandwidth, MHz	F10.0
3	13 to 22	Allotted arc equation constant, C1	F10.0	8	63 to 72	Minimum earth station power, dBW	F10.0
4	23 to 32	Allotted arc length equation constant, C3	F10.0	9	73 to 82	Minimum satellite power, dBW	F10.0
5	33 to 42	Allotted arc length equation constant, C3	F10.0				

(b) Subsequent records

Item	Column	Description	Format	Item	Column	Description	Format
1	1 to 3	Three-character service area code	A3	13	88 to 95	Earth station receive antenna parameter	F8.3
2	4 to 11	Western service arc boundary, deg east longitude	F8.2	14	96 to 103	Earth station antenna efficiency	F8.3
3	12 to 19	Eastern service arc boundary, deg east longitude	F8.2	15	104 to 111	Earth station noise temperature, dB	F8.3
4	20 to 22	Numeric code for set affiliation	I3	16	112 to 119	Earth station power, dBW	F8.3
5	24 to 29	Spacecraft antenna pattern code	A6	17	119 to 126	Uplink C/N, dB	F8.3
6	30 to 37	Spacecraft antenna parameter value	F8.3	18	127 to 134	Downlink C/N, dB	F8.3
7	38 to 45	Spacecraft antenna efficiency	F8.3	19	135 to 142	Target single-entry carrier-to-interference ratio	F8.3
8	46 to 53	Spacecraft noise temperature, dB	F8.3	20	144	Power calculation option, uplink	A1
9	54 to 61	Spacecraft power, dBW	F8.3	21	144	Power calculation option, downlink	A1
10	63 to 70	Earth station transmit antenna pattern code	A6	22	146	Existing system flag	A1
11	7 to 78	Earth station transmit antenna parameter		23	150	Uplink/downlink/both flag	A1
12	80 to 87	Earth station receive antenna pattern code					

#### 2.3.1.4 Point Sets File

The Point Sets file may either be generated automatically from the Requirements Data file, via use of the NASINTRF (interface) module, or it may be constructed via an editor by the user. Should the user construct the file, the format described in this section must be followed.

The Point Sets file is utilized by the NASARC0, NASARC1, and NASARC3 modules to perform link calculations for assessing interference between systems. As its name suggests, the Point Sets file contains sets of polygon points defining boundaries of service areas. The general structure of the Point Sets file is illustrated in figure 2.3-1.

The point set data contained in the Point Sets file include a set of polygon points, expressed as latitude-longitude pairs, for each of up to 300 service areas. Polygon points are those which define the boundaries of the service area or administration and are selected so as to form a convex polygon on the surface of the Earth. For NASARC (Version 4.0) up to 10 such points may be specified for each service area. The user will save a considerable amount of time in file editing and construction by employing a master Point Sets file that includes point set data for all administrations and service areas rather than constructing an individual Point Set file for each scenario. Polygon point sets may be added to the Points Sets file for new service areas, such as subregional coverages which may be identified. The data contained in the Point Sets file must conform to a specific format. The format is described in table 2.3-2.

Each set of points corresponding to an individual service area contains an initial descriptive record. In this record are the three-character service area code, the number of polygon points for the service area, and the corresponding eight-character beam code found in the Requirements file. This initial descriptive record is followed by a series of records containing the polygon points themselves. The number of such records utilized for the service area depends on the total number of points specified in the initial record; up to five points are listed on each record following the initial record. Each of these records contains a series of five sets of columns, each set containing the point latitude and point longitude.

The Point Sets file may occupy up to 90 kilobytes of memory, depending on the number of service areas included in the file and the number of points supplied for each service area.

TABLE 2.3-2—FORMAT FOR POINT SET DATA FOR INDIVIDUAL SERVICE AREA

Item	Column	Description	Format
Initial record			
1	1 to 3	Three-character service area code	A3
2	9 to 10	Number of points for service area	I2
3	16 to 23	Requirements file eight-character beam code	A8
Subsequent records (2)			
1	1 to 10	Point latitude (north, +; south, -)	F10.0
2	11 to 20	Point longitude (east, +; west, -)	F10.0
3	21 to 30	See item 1	
4	31 to 40	See item 2	
5	41 to 50	See item 1	
6	51 to 60	See item 2	
7	61 to 70	See item 1	
8	71 to 80	See item 2	
9	81 to 90	See item 1	
10	91 to 100	See item 2	



### 2.3.1.5 Affiliated Sets File

Like the Service Area and Point Sets files, the Affiliated Sets file may be generated from requirements data via the interface module, or it may be constructed by the user.

In section 2.3.1.3, which describes the Service Area file, reference was made to an optional entry for each service area that allows the user to indicate that a service area is a member of an affiliated set of service areas that are to be served from a single space station location. In the Service Area file, membership in such a set was signified by placing the same integer numeric code in the appropriate service area records. The result of specifying such membership in an affiliated set was stated to be that all such service areas would be treated in an all or nothing manner in the determination of compatible groups of service areas and the generation of allotted arcs: that is, either all affiliated member service areas must be included in a compatible group of service areas or no members must be included.

The purpose of the Affiliated Sets file is to aid in implementing the all or nothing treatment of member service areas. Each record of the Affiliated Sets file contains an integer numeric code, corresponding to the code specified on the records of the member service areas within the Service Area file. The integer codes should be in ascending numeric order starting with one (1) and proceeding through to the number of separate affiliated sets (i.e., 1, 2, 3, etc.). This integer code is followed by a three character code, for the affiliated set of service areas, that will replace individual service area codes within a compatible grouping. The final item in each record is an integer, equal to the number of individual service areas that are to be included as members in the affiliated set. The format of each record is described in table 2.3-3.

The Affiliated Sets file may contain up to 25 such records. As each record is of fixed 80-byte length, the Affiliated Sets file may occupy up to 2 kilobytes of memory.

The user is referred to the *NASARC (Version 4.0) Technica Manual* for further discussion of the affiliated set concept, and to section 3.2.4 herein for further directions on use of the concept in construction of NASARC (Version 4.0) input data.

TABLE 2.3-3—FORMAT FOR DATA IN AFFILIATED SETS FILE

Item	Column	Description	Format
1	2 to 3	Numeric code for affiliated set (=1, 2, 3, ...)	I2
2	5 to 7	Three-character code for affiliated set	A3
3	9 to 10	Number of member service areas in set (=2 or more)	I2

### 2.3.1.6 Input Data File

The input Data file is created via execution of the NASARC0 module. The Input Data file contains a series of records created primarily, though not exclusively, in response to the user's interactively supplied answers to a series of input prompts issued by the NASARC0 module. In addition to these records, the Input Data file contains several flags indicating various conditions of the input to the NASARC1, NASARC2, NASARC3, and NASARC4 modules. These flags are the product of file checking and correlation operations performed by the NASARC0 module and are thus only indirectly influenced by the user's input. Finally, the Input Data file contains the four constants used in calculating the length of the allotted arcs to be given to service areas; as mentioned previously, these constants are extracted from the Service Area file.

Further information on correct responses to the interactive prompts mentioned previously may be found in section 3.2.5 herein along with further details on the remainder of the Input Data file.

The Input Data file contains 18 records of fixed 80-byte length and thus occupies 1.44 kilobytes of memory.

### 2.3.1.7 Separation Matrix File

The Separation Matrix file, required by the NASARC2 and NASARC4 modules as input, is created by using the NASSEP (the satellite separations program) module. The Separation Matrix file contains required orbital separations for all possible pairs of satellites for a given scenario, in degrees, and represents a symmetric matrix. Thus, the separations presented in the file are structured to reduce the storage space required: separations are listed in the file for the first service area paired with the second and all subsequent areas, followed by the separation required for the second service area paired with the third and all subsequent areas, and so on.

Further details of the method by which the separations are calculated may be found in the *NASARC (Version 4.0) Technical Manual* and in section 3.1.3 of this *User's Manual*.

The specific format of each record of the separation matrix file is (1X, A3, 2X, A3, 2X, F7.2) and may be illustrated as follows:

	A	A	A			B	B	B			X	X	X	X	.	X	X	
Column:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

The separation matrix file may contain up to approximately 45,000 records of 20 bytes each; therefore, it may occupy up to 0.9 megabyte of memory.

### 2.3.1.8 Ellipse File

The Ellipse file, an input to the NASSEP, NASARC1, and NASARC3 modules, contains ellipse and rain attenuation data for service areas. For each service area, the Ellipse file contains ellipses at all possible integral locations within the service area's visible arc (0° elevation angle) plus uplink and downlink rain attenuation data for two sets of frequencies for all test points for the service area.

Each ellipse contained in the ellipse file is actually represented by three records. The first record describes the ellipse beam parameters for a particular service area at a particular satellite longitude. The second record contains rain attenuation data for one set of uplink and downlink frequencies for each test point defining the service area. The third record contains rain attenuation data for a second set of uplink and downlink frequencies for each test point defining the service area. The two sets of frequencies expected by the NASARC programs are currently those *expansion band* frequencies subject to allotment planning at the 1988 World Administrative Radio Conference. Should the user wish to use other frequency bands, some minor modifications to the NASARC programs may be necessary. Rain attenuation data are presented at each longitude represented in the file because attenuation varies with the variations in path length for each test point produced by a change in satellite longitude.

Each set of three records that corresponds to a given service area and satellite longitude is composed according to the format presented in table 2.3-4. The first of the three records contains ellipse beam parameters: an eight character beam code corresponding to a service area, the satellite longitude for which the ellipse and rain attenuation data were calculated, the longitude and latitude of the elliptical beam aimpoint, the major and minor axes of the ellipse, and the ellipse orientation angle. The second and third records are identical in content; as stated previously, they correspond to two sets of uplink and downlink frequencies and contain rain attenuations (in dB) for each of up to 10 service area test points. In each such record the series of downlink attenuations for all test points is followed by the series of uplink attenuations for all test points.

The sets of records in the Ellipse file must conform to a specific ordering. Sets of records are arranged in blocks corresponding to service areas; sets of ellipse records for a given service area must all appear consecutively in

the same block of data. Within a block of records corresponding to a given service area, the sets of records should be arranged by the longitude for which they were calculated in a west-to-east direction over the service area's service arc. Ellipse records within each block should represent calculations performed at 1° intervals across the service area's possible service arc; that is, if the service arc crosses the 180° meridian, the ellipse calculated at 180° east longitude should be immediately followed by the data corresponding to -179° east longitude. Further, the blocks of data corresponding to individual service areas should appear with service area codes in an order corresponding to the ordering of the Service Area/Service Arc file, discussed in section 2.3.1.3.

An Ellipse file that corresponds to a world-sized scenario occupies approximately 12.3 megabytes of storage.

TABLE 2.3-4—FORMAT FOR ELLIPSE AND RAIN ATTENUATION DATA

(a) First record of three

Item	Column	Description	Format	Item	Column	Description	Format
1	7 to 14	Eight character beam code	A8	5	36 to 40	Major axis beamwidth, deg	F5.2
2	15 to 21	Satellite longitude for which ellipse and rain data were calculated, deg	F7.2	6	41 to 45	Minor axis beamwidth, deg	F5.2
3	22 to 29	Beam aimpoint longitude, deg	F7.2	7	46 to 52	Orientation angle of ellipse, deg	F7.2
4	30 to 35	Beam aimpoint latitude, deg	F6.2				

(b) Second/third record of three

Item	Column	Description	Format	Item	Column	Description	Format
1 to 10	1 to 6, 7 to 12, 13 to 18, 19 to 24, 25 to 30, 31 to 36, 37 to 42, 43 to 48, 49 to 54, 55 to 60	Rain attenuation (dB) for each of up to 10 test points, calculated at downlink frequency	F6.2	11 to 20	61 to 66, 67 to 72, 73 to 78, 79 to 84, 85 to 90, 91 to 96, 97 to 102, 103 to 108, 109 to 114, 115 to 120	Rain attenuation (dB) for each of up to 10 test points, calculated at uplink frequency	F6.2

### 2.3.2 Intermediate Files

To utilize the NASARC (Version 4.0) software package for planning exercises, it is necessary to execute the NASARC1 module (the grouping program), the NASARC2 module (the arc determination program), the NASARC3 module (the group arc extension program), and the NASARC4 module (the arc interchange program) over all portions of the geostationary orbit that the user has defined within the Segments file. As results are considered to be final only when all segments of the orbit specified by the user have been examined, it is clear that intermediate results achieved using the NASARC1, NASARC2, NASARC3, and NASARC4 modules in one portion of the arc must be stored for possible future consideration as other portions of the arc are examined.

Thus, intermediate files include those files which are generated and used by the NASARC (Version 4.0) program modules on an interim basis; that is, they are files which contain data that are altered or updated periodically by one or more modules for use by other modules in determining a final output solution. As such, these files require no user intervention and may be treated as being transparent to the user. However, the user should be aware of the contents of each such file and their approximate storage requirements, which are presented in the subsequent sections.

### 2.3.2.1 Intermediate Segments File

The **Intermediate Segments** file is identical in format to the **Segments file** discussed in section 2.3.1.1 and contains similar **data**—western and eastern longitudinal limits of portions of the orbital arc and the grouping criterion value to be applied within that segment. However, while the **Segments** file contains portions of the orbit that are yet to be operated on by the NASARC1, NASARC2, NASARC3, and NASARC4 modules, the **Intermediate Segments** file contains portions of the orbital arc that have already undergone analysis by these four modules. At the conclusion of the analysis—when all portions of the orbit have been examined—the **Intermediate Segments** file is identical to the original **Segments** file constructed by the user.

As each segment of orbit within the user's **Segments** file is encountered by NASARC1, it is copied to the bottom of the **Intermediate Segments** file. The **Intermediate Segments** file is then utilized by the NASARC2 module to determine the cumulative orbital arc analyzed in order to rearrange prior allotted arcs for the accommodation of newly allotted arcs within the orbit. Finally, the **Intermediate Segments** file is used by the NASARC4 module to restore the user's original **Segments** file after all portions of the orbital arc listed have been examined for potential arc allocation.

The **Intermediate Segments** file may contain up to 40 records of fixed 80-byte length. Thus, the file may occupy up to 3.2 kilobytes of memory.

### 2.3.2.2 Groups File

The **Groups** file, which is generated by executing the NASARC1 module, is utilized as input by the NASARC2 and NASARC4 modules.

The **Groups** file contains a complete listing of all service areas, their corresponding service arcs, and transitional arcs processed within the most recently examined portion of the orbit. It also contains a complete listing of all compatible groups of service areas (and arc segments over which they exist) that have been found by the NASARC1 module. The NASARC2 module chooses from this list in constructing sets of allotted arcs. As its first record the **Groups** file contains a global transitional arc length that is read and reported by NASARC4.

Actual storage requirements for this file are somewhat difficult to predict since the number of records produced by the NASARC1 module depends on both the number of service areas processed and the set of technical parameters supplied as input. However, NASARC1 (Version 4.0) is capable of generating 90,000 groups and arc segments; the list of service areas processed may occupy up to 300 records of the output file. As each record has a fixed 80-byte length, this file may occupy up to 7.2 megabytes of storage.

### 2.3.2.3 Intermediate Allotted Groupings File

The **Intermediate Allotted Groupings** file, which is generated by the NASARC2 module, is utilized as input by the NASARC1 module and may be updated by the NASARC3 and NASARC4 modules.

As stated in the previous section, the NASARC2 module selects groups of compatible service areas, from the list of groups and arc segments produced by the NASARC1 module, and attempts to allot portions of the orbit to such groups. When the NASARC2 module finishes making such selections, the selections are appended to the list of selections that may have been made in processing prior portions of the orbit within the **Segments** file. Prior selections are also subject to revision by the NASARC2 module should revision become necessary to accommodate the allotted arcs of new groups of administrations. Thus, the **Intermediate Allotted Groupings** file contains all the compatible groups of service areas that have received allotted portions of the geostationary arc via the NASARC2 module. The file also contains, for each such group of service areas, the boundaries of the portion of arc that they have received (the *allotted arc*) as well as the boundaries of the segment of orbital arc over which each such grouping has been found to exist (the *group arc*).

This file is examined by the NASARC3 module, which determines if any group arc may be extended further over the orbit. If such extension is possible for any group within the file, the **Intermediate Allotted Groupings** file is modified to reflect such revised group arcs. The file is also examined by the NASARC4 module in seeking an

improved arrangement of allotted arcs. If such an improved arrangement is found, the intermediate Allotted Groupings file is updated to reflect revised allotted arcs. The Intermediate Allotted Groupings file is then utilized by NASARC1 to eliminate service areas that have already received allotted arcs in prior steps from consideration in the next portion of the arc to be analyzed.

The file may contain up to 150 records of 80 bytes each; therefore, the file may occupy up to 12 kilobytes of memory.

#### 2.3.2.4 Unallotted Groups File

The Unallotted Groups file is utilized as both an input and output file for the NASARC2 module.

As stated earlier, the NASARC1, NASARC2, NASARC3, and NASARC4 modules are exercised repeatedly over the portions of the geostationary orbital arc that the user has defined within the Segments file. This is a cumulative process, which results in the gradual development of a set of groups of compatible service areas and their allotted arcs, over the span of orbital arc locations defined by the user's portions within the Segments file.

At the end of the NASARC2 arc allotment process for a particular segment (and cumulative arc), there may still exist unallotted groups whose group arc extends to one or both edges of this cumulative arc. The Unallotted Groups file saves all groups whose group arc adjoins an edge of any previous cumulative arc. The file also contains the group arc for each such group and the number of member service areas of each group. Since these groups have the potential of existing beyond the bounds of the current cumulative arc, they appear in the NASARC1 output during processing of a future portion of arc in the Segments file. If they appear in the NASARC1 output groups list, their group arcs appear to extend only as far as the bounds of the segment currently being processed. Hence, in order to work with complete group arcs, it is necessary to save the unallotted groups just described and merge them with the groups output by NASARC1 in processing subsequent segments. This is accomplished at the start of each NASARC2 run by appending the unallotted groups to the end of the present NASARC1 groups and combining the group arcs of duplicate groups where they are contiguous. The maximum amount of group arc that exists within the current cumulative arc is then identified for each group.

Storage requirements are somewhat difficult to predict since the size of the file will depend on user-supplied technical parameters; however, 4 megabytes should be a sufficient storage allocation.

#### 2.3.2.5 Intermediate Selection File

The Intermediate Selection file is created and modified by the NASARC2 module. It contains information generated by the NASARC2 module during each step of the arc determination process. The file contains cumulative information in the sense that such information is gathered and retained within the file for each user-specified portion of the orbit that undergoes analysis. As a new portion is analyzed, the information generated is added to existing information generated during performance of the arc determination process on previously analyzed portions of the orbital arc. Thus, by examining the contents of this file, the user may follow the decision-making of the NASARC2 arc generation process as applied to all portions of the arc analyzed.

The file contains information related to the current status of the analysis and to the decision-making processes of arc determination. The current status of the analysis is reflected by the number of user-specified portions of the orbit that have been processed, the longitudinal edges of the cumulative orbital arc span that has been analyzed, and the edges of the portion of the orbit most recently examined. For informational purposes, the data contained in the Input Data file are echoed within the Intermediate Selection file; also included is a list of service areas, service arc boundaries, and any buffer arc lengths included in the most recent analysis of a portion of the arc.

The course of the decision-making processes involved in arc determination may be followed by examining various ordered lists generated by the NASARC2 module. A list of *critical* service areas is produced; it is ordered by the number of occurrences of each such service area in groups contained in the most current list of compatible



groups and group arc segments. That service area occurring in the fewest such groups appears at the top of the list. This list also contains the priority (P1, P2, or P3) with which each service area is to receive an allotted arc length. A list of *critical groups*—compatible groups of service areas which contain the critical service area—is also generated and ordered by group arc boundaries, number of service areas included in the group, and the sum of frequency of occurrence within any group of each critical group member. The frequency of occurrence of any service area within a group is calculated by examining the most current list of compatible groups of service areas. This list is periodically updated as service areas receive allotted arc lengths. While the list itself is not presented in the file, information related to updating this list is presented in the file—for example, the number of groups contained in the list before and after updating, the number of groups from which members were extracted (due to receiving an allotted arc length), and the number of groups (if any) eliminated by selection of the critical group to receive an allotted arc. The updated list is searched to determine if elimination of any service area not a member of the critical group has occurred; such service areas are listed within the Intermediate Selection file as are those service areas for which no allotted arc can be found. Finally, a complete list of groups selected, their arc length requirements, and received allotted arc boundaries is generated.

Exact storage requirements for this file are difficult to predict. Once again, storage requirements depend to a great extent on the scenario undergoing analysis. However, 4 megabytes for records of fixed 80-byte length is felt to be a sufficient allocation for most scenarios.

#### 2.3.2.6 Intermediate Improvement File

The Intermediate Improvement file is created and modified by the NASARC4 module. It contains information generated by NASARC4 during the process of attempting to improve the most current arrangement of allotted arcs in orbit. As was true for the Intermediate Selection file, the information contained in the Intermediate Improvement file is cumulative over all segments of the orbit for which the NASARC4 module has been executed. By examining the contents of this file, the user may follow the decision-making of the NASARC4 Arc Interchange process over all portions of the arc analyzed.

As NASARC4 is executed during each new portion of the orbital arc specified in the Segments file, the program reads and evaluates the arrangement of allotted arcs in orbit most recently determined by NASARC2 as an initial arrangement. The initial arrangement and its corresponding objective values are reported in the Intermediate Improvement file. After evaluating the initial incoming arrangement, the NASARC4 program attempts to find a more efficient initial arrangement by performing improving pair-restricted interchanges of allotted arcs. An interchange is pair-restricted if two candidate arcs may only be interchanged with each other. After this operation, the improved initial arrangement and its objective values are reported in the Intermediate Improvement file. When an efficient initial arrangement has been found, NASARC4 begins to examine alternative arrangements generated by performing interchanges of allotted arcs. As improved arrangements are found, they are compared with the best existing arrangement; NASARC4 determines which arrangement is preferred. As new preferred arrangements are determined, the preferred arrangements are reported, with their objective values, in the Intermediate Improvement file. When no more improved arrangements can be found, the best alternative arrangement is indicated as such and written to the file, along with its objective values. The NASARC4 module then attempts to ensure that allotted arcs within the best existing arrangement have sufficient separation from other allotted arcs. If further separation for a given pair of arcs is not needed, NASARC4 reports that fact in the Intermediate Improvement file. If, however, a pair of allotted arcs requires further separation, this is also reported. The program attempts to gain as much separation as possible by progressively reducing the required spacing between the two arcs. Each such attempt is also reported in the file. Finally, when maximal separation between the necessary allotted arcs has been obtained, the final arrangement of the allotted arcs is reported to the file along with objective function values for the arrangement.

Storage requirements for this file are, once again, difficult to predict; however, an allocation of 200 kilobytes of storage for fixed-length, 80-byte records should be sufficient.

#### 2.3.3 Output Files

Output files are those produced by one or more modules of the NASARC software package that are used to store results at the conclusion of an exercise of the NASARC modules on a particular scenario. These results may be

those of a successful exercise which are output to the NASARC Report file described in section 2.3.3.1, the Condensed Report file described in section 2.3.3.2, and the Predetermined Arc file described in section 2.3.3.3, or they may be those of an unsuccessful exercise—an exercise in which data input errors have resulted in premature termination of one or more modules—which are output to the Error Message file described in section 2.3.3.4.

### 2.3.3.1 NASARC Report File

As stated previously, the NASARC Report file is produced at the conclusion of a successful exercise of the NASARC package on a particular scenario. (“Successful exercise” refers only to the fact that all modules have executed successfully on the input data provided; the user may still wish to improve on the results obtained by altering his or her input data.) The NASARC Report file is produced by the NASARC4 module at the conclusion of examination of all portions of the orbit specified by the user within the Segments file.

The NASARC Report file contains complete information on all scenario input data such as a complete list of service areas considered, their associated service arcs, associated parameters supplied by the user for each service area, a list of all user-specified portions of the orbital arc that have been examined, and a list of all interactively specified input parameters. If applicable, additional information is printed about affiliation of service areas.

Following a complete description of the input supplied to the program, the NASARC Report file presents the results of exercising the NASARC1, NASARC2, NASARC3, and NASARC4 modules on the data just described. First, a table of compatible groups of service areas selected to receive allotted arcs is presented, containing the groups selected, their allotted arc boundaries, their group arc boundaries, the length of their allotted arc, and the number of member service areas contained in each group. Overall results, such as the total amount of orbital arc utilized for allotted arcs, the number of groups of service areas that received such allotted arcs, the number of service areas that received such allotted arcs, and (if any) the number of service areas that did not receive allotted arcs, are presented with the table. A pictorial representation of the allotted portions of the orbit and the groups of service areas to which they have been allotted is produced, presenting a visual summary of the scenario results. Further information, on a service area by service area basis, is presented following the graph. After information for individual service areas is given, detailed information is given, if necessary, for unallotted service areas. This is followed by a cross reference table for three-character and eight-character service area codes.

Exact storage requirements of the NASARC Report file are, once again, dependent on the scenario supplied by the user. However, an allocation of 160 kilobytes for fixed-length, 132-byte records is sufficient for most scenarios.

When printing the NASARC Report file, it is suggested that the carriage control option be selected, as this file contains carriage control characters and the resulting document is easier to read.

### 2.3.3.2 Condensed Report File

The Condensed Report file is also produced by the NASARC4 module at the conclusion of scenario processing. This file contains selected information that is also presented in the NASARC Report file, discussed in the previous section.

As is true for the NASARC Report file, the Condensed Report file contains complete information on all inputs supplied to the NASARC software. Results are then presented, followed by information on unallotted systems (if any) and concluding with a graphical representation of the predetermined arcs found by the NASARC software.

### 2.3.3.3 Predetermined Arc File

For applications of allotment planning of the Fixed Satellite Service at the 1988 World Administrative Radio Conference, the NASARC software was used in conjunction with another planning software package residing at

the International Frequency Registration Board—the ORBIT program. The Predetermined Arc file, which is produced by NASARC4, contains for each service area a three-character code, a corresponding eighth-character code, the western boundary of the system's allotted arc, and the eastern boundary of the system's allotted arc. This information was utilized by an external interface program to modify arc limits for each service area within the Requirements Data file prior to using the modified file as input to the ORBIT program.

For the reasons just stated, it is not strictly necessary to generate the Predetermined Arc file. However, the file is a useful short summary of the results of the NASARC programs on arc placement of systems for individual service areas.

The Predetermined Arc file may occupy up to 24 kilobytes of memory, composed of up to 300 80-byte records.

#### 2.3.3.4 Error Message File

The Error Message file may be written to by any of the NASARC0, NASSEP, NASARC1, NASARC2, NASARC3, or NASARC4 modules under a variety of circumstances. Generally, these circumstances represent errors in data input that result in a premature termination of the appropriate modules. Should the user encounter such a premature termination, the Error Message file is an aid to discovering the source of the problem. Generally, error messages that are written to the Error Message file are also written to the user's terminal; the file provides a record of such messages for consideration at the user's leisure.

As errors that produce error messages are generally of sufficient severity to halt execution of the program, the Error Message file will almost always contain only one such message. Thus, a storage allocation of 0.8 kilobyte for fixed-length, 80-byte records should be adequate.

### 3.0 USE OF NASARC SOFTWARE PACKAGE IN PLANNING EXERCISES

This section provides the user with the information necessary to utilize the NASARC (Version 4.0) software package for generation of predetermined arcs for allotment planning exercises. Interface (NASINTRF), input (NASARC0), satellite separation (NASSEP), grouping (NASARC1), arc determination (NASARC2), group arc extension (NASARC3), and arc interchange (NASARC4) program structures are briefly discussed with the aid of flowcharts also provided in this section. Guidelines for preparing input files are given as are suggestions for interactively input technical parameter values. Suggestions for using ORBIT in conjunction with NASARC are also given. Finally, a complete list of program-generated error messages is given along with information on possible causes of such errors.

It is suggested that the user refer to the *NASARC (Version 4.0) Technical Manual* for detailed information on the technical basis of the NASARC (Version 4.0) software package. It is also suggested that, if he or she has not done so, the user refer to section 2.0 of this manual for information on input and output file structures and formats as this information will greatly aid the user in constructing new files.

#### 3.1 Overview of NASARC Procedure and Program Structures

During the development of the NASARC software package, it was recognized that, for the software to be useful for planning exercises involving large numbers of service areas, a *piecewise* approach to allotting orbital arcs would have to be applied to the geostationary orbital arc. The NASARC procedure allows the NASARC1, NASARC2, NASARC3, and NASARC4 modules to be applied in such a piecewise approach to a user-specified partitioning of the orbital arc into individual segments of arc to be successively examined. The user is referred to figure 3.1-1, which presents a flowchart of the NASARC procedure, and to figure 3.1-2, which presents a flowchart of the interaction between modules.

Before using any of the NASARC0, NASSEP, NASARC1, NASARC2, NASARC3 or NASARC4 modules, it is necessary to create input files for the programs. If the user possesses a Requirements Data file (see section 2.3.1.2), NASINTRF—the *interface* program—may be utilized to create the Service Area file, the Point Sets file, and the Affiliated Sets file. If the files are to be created independently of the interface program, they must adhere to the formats described in sections 2.3.1.3, 2.3.1.4, and 2.3.1.5, respectively.

Prior to use of the NASARC1, NASARC2, NASARC3, and NASARC4 modules within a portion of the orbit, it is necessary to collect data from the user and to verify the input data supplied in external files to assure that the NASARC1, NASARC2, NASARC3, and NASARC4 modules will be able to execute successfully. These functions are performed by the NASARC0 module—the *input* program. The NASARC0 module is utilized once (see figs. 3.1-1 and 3.1-2); the data that are collected and verified are then utilized over all portions of the orbit to be examined for the given scenario.

Required satellite separations are needed as input data by both the NASARC2 and NASARC4 programs to determine the most compatible arrangement of allotted arcs within the orbit. The satellite separations are calculated by NASSEP—the *satellite separations* program. Since NASSEP also requires the input data supplied to NASARC0, it is executed just after NASARC0 in the NASARC procedure. The resulting separation matrix file may then be used in the remaining steps of the procedure.

Within each segment of the arc examined within the NASARC procedure, several major functions must be performed to obtain allotted arcs for service areas. First, all possible compatible groupings of service areas and the arc spans over which each such grouping exists (the group arc) must be determined within the portion of the orbit currently being examined. This function is accomplished by the NASARC1 module—the *grouping* program. Next, selections of compatible groups and allotted arcs must be made in a manner which includes as many service areas as possible and which provides each chosen group with an allotted arc within its group arc. This function is accomplished by the NASARC2 module—the *arc determination* program. Groups of service areas that have been selected to receive allotted arcs within their group arcs must next be examined to determine if their group arcs may be extended further into the orbit. This step is necessary to provide as much flexibility as possible in remaining portions of the orbit when exercising the arc determination procedure, as the procedure may need to adjust previously allotted arcs in order to accommodate new allotted arcs. This function—the extension of group arcs for possible future use—is performed by NASARC3—the *group arc extension* program. Finally, it is possible that the existing arrangement of allotted arcs found by NASARC2 may be improved with respect to compatibility of systems in adjacent allotted arcs. This function is performed by NASARC4—the *arc interchange* program.

A flowchart illustrating the sequence of, and interaction between, the NASINTRF, NASARC0, NASSEP, NASARC1, NASARC2, NASARC3, and NASARC4 modules appears in figure 3.1-2. The data conversion and translation operations performed by the NASINTRF module are illustrated in the flowchart appearing in figure 3.1-3. The data-gathering and verification operations performed by the NASARC0 module are illustrated in the flowchart appearing in figures 3.1-4(a) to (c). The operations of the NASSEP module are illustrated in the flowchart appearing in figures 3.1-5(a) and (b). The operations of the NASARC1 module, are described by the flowchart contained in figures 3.1-6(a) to (f), 3.1-7(a) to (d), and 3.1-8. Processes of the NASARC2 module, are described in the flowchart in figures 3.1-9(a) to (b) and 3.1-10(a) to (c). The operations performed in NASARC3 are illustrated in the flowchart appearing in figures 3.1-11(a) to (e). Finally, the operations performed by the NASARC4, module are illustrated in the flowcharts appearing in figures 3.1-12(a) to (g), 3.1-13(a) to (b), and 3.1-14(a) to (c). These flowcharts are referred to throughout the remainder of this section when the NASARC modules are described. Where possible, references are also made to specific subroutine names; the user will recall that complete lists of subroutine names for the NASARC modules appear in tables 2.2-2 through 2.2-8. (Text resumes on page 70.)

### 3.1.1 NASINTRF Module

The NASINTRF module, as stated previously, serves as an interface from the Requirements Data file (see section 2.3.1.2) to the remaining NASARC modules. The NASINTRF module extracts and translates data from the Requirements Data file into files that are usable by NASARC—the Service Area file, the Point Sets file, and the Affiliated Sets file.

# The NASARC EXEC Procedure

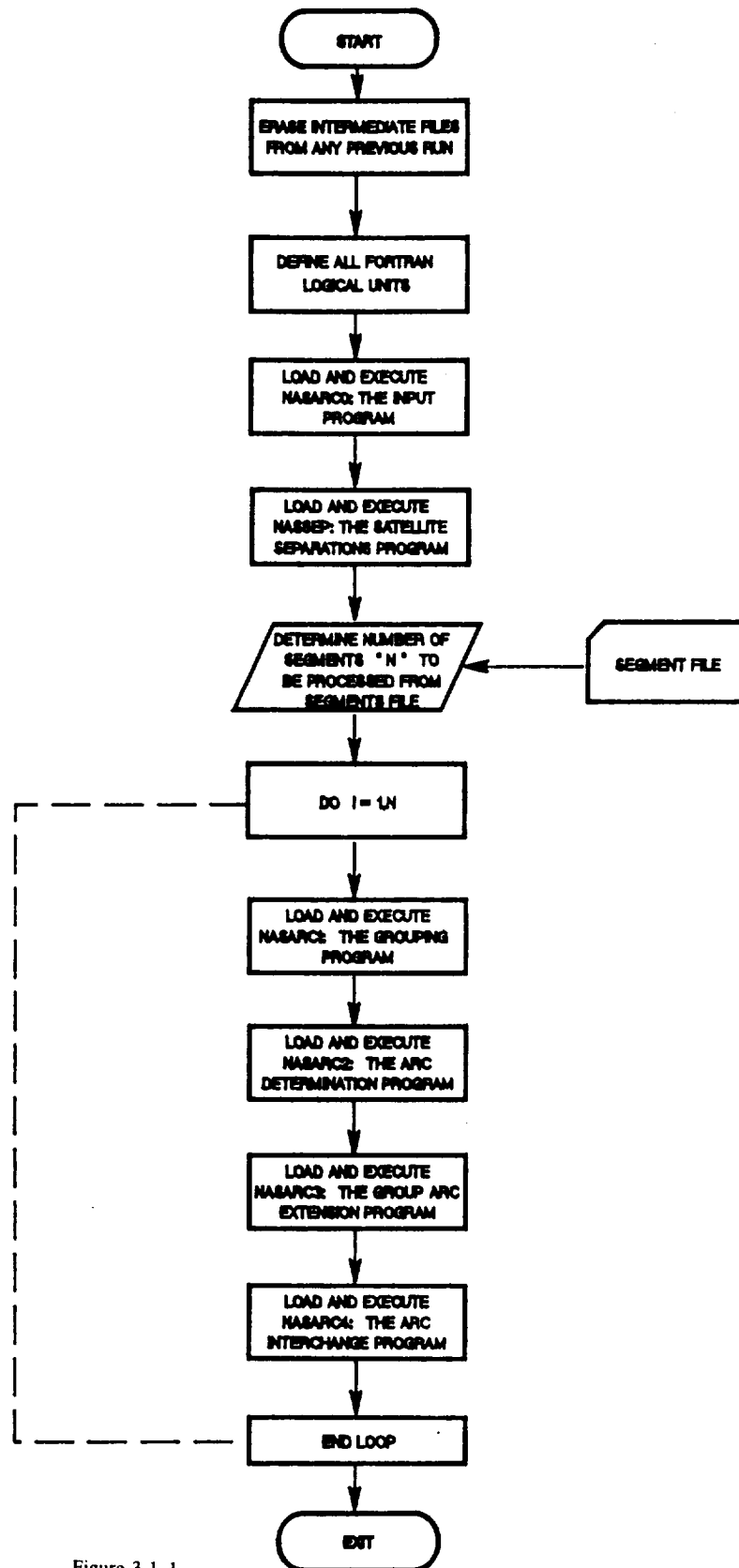


Figure 3.1-1.

# NASARC Program Module File Overview

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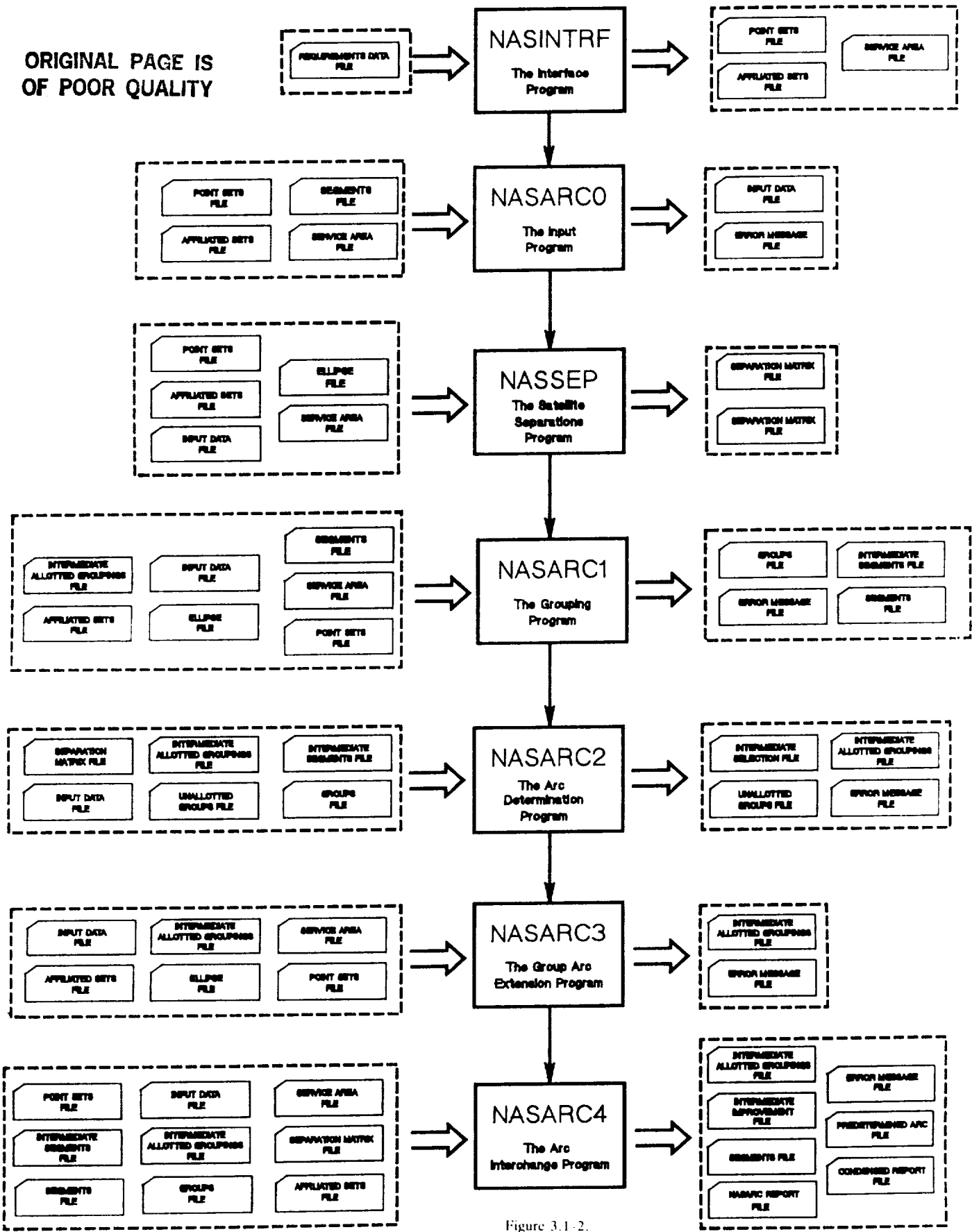


Figure 3.1-2.

# NASINTRF -- The Interface Program

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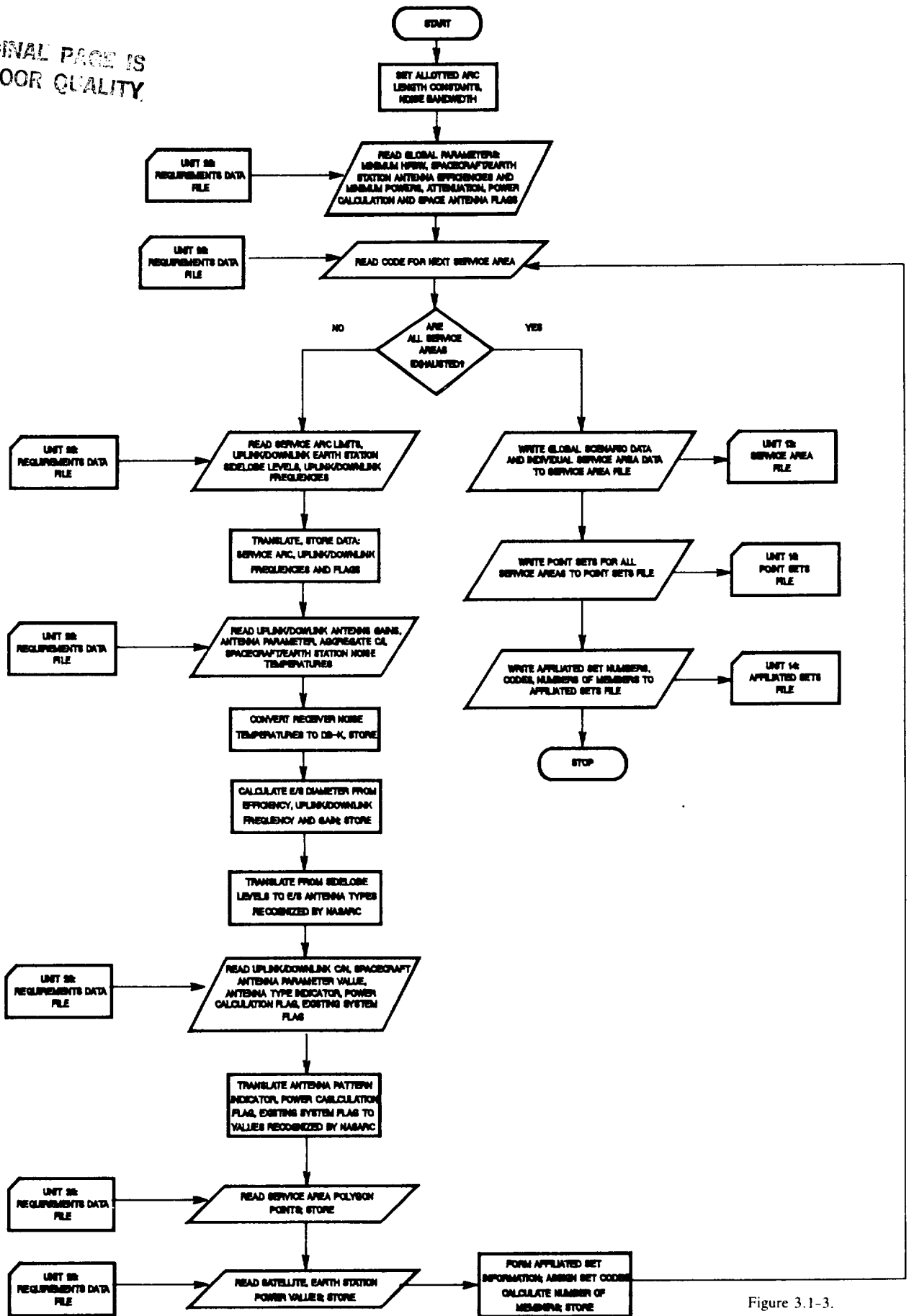


Figure 3.1-3.

# NASARCO -- The Input Program

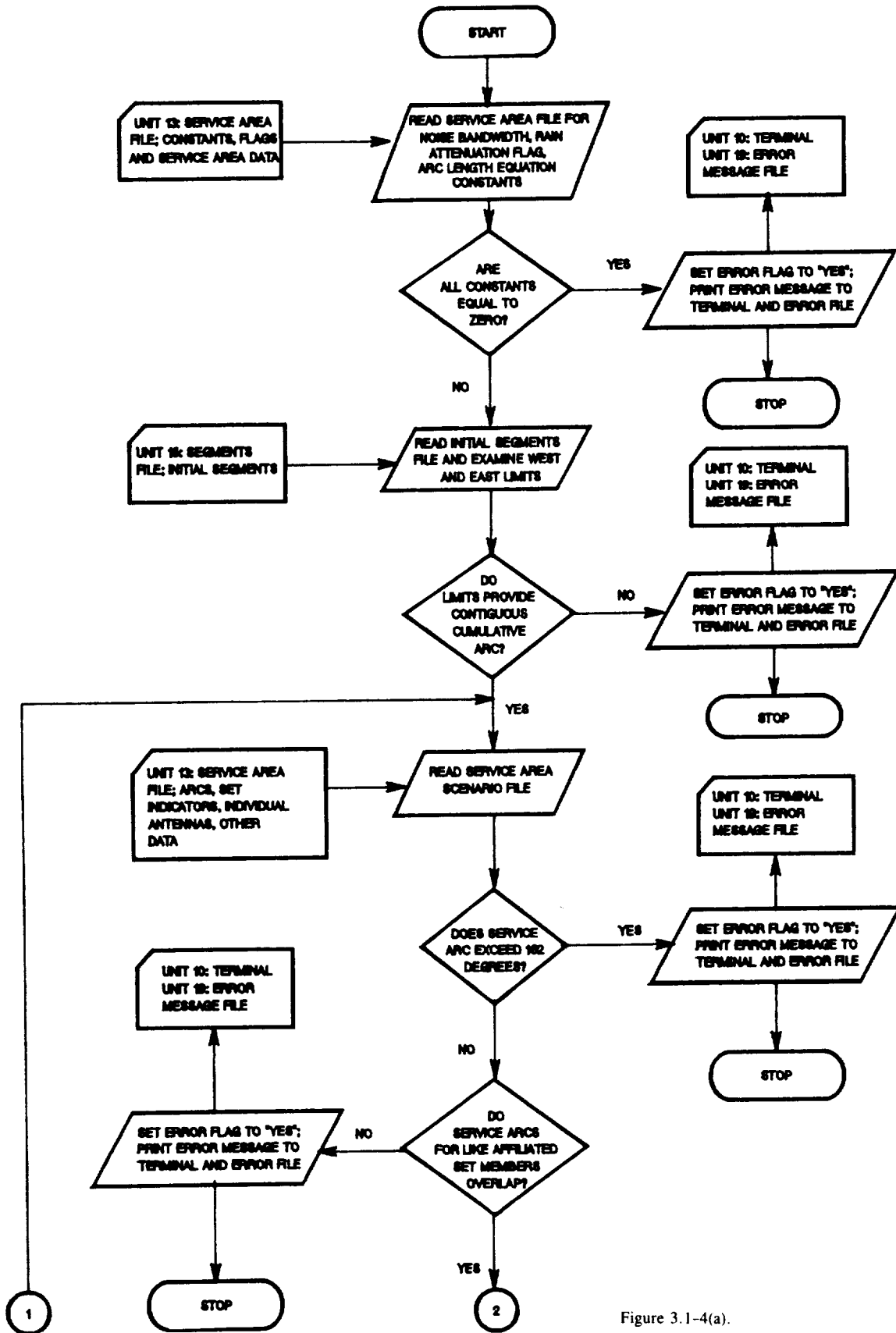


Figure 3.1-4(a).



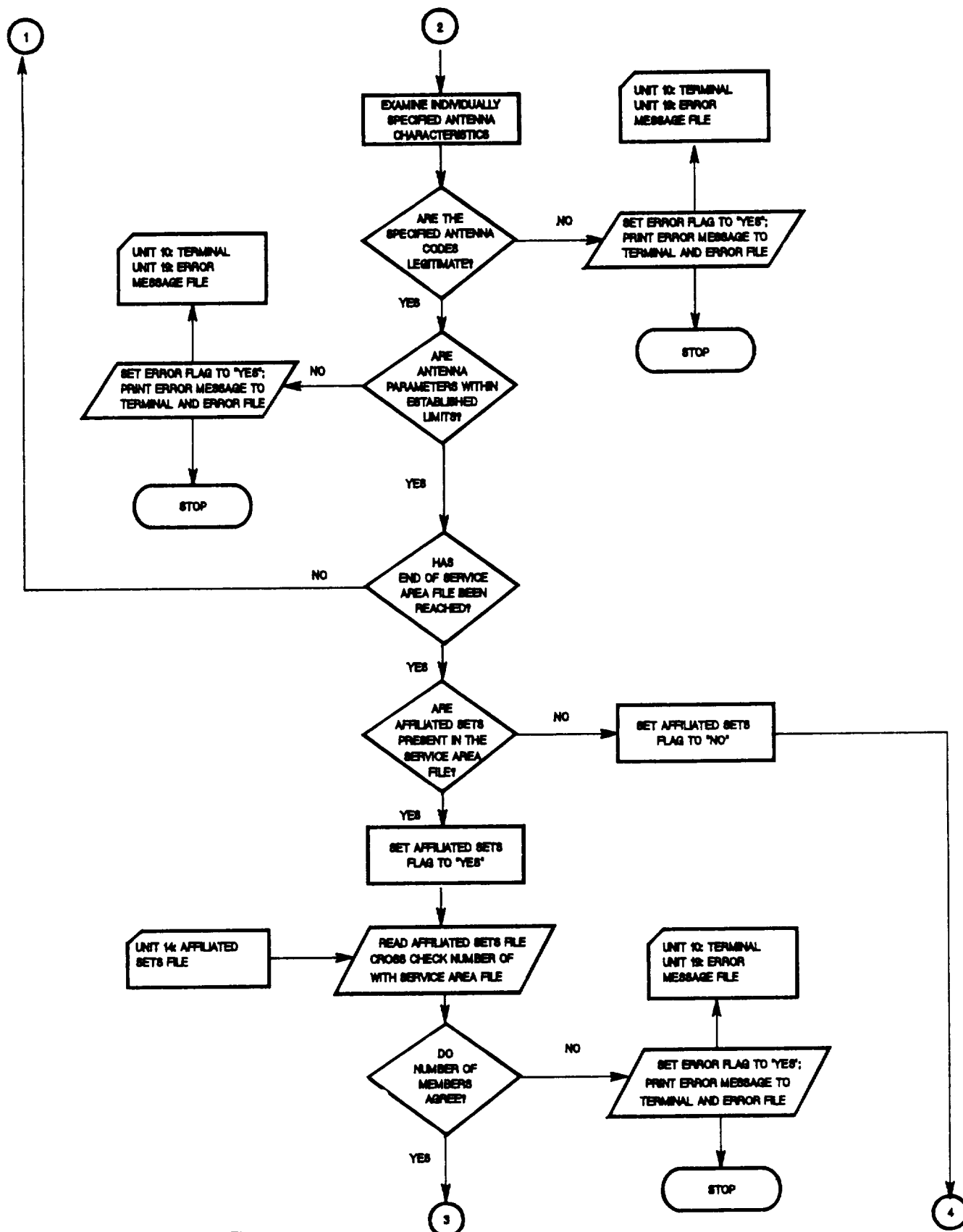


Figure 3.1-4(b).

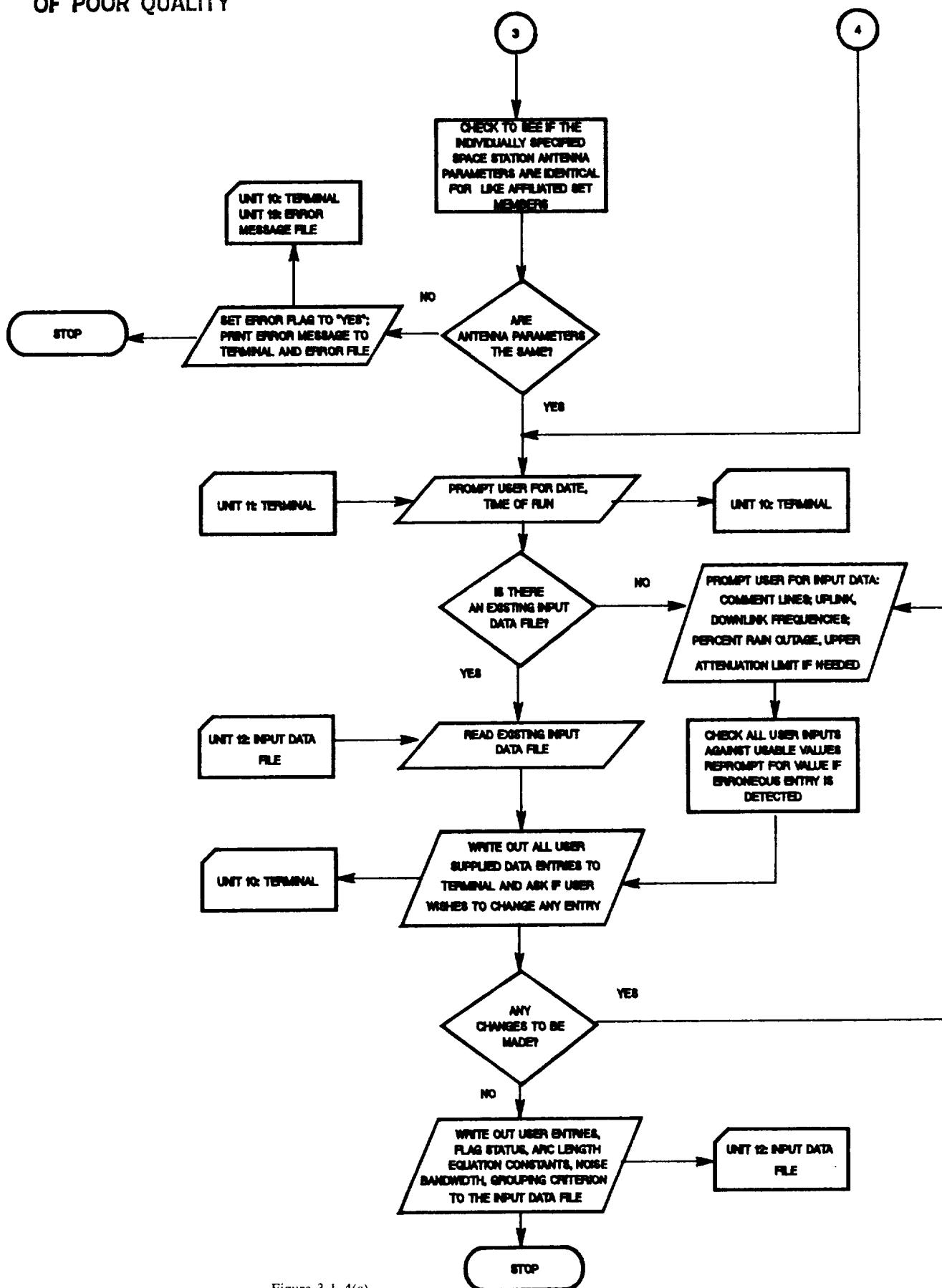


Figure 3.1-4(c).

# NASSEP -- The Satellite Separations Program

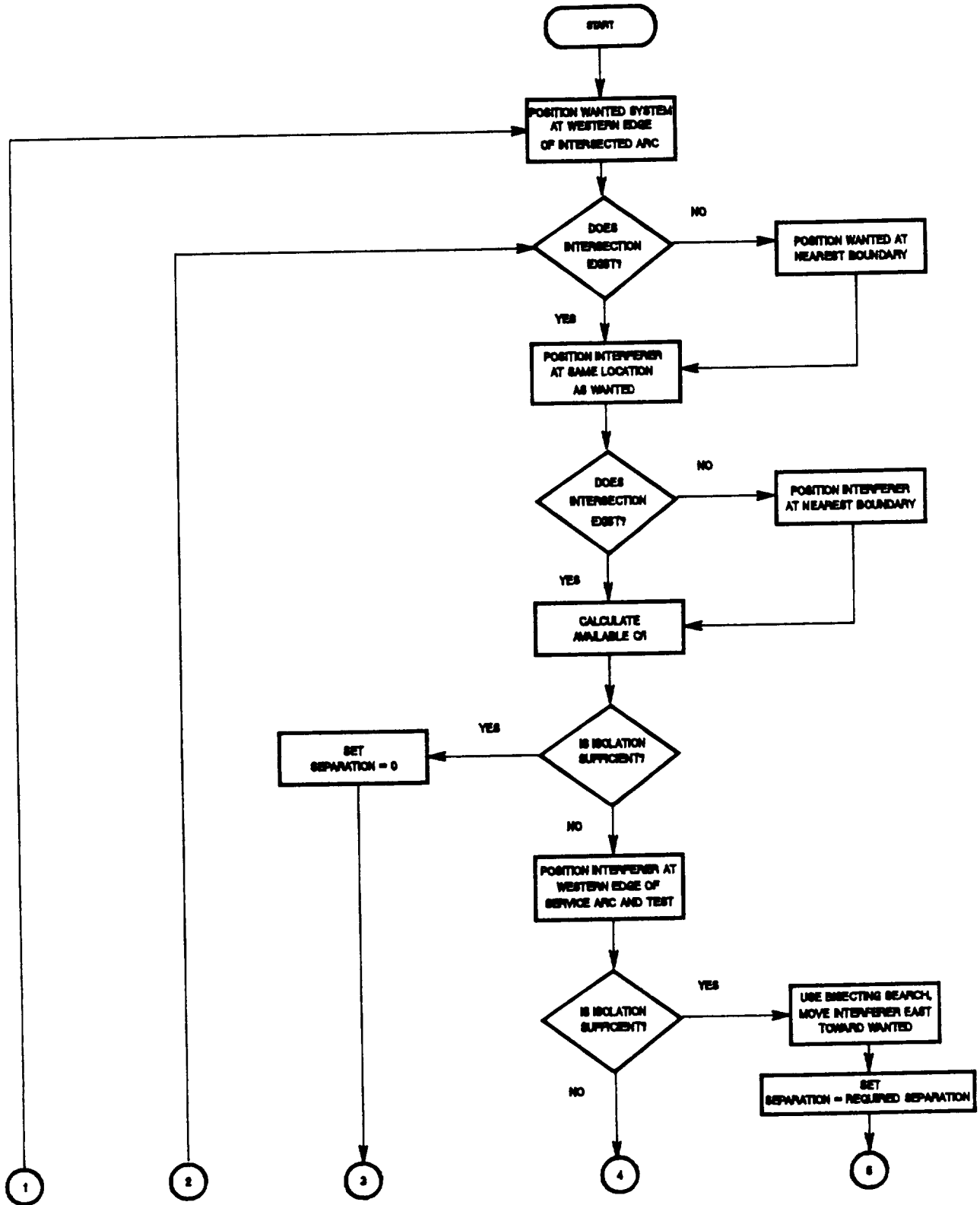


Figure 3.1-5(a).

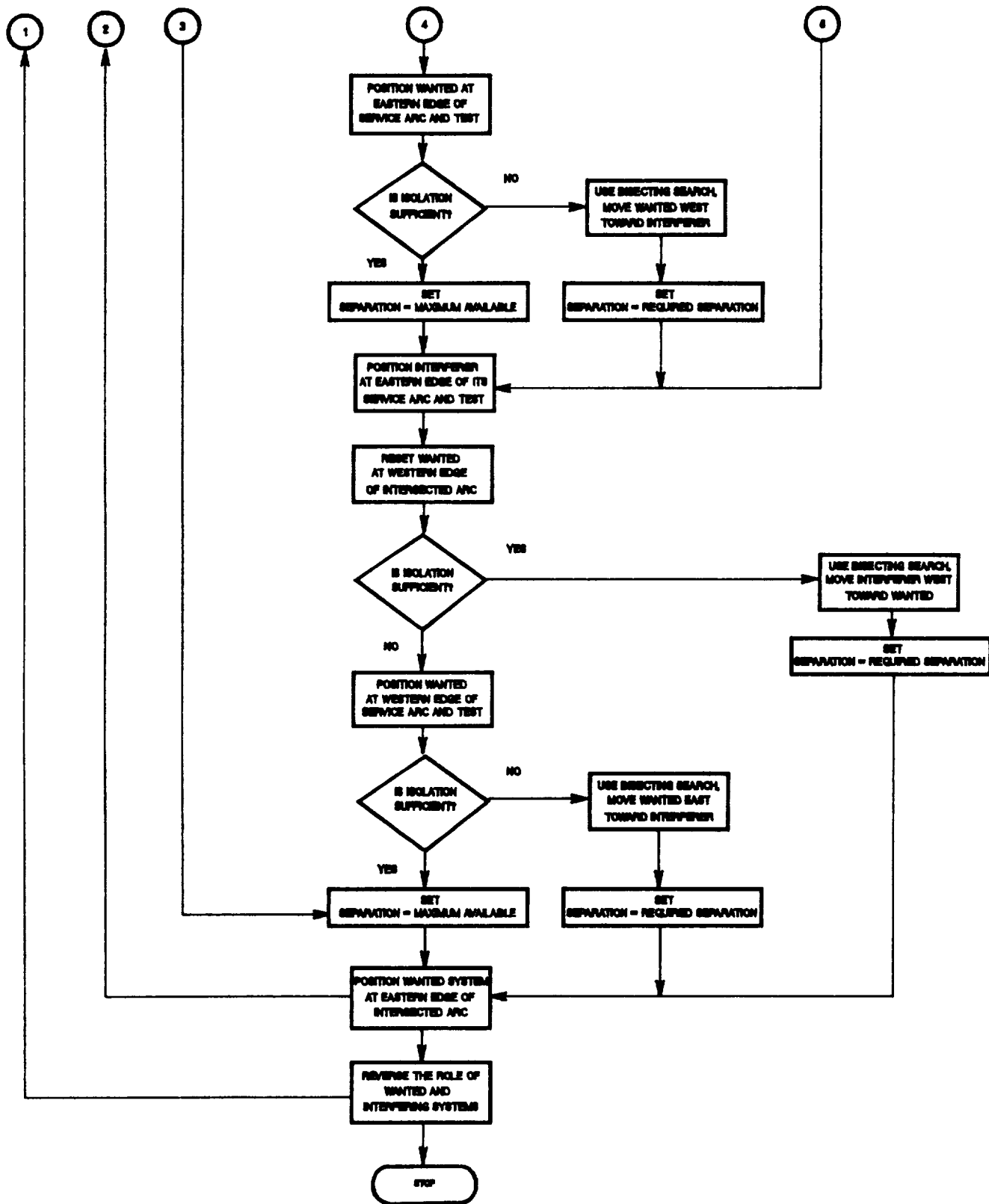


Figure 3.1-5(b).

# NASARC1 -- The Grouping Program

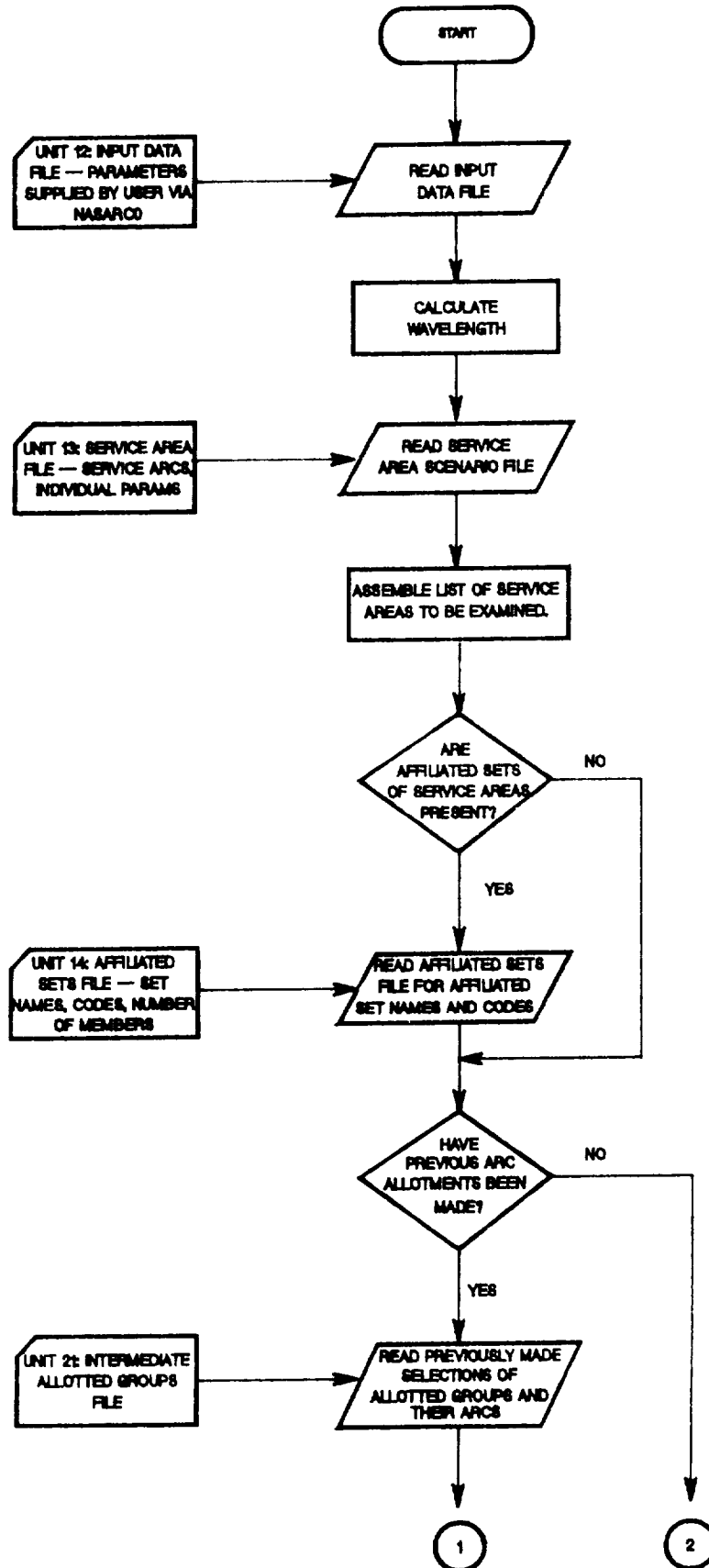


Figure 3.1-6(a).

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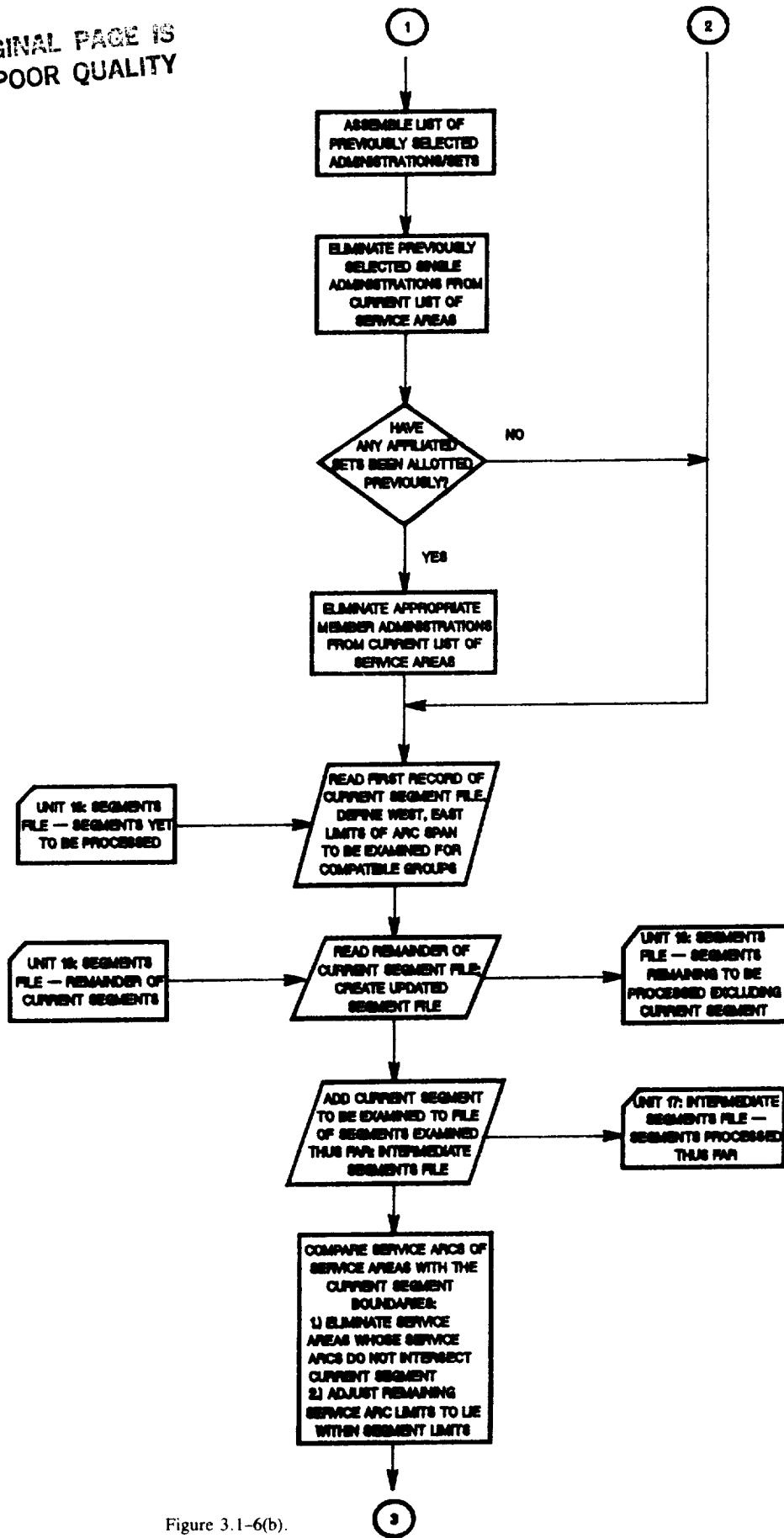


Figure 3.1-6(b).

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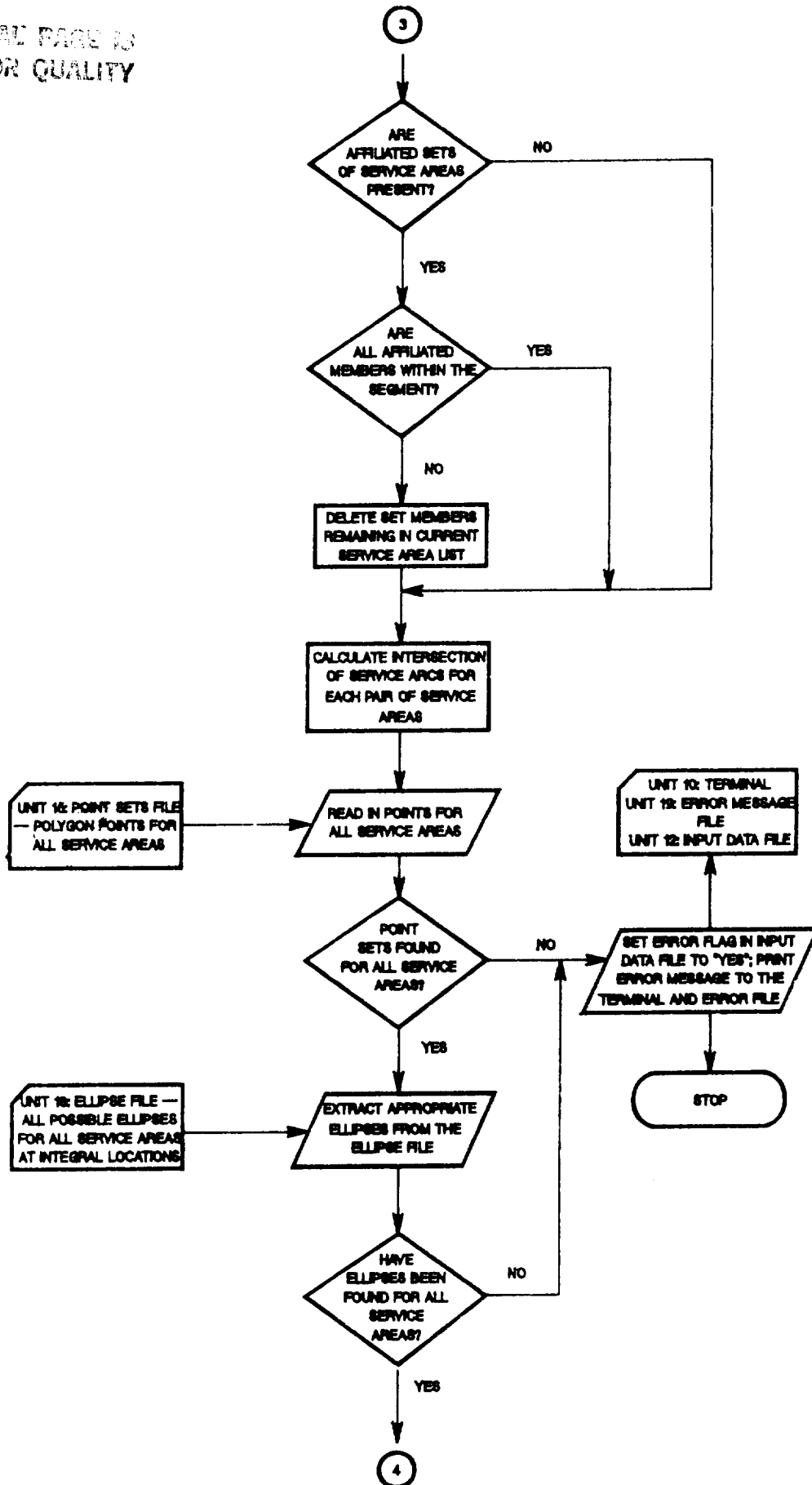


Figure 3.1-6(c).

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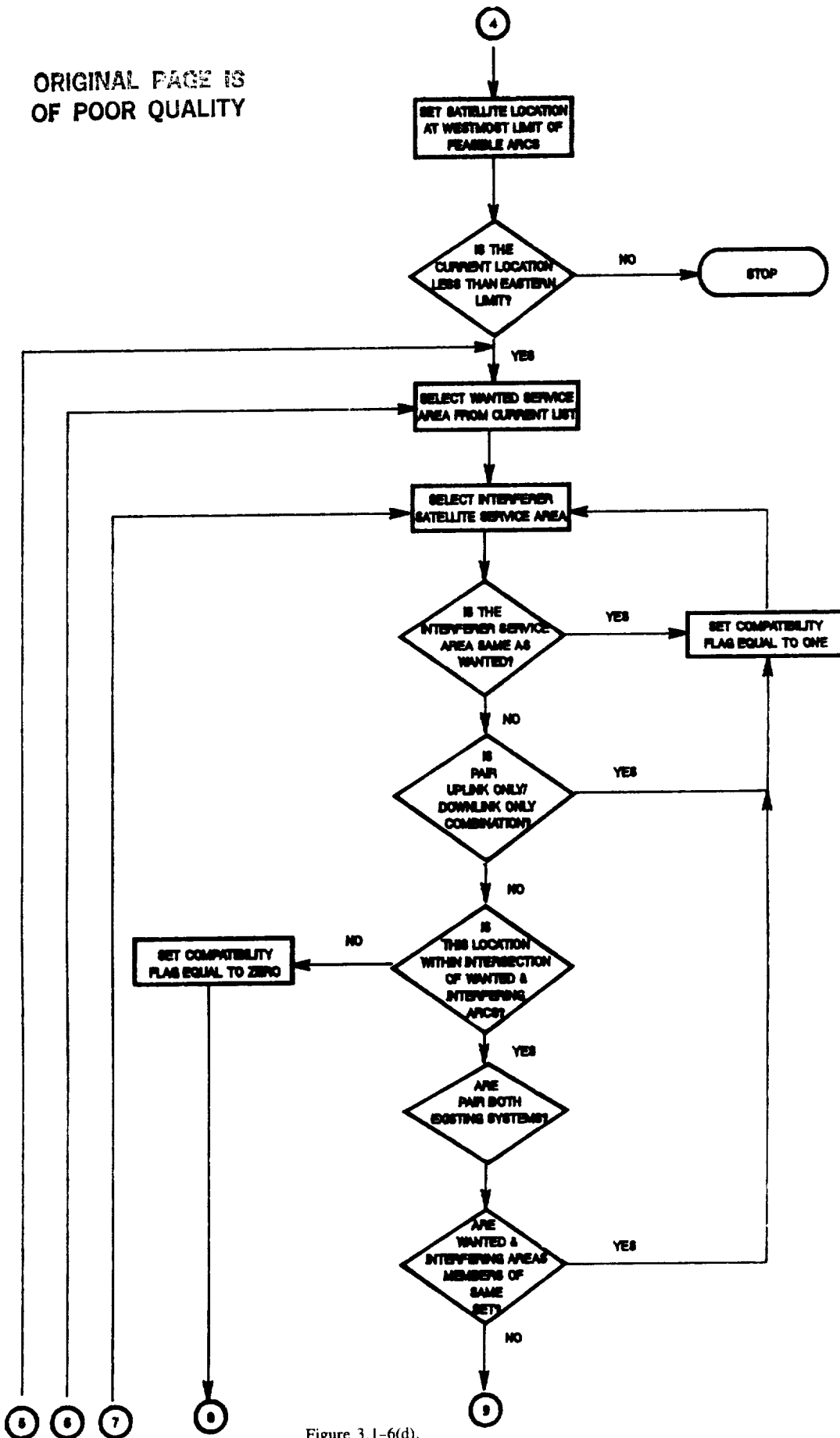


Figure 3.1-6(d).



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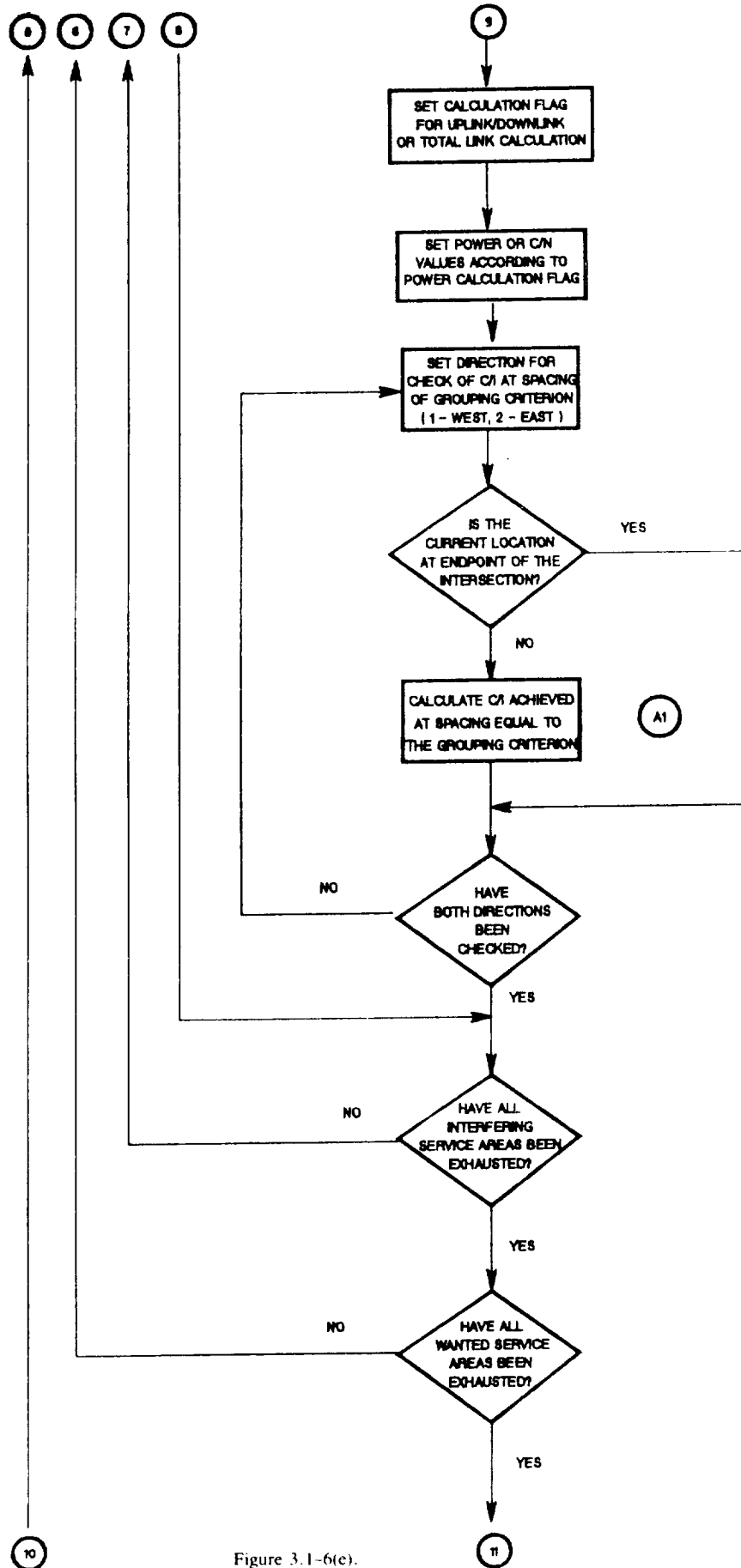


Figure 3.1-6(e).

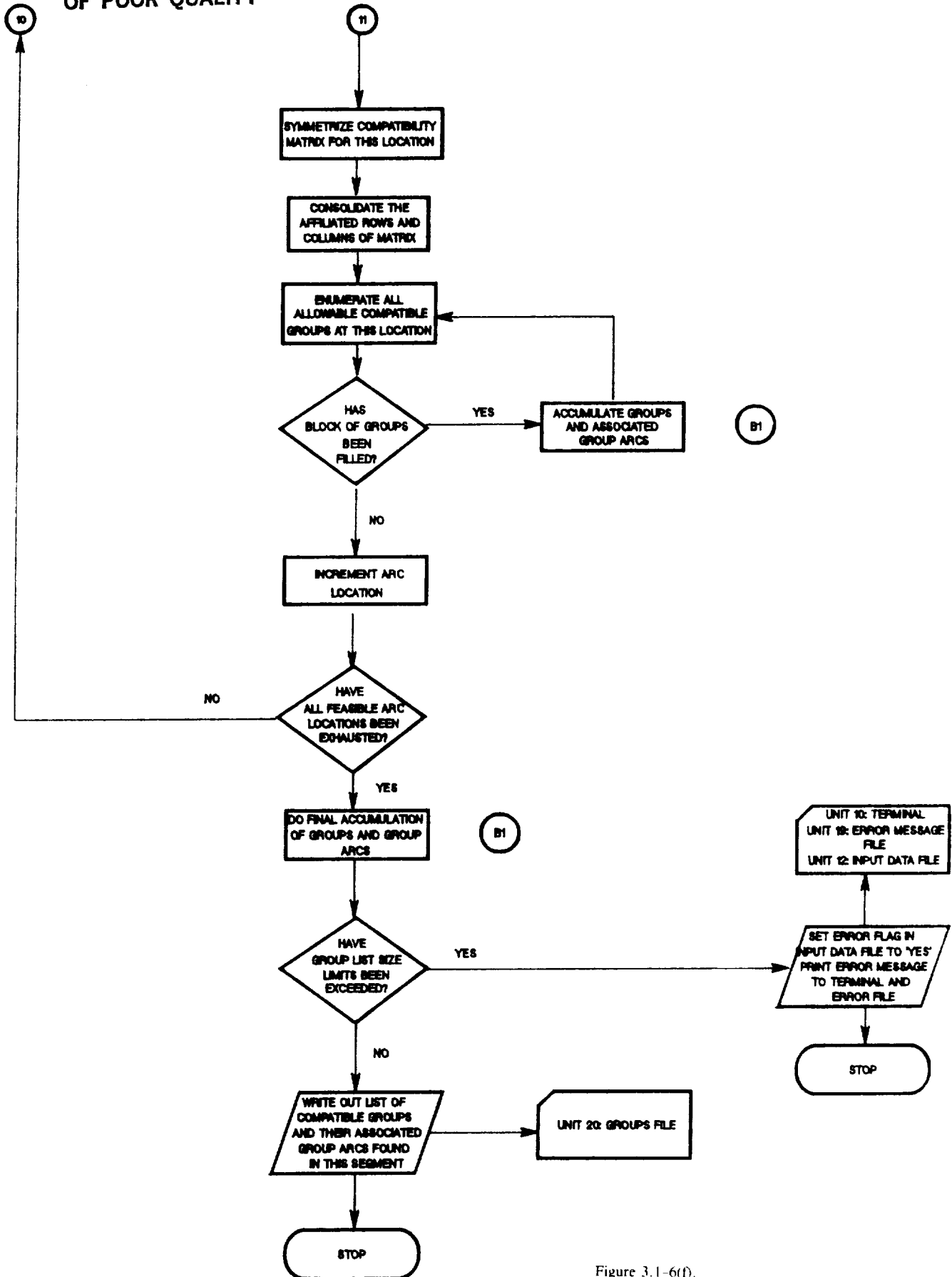


Figure 3.1-6(f).

### Verification of Sufficient Space Station Separation at Grouping Criterion

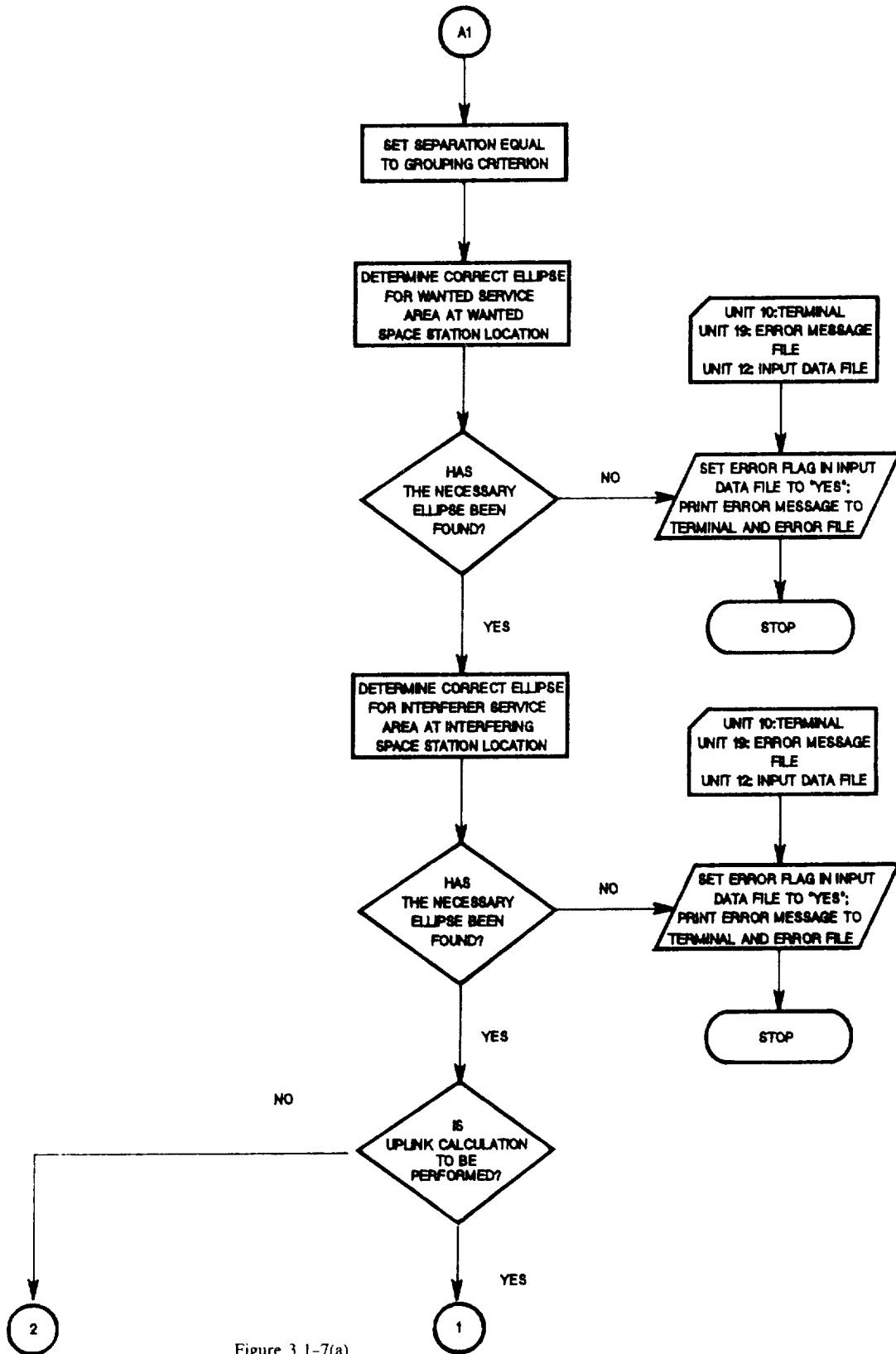


Figure 3.1-7(a).

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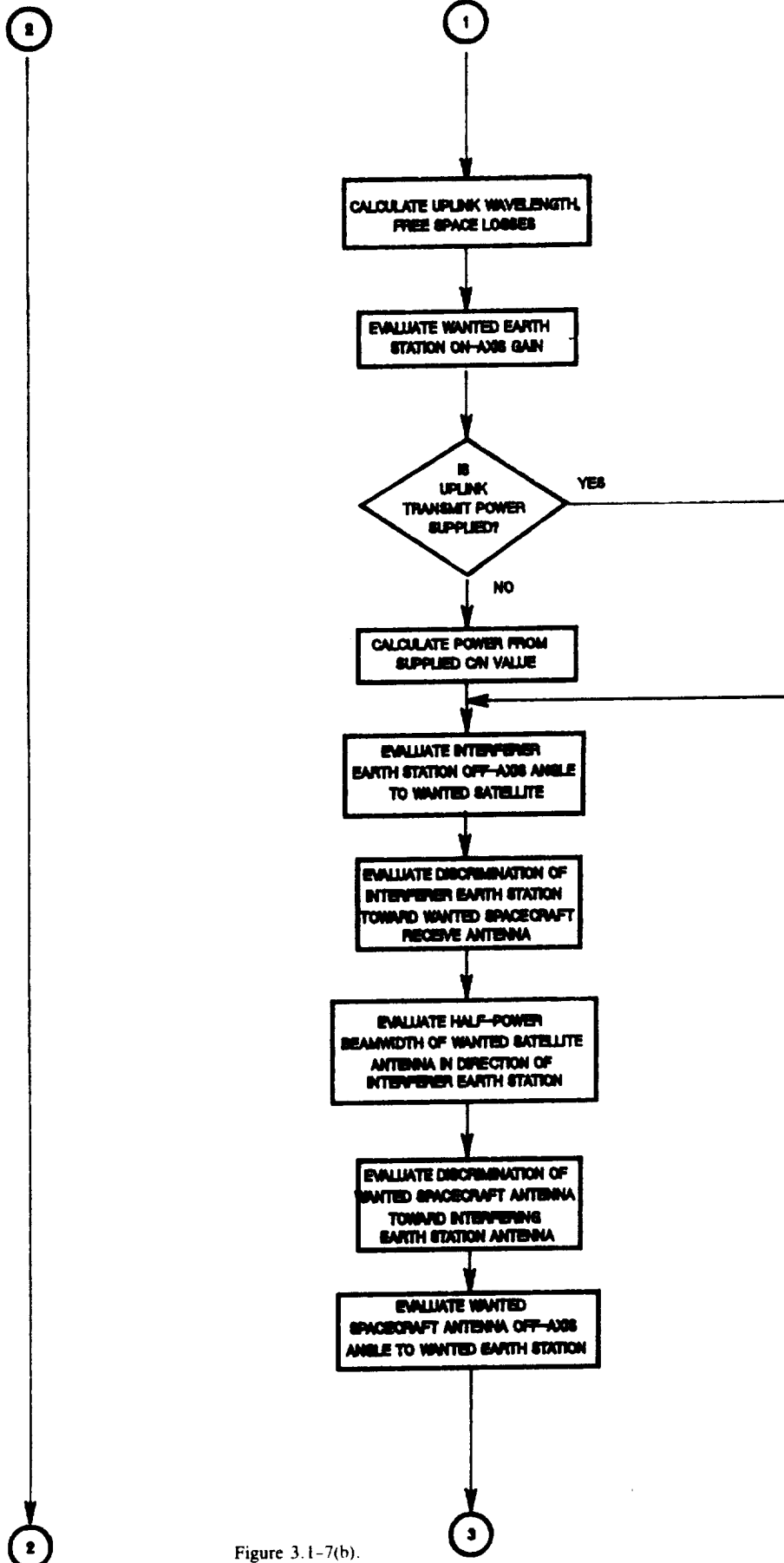


Figure 3.1-7(b).

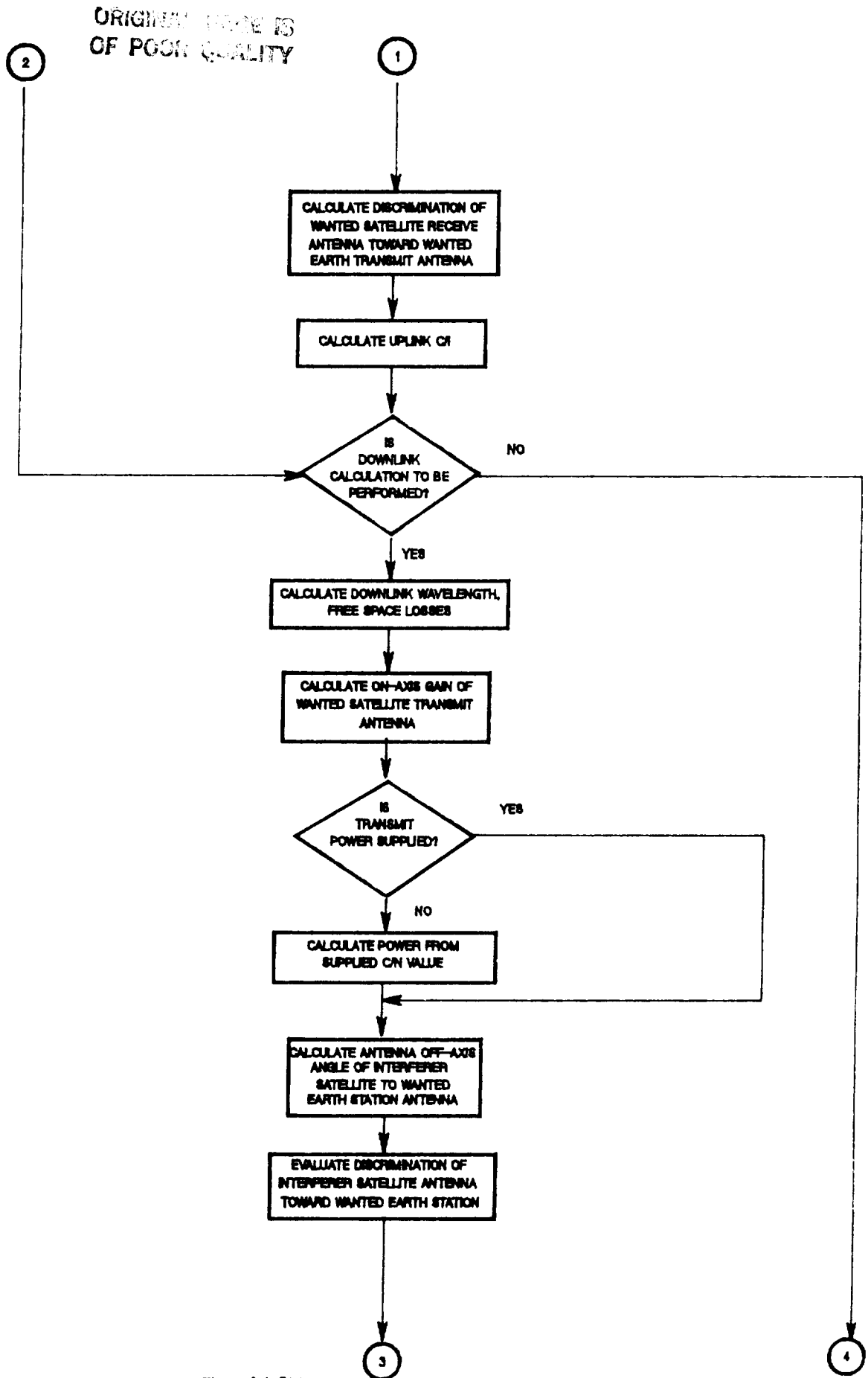


Figure 3.1-7(c).

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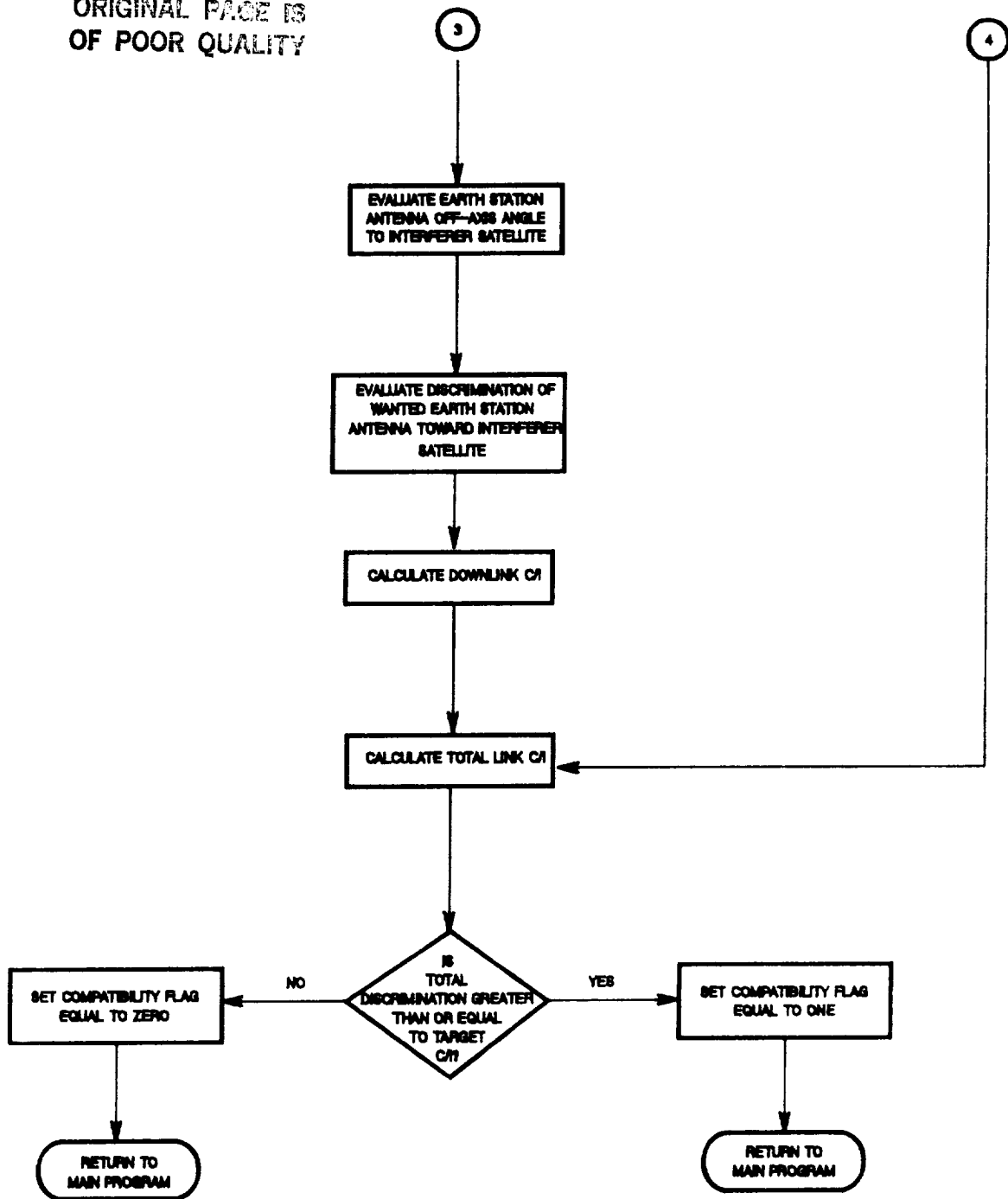


Figure 3.1-7(d).

## FORMATION OF GROUP ARC SEGMENTS AND CREATION / UPDATING OF MASTER GROUPS LIST

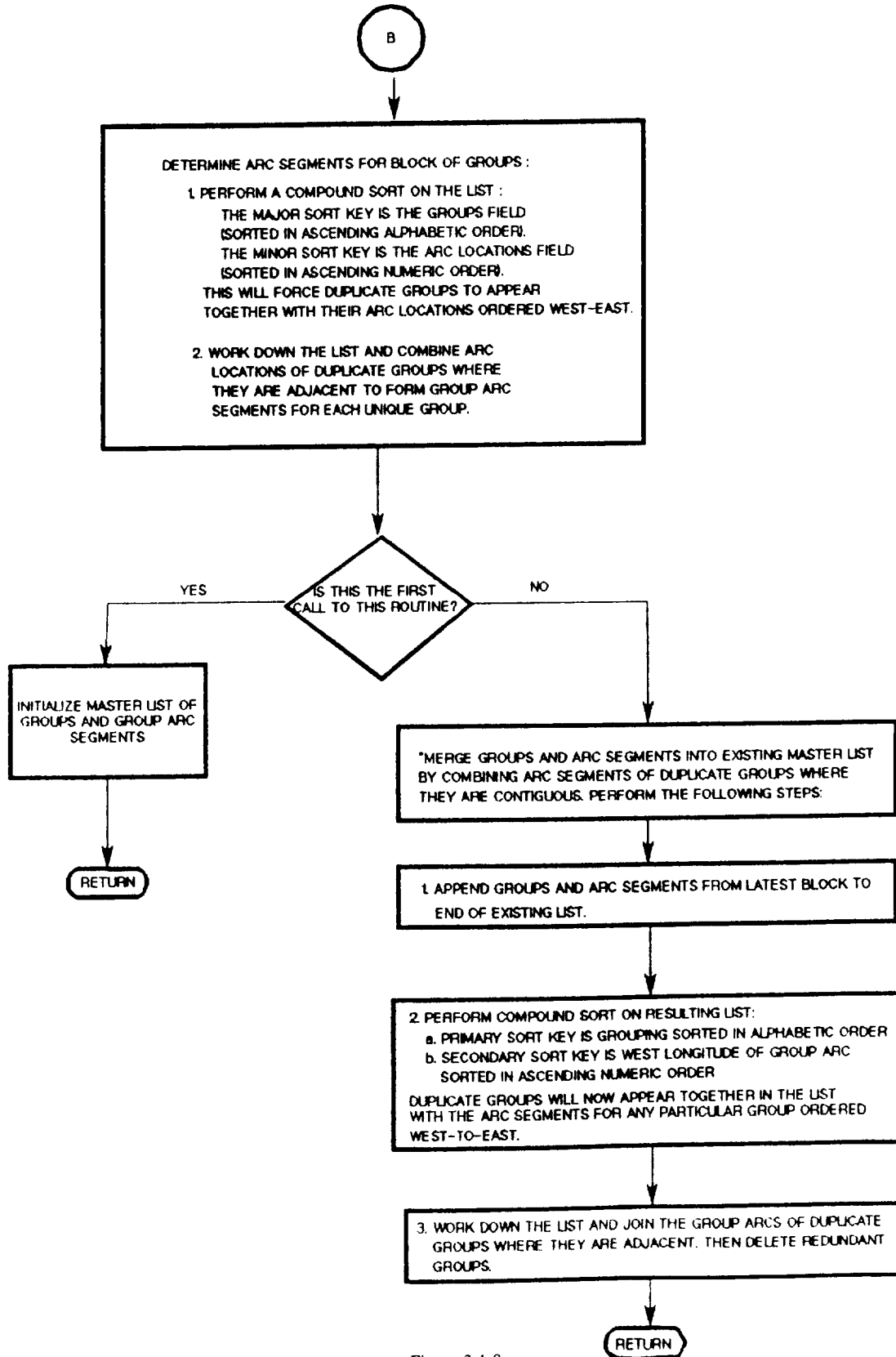


Figure 3.1-8.

# NASARC2 - THE ARC DETERMINATION PROGRAM

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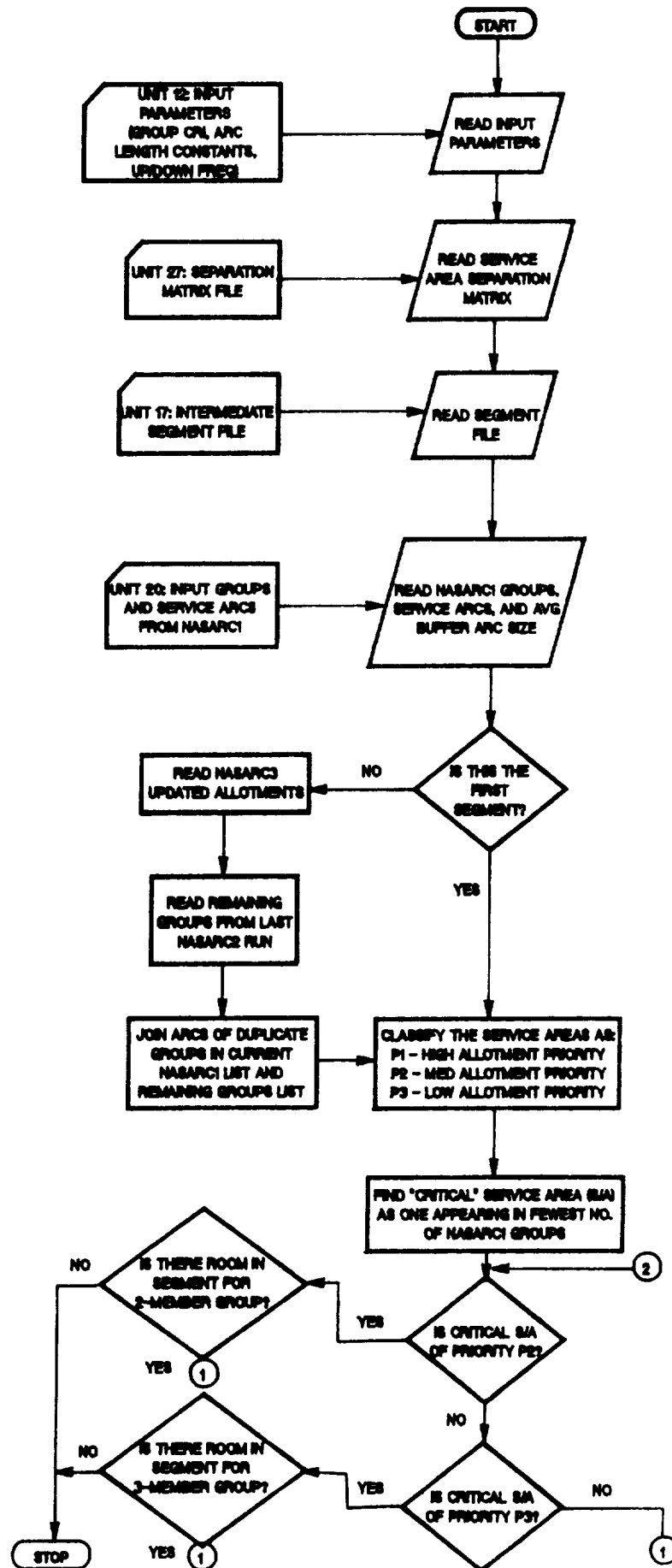


Figure 3.1-9(a).



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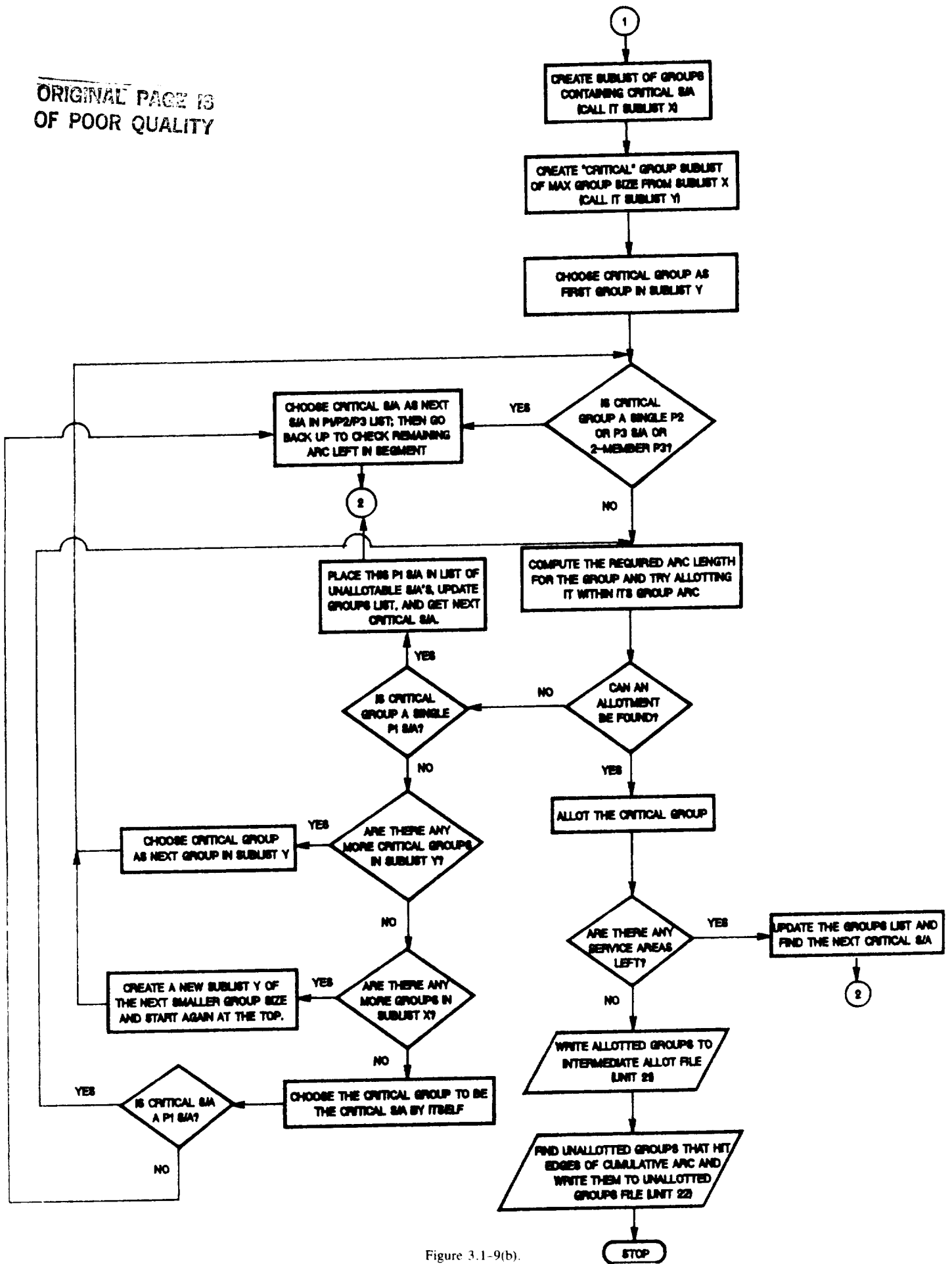


Figure 3.1-9(b).

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NASARC2  
ALLOTTED ARC  
SUBROUTINE

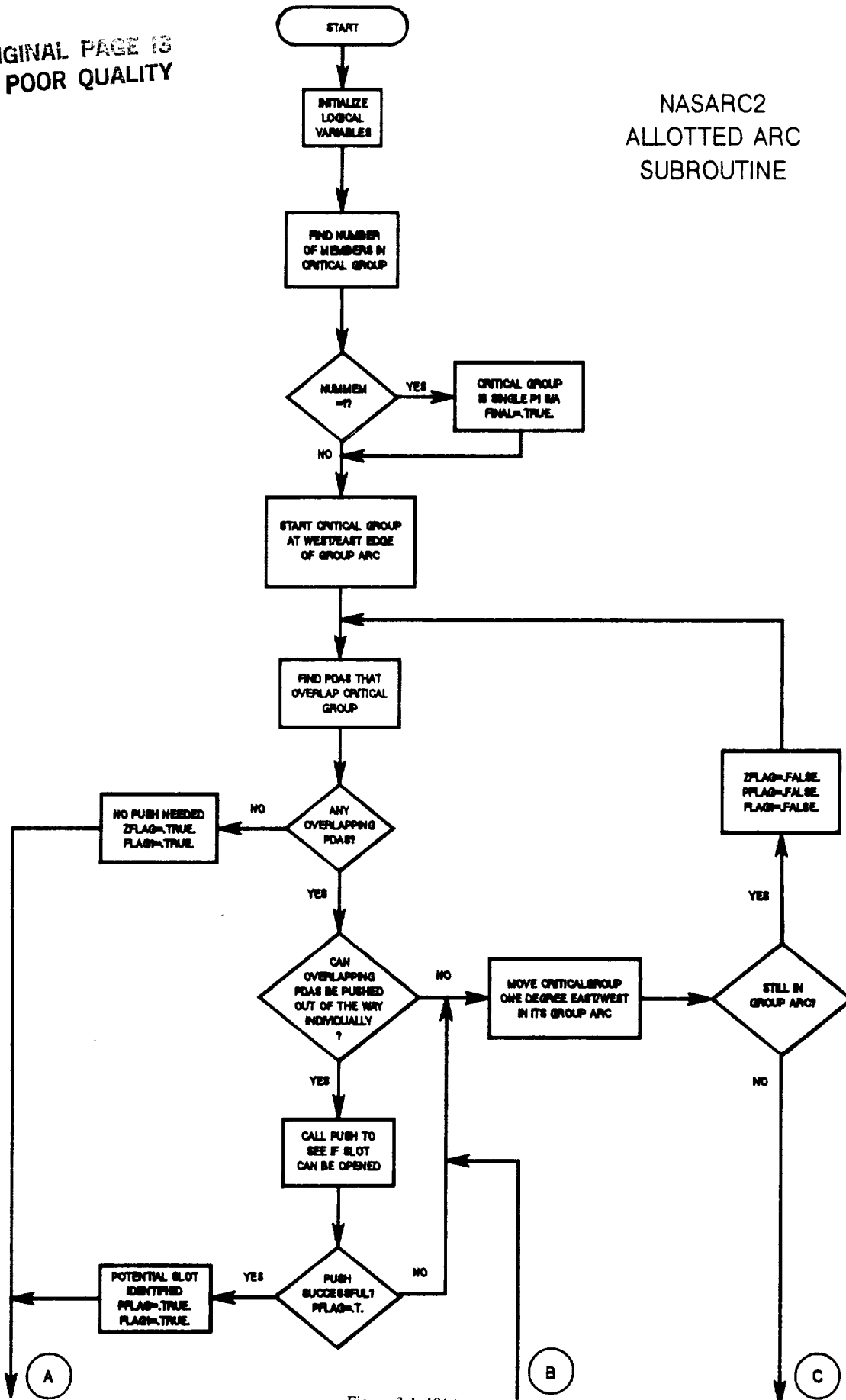


Figure 3.1-10(a).

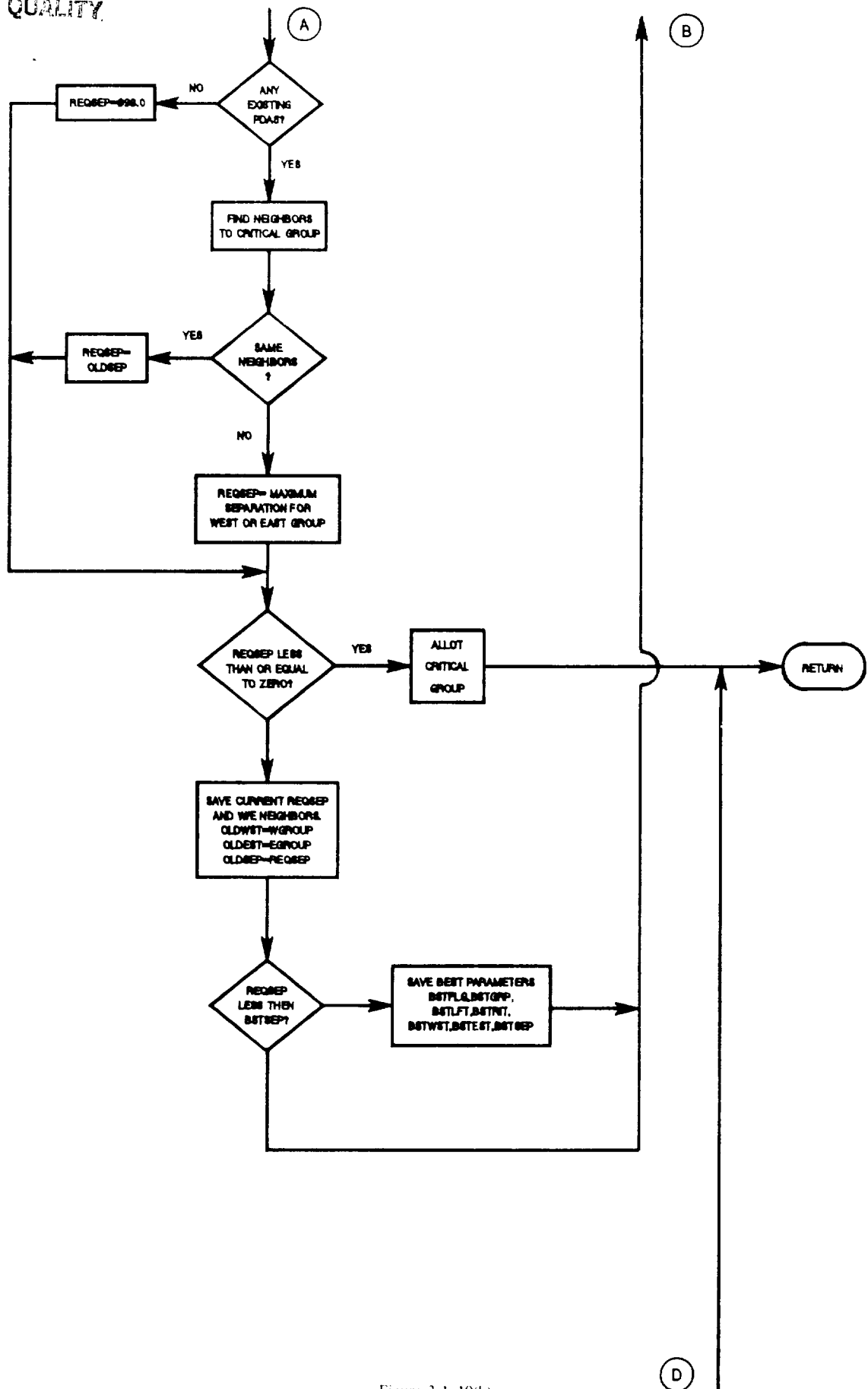


Figure 3.1-10(b).

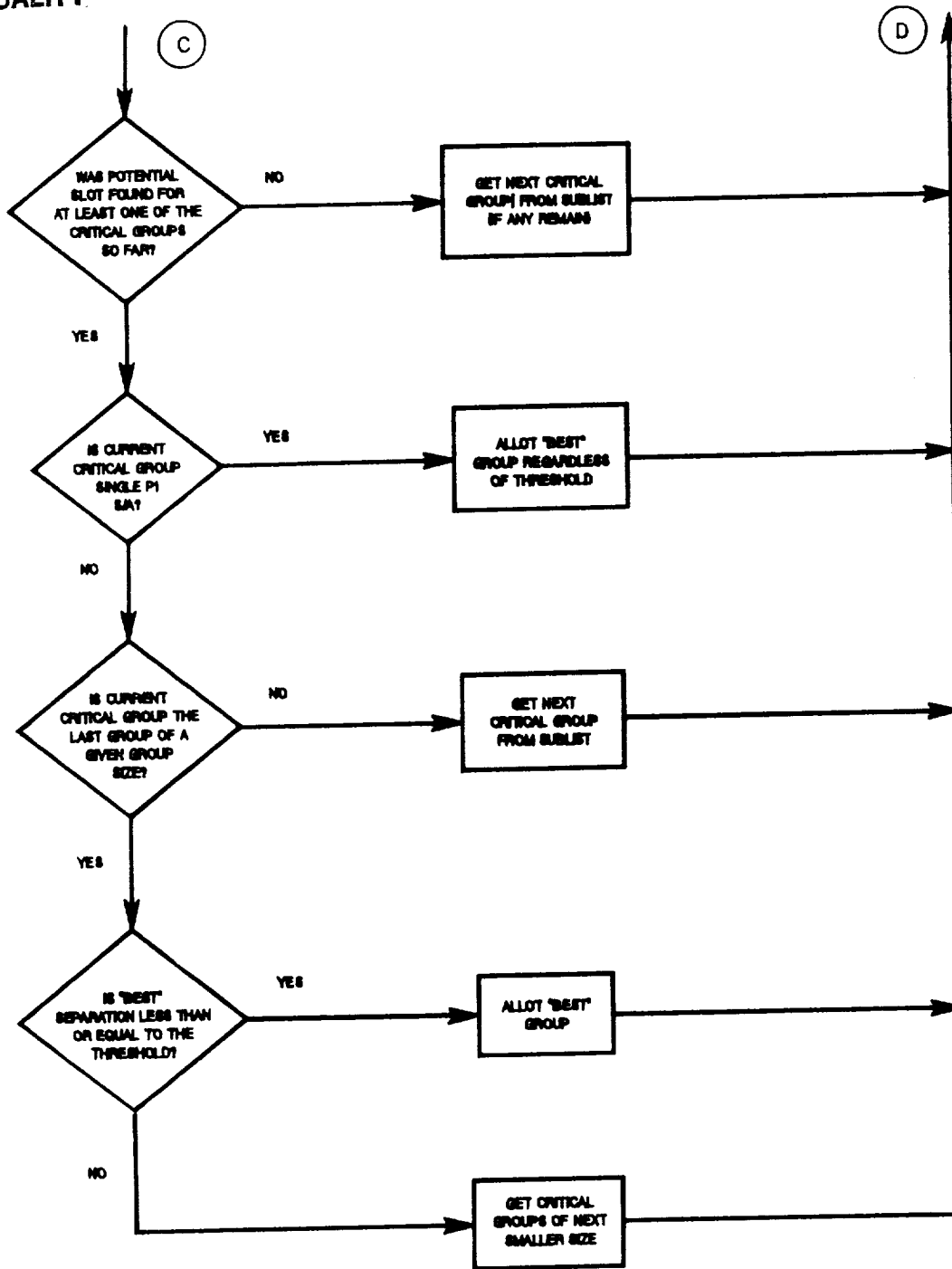


Figure 3.1-10(c).

# NASARC3 -- The Group Arc Extension Program

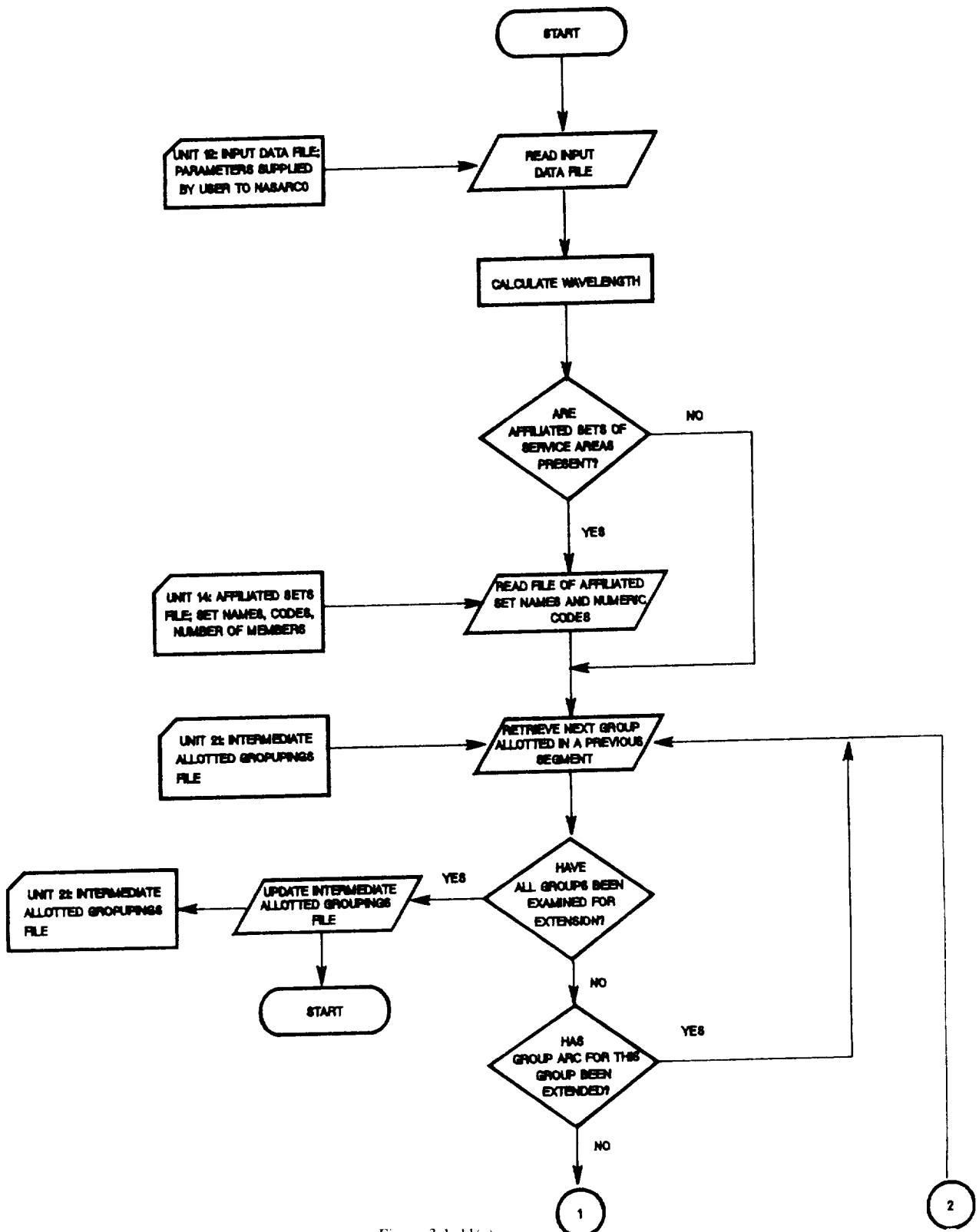


Figure 3.1-11(a).

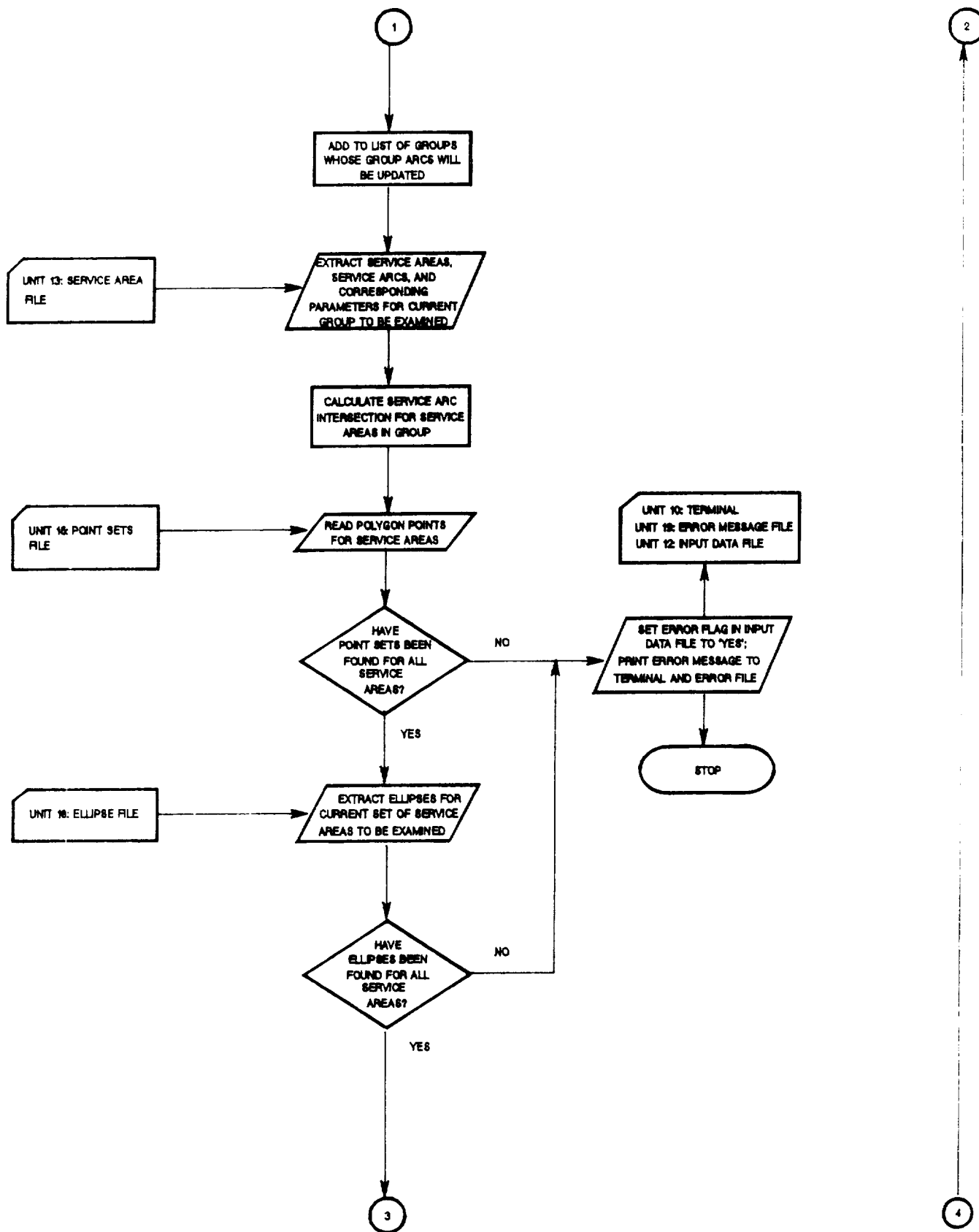


Figure 3.1-11(b).

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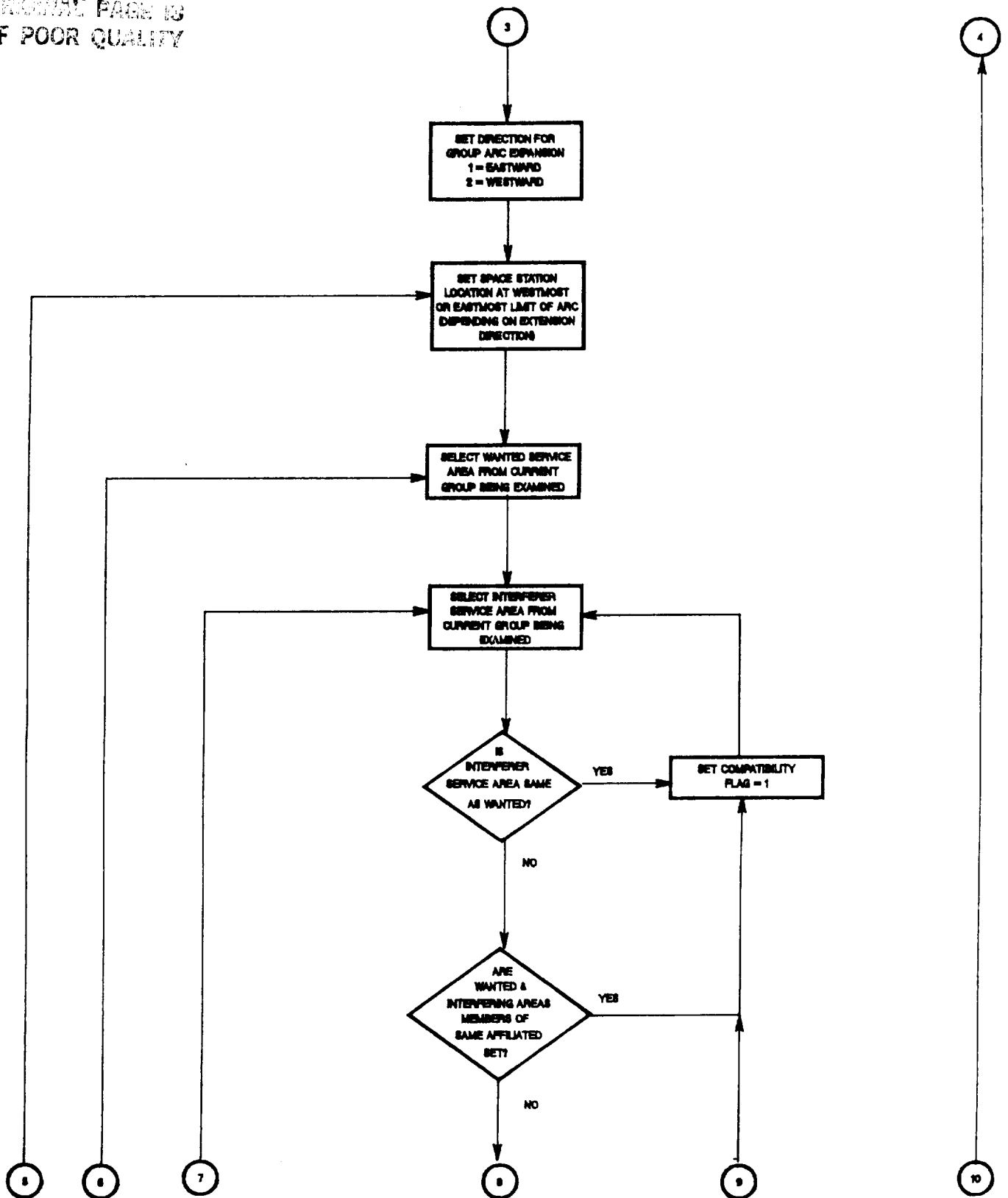


Figure 3.1-11(c).

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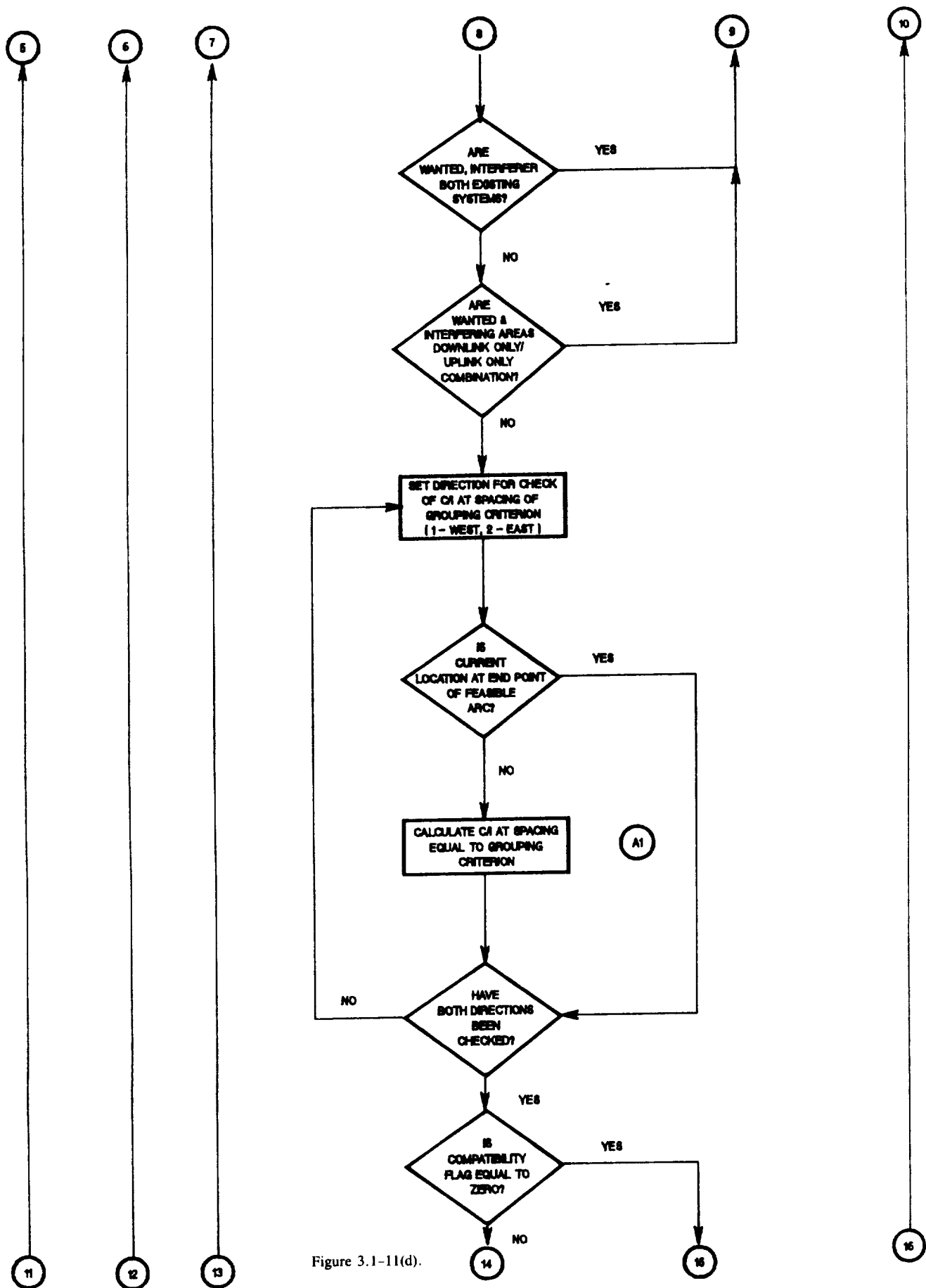


Figure 3.1-11(d).



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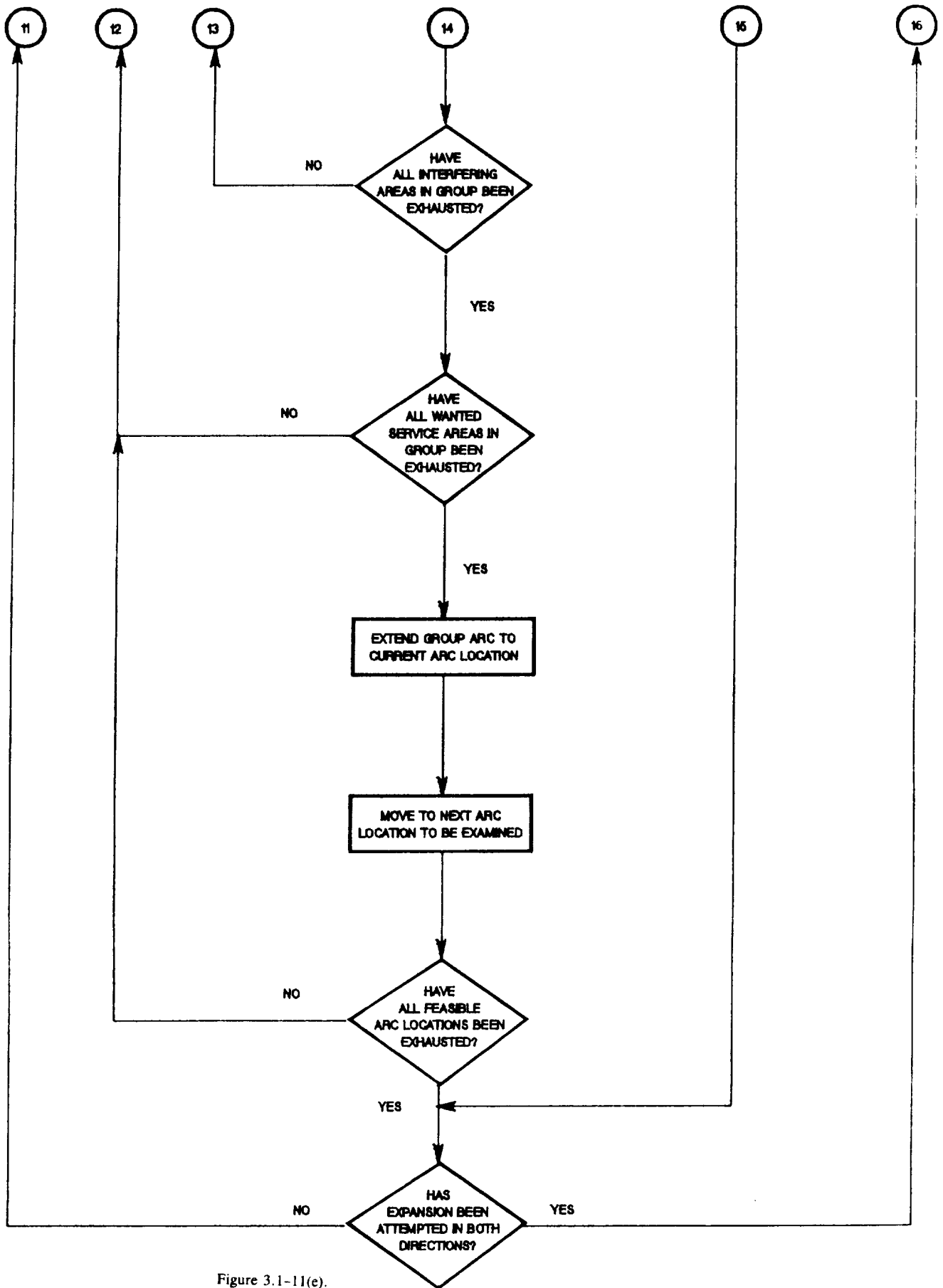


Figure 3.1-11(e).

# NASARC4 -- The Arc Interchange Program

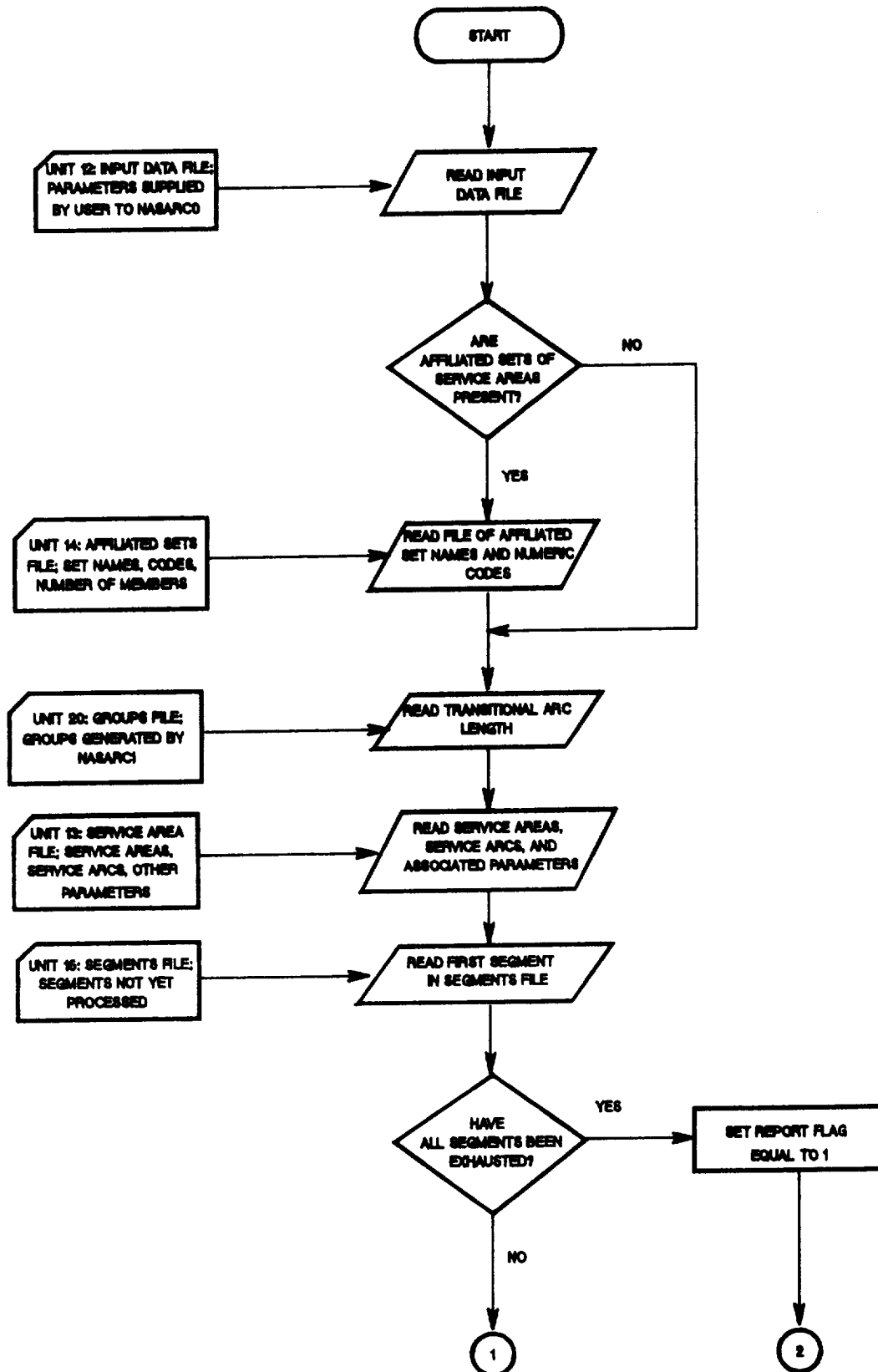


Figure 3.1-12(a).

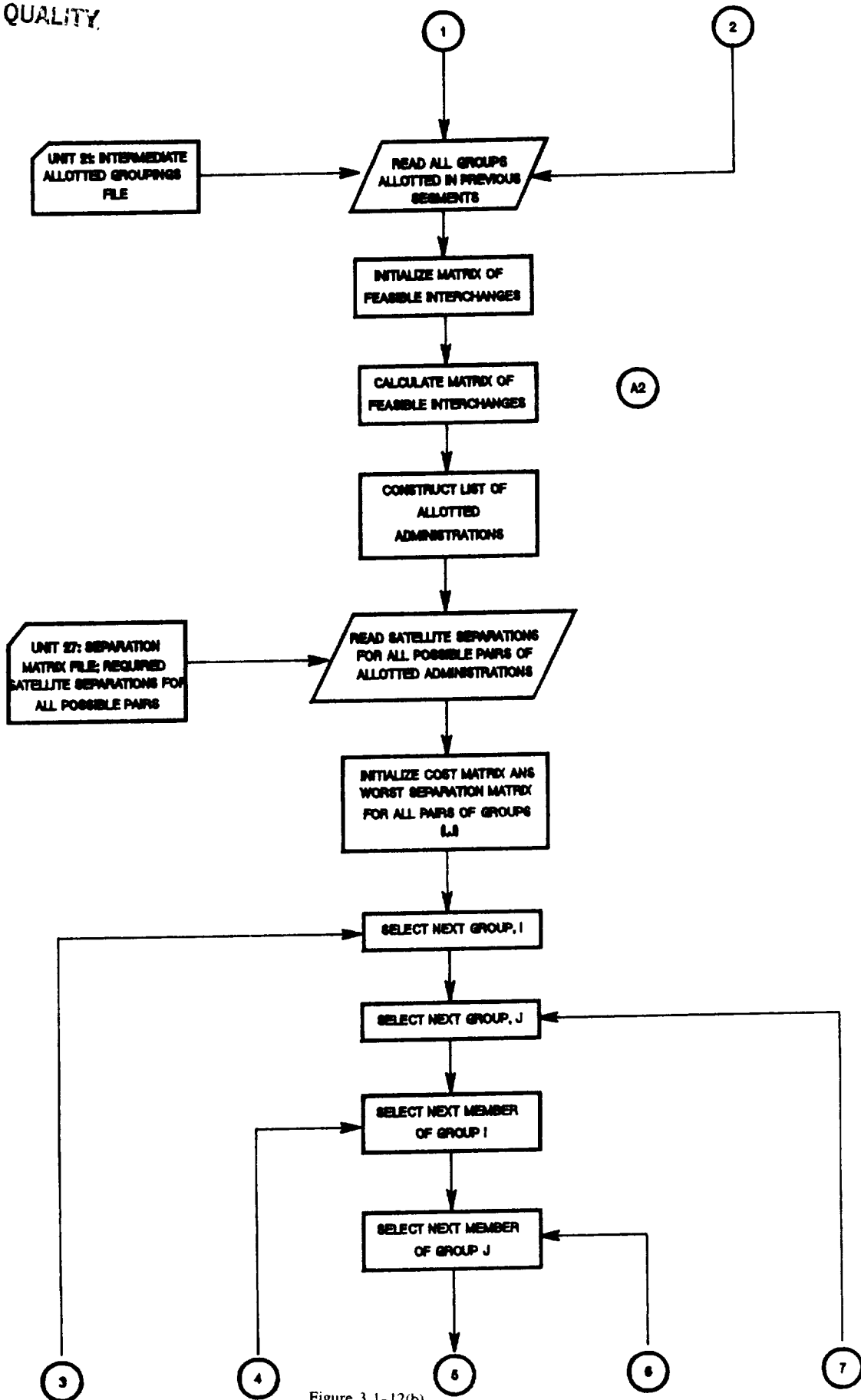


Figure 3.1-12(b).

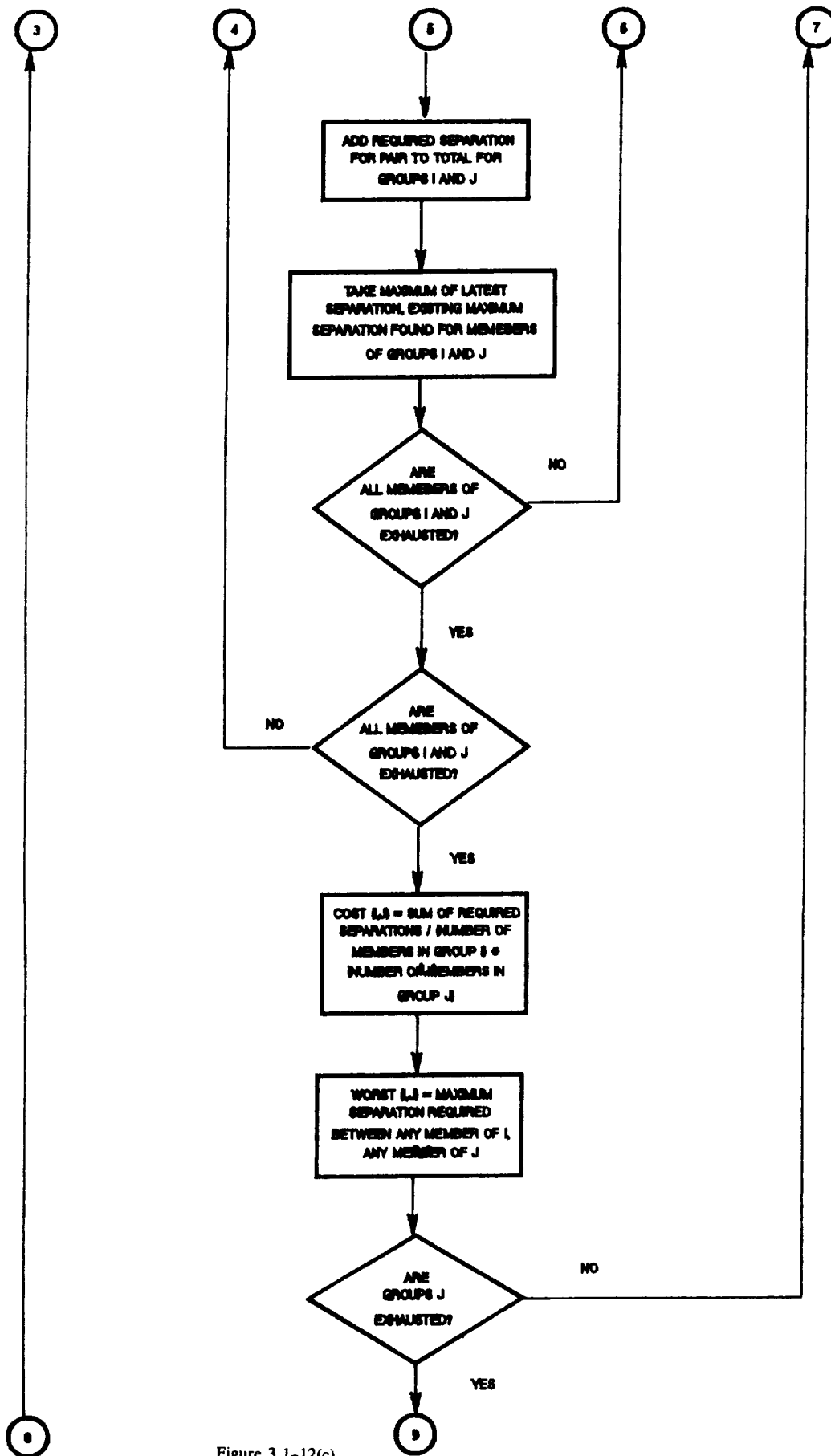


Figure 3.1-12(c).

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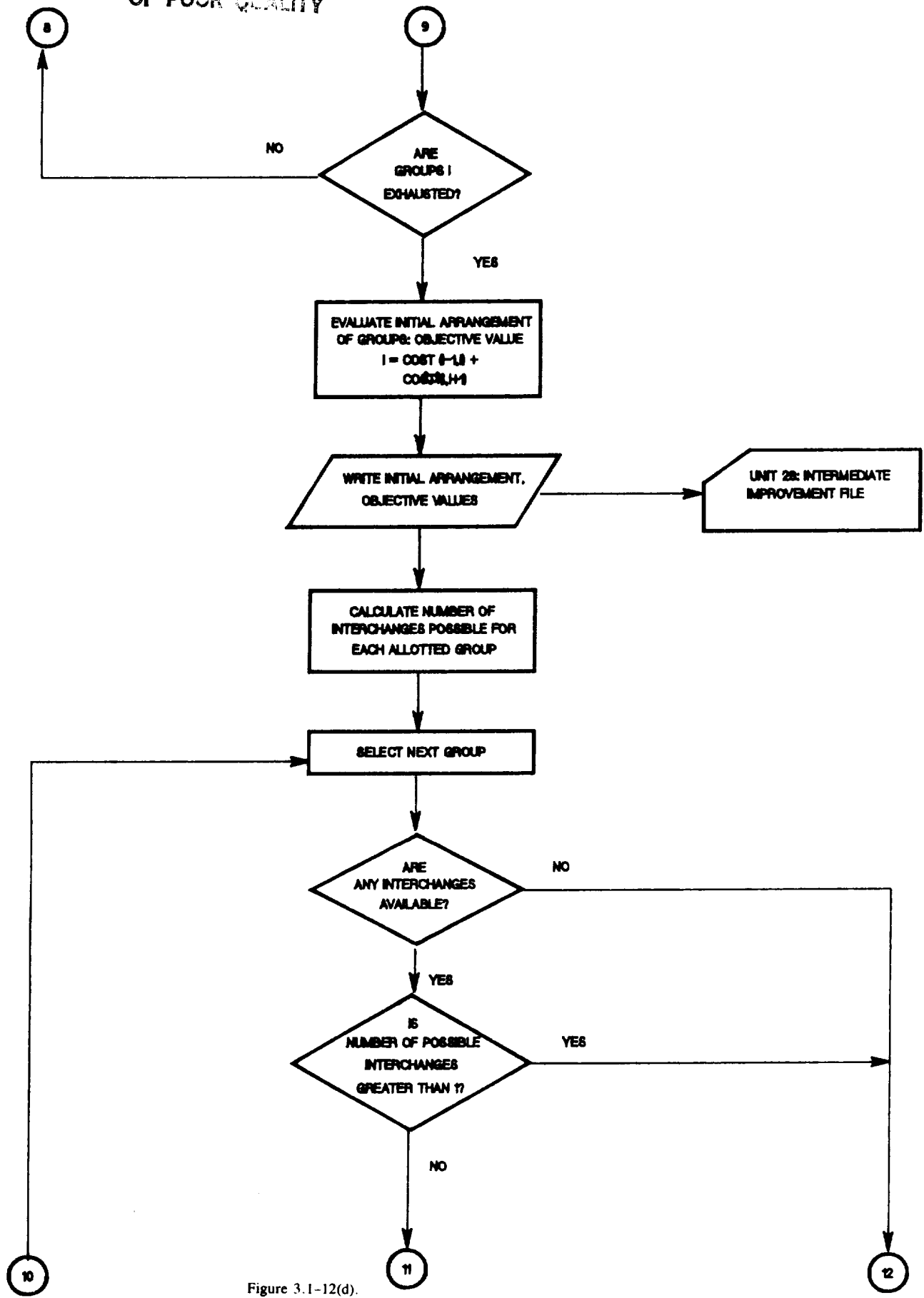


Figure 3.1-12(d).

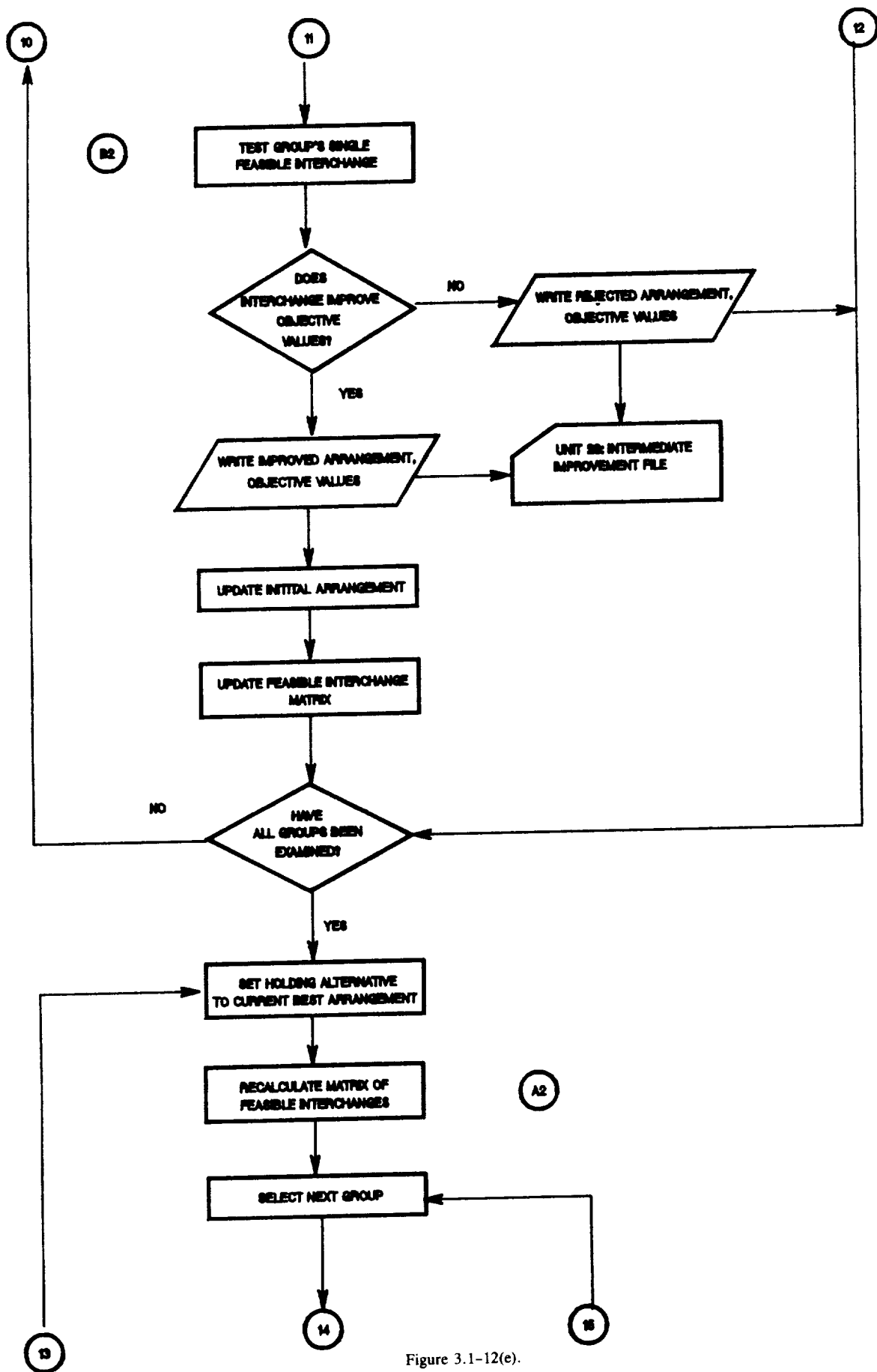


Figure 3.1-12(e).

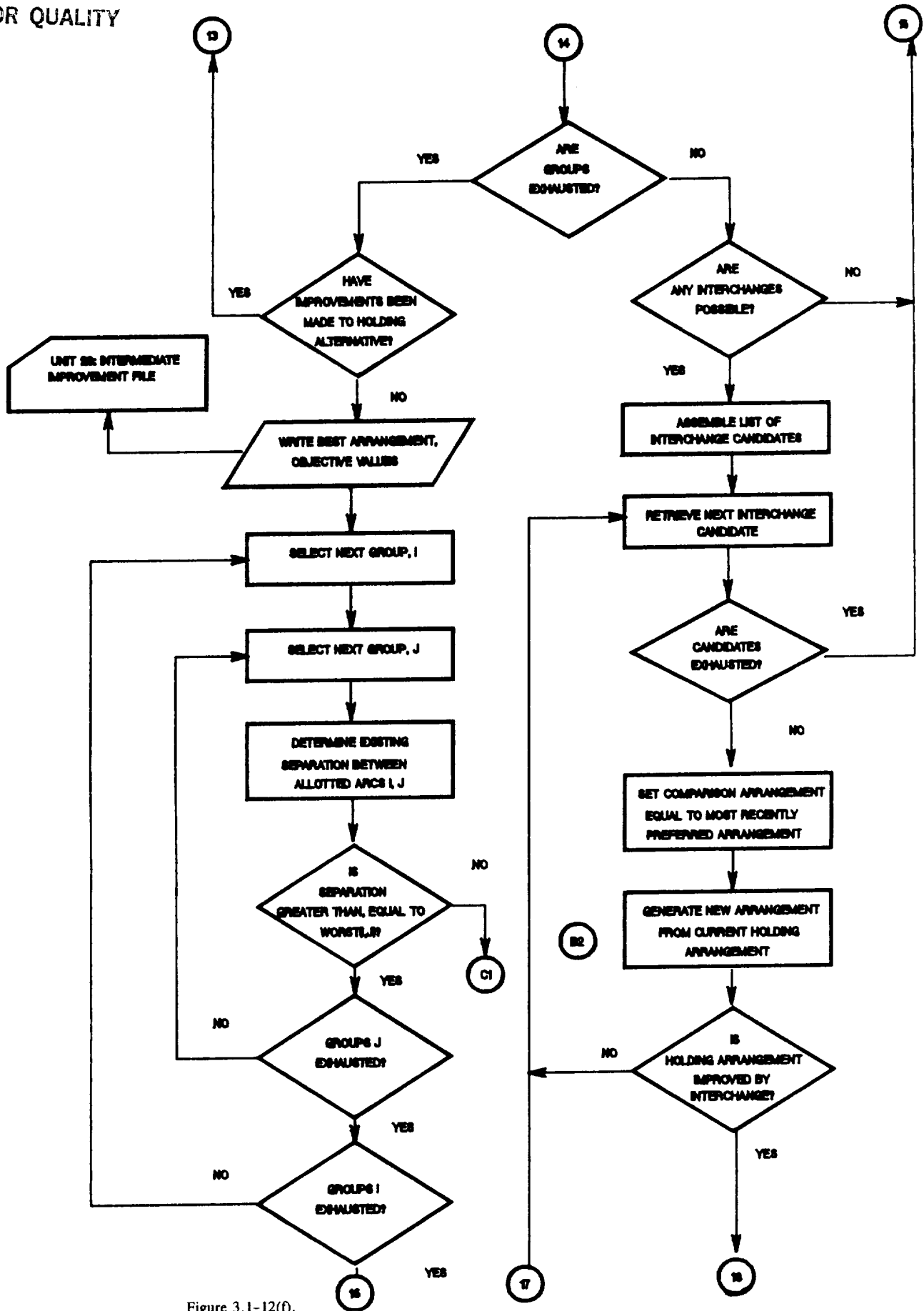


Figure 3.1-12(f).

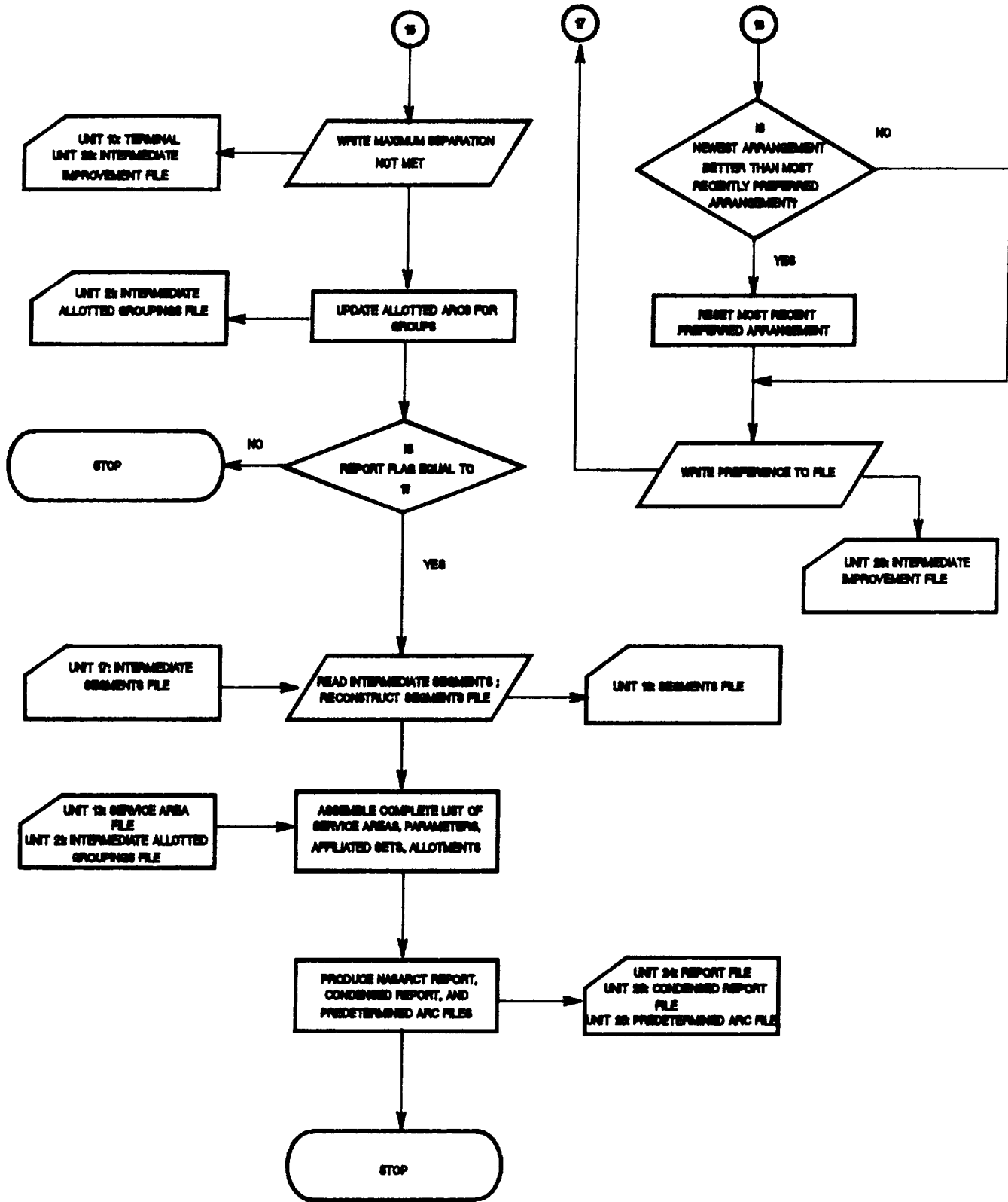


Figure 3.1-12(g).



### Calculation of Matrix of Feasible Interchanges

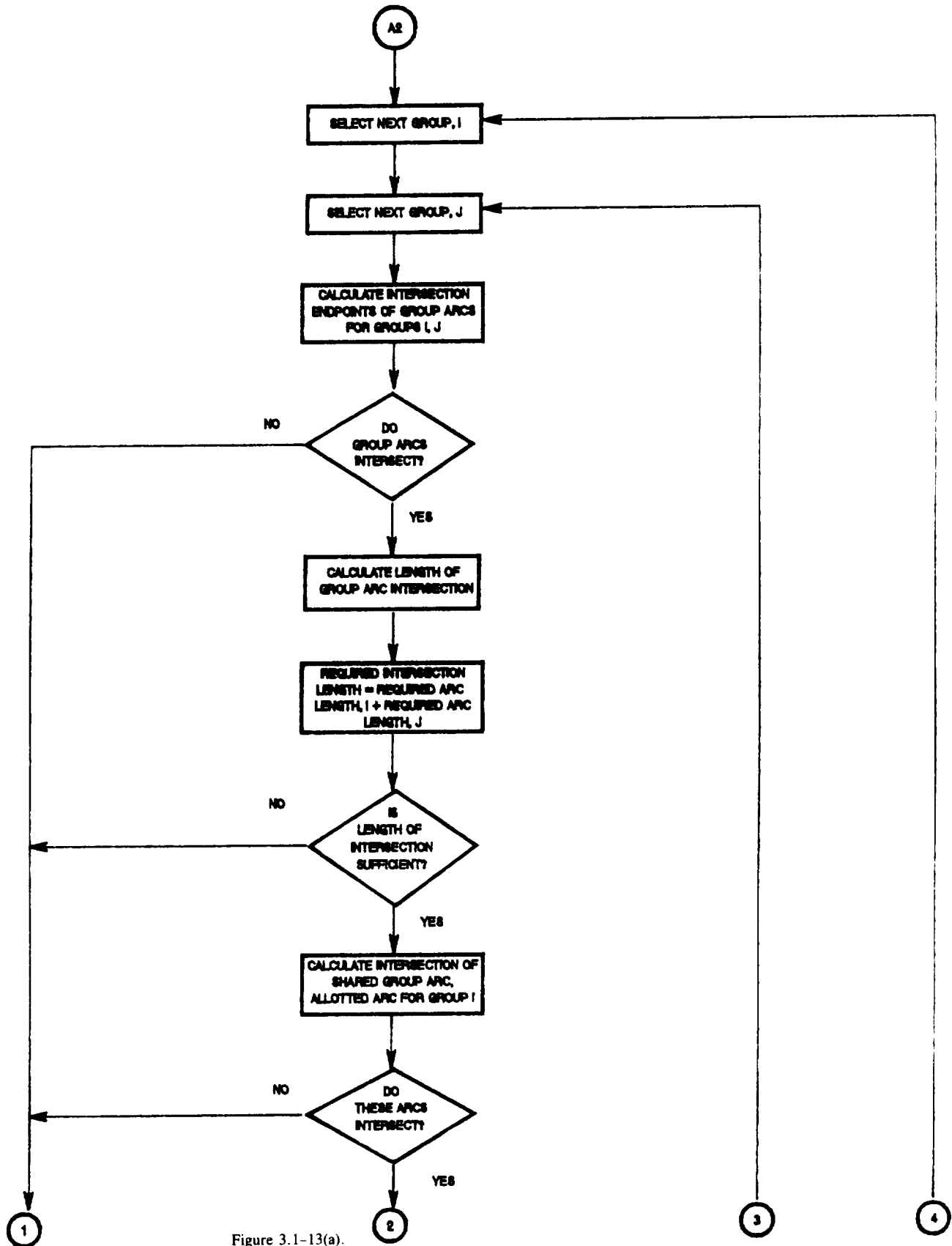


Figure 3.1-13(a).

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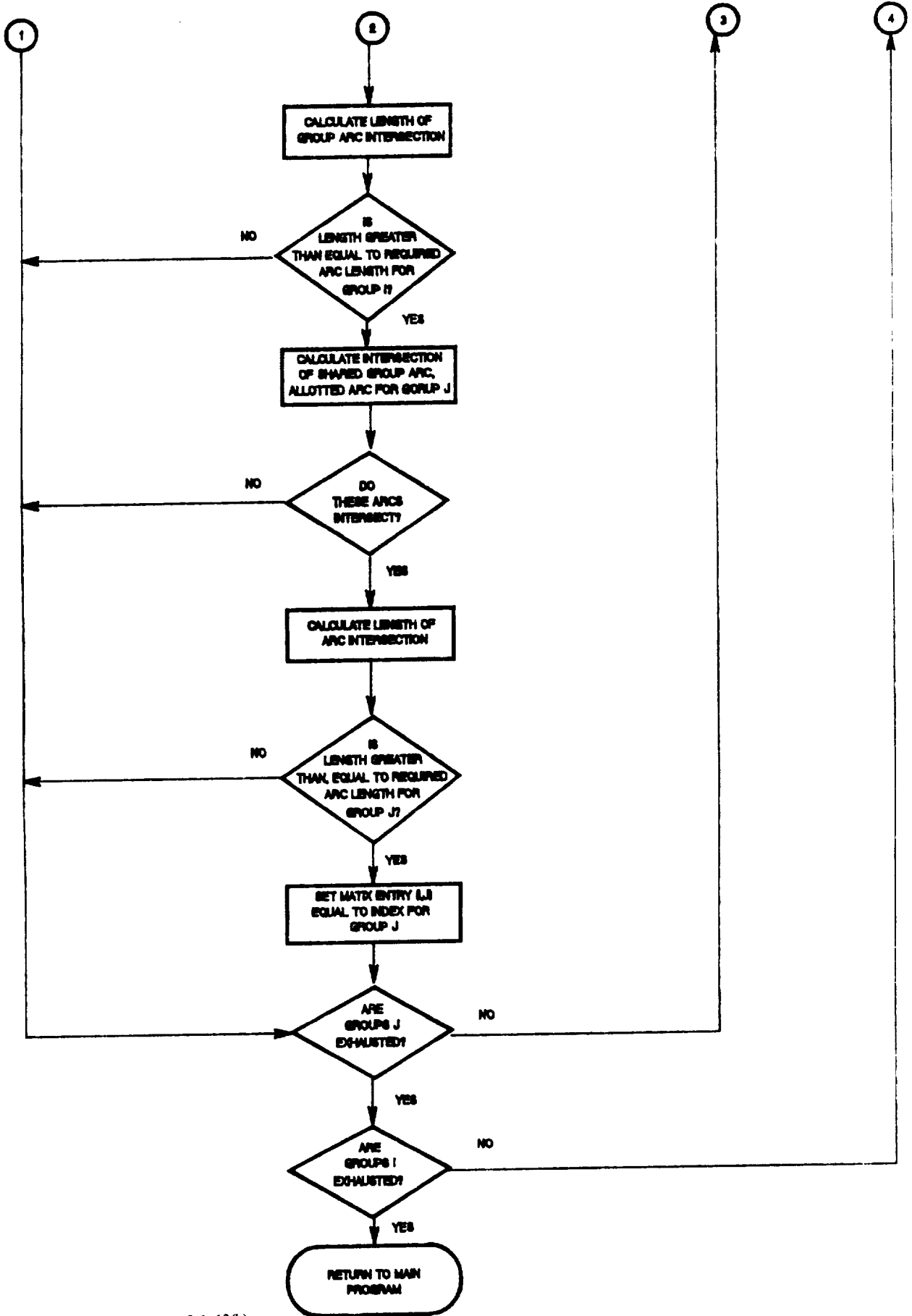


Figure 3.1-13(b).

## Generation of New Arc Arrangement Through Allotted Arc Interchange

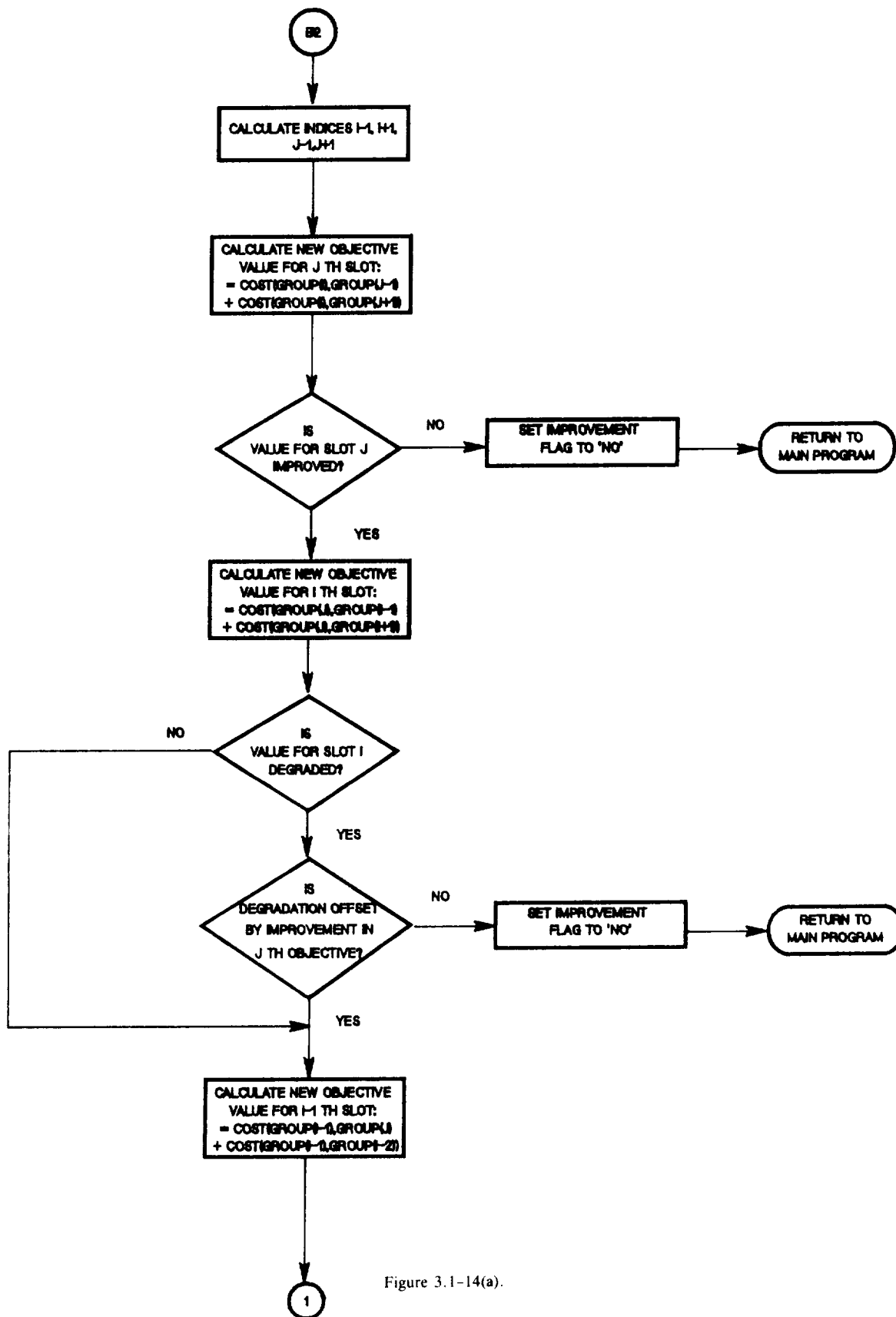


Figure 3.1-14(a).

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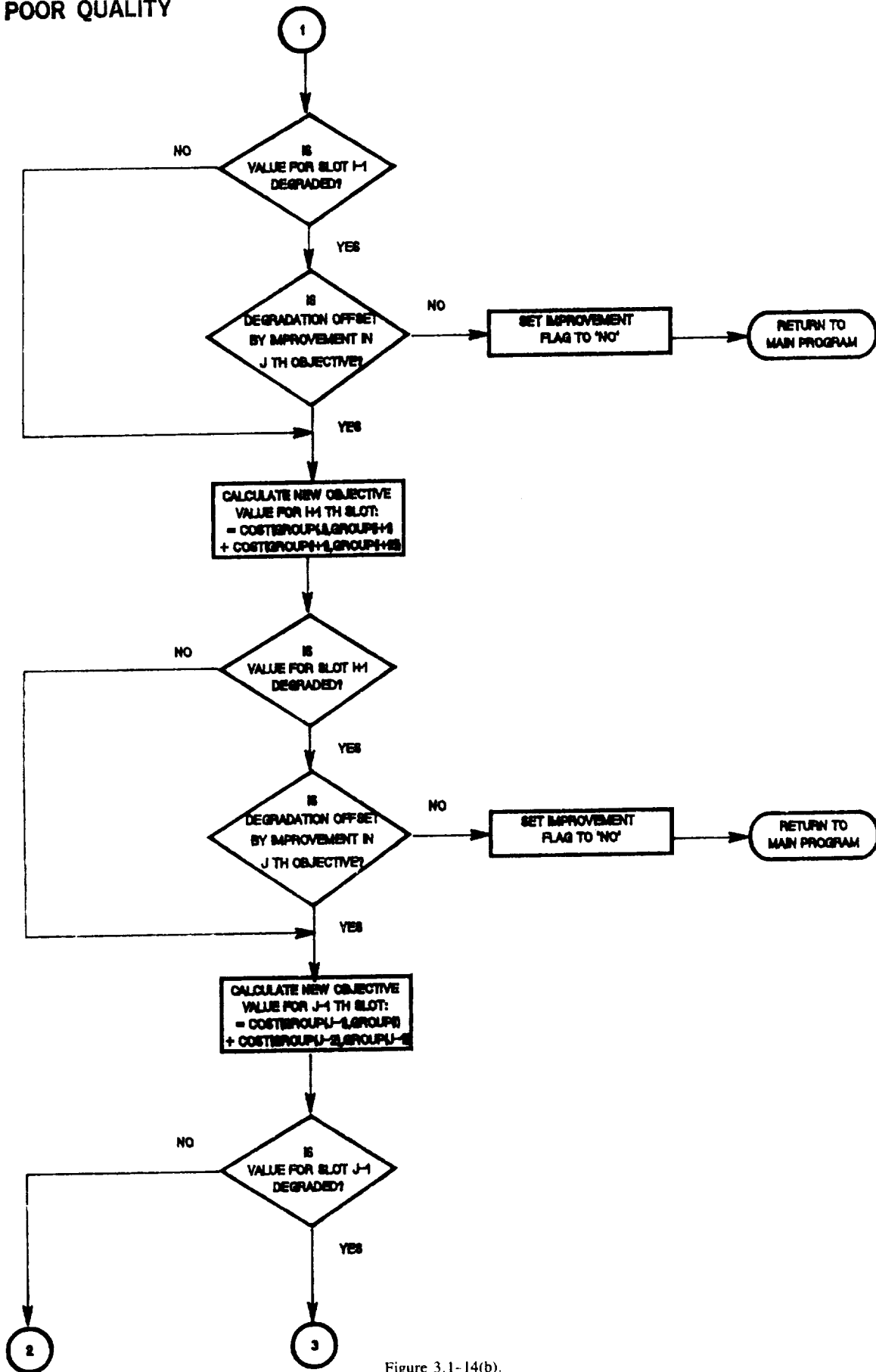


Figure 3.1-14(b).

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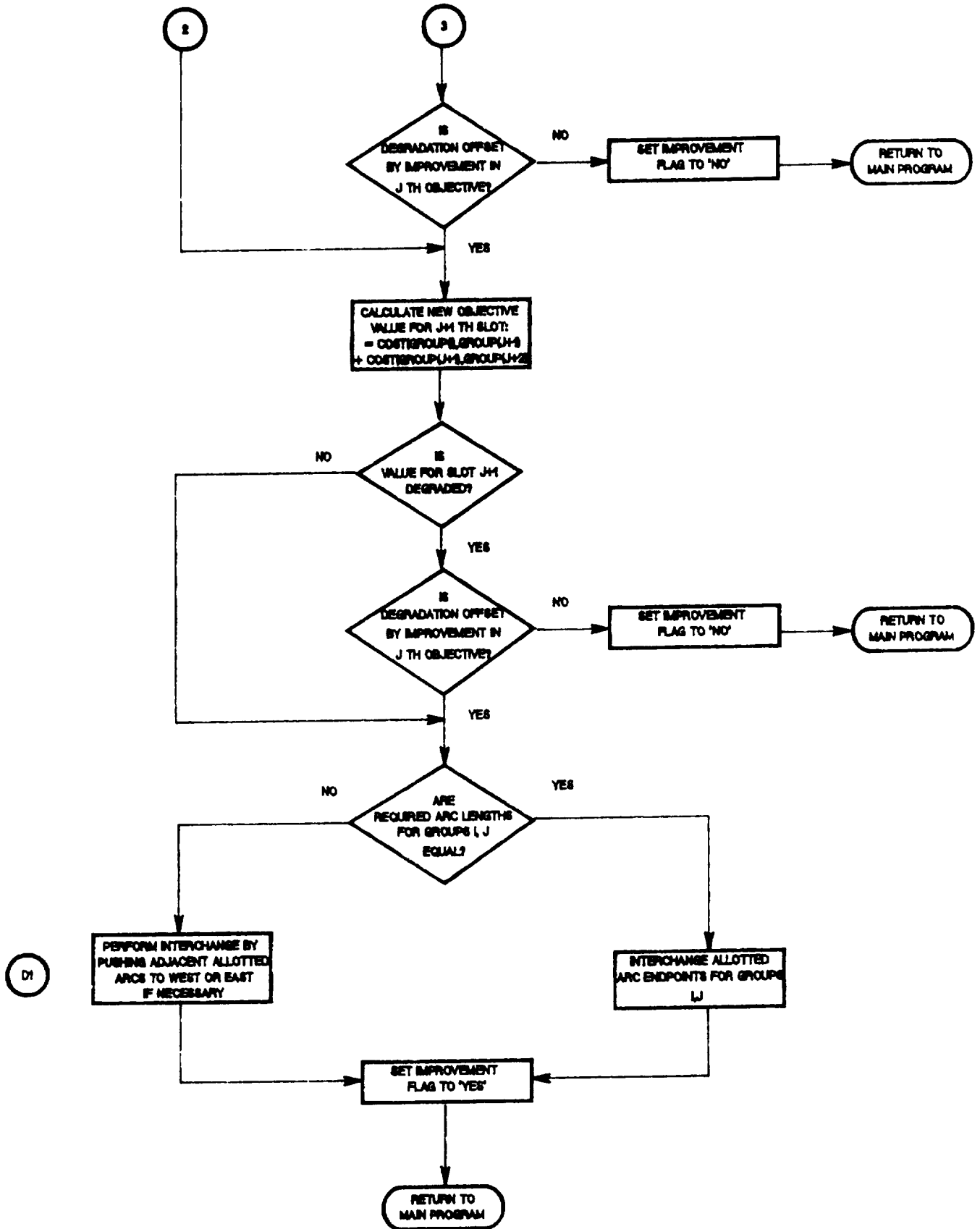


Figure 3.1-14(e).

The NASINTRF module need not be used unless the user wishes to utilize a Requirements Data file; for most applications, the user will want to create his own Service Area, Point Sets, and Affiliated Sets files. Therefore, further information on the NASINTRF module is not presented in this manual, with the exception of the flowchart presented in figure 3.1-3.

### 3.1.2 NASARCO Module

As stated previously, the NASARCO module collects data from the user and verifies data present in externally prepared input files to ensure successful execution of NASARC1, NASARC2, NASARC3, and NASARC4 over all portions of the orbit to be examined. (See fig. 3.1-2.)

Input data file verification is performed first. The NASARCO module first collects constants from the Service Area file (see section 2.3.1.3) that will be used in the allotted arc length equation within NASARC2. If all four constants are zero, NASARCO prints an error flag at the top of the Input Data file and writes an appropriate message to the terminal and the Error Message file; otherwise, NASARCO proceeds. The Segments file is then read by NASARCO; the user will recall from section 2.3.1.1 that the Segments file contains user-specified portions of the orbit to be successively examined by the NASARC1, NASARC2, NASARC3, and NASARC4 modules. NASARCO verifies that the portions of the orbit specified within the Segments file form a contiguous cumulative arc when joined together. If the specified portions of arc do not form such an arc, the error flag within the Input Data file is appropriately set, and error messages are written to the terminal and the Error Message file. After verification of the Segments file, NASARCO proceeds to perform several checks on the Service Area file data (see section 2.3.1.3): lengths of service arcs are checked to ensure that they are feasible; service arcs of affiliated service areas are checked to ensure that they intersect; and individually specified antenna characteristics are verified as valid. If any invalid specifications are found, the appropriate error flags and messages are written to the appropriate files. Information gathered from the service area file—such as presence or absence of affiliations between service areas—is used to set appropriate flags within the Input Data file produced by NASARCO. If affiliated sets of service areas are present, NASARCO reads the Affiliated Sets file (see section 2.3.1.5) and verifies that the appropriate number of member service areas for each set are present within the Service Area file. If the Service Area file and Affiliated Sets file are not in agreement, appropriate error flags and error messages are sent to the appropriate locations. If the two files are in agreement, NASARCO then verifies that the same set of space station antenna parameters have been specified for all member service areas. (The user will recall that an affiliated set of service areas consists of dispersed service areas that are intended to be served from the same satellite.) If such agreement is not found, the appropriate error messages and flags are produced. If agreement exists, NASARCO has concluded the file verification portion of its operation. (See figs. 3.1-4(a), (b), and (c).)

Following verification of externally prepared input data files, NASARCO queries the user for input parameter values to be supplied interactively, such as date and time of run, uplink and downlink frequencies, percent-of-time outage due to rain, and an upper limit on rain attenuation, default earth station antenna characteristics, and default space station antenna characteristics (see fig. 3.1-4(c)). Further information on the interactive prompts issued by NASARCO, and expected responses, is presented in section 3.2.5.

Prior to conclusion of the NASARCO program, the user's responses to interactive prompts are written to the terminal; the user is at this time afforded the opportunity to alter his or her input values. If any values are altered, the appropriate NASARCO operations are repeated. When all values are specified to the user's satisfaction, NASARCO concludes by producing the Input Data file (see section 2.3.1.6) utilized by NASSEP, NASARC1, NASARC2, NASARC3, and NASARC4 (see fig. 3.1.4(c)).

### 3.1.3 NASSEP Module

The functions of NASSEP, the satellite separations program, are to find the required separations between each pair of satellites corresponding to each possible pair of service areas present in the Service Area file and to write a separation data matrix to be utilized by the NASARC2 and NASARC4 modules in performing their functions of

positioning the interchanging allotted arcs. The format and use of the Separation Matrix file are given in section 2.3.1.7 of this manual. This program requires much the same input data as does NASARC1, the grouping program. The Input Data file, the Point Sets file, the Affiliated Sets file, the Service Area file, and the Ellipse file are used as inputs to the separation program. This program does not require any segment information as it operates on the entire geostationary orbital arc.

The satellite separations program is used in the NASARC process to calculate the maximum required orbital separations between the satellites of each service area or affiliated set of service areas based on achieving a given single-entry  $C/I$ . A bisecting search process is utilized to collapse on the required separation which allows the target  $C/I$  for the wanted system to just be met. The target  $C/I$  for each system is determined from the aggregate  $C/I$  value given in the Service Area file for each service area by using set ratio between aggregate and single-entry  $C/I$ s which is set in the main program module of this program. It should be noted that larger values of the ratio in question result in larger required separations and smaller values result in smaller required separations. Ultimately, the separation information stored in the output file is used by NASARC2 and NASARC4 to effect a reduction in the interference between adjacent groupings which are selected in the NASARC process.

NASSEP first sets various constants required for the calculations in subroutine SETCON and places them in a common block for use by the many subprograms in NASSEP. Input parameters are read from the Input Data file and the wavelength is calculated from the transmission frequency for use in antenna calculations. The global scenario information is read from the Service Area file and then the individual service area information is read in for each service area present in the Service Area file. Next, the program checks the affiliated set flag from the Input Data file to determine if affiliated sets are present in the scenario. If they are present, the program determines who the members are in each affiliated set and uses subroutine INTRST to find the intersection of the component service areas' service arcs; this intersection then becomes the affiliated set's service arc.

The polygon/test point data for each service area are read from the Point Sets file using subroutine RDPTS2. The number of arc increments (integral orbital locations) for each service area are calculated from the service arc information. The program then calls subroutine CREAT2 to fill the ellipse array with all the required ellipse information for the scenario.

The satellite separations program operates on the premise that the worst-case required orbital separations between any two service area's satellites occur at the ends of the intersections of their service arcs. This has been shown inductively in several informal studies. Thus, for each pair of wanted and interfering satellites corresponding to the service areas delineated in the Service Area file, the following procedure is performed. First, the program checks each pair of satellites to see if (1) the wanted and the interferer are the same service area, (2) the wanted satellite is operating as uplink only and the interferer as downlink only or vice versa, (3) both wanted and interfering satellites are *existing systems*, or (4) both wanted and interfering satellites are from the same affiliated set. If any of these four cases are true, the program sets the maximum required separation to  $0^\circ$  and goes on to the next pair to be examined.

The program next checks to see if the two service areas in question have service arcs that intersect. If they do not, subroutine NEAR is called to find the two closest endpoints, the wanted satellite is put at the edge of its service arc closest to the interfering satellite, and the interfering satellite is placed at the edge of its service arc closest to the wanted satellite. This situation represents the least possible orbital separation for the pair of satellites in question. If the service arcs do intersect, both the wanted and interfering satellites are placed at the western edge of the intersected arc.

At this point, subroutine CICHK2 is called to determine the achieved  $C/I$  value for the present separation (i.e.,  $0^\circ$  for the intersecting case and the nearest separation possible for the nonintersecting case). Subroutine CICHK2 calculates the achieved  $C/I$  value for the current positions of the satellites using all the technical parameters available to it. It calls subroutine ANGLES to calculate the satellite and earth station antenna off-axis angles and the half-power beamwidths in the direction of interest (i.e., towards the worst-case point) and subroutine DISC to calculate the satellite and earth station antenna discrimination values. If the achieved  $C/I$  is greater than or equal to the required  $C/I$ , then the required separation for this arrangement is set to zero.

If this arrangement, which corresponds to the minimum possible separation for the two satellites under investigation, does not achieve the required  $C/I$ , then the interfering satellite is placed at the western edge of its service arc and the available  $C/I$  is again calculated. If the available  $C/I$  exceeds the required amount, the interferer is moved toward the wanted satellite using subroutine BISECT to do a bisecting search routine and find the minimum required spacing. If the available  $C/I$  does not exceed the required  $C/I$ , then the wanted satellite is positioned at the eastern edge of its service arc and the available  $C/I$  is calculated. If the achieved  $C/I$  is still not greater than the required  $C/I$ , then the required separation for this case is set to the difference between the two satellite positions. If the achieved  $C/I$  is greater than necessary, then the current interval is reduced using the bisecting search algorithm by moving the wanted satellite toward the interferer satellite until the separation found is the minimum necessary to achieve the required  $C/I$ .

Similarly, the next operation is to position the wanted satellite at the western edge of the intersected arc and the interfering satellite at the eastern edge of its service arc to get the opposite case to that which was just examined. Once again, the achieved  $C/I$  is evaluated and if it is greater than necessary, another bisecting search is performed moving the interferer rather than the wanted satellite until the minimum separation which provides sufficient  $C/I$  is found. If greater separation is required than this case provides, the wanted satellite is positioned at the western edge of its service arc and the achieved  $C/I$  is found once again. If the available  $C/I$  exceeds the required  $C/I$ , then the bisecting search is used to reduce the separation to the correct amount by moving the wanted satellite toward the interfering satellite. If the achieved  $C/I$  does not meet or exceed the required  $C/I$ , then the required separation for this case is set equal to the maximum allowable within the service arc constraints of the given pair which is defined by the wanted and interfering satellite locations.

Next, the identical operations must be repeated for the case of the wanted satellite being placed at the eastern edge of the intersected arc. If the service arcs of the pair in question intersect, then both the wanted and interfering satellites are placed at the eastern edge of the intersected arc. If the service arcs do not intersect, then the wanted and interfering satellites are placed at their nearest boundaries with respect to each other as given by subroutine NEAR. The  $C/I$  is evaluated for this arrangement; if the available  $C/I$  exceeds the required value, the required separation for this case is set to  $0^\circ$ . If the achieved  $C/I$  does not exceed the requirements, the interferer is positioned at the western edge of its service arc and  $C/I$  is evaluated once again. The rest of the process for this pair of wanted and interfering satellites is analogous to that presented in the preceding paragraphs except that the wanted system is initially positioned at the eastern edge of the intersected arc rather than at the western edge.

Once the maximum required separation between this pair of wanted and interfering satellites has been found, the roles of wanted and interferer are reversed and the exhaustive examination of all possible arrangements of the two satellites in question is repeated. When the separation has been found for that pair of satellites, all other possible pairs of satellites are examined in like fashion. For each pair of satellites, the maximum required separation found is the maximum of all the described cases regardless of which satellite was the wanted and which was the interferer. Both separation matrix entries will have the same value; thus, the separation matrix will be symmetric.

If there are any affiliated sets present in the given scenario, the program consolidates their separation entries into a single row and column as if each affiliated set were a single service area because members of an affiliated set of service areas are served from the same satellite. Lastly, NASSEP outputs the separation data to the Separation Matrix file.

A flowchart of the NASSEP module is presented in figures 3.1-5(a) and (b).

#### 3.1.4 NASARC1 Module

The NASARC1 module, as stated previously, enumerates compatible groupings of service areas and the arc spans over which each such grouping may exist within the portion of the arc currently being examined.



A compatible group of service areas consists of a set of service areas, each of which is compatible with all other members on a pairwise basis. Pairwise compatibility between service areas is assessed on the basis of the satellite separation required to allow systems serving both service areas to meet a target single-entry  $C/I$  value. A user-supplied grouping criterion, extracted by the NASARC1 module from the Segments file, expresses (in degrees of orbital arc) the maximum orbital separation allowable between systems at which the target  $C/I$  value may be achieved for compatibility. That is, if systems serving two service areas achieve or exceed the target  $C/I$  value at the grouping criterion spacing, they may be placed closely together in the orbit and are hence compatible.

Over the range of orbital locations currently being examined, assessment of compatibility between all possible pairs of service areas takes place. Groups of systems that may be spaced closely together in orbit (i.e., those that are compatible) are enumerated at each discrete location in the current portion of the orbit. These groups are periodically accumulated into a list of compatible groups and arc spans over which each such group may exist until all possibilities for compatibility in the current portion of the orbit have been exhausted.

The NASARC1 module first collects needed inputs from the Input Data file (see fig. 3.1-6(a)). These inputs include technical parameter values supplied by the user as well as other data that affect various operations within the program (see section 2.3.1.6).

The second input file required by the procedure is the Service Area file, which contains a list of service area, their eastmost and westmost feasible arc locations, and data specified for each service area (see section 2.3.1.3). This file is utilized to establish a preliminary list of service areas to be examined for compatibility within the current portion of the orbit.

If the appropriate flag within the Input Data file indicates that affiliated sets of service areas are to be taken into consideration, NASARC1 then reads the Affiliated Sets file (see section 2.3.1.5). The user will recall that affiliated sets of service areas—geographically dispersed areas that are to be served from a single satellite—require special handling within NASARC1 (see figs. 3.1-6(a) to (d) and (f)).

As described in section 3.1, the NASARC1, NASARC2, NASARC3, and NASARC4 modules are applied to successive portions of the orbit specified by the user. Thus, any given execution of the NASARC1 module may follow an application of the NASARC1, NASARC2, NASARC3, and NASARC4 modules to a prior portion of the orbit. The user will also recall from section 3.1 that the purpose of the NASARC2 module is to select compatible groups of service areas from those found within a portion of the orbit and to determine allotted arcs for the selected groups. Thus, service areas that are included in such groups have already received allotted arcs and do not need to be considered further by the NASARC1 module in subsequent segments of the orbit. For this reason, the NASARC1 module utilizes the Intermediate Allotted Groupings file (see section 2.3.2.3) as input; the service areas that have received allotted arcs are eliminated from the preliminary list of service areas to be considered. If a service area that has received an allotted arc is, in fact, an affiliated set of service areas, its member service areas have received allotted arcs and are thus also eliminated from the preliminary list of service areas to be considered within the current portion of the orbit (see figs. 3.1-6(a) and (b)). Such elimination of service areas that need no longer be considered greatly reduces the computer time required to analyze all portions of the orbit.

The NASARC1 module must next determine the portion of the orbit to be examined for compatible groups of service areas. The user will recall that the portions of the orbit that are to be analyzed are specified within the Segments file (see section 2.3.1.1). The top record of the Segments file defines the western and eastern arc limits of the current portion of the arc to be examined and the grouping criterion to be applied within that segment; when the top record has been read, the remaining records are read and rewritten to the Segments file; the updated Segments file thus contains, in its top record, the longitudinal limits and grouping criterion for the next portion of the orbit to be examined. The limits and grouping criterion of the current portion of the arc to be examined by NASARC1 are also written to the Intermediate Segments file (see section 2.3.2.1), which contains the portions of the orbit that have been examined (see fig. 3.1-6(b)).

The service arcs of the service areas contained in the current list are then compared with the current segment to be analyzed by NASARC1; service arc boundaries are adjusted internally—i.e., within NASARC1—to conform to

the boundaries of the current segment. If a service area's service arc does not intersect the current segment to be examined, that service area is eliminated from the list of service areas to be considered (see figure 3.1-6(b)). A further check is performed, if applicable, to determine if all affiliated service areas within a set are present within the current segment. The user will recall that affiliated sets of service areas must be treated in an all or nothing manner—that is, all numbers of an affiliated set of service areas must be able to be included in a compatible group or no members must be included. Thus, if the service arc of any member service area of an affiliated set does not intersect the current segment, the remaining member service areas must be eliminated from the list of service areas to be considered (see fig. 3.1-4(c)).

The list of service areas to be considered has now been finalized. Intersections of their modified service arcs (i.e., the segments of service arc that lie within the segment currently being examined) are determined for all pairs of service areas using subroutine INTRST. Sets of polygon points for service areas are extracted from the Points Sets file using subroutine RDPTS; if point sets are not found for all service areas, the error flag within the Input Data file is changed appropriately, error messages are written to the Error Message File and the terminal, and NASARC1 ceases execution (subroutine ERR) (see fig. 3.1-6(c)).

After the extraction of polygon points from the Point Sets file, NASARC1 creates an array of needed ellipse data extracted from the Ellipse file using the CREATE subroutine. Once again, if an error in collecting the needed data is encountered, appropriate flags and messages are written and the NASARC1 module stops (subroutine ERR).

Beginning with the westmost possible arc location for any service area, the NASARC1 module calculates a compatibility matrix and enumerates groups of compatible systems for that location. The location is then incremented and the process is repeated until all possible discrete arc locations within the current segment are exhausted. In constructing the compatibility matrix for each location, compatibility assessment for a pair of satellites is not performed unless the current location lies within the intersection of the feasible arcs for both service areas (see figs. 3.1-6(d) and (e)).

At each arc location, calculation of a compatibility matrix takes place. Each entry indicates whether or not a target  $C/I$  value is achieved with a specified orbital separation between two satellites, serving a pair of service areas, where the satellite regarded as wanted is represented by the row index and the interfering satellite is represented by the column index. Due to differences in the geographical extent of the service areas corresponding to the satellites (and thus, beam coverage size), the  $C/I$  achieved when one satellite is seen as wanted and the other is regarded as an interferer may not be identical to the  $C/I$  achieved when the roles of the two satellites are reversed. Thus, the compatibility matrix is initially nonsymmetric (see fig. 3.1-6(f)). Compatibility is indicated by a one (1); incompatibility is indicated by a zero (0).

The user will recall that affiliated sets of service areas require special treatment in the determination of compatible groups of service areas. If two service areas are members of the same affiliated set, they are regarded, automatically, as compatible. However, compatibility between each member service area and all other nonmember service areas is assessed in the manner to be described.

Calculation of the  $C/I$  achieved by each pair of systems at the orbital separation specified by the grouping criterion is performed on the basis of the total link performance achieved (subroutine CICHK—see figs. 3.1-7(a) to (d)). Thus, system characteristics are required by the program and are read from the Service Area file. The characteristics required are those representing the satellite antenna pattern, earth station antenna patterns, satellite and earth station receiver noise temperatures, satellite and earth station power levels, uplink and downlink  $C/I$ s, target aggregate  $C/I$ , uplink and downlink power calculation flags, existing system flag, and link calculation flag. As falloff from the on-axis satellite antenna gain is most often expressed in terms of relative off-axis angle (i.e., the off-axis angle of the satellite antenna divided by the half-power beamwidth in the direction of interest), the half-power beamwidth in the direction of interest must be calculated (subroutine ANGLES). For this reason, a file of ellipses covering the service areas is also utilized by the program. The ellipses needed by the program are extracted from the Ellipse file using the CREATE subroutine. The achieved  $C/I$  value is calculated at the given orbital separation between satellites as follows (see figs. 3.1-7(a) to (d)). The current arc location is assumed to be the location of the wanted satellite; what must be determined is whether or not a given orbital separation

between this location and the location of the interferer satellite allows the wanted system to meet a target  $C/I$  calculated from user inputs. First, the uplink  $C/I$  is calculated, provided that the link calculation flag indicates to the program to do so. Free space losses are calculated on both wanted and interfering uplink path. Depending on the power calculation option for the uplink, the user-supplied values for wanted and interfering earth stations may be utilized or the values may be calculated from the uplink carrier to noise ratio ( $C/N$ ). Antenna discriminations are calculated for the interfering earth station toward the wanted spacecraft, the wanted spacecraft toward the interfering earth station, and the wanted spacecraft toward the wanted earth station (subroutines ESOFF, ANGLES, and DISC). The achieved uplink  $C/I$  value is then determined.

A similar operation is performed for the downlink if required by the link calculation flag. Depending on the value of the downlink power calculation option, user-supplied values for spacecraft powers may be utilized or calculated from downlink  $C/N$  values. Antenna discriminations are calculated (subroutines ESOFF, ANGLES, and DISC) for the interfering spacecraft antenna toward the wanted earth station and the wanted earth station toward the interfering spacecraft. The downlink  $C/I$  value is then evaluated and combined with the uplink  $C/I$  value for the overall single-entry  $C/I$  achieved.

When evaluation of the achieved  $C/I$  values has been completed at a location, the compatibility matrix for the location is made symmetric, using the results obtained by CICHK. Each entry of the compatibility matrix corresponding to a row and column index is compared to its corresponding entry—that with the row and column indices reversed. If the two entries both indicate compatibility, 1's are present in the corresponding locations of the compatibility matrix. If either or both of the compatibility matrix entries contains a 0, 0's are placed in both corresponding locations of the compatibility matrix.

The compatibility matrix which results thus expresses in 1's and 0's whether any two service areas are compatible at the particular location. The compatibility matrix is now symmetric; symmetry is required for the enumeration of groups of compatible service areas at the current location. Diagonal entries will be set to 1, as each service area is regarded as being compatible with itself (see figs. 3.1-6(d) to (f)). The symmetric compatibility matrix may be regarded as a collection of vectors—one vector for each service area—which expresses compatibility between that service area and all others. A compatible group consists of a set of service areas whose members are each compatible with all other members. Affiliated sets of service areas are, once again, treated in an all-or-nothing fashion; rows and columns of the compatibility matrix that correspond to single service areas that are members of an affiliated set must be consolidated into a single row and column that expresses the set's compatibilities with other nonmember service areas.

To enumerate groups of compatible service areas, each vector is examined in turn. Each vector has 1 in the element corresponding to its own service area index, and additional 1's and 0's indicating compatibilities with other service areas. A complete list of compatible groupings for the current arc location is found by exhaustively examining all possible compatibilities. When a large number of such groups, over several arc locations, have been determined, the groups and arc locations are accumulated into a list of groupings and their associated group arcs over which they have been found (subroutine ACCUM—see fig. 3.1-8). Finally, when all locations have been exhausted, the list of groupings and arc spans is processed one final time in subroutine ACCUM to ensure that the list contains all compatible groupings and the arc spans over which they may exist. This final list is output by subroutine OUTLST to the NASARC1 output file—the Groups file (see section 2.3.2.2) which is utilized by the NASARC2 module as input.

### 3.1.5 NASARC2 Module

The function of NASARC2, the arc determination program, remains the same in Version 4.0 as in previous versions. NASARC2 performs the following functions: (1) selects appropriate groups of service areas from an exhaustive list of groups generated by NASARC1 for a given portion of the orbit; (2) determines allotted arc lengths for these selected groups; and (3) allots each selected group an arc segment within its group arc that is of the appropriate size.

The major change to NASARC2 in Version 4.0 is that it has been modified to take advantage of the satellite separation information available in the satellite separation matrix file during the group selection process. This file contains the minimal satellite orbital separations needed between each pair of systems in the scenario such that a specified single-entry *C/I* criterion is satisfied. These values are used to aid in selecting a critical group and positioning the group in an allotted arc which improves the compatibility between satellites in adjacent arcs. This selection process is described in more detail subsequently. What follows is an overview of the NASARC2 group selection and arc determination procedures. The reader is referred to the NASARC2 flowcharts in figures 3.1-9(a) and (b) throughout this description.

NASARC2 begins by reading in required input data as shown in the top portion of figure 3.1-9(a). This includes the grouping criterion and arc length equation constants from the Input Parameters file (unit 12); the pairwise minimum satellite orbital separations from the Separation Matrix file (unit 27); and the orbit segments that have been processed thus far by NASARC1 from the Intermediate Segments file (unit 17). Using the segment information, NASARC2 determines the west and east bounds of the current cumulative arc, the west and east bounds of the current segment, and the direction (east or west) in which the arc determination procedure will proceed. If the current segment boundaries are eastward of the previous cumulative arc (in the last NASARC2 execution), the allotted arc buildup occurs west-to-east. If the current segment boundaries are westward of the previous cumulative arc, allotted arc buildup is east-to-west. This prevents large gaps from occurring between adjacent allotted groups. NASARC2 next reads the Groups and Service Arcs file (unit 20) to obtain the service areas for the current segment, their service arc boundaries, the service area individual buffer arc sizes, the compatible groups generated by NASARC1 for the current segment and their respective group arc boundaries. Finally, if the current segment is not the first segment to have been processed, then information related to groups which have been allotted in past segments must also be read in along with any unallotted groups whose group arc adjoins an edge of the current segment. The unallotted groups are then appended to the groups list from the Groups file and the group arcs of duplicate groups are combined where appropriate to form a master groups list for the current cumulative arc.

The next major step in the NASARC2 procedure involves sorting the service areas into a priority order. Service areas are partitioned into three classes, designated P1 (priority 1), P2 (priority 2), and P3 (priority 3), according to the amount of contiguous service arc they have outside of the cumulative arc. P1 service areas have the highest priority for inclusion in an allotted group. The amount of service arc they have that extends outside the cumulative arc is no more than their transitional arc size. Therefore, almost all their service arc falls within the present cumulative arc. It is important, then, that groups which contain P1 service areas be given the first chance of being allotted in the present execution, since they will probably not appear in groups generated in subsequent segments. P2 service areas have an amount of service arc outside the cumulative arc which is greater than their transitional arc size but less than or equal to  $20^\circ$ . They have medium priority. Finally, P3 service areas have more than  $20^\circ$  of service arc outside the cumulative arc. They have a low priority to be allotted in the current segment since there is a good chance that they may be accommodated in later segments. After the service areas have been classified into P1, P2, and P3 classes, further sorting is done on the service areas within each class. For each class, service areas are sorted in ascending order according to their frequency of occurrence within the master groups list (i.e., the number of groups that the service area appears in). If two service areas have the same frequency, then the service area that has the smaller service arc has priority. Thus, in the end, a service area list is created in which the service area at the top of the list is considered to be the *critical* service area. This means it has the highest priority (P1) and appears in the fewest number of groups of any of the service areas represented in the current segment. Groups in the master list which contain this service area will be the first ones considered for selection. Before compiling these *critical* groups, however, NASARC2 first checks to see if any of the P1 service areas are missing from the master groups list. If a P1 service area is missing, the program computes its arc length requirement using the service area's transitional arc and tries to allot the service area an arc (equal to its computed arc length) within its service arc.

Once NASARC2 has sorted the service areas into the allotment priority described previously and taken care of any missing P1 service areas, the program enters a loop and repeatedly performs the steps outlined below. Iteration continues until either (1) all service areas in the present segment have been included in allotted groups, (2) there are no more groups left in the master groups list, or (3) there is no more unoccupied arc left in the current segment. The steps performed in the loop are as follows:

- (1) Groups containing the current critical service area are collected from the master groups list.
- (2) This subset of groups is prioritized to choose a critical group.
- (3) An allotted arc length is computed for the critical group.
- (4) NASARC2 tries to allot the critical group an arc segment within its group arc that is equal to the size computed in step (3) and which is most compatible to neighboring allotted groups.
- (5) If the group can be allotted, the master groups list is updated to reflect the most recent allotment.
- (6) The next critical service area is found by recomputing the frequency of occurrence of each remaining service area in the updated master groups list, and the steps are repeated.

A more detailed description of each step is presented in the following paragraphs.

Step (1) in the loop involves forming a sublist of groups from the master groups list. Each group in the sublist contains the critical service area. For P2 and P3 critical service areas, a check is first done to see if there is enough arc in the present segment for a two-member P2 group or a three-member P3 group, respectively. If there is not, the allotment process for the present segment stops and the run ends. This is done to prevent inefficient use of the arc by the allotment of large numbers of single P2 and two-member P3 groups. Once the sublist of groups has been formed, processing is done within this sublist to extend the group arcs of groups which are subsets of other groups. This is done in order to work with each group's total available group arc.

In step (2), the sublist groups are prioritized by performing a compound sort. The groups are first sorted according to the number of service areas in each group so that the group with the largest number of service areas appears at the top of the list. Then, groups with equal numbers of service areas are sorted so that the group with the largest group arc length appears first. Finally, groups with equal group size and equal group arc length are sorted so that the group with the smallest total frequency of occurrence is first. A group's total frequency of occurrence is defined to be the sum of the frequencies of occurrence of its constituent members. Once the sublist has been ordered in this way, the critical group is chosen as the first group in the list. The group transitional arc size for this critical group is then determined as the largest individual transitional arc area buffer among its constituent members.

In step (3), an allotted arc length is computed for the critical group as follows:

$$AL = C_1 * (N - 1) * GRP + C_2 * T + C_3 * N + C_4$$

where

<i>AL</i>	allotted arc length, deg
<i>C<sub>1</sub>, C<sub>2</sub>, C<sub>3</sub>, C<sub>4</sub></i>	user specified constants from NASARCO
<i>N</i>	number of service areas in group
<i>GRP</i>	grouping criterion, deg
<i>T</i>	group transitional arc length, deg

The result is then rounded up to the nearest whole degree.

In step (4), NASARC2 tries to allot the critical group an arc segment within its group arc that is equal in size to the value computed in step (3). The orbital separation values in the Satellite Separation Matrix file (unit 27) are used in positioning the group within its group arc to improve the compatibility between satellites in adjacent PDA's. In the positioning process, the critical group is moved along its group arc in 1° increments. At each position, tests are performed to determine if an orbital slot of sufficient width (equal to the critical group's computed arc length) exists to possibly accommodate the group or if such a slot can be opened by *pushing* existing allotted groups within their respective group arcs (the relative west-to-east ordering of existing groups

remains unchanged during the process). If a slot cannot be opened, then the critical group is simply stepped  $1^\circ$  further eastward (or westward) in its group arc and the tests are repeated. If a slot can be opened, then the required separation between the critical group and its potential east and west neighboring groups is determined using the values in the separation matrix and the arc lengths of the critical group and its potential neighbors. Specifically, the required separation between two groups (between the nearest edges of their allotted arcs) is found by taking the difference of the worst-case (largest) separation required between any pair of service areas in the two groups and the available separation that can be achieved by placing this worst-case pair of service areas at the extreme ends of their respective allotted arcs. Required separation is calculated on the worst-case assumption that the two groups abut one another, although they may, in fact, have several degrees of arc between them. If the required separation between the critical group and its east and west neighbors is negative or zero (i.e., the available separation is greater than or equal to the worst-case separation), then satellites of service areas in the critical group will experience minimal interference from neighboring satellites in the adjacent groupings. Accordingly, for each critical service area, NASARC2 will attempt to select the largest critical group and position it between neighbors where it has minimal separation requirements. Further improvement in the allotted group arrangement is accomplished in the NASARC4 arc interchange program.

If an allotment can be made, then the critical group is recorded as an allotted group and its group arc boundaries and allotted arc boundaries are also recorded. Execution then proceeds to step (5). If an allotment can not be made, then the critical service area is checked to see if it is a single P1 service area. If it is, then it is listed as an unallottable service area. If it is not, then the next group in the sublist of step (2) is designated as the critical group and execution proceeds from there.

In step (5), the master groups list is updated to reflect the critical group selection by deleting the critical group members from all groups in the master list in which they appear. As a result of these deletions, groups which were previously different from each other may now become duplicates, with their group arcs being adjacent or overlapping in some cases. Hence, it is necessary to examine the list and combine the group arcs of these duplicate groups where they are contiguous or overlapping. Lastly, because selection of the next critical service area is partly based on frequency of occurrence in the master list, redundant groups must be eliminated from the list in order to maintain the integrity of the selection criterion in choosing the true critical service area.

Step (6) in the loop involves finding the next critical service area by recomputing the frequency of occurrence of each of the remaining service areas in the updated master groups list. Then, within each of the P1/P2/P3 priority classes, service areas are sorted in ascending order: first with respect to frequency of occurrence, then with respect to service arc length. The separate ordered P1/P2/P3 sublists are then appended to one another to form the complete updated service area list. The service area at the top of the list is then chosen as the new critical service area. Execution then proceeds back to step (1) and the entire process is repeated.

As mentioned before, NASARC2 stops when either all service areas in the present segment have been included in allotted groups, there are no groups left in the master groups list, or there is no arc left in the current segment. Before NASARC2 stops, however, it writes all allotted groups to the Intermediate Allotted Groups file (unit 21). It also finds the unallotted groups in the master list (if there are any) that adjoin either edge of the cumulative arc and writes them to the Unallotted Groups file (unit 22). Control then passes to the NASARC3 module.

### 3.1.6 NASARC3 Module

The NASARC3 module—the group arc extension program—examines groups of systems that have received allotted arcs through the arc determination process (NASARC2 module) in order to determine if their group arcs may be extended further in the orbital arc. This operation is performed to retain as much flexibility as possible in the arc determination process as applied to all segments of the orbit; that is, should adjustment of prior allotted arcs become necessary in order to accommodate newly allotted arcs, the full group arc will be available for the adjustment.

When a group of compatible systems has been selected by NASARC2 to receive an allotted arc, the NASARC2 module will examine the arc span over which the group has been found to exist—the group arc—and will select a

suitable portion of the group arc to become the group's allotted arc. As stated previously, it may become necessary to revise prior allotted arcs by moving them from their original locations in order to accommodate additional allotted arcs. However, a revised allotted arc for a compatible group of systems must still lie within that group's group arc. For this reason, the full extent of each group arc into the remainder of the orbit to be analyzed must be determined.

Group arc extension is accomplished by the NASARC3 module in much the same way that group arcs are determined by the NASARC1 module; however, the computational effort required is considerably less. In NASARC1, all possible compatible groups of systems, and their group arcs, are found within the segment currently being examined; in NASARC3, the group arc that exists for known, previously selected groups of systems is determined over the full extent of the remaining orbital arc. Thus, analysis of compatibility is restricted to a small, known set of service areas.

The NASARC3 module first collects needed information from the Input Data file (see section 2.3.1.6); as in NASARC1, various operations of the program are affected by data within this file—such as treatment of affiliated sets of service areas. If affiliated sets of service areas are to be considered, the Affiliated Sets file (see section 2.3.1.5) is read and processed by NASARC3 (see fig. 3.1-12(a)).

A group of service areas and its group arc are retrieved from the Intermediate Allotted Groupings file (see section 2.3.2.3). The group is checked to determine if its group arc has been previously extended, which is indicated by a flag at the end of the group's record. If the flag indicates that the group's group arc has already been extended, the NASARC3 module returns to the Intermediate Allotted Groupings file to obtain and check the next group and group arc. If the flag indicates otherwise, the program attempts to extend the group arc in question. When all groups have been exhausted, the Intermediate Allotted Groupings file is updated (if necessary) and the program terminates.

If group arc extension has not yet taken place for a particular group, the NASARC3 module extracts information about the service areas contained in the group from the Service Area file (see section 2.3.1.3). The service arcs of the service areas are then intersected; if the intersection is not sufficient to provide room for further expansion of the group arc, NASARC3 retrieves the next group from the Intermediate Allotted Groupings file. If the intersection is sufficient, then group arc extension is feasible.

If group arc extension is feasible for the group of service areas in question, polygon points for the appropriate service areas are extracted from the Point Sets file (subroutines POSPAR, RDPTS). As in NASARC1, if point sets are not found for all service areas, error flags and error messages are written to the appropriate locations (subroutine ERR), and the program ceases execution. If point set data are collected successfully, ellipse data are then extracted from the Ellipse file (see section 2.3.1.8). Once again, if the data cannot be successfully extracted, subroutine ERR is called and the NASARC3 module stops (see figs. 3.1-11(b)).

The initial arc location is set to the appropriate western or eastern longitudinal limit of the existing group arc; this arc location is incremented if expansion of the group arc is to take place in a west-to-east direction or decremented if expansion is in an east-to-west direction. Expansion is attempted in both directions.

Over the remainder of the orbital arc, pairwise compatibility between service areas is assessed for each pair of service areas within the current group whose arc is to be extended as in NASARC1 (subroutine CICHK). At each discrete arc location where compatibility between all service areas within the group still holds, the appropriate group arc boundary is adjusted to encompass the new location where the compatible grouping continues to exist. When the group of service areas no longer continues to be compatible, or the intersected service arc has been completely examined for group arc extension, the next compatible group to be examined is taken from the Intermediate Allotted Groupings file (see figs. 3.11(a), (d), and (e)).

When all groups and group arcs in the Intermediate Allotted Groupings file have been examined for possible extension, the Intermediate Allotted Groupings file will be updated to reflect the revised group arcs (see fig. 3.1-11(a)). When this operation has been performed, the NASARC3 module concludes operation.

### 3.1.7 NASARC4 Module

The NASARC4 module is the arc interchange program. NASARC4 seeks to improve the most current arrangement of allotted arcs in orbit through a heuristic swapping procedure. Like NASARC1, NASARC2, and NASARC3, the NASARC4 module is applied within each segment of the orbital arc specified by the user in the Segments file. Thus, in each segment, NASARC4 seeks to improve the arrangement of arcs derived from use of the NASARC modules during all segments of the orbit up to and including the segment currently being processed.

The NASARC software package utilizes heuristic algorithms to produce a collection of allotted arcs, each shared by a group of compatible satellite systems. Systems are compatible if their service areas are sufficiently geographically separated to allow achievement of a required single-entry (pairwise)  $C/I$  with relatively little ( $1^\circ$  or less) orbital separation between satellites. Within each allotted arc, satellites have a high degree of flexibility in positioning due to minimal intersatellite spacing requirements.

However, when several allotted arcs are placed adjacent to one another in orbit, flexibility in positioning within a given arc may be reduced if a system in an adjacent arc is highly incompatible. In other words, a satellite within a given arc may have its flexibility in positioning limited by the need to maintain a large orbital separation from a system in an adjacent arc. Thus, while satellites within a given allotted arc are compatible, satellites grouped in different segments are incompatible. Some arrangements of allotted arcs in orbit are thus less beneficial than other arrangements in terms of both flexibility in positioning and aggregate  $C/P$ 's achieved for individual systems within allotted arcs.

For this reason, an additional module was developed for the NASARC (Version 4.0) software package. This module—NASARC4—is designed to improve the arrangement of allotted arcs in orbit produced by NASARC2 by placing more compatible allotted arcs in adjacent portions of the orbital arc.

The user will recall from section 3.1.5 that NASARC2 produces an arrangement of allotted arcs in orbit. This arrangement is treated as an initial arrangement by the NASARC4 module. NASARC4 seeks to improve the arrangement of allotted arcs in orbit via an heuristic *swapping* procedure which has proven to be both effective and computationally efficient.

The degree of incompatibility experienced by each allotted arc, with respect to its neighboring allotted arcs, can be evaluated by summing the incompatibility contributions presented by the arcs immediately adjacent to the west and east of the allotted arc in question. The *incompatibility* is evaluated as the normalized orbital separation required between systems in adjacent arcs as follows:

$$E_K \text{ (or } W_K) = \frac{\sum_{i=1}^M \sum_{j=1}^N s_{ij}}{MN}$$

where

- $M$  number of systems in allotted arc  $K$
- $N$  number of systems in  $K+1$  or  $K-1$
- $s_{ij}$  orbital separation required between system  $i$  and  $j$

NASARC4 seeks improvement in  $n$  objectives for  $n$  allotted arcs, i.e.,

$$\text{Minimize } I_K = E_K + W_K \quad K = 1, \dots, n$$

While the objectives described provide a measure of each allotted arc's compatibility with its immediate neighbors, they do not account for situations where two allotted arcs are not adjacent but may still have insufficient orbital separation. To assess the separation required between all pairs of allotted arcs, the worst-case



orbital separation between any two systems in a pair of arcs is found. Since we wish to evaluate the orbital separation that is desired between the closest endpoints of the pair of allotted arcs, we must first determine the separation that may be achieved between the two most incompatible systems if the arc were immediately adjacent. The available separation is calculated as follows:

$$A_{ij} = R_i + R_j - T$$

where

- $A_{ij}$  available separation between worst-case pair of systems in allotted arcs  $i$  and  $j$
- $R_i$  arc length of allotted arc  $i$
- $R_j$  arc length of allotted arc  $j$
- $T$  transitional arc length

If the available separation is greater than or equal to the worst-case separation required, no additional separation is required between the closest endpoints of the allotted arcs. If, however, the available separation is not sufficient, the difference between the worst-case separation required and the available separation represents the additional separation that is sought between the endpoints of the allotted arcs.

As stated earlier, the original arrangement of allotted arcs in orbit, as derived by NASARC2, is rearranged and improved by NASARC4 via a heuristic swapping procedure. That is, pairs of allotted arcs are interchanged to occupy different arc segments than they did originally in an attempt to place more compatible allotted arcs in adjacent portions of the orbit.

To perform such interchanges, NASARC4 first determines a complete list of all arc interchanges that are feasible. For an interchange of allotted arcs to be feasible, the two allotted arcs must meet the following conditions:

- (1) The group arcs associated with each allotted arc must intersect by at least the sum of the required arc lengths for each allotted arc.
- (2) The intersection of the group arcs associated with each allotted arc must encompass both allotted arc locations.

Condition (1) restricts consideration of alternatives to **meaningful** alternatives; if condition (1) is not met by two allotted arcs, the two segments are restricted to portions of the orbit that are sufficiently distant to imply that the appropriate service area cannot be served by the appropriate satellites if the locations of the allotted arcs were to be interchanged. Condition (2) ensures that slots in the arrangement may be directly interchanged, subject to minor adjustments for slightly different length requirements for the two segments.

When a complete list of feasible interchanges has been assembled and stored in a matrix (subroutine FEASIN), NASARC4 begins the improvement process. The improvement process has three major phases:

- (1) Generation of an improved starting arrangement
- (2) Generation of the best alternative arrangement over all possible interchanges
- (3) *Spreading* of the allotted arc arrangement found in phase (2) to achieve the necessary separation between endpoints of allotted arcs

To generate an improved starting arrangement, the matrix of feasible interchanges is examined for pairs of elements that may be interchanged only with each other. Such elements are termed *pair-restricted*. If these interchanges result in an improvement of the arrangement's objective function values, they may be performed without affecting the outcome of any other interchanges. When all such pairs have been found and interchanged, NASARC4 has an improved starting arrangement. As the pair-restricted interchanges need no longer be

considered, they are eliminated from the matrix of feasible interchanges, which are then used to generate arrangements that improve further on the starting solution. If no pair-restricted interchanges exist, the starting arrangement is that derived by the NASARC2 module.

The search for the best alternative over all possible interchanges begins with a reexamination of the matrix of feasible interchanges. When an arc with one or more candidate interchanges has been found, alternative arrangements of allotted arcs are generated (subroutine SWAP). The *basic* arrangement—initially, our starting arrangement found in phase (1)—is held constant. Alternatives to the basic arrangement are generated by examining all possible interchanges for each allotted arc. Each interchange is examined for **efficiency**—i.e., improvement of the objective functions of the basic arrangement. If an interchange produces an efficient alternative arrangement, the new alternative is then compared with the current best alternative to determine which alternative is **preferred**. Preference of one arrangement over another is measured, first, by counting both the number of allotted arcs for which the first alternative's objective values are lower than the corresponding values for the second alternative, and vice versa. The alternative with the greater number of lower objective values is preferred. If, however, a tie results, the average objective function value is calculated for each alternative; the arrangement with the lower average objective is preferred. Finally, in the unlikely event that both alternatives have the same average objective value, the current best alternative is retained.

During the process just described, the basic arrangement is held constant. When all alternatives reachable from the current basic alternative have been examined, the basic alternative is replaced by the best alternative found over all interchanges. The process of generating new alternatives begins again with the new basic alternative. The matrix of feasible interchanges is regenerated (subroutine FEASIN) to account for the effects of changes in allotted arc locations. When no further improvement of the current basic alternative is possible, no further alternatives are generated and phase (2) is concluded.

Phase (3) of the arc rearrangement process attempts to spread the allotted arc segments, as ordered by phase (2), further apart if needed. Additional separation requirements consist of orbital spacings necessary between the nearest endpoints of allotted arc segments. In the majority of cases, no orbital separation is required between allotted arcs; in other cases, the required distance between allotted arcs is acquired through the swapping process of phase (2). Phase (3) attempts to provide further required separation between both adjacent and nonadjacent allotted arc segments by pushing allotted arcs in an east-to-west direction (subroutine TEMPOR). This process is nearly identical to the pushing operation of NASARC2 and is not discussed in further detail here. The operations differ in that while NASARC2 attempts to create an unoccupied orbital segment of a single specified length NASARC4 first attempts to obtain the full separation still needed between allotted arcs; if this separation cannot be obtained, successive reductions of the required separation take place until the maximum obtainable separation is achieved.

When all phases of the improvement process are completed, the new orbital locations are output to the Intermediate Allotted Groupings file originally produced by NASARC2.

When all segments of orbital arc specified within the Segments file have been processed, the NASARC4 module produces the NASARC Report file (subroutine REPORT) and the Condensed Report file (subroutine CNDREP).

Flowcharts of the NASARC4 module and selected subroutines are presented in figures 3.1-12(a) to (g), 3.1-13(a) and (b), and 3.1-14(a) to (c), respectively.

### 3.2 Creation of NASARC (Version 4.0) Input Files

In this section details are given on the preparation of data for files input to the NASARC modules. The user will recall that detailed discussions of the structures and formats of the Segments file, the Service Area file, the Point Sets file, the Affiliated Sets file, the Input Data file, and the Ellipse file were given in sections 2.3.1.1 and 2.3.1.3 to 2.3.1.6; the user is urged to refer to these sections for information on the specific format for the data the user wishes to input. This section is concerned with the derivation of data for input to the NASARC software package and with the transformation of the data into a form compatible with the formats described in section 2.3; the user is also urged to refer to the *NASARC (Version 4.0) Technical Manual* for conceptual discussion of material presented in this section.

### 3.2.1 Segments File Data

As was stated in section 2.3.1.1, the NASARC (Version 4.0) software package is designed to apply the NASARC1, NASARC2, NASARC3, and NASARC4 modules in sequential fashion to successive portions of the orbital arc defined by the user within the Segments file.

Segments to be examined by NASARC1, NASARC2, NASARC3, and NASARC4 must be specified in the format presented in section 2.3.1.1. The only restriction on ordering records within the Segments file is that following the first record all subsequent records must adjoin either the eastern or western boundary of the cumulative arc segment defined by preceding records. A segment adjoins a prior segment if the western and eastern arc limits or eastern and western arc limits, respectively, differ by exactly  $1^\circ$ . As may be inferred from the preceding statement, no two segments specified within the Segments file may overlap—that is, encompass any of the same orbital locations.

The segments to be examined by the NASARC1, NASARC2, NASARC3, and NASARC4 modules are defined by longitudinal limits expressed in decimal degrees. In each record, the western longitudinal limit of the segment to be examined must be followed by the eastern longitudinal limit. Such longitudes must be in the range ( $-179.00^\circ$ ,  $180.00^\circ$ ); should a segment cross the  $180^\circ$  meridian, the western longitudinal limit is numerically greater than the eastern longitudinal limit. Thus, it is possible that a segment described within the Segments file has a positive (greater than or equal to 0.0) western limit and a negative eastern limit. It is also possible (if a large portion of the orbit is used) that both limits are negative but that the western limit is less negative than the eastern limit.

Each set of segment limits is also accompanied by a grouping criterion value to be applied within that portion of the orbital arc. As stated earlier, the grouping criterion expresses, in degrees of orbital arc, the maximal orbital separation that may be required between two systems for the systems to be considered compatible.

While all sets of segments specified according to the previous guidelines are valid, the most effective and efficient use of the NASARC (Version 4.0) software package is achieved if the segments to be analyzed, and their associated grouping criterion, are selected in a strategic manner. The primary goal of the piecewise approach to allotting orbital arcs is to reduce memory requirements and run time needed for execution of the overall software package while obtaining useful allotted arcs for all service areas considered. This goal may be achieved by attempting to equalize the number of service areas to be considered within each segment of the orbital arc and by adjusting the grouping criterion to make grouping of systems either more likely or less likely.

Figure 3.2-1 presents a graph of the number of service areas whose service arcs encompass an orbital location (longitude) versus orbital location (longitude). From the figure, we see that there is a portion of the orbital arc—extending from approximately  $-10^\circ$  east longitude to  $40^\circ$  east longitude—that contains the area of peak density of service arcs for service areas. However, many service areas whose service arcs intersect the peak-density portion of the orbit have service arcs that include significant portions of arc that fall outside the peak-density segment. If allotted arcs can be obtained for these service areas in portions of the orbit outside the peak-density area, the number of service areas that must be considered for the peak-density portion of the orbit can be reduced—requiring less computer time and memory for use of the NASARC modules on this portion of the orbit.

After consideration of the previous discussion, it should be clear to the user that it is desirable to begin use of the software package in a low-density portion of the orbital arc. It is not necessarily more advantageous, however, to begin with the portion of the orbit which encompasses the *lowest* density of service arcs. The user must keep in mind that the goal is to equalize the number of service areas examined within each segment of the arc. Thus, the most effective approach may be to begin with a portion of the orbit to the east or west of the peak area and progress through areas of lower density using larger segments of arc until all the segments that the user wishes to examine have been considered. Alternatively, the user might choose a large segment of arc encompassing low-density areas of the curve and alternate segments of arc to the east or west of the original segment in approaching the peak-density portion of the orbit. It is difficult to quantify a precise recipe for selecting the segments to be analyzed and the order in which to analyze them; the user will quickly learn from his own experience which approaches are suited to particular sets of circumstances.

# SERVICE ARC DENSITY

WORLD ARCS FILE

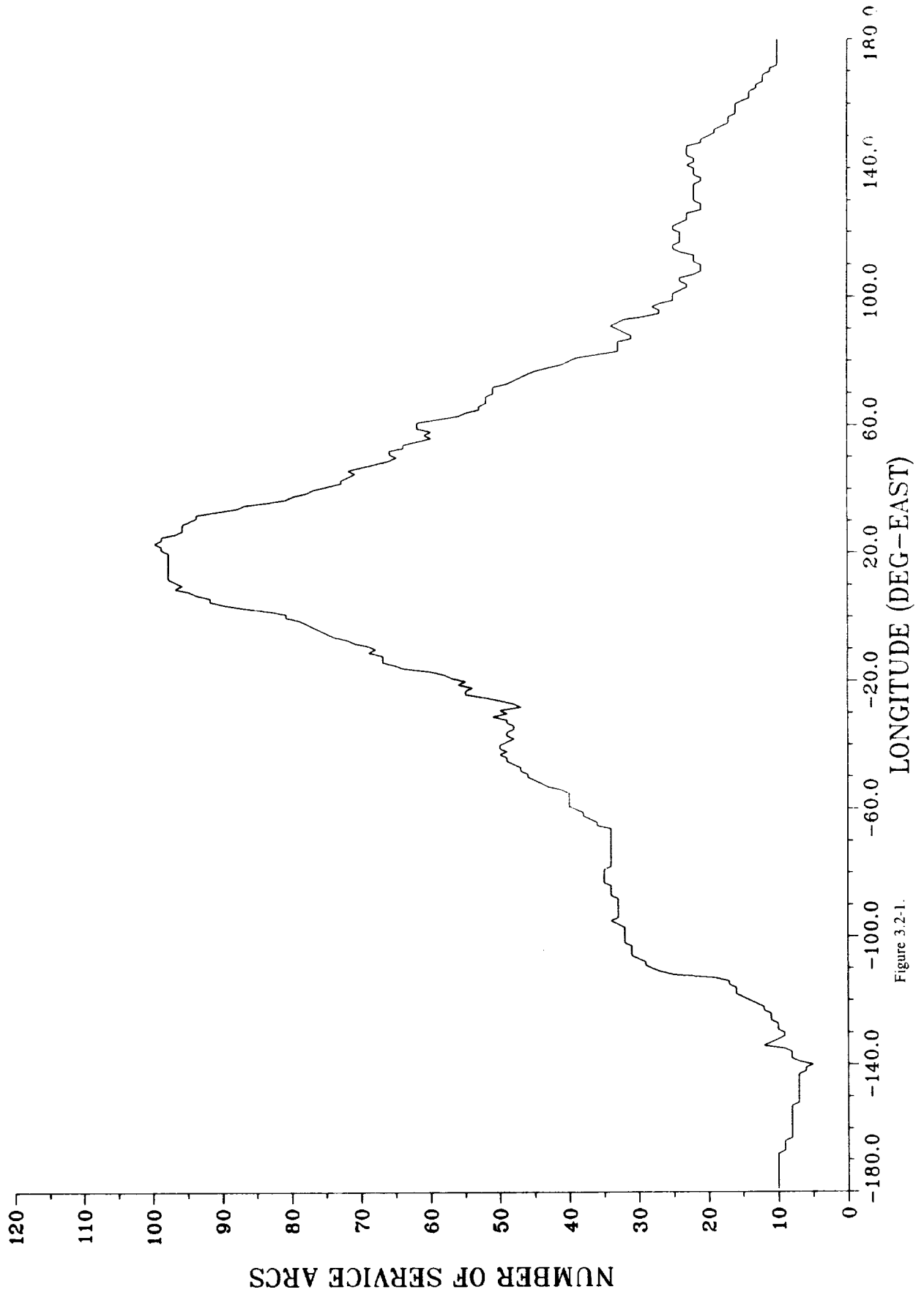


Figure 3.2-1.

It is also difficult to present a precise recipe for selecting a grouping criterion to be applied within each segment. The purpose of applying a separate grouping criterion value for each segment is to allow the user to influence the number of compatible groupings in a particular segment. This ability is particularly useful if a NASARC run results in an unallotted administration within a particular segment; the grouping criterion for this segment could be adjusted to a higher value to make accommodation of the administration within a compatible group more likely. Once again, the user will learn from experience what combinations of segments and grouping criteria are suited to his particular scenario. An example Segments file (see fig. 3.2-2) may help to illustrate the discussion presented in this section.

FILE:	INITIAL	SEGMNTS	A1
	120.00	-124.00	1.000
	80.00	119.00	0.750
	60.00	79.00	0.750
	-123.00	-55.00	0.500
	-54.00	-28.00	0.750
	45.00	59.00	0.750
	-27.00	0.00	0.750
	1.00	44.00	1.000

Figure 3.2-2.—Segments file

### 3.2.2 Service Area Data

Data in the Service Area file, as discussed in section 2.3.1.3, have a variety of functions. First and foremost, the data in the Service Area file establish a complete list of service areas to be examined for arc determination within the segments defined by the user along with service arc limits for each area. Each record of the file also contains data that are applied to the individual service area in question. The required inputs are described in subsequent sections; details of their format appear in section 2.3.1.3. Prior to the data for individual service areas, however, the file contains a single record with global data to be applied to the entire scenario.

#### 3.2.2.1 Global Data

As discussed in section 2.3.1.2, the Service Area contains, in its first record, global data that are to be applied to the entire scenario described by the Service Area file. These inputs are described in the following sections.

##### 3.2.2.1.1 Rain Attenuation Flag

The rain attenuation flag is a single character code that indicates whether or not rain attenuation is to be included in *C/I* calculations. If the flag is set to Y (yes), rain attenuation is added to the power calculated from the *C/N* value. If a user-supplied power value is to be utilized, that value is assumed to be sufficiently high to include compensation for rain fade. If the flag is set to N (no), all calculations are performed on a clear-sky basis.

Further discussion on the use of rain attenuation in *C/I* calculations is provided in the *NASARC (Version 4.0) Technical Manual*.

##### 3.2.2.1.2 Minimum Half-Power Beamwidth of Satellite Antenna

The minimum half-power beamwidth of the satellite antenna serves two purposes. As ellipses are read from the Ellipse file, those having major and/or minor axis beamwidths less than this minimum value are adjusted so that the minimum value is satisfied. In addition, the minimum half-power beamwidth is utilized within the fast rolloff antenna patterns—where the gain for any size beam falls off at the same rate as for the minimum size beam.

The minimum half-power beamwidth for the satellite antenna is interpreted as the entire half-power beamwidth, from edge-to-edge of coverage, rather than from center to edge. All calculations within the NASARC programs involving satellite half-power beamwidth interpret the beamwidth in this way.

It is suggested the user calculate a minimum beamwidth that is suitable for the chosen frequency and a reasonable physical size for the satellite antenna. As an example, a minimum beamwidth of 1.4° would correspond to a satellite antenna diameter of 3.3 m operating at a frequency of 4.50 GHz. Values of 0.8° and 1.6° have been suggested for allotment planning in the Fixed Satellite Service.

### 3.2.2.1.3 Constants for Allotted Arc Equation

The four constants contained within the first record of the Service Area file are used to calculate the length of the allotted arc to be given to a particular group of compatible systems. The allotted arc length is determined in the NASARC2 module as follows:

$$AL = C_1 \cdot (N - 1) \cdot GRP + C_2 \cdot T + C_3 \cdot N + C_4 \quad (3.2-1)$$

where

$C_1, C_2, C_3, C_4$  constants specified within first line of Service Area file

$AL$  allotted arc length

$N$  number of compatible service areas contained in group

$GRP$  user-supplied grouping criterion, deg

$T$  calculated group transitional arc length, deg (see *NASARC Technical Manual*)

Equation (3.2-1) shows that it is not desirable to set all constants  $C_1$ ,  $C_2$ ,  $C_3$ , and  $C_4$  equal to 0.0 as this would result in an allotted arc length of 0°. For this reason, an error message is generated by the NASARCO module during verification of user input files if  $C_1 = C_2 = C_3 = C_4 = 0.0$  exists within the Service Area file.

The user will observe that equation (3.2-1) allows for weighting the factors to be taken into account when calculating the allotted arc length. For instance, the user might have selected 0.0° (colocation) for the value of the grouping criterion  $GRP$ . In this situation, the user would be well advised to include provision in the equation to adjust the value of the allotted arc length for the number of compatible service areas involved. Thus, the user would wish to provide a nonzero value for the constant  $C_3$ . A variety of other situations may be taken into account in a similar manner.

The user is strongly advised to consult the *NASARC (Version 4.0) Technical Manual* (section 3.3.4.2) before experimenting with values for  $C_1$ ,  $C_2$ ,  $C_3$ , and  $C_4$ .

### 3.2.2.1.4 Reference Noise Bandwidth

The reference noise bandwidth is used to present a noise bandwidth that an input  $C/N$  may be referenced to. Typically, this input has a value of 1 MHz. The reference noise bandwidth must be included in the calculation of power from the input  $C/N$  value.

### 3.2.2.1.5 Minimum Earth Station and Satellite Power

Minimum earth station and satellite power limits may be used to set a lower bound for transmitter power levels for all systems. Power levels are either calculated, based on the  $C/N$  criteria, or taken directly from input values, as required by power calculation options, and compared against the appropriate lower power limit. The maximum of the two values is utilized in  $C/I$  calculations. This feature is provided as a means of reducing power inhomogeneities between systems.

Further information on the use of these values is provided in the *NASARC (Version 4.0) Technical Manual*.

### 3.2.2.2 Service Area Data

As stated in section 2.3.1.3, the Service Area file utilized by NASARC modules contains a list of service areas and the western and eastern longitudinal limits of the service arc associated with each. Each service area is

symbolized by a three-character service area code. It is most convenient to use the designations utilized by the International Telecommunication Union (ITU); however, any ITU designation containing less than three characters must be padded with 0's for proper processing by the NASARC modules. Western and eastern limits of each service area's associated arc are expressed in integral decimal degrees of east longitude, ranging from  $-179.00^\circ$  to  $180.00^\circ$ . These limits correspond to the limits of a service area's service arc for the elevation angle desired by the user. However, it must be remembered that high-latitude service areas may have narrow or nonexistent service arcs for high elevation angles. It is suggested that, in such cases, the user choose the elevation angle that produces a service arc length of at least  $30^\circ$  when available. This will greatly increase the likelihood of finding compatible groups containing the service area in question and of allotting an arc to that service area. For precise detail of a suggested service arc determination method the user is referred to section 3.1.1.5 of the *NASARC (Version 4.0) Technical Manual*.

Within the Service Area file, records for service areas must be placed in an order that maintains consistency with the Ellipse file that is to be used with the NASARC (Version 4.0) software package.

### 3.2.2.3 Additional Service Area Data

As discussed in section 2.3.1.3, specification of additional service area data depends on the precise situation the user wishes to examine with the NASARC (Version 4.0) software package; the inputs have a variety of purposes described in the following sections. The user is also referred to the *NASARC (Version 4.0) Technical Manual* for a detailed discussion related to these inputs; the data items are described in subsequent sections in the order in which they appear following the data entries described in section 3.2.2.2.

#### 3.2.2.3.1 Set Affiliation Code Data

The set affiliation code is an integer which indicates that a service area is to be included in an affiliated set of service areas. The user will recall that an affiliated set of service areas consists of geographically dispersed areas that are to be served from a single satellite. By placing the same numeric code in the records of several service areas, the user indicates that the service areas are all members of the same set. Service areas with nonidentical codes are not considered to be members of the same set. If no code is specified, or the code specified is equal to zero, the service area is regarded as independent—that is, not a member of any set.

Integer codes utilized to express set affiliation must correspond with numeric codes in the Affiliated Sets file—that is, no code (other than zero or blank) should appear in the Service Area file unless that code also appears in the Affiliated Sets file. Codes utilized in both files should follow the sequence 1, 2, ..., etc.; that is, 3 should not be utilized as a set affiliation code unless 1 and 2 have already been utilized to designate other affiliated set members.

Finally, the number of service area records containing a particular set affiliation code should correspond to the number of members identified for the appropriate affiliated set in the Affiliated Sets file.

For further discussion of the concept of affiliated sets the user is referred to the *NASARC (Version 4.0) Technical Manual*.

#### 3.2.2.3.2 Space Station and Earth Station Characteristic Data

Section 2.3.1.3 states that space station characteristics are specified individually for each service area. These characteristics are described by five inputs—the space station antenna pattern code, the space station antenna parameter, the space station antenna, the space station receiver noise temperature, and satellite transmitter power. The format for specifying these items is given in section 2.3.1.3.

Similarly, earth station characteristics are specified individually for each service area. Earth station characteristics are described by seven inputs—in this case, the earth station transmit antenna pattern code, the earth station

transmit antenna diameter (expressed in meters), the earth station receive antenna pattern code, the receive antenna diameter, the earth station antenna efficiency, the earth station receiver noise temperature, and the earth station transmitter power. The format for specifying these items is given in section 2.3.1.3.

Antenna efficiencies are always expressed as decimal percentages—that is, 55-percent efficiency is expressed as 0.55. Thus, any antenna efficiency specified must be greater than or equal to 0.0 and less than or equal to 1.0. Antenna efficiency for space station and earth station antennas is expressed in this manner regardless of the antenna pattern type and antenna parameter value otherwise specified.

The user may select a space station antenna pattern type from a collection of patterns implemented within the NASARC programs; once a six-character pattern code has been selected, the user need specify at most one additional space station antenna parameter value in order to fully describe the desired antennas.

The eleven types of space station antennas available in the NASARC (Version 4.0) software package, and their associated six-character codes, are as follows:

SCA558	Satellite antenna pattern presented in CCIR Report 558-3
RARCST	Standard rolloff satellite antenna pattern given in RARC-83 Final Acts
RARCFR	Fast rolloff satellite antenna pattern given in RARC-83 Final Acts
FASTRO	Improved fast rolloff satellite antenna pattern presented in Document No. AH-178-296 of the Interdepartmental Radio Advisory Committee
ORBIT0	Satellite antenna pattern utilized in ORBIT-II synthesis program developed by Kokusai Denshin Denwa of Japan
ORBITF	ORBIT-II satellite antenna pattern with a $-10$ dB floor added for use in NASARC
WARC77	Satellite antenna pattern given in the WARC-77 Final Acts
IW4/1	Fast rolloff satellite antenna pattern presented in CCIR Report 558-3 and recommended by IWP4/1 (June 1986)
IWPREV	Similar to IWP4/1, but utilizing simple ellipse as main beam
JIWPRF	Fast rolloff satellite antenna pattern presented in the CCIR Report to Second Session of the Space World Administrative Radio Conference (WARC-88) (December 1987)
JIWPRV	Similar to JIWPFR, but utilizing simple ellipse as main beam

The user may select from three earth station antenna patterns implemented within the NASARC (Version 4.0) software. The three patterns available are the following:

ETA391	Earth station antenna pattern presented in CCIR Report 391-4 with $32-25 \log(\varphi)$ characteristic
ETAIMP	Earth station antenna pattern presented in CCIR Report 391-4 with $29-25 \log(\varphi)$ characteristic
ETACOM	Earth station antenna pattern, combining features of ETA391 and ETAIMP

The associated input parameters related to each of the antenna patterns are given in table 3.2-1; the corresponding falloff equations are given in the *NASARC (Version 4.0) Technical Manual* in section 3.1.1.2.4. Satellite and earth station receiver noise temperatures (expressed in dB-K) are also specified for each service area's system. Satellite and earth station transmitter powers (expressed in dBW) are specified for each service area's system. These values are utilized unless the user specifies that the powers are to be calculated to meet a target uplink or downlink  $C/N$ . The user is referred to section 3.2.2.3.5 herein for information on power calculation options.



TABLE 3.2-1—ANTENNA PATTERNS AND ASSOCIATED INPUT PARAMETERS

Antenna code	Associated input parameter	Typical range of values	Technical Manual reference section
ETA391	Antenna diameter	3.0 to 10.0 m	3.1.1.2.4.1
ETAIMP	Antenna diameter	3.0 to 10.0 m	3.1.1.2.4.2
ETACOM	Antenna diameter	3.0 to 10.0 m	3.1.1.2.4.3
SCA558	Falloff to first sidelobe level	20.0 to 30.0 dB	3.1.1.2.4.4
RARCST	None required	-----	3.1.1.2.4.5
RARCFR	None required	-----	3.1.1.2.4.6
FASTRO	None required	-----	3.1.1.2.4.7
ORBIT0	Decay constant, $\alpha$	3.5 to 5.5	3.1.1.2.4.8
ORBITF	Decay constant, $\alpha$	3.5 to 5.5	3.1.1.2.4.9
WARC77	None required	-----	3.1.1.2.4.10
IWP4/1	Falloff to first sidelobe level	20.0 to 30.0 dB	3.1.1.2.4.11
IWPREV	Falloff to first sidelobe level	20.0 to 30.0 dB	3.1.1.2.4.12
JIWPFRR	Focal length to diameter ratio	0.73 to 1.3	3.1.1.2.4.13
JIWPRV	Focal length to diameter ratio	0.73 to 1.3	3.1.1.2.4.14

### 3.2.2.3.3 Uplink and Downlink Carrier to Noise Ratios

Target uplink and/or downlink  $C/N$ 's may be included for each service area's system. As was briefly discussed in section 3.2.2.3.2, satellite and/or earth station power may be supplied by the user or it may be calculated as that power necessary to achieve a target  $C/N$  value. Thus, the uplink and downlink  $C/N$  values are intended as criterion values that must be achieved with appropriate power levels. The  $C/N$  criteria are expressed in decibels per megahertz (dB/MHz). Further information on power calculation options is provided in section 3.2.2.3.5 herein.

### 3.2.2.3.4 Aggregate Carrier to Interference Ratio

The aggregate  $C/I$  is also specified as a criterion value for each service area's system. However, unlike the target  $C/N$  values described in the previous section, the aggregate  $C/I$  criterion is not utilized directly by major calculations in NASARC. As stated previously, NASARC determines compatibility between systems based on the single-entry  $C/I$  achieved at the orbital spacing between satellites specified by the grouping criterion. The aggregate  $C/I$  criterion is used to determine the single-entry  $C/I$  criterion to be achieved as follows:

$$C/I_{\text{single entry}} = C/I_{\text{aggregate}} + \text{RATIO}$$

where *RATIO* is the margin of difference necessary to achieve an aggregate  $C/I$ , given a single-entry  $C/I$  (in dB).

Program variable *RATIO* is currently set within the NASARC modules to a value of 6 dB. Thus, for example, Version 4.0 of the NASARC software assumes that a target aggregate  $C/I$  value of 26 dB will be achieved for a system if single-entry  $C/I$  calculations are performed on the basis of a 32-dB criterion.

### 3.2.2.3.5 Uplink and Downlink Power Calculation Flags

The uplink and downlink power calculation flags provide the user with the capability to specify, for each system, the bases on which both satellite and earth station powers are included in calculations of effective isotropically radiated power (EIRP).

Two options are available for both the uplink and the downlink. The user's choice in each case is indicated numerically with a single-digit specification. If the user selects option 1, the power utilized in the EIRP calculation is the value that the user supplies in specifying space station and earth station characteristics. If the user selects option 2, the appropriate power value is first calculated from the user's specified target uplink or downlink  $C/N$  ratio (see section 3.2.2.3.3 herein), and other values, as follows:

$$P = C/N - G_t + L + B + k - G_r/T + R$$

where

- $C/N$  link carrier to noise ratio
- $L$  free space loss on desired path
- $B$  noise bandwidth in specifying  $C/N$
- $k$  Boltzmann's constant
- $G_r$  on-axis gain of wanted receive antenna
- $T$  noise temperature of wanted receive antenna
- $G_t$  on-axis gain of transmit antenna
- $R$  link rain attenuation compensation

Since two options are available for both the uplink and downlink, four combinations of options are available to the user. For example, the user may specify use of a supplied transmit power value for the uplink and calculation of power from the target  $C/N$  value for the downlink. Thus, the specification of power calculation options for the uplink and downlink are independent of one another.

### 3.2.2.3.6 Existing System Flag

The existing system flag is of limited application, but it can affect how compatibility assessment takes place. This single-character flag allows the user to indicate whether or not a given service area's system is an *existing* system (indicated by a Y) or a *planned* system (indicated by an N). Originally, this flag was incorporated as an input to allow the NASARC software to properly accommodate existing systems as defined for purposes of allotment planning at the 1988 World Administrative Radio Conference. However, an explanation of this option is provided herein in the event that the user may have an alternative application for the NASARC software for which this option is appropriate.

The existing system option affects compatibility assessment for the system in question with all other systems. If the system in question is designated as an existing system, it is regarded as being automatically compatible with other systems also designated as existing. That is, the usual evaluation of the single-entry  $C/I$  value achieved at the grouping criterion orbital spacing is suppressed. In all other cases—where one or both systems of the pair being examined for compatibility are designated as planned rather than existing—compatibility assessment takes place as usual, unless it is suppressed by some other factor such as service area affiliation.

### 3.2.2.3.7 Link Calculation Flag

Like the existing system flag, the link calculation flag is also of limited application, and also affects compatibility assessments involving the system in question. The link calculation flag allows the user to specify, via a single-

character option, whether the system is to be considered on an uplink-only basis (indicated by a U), downlink only basis (indicated by a D), or on the basis of both uplink and downlink (indicated by a B).

In compatibility assessment, pairs of systems in which one system is uplink only and one system is downlink only are regarded as automatically compatible. For all other combinations, compatibility is assessed in the usual manner.

### 3.2.3 Point Sets File Data

In order for the NASARC modules to run successfully, the Point Sets file must contain (at minimum) a set of polygon points for each service area included in the Service Area file. Up to ten such points may be specified for each service area; the points should define a convex polygon of latitude-longitude pairs that closely approximates the geographical boundary of the service area. Generally, a good representation may be obtained with ten or fewer points. The data that the user must provide, if constructing a point set for a given service area, are listed and described in table 2.2-3.

Precise format requirements for this type of data are given in section 2.3.1.4.

### 3.2.4 Affiliated Sets Data

The Affiliated Sets file, described in section 2.3.1.5, contains an integer numeric code, a three-character code, and the number of member service areas for each affiliated set of service areas to be examined by the NASARC modules. The user will recall that an affiliated set of service areas consists of a collection of geographically dispersed service areas that are to be served from a single spacecraft.

Each item of data furnished for each affiliated set of service areas has a specific purpose. The user will recall from the discussion presented in section 3.2.2.3.1 that each service area within the Service Area file may be assigned an integer numeric code indicating membership in an affiliated set of service areas. The integer numeric code provided for each affiliated set within the affiliated sets file provides a link between each affiliated set and its member service areas; thus, the numeric code supplied for each affiliated set within the Affiliated Sets file must match the numeric code in number of records of member service areas within the Service Area file. Codes utilized should follow the sequence 1, 2, ..., etc.; that is, the first affiliated set represented within the Affiliated Sets file should have numeric code 1; the second, 2; and so on. Service Area file records for service areas that are members of the set with code 1 should all contain a 1 in the affiliation code field.

Each affiliated set's numeric code is followed by a three-character set code. The user will recall from previous discussions within this manual that affiliated sets of service areas must be treated in an all-or-nothing manner within the NASARC modules. As an affiliated set is a set of geographically separated service areas that are to be served from a single satellite, affiliated set members may only be placed in a larger compatible group of service areas if all set members are eligible for inclusion. Service area codes for individual member service areas do not appear in any compatible groups of service areas generated by NASARC1. Rather, if and only if all member service areas of an affiliated set may be included in a compatible group of service areas, can the three character set code take the place of individual three-character codes for member service areas. In this way, it is ensured that all members of an affiliated set of service areas are treated as a single entity in the arc determination process, as desired. The choice of a three-character set code is left to the user; however, care should be taken to avoid accidental duplication of any administration code.

The final item to be included for each affiliated set in the Affiliated Sets file is an integer, expressing the number of members in each affiliated set of service areas. This item is used for a variety of purposes within the NASARC modules, including file checking and verification in NASARC0, construction of the list of service areas to be examined within a portion of the orbit in the NASARC1 module, and assembling a list of compatible candidate service areas for group arc extension in the NASARC3 module.

Precise format information is contained in section 2.3.1.4 of this manual; for further discussion of the affiliated sets concept, the user is referred to the *NASARC (Version 4.0) Technical Manual* (see section 3.1.1.2.2).

An example Affiliated Sets file and a partial Service Area file are presented in figure 3.2-3.

### 3.2.5 Inputs to NASARCO Program/Input Data File

As discussed in section 2.3.1.6, the Input Data file is produced by execution of the NASARCO module. The Input Data file is composed partially of data drawn from several files; variables included in this category are the allotted arc length equation constants and the grouping criterion. The file also contains the user's responses to queries generated by the NASARCO program. The input parameters to be supplied by the user are detailed in the subsequent sections; guidelines are also given for the selection of appropriate values.

Following the discussion of required user inputs in the subsequent sections, the interactive prompts issued by the NASARCO program and the correct formats for responses are presented in table 3.2-2. An example Input Data file is presented in figure 3.2-4. Those user inputs discussed in the subsequent sections are technical parameter values; inputs such as the date and time of run and scenario description comments are also prompted for by NASARCO but are self-explanatory.

#### 3.2.5.1 Downlink Frequency

The user is requested by the NASARCO module to supply a single downlink frequency (expressed in GHz). The frequency parameter has an important effect on antenna gain calculations and, therefore, on antenna discrimination calculations. The value of frequency supplied by the user is utilized directly or indirectly in the calculation of antenna on-axis gains, antenna half-power beamwidths, and coefficients for antenna discrimination equations; the frequency affects antenna diameter-to-wavelength ratio and thus may determine which set of equations is utilized to model the antenna fall-off characteristics for the earth station.

It is suggested that the user supply a frequency equal to the midpoint of the downlink band for which he or she intends to apply NASARC; for exercises related to allotment planning of the Fixed Satellite Service, the selected frequency should lie in one of the following intervals:

$$\begin{aligned} 4.5 \text{ GHz} &\leq \text{FREQ} \leq 4.8 \text{ GHz} \\ 10.7 \text{ GHz} &\leq \text{FREQ} \leq 10.95 \text{ GHz} \\ 11.2 \text{ GHz} &\leq \text{FREQ} \leq 11.45 \text{ GHz} \end{aligned}$$

#### 3.2.5.2 Uplink Frequency

The user is requested by the NASARCO module to supply a single uplink frequency (expressed in GHz). As for the downlink, this parameter has an important effect on antenna gain calculations and antenna discrimination calculations.

For the uplink frequency, it is suggested that the user supply a frequency equal to the midpoint of the uplink band for which he or she intends to apply NASARC; for exercises related to allotment planning of the Fixed Satellite Service, the selected frequency should lie in one of the following intervals:

$$\begin{aligned} 6.425 \text{ GHz} &\leq \text{FREQ} \leq 7.075 \text{ GHz} \\ 12.75 \text{ GHz} &\leq \text{FREQ} \leq 13.25 \text{ GHz} \end{aligned}$$

FILE: CINP14AN CODES	A1	FILE: PART	ARCS	A1	
1 500 5		Y	0.8000	1.0000	
2 510 12		ABW	-119.00	-19.00	
3 520 2		ADL	104.00	176.00	1
4 530 4		AFG	43.00	95.00	
5 540 2		AFS	-25.00	84.00	
6 550 5		AGL	-37.00	74.00	
7 560 3		ALB	-29.00	69.00	
8 570 2		ALG	-30.00	37.00	
9 580 3		ALS	-169.00	-139.00	2
10 590 3		AND	-48.00	51.00	
11 600 6		ARG	-89.00	-55.00	3
12 620 3		AR2	-58.00	-24.00	3
13 630 2		ARS	21.00	60.00	
14 640 2		ASC	-76.00	53.00	4
15 650 2		ATG	-112.00	-12.00	
16 660 2		ATN	-133.00	1.00	5
		AUS	85.00	-178.00	6
		AU2	100.00	-133.00	6
		AU3	35.00	167.00	6
		AU4	103.00	-145.00	6
		AU5	73.00	148.00	6
		AUT	-18.00	46.00	
		AZR	-65.00	6.00	7
		B00	-70.00	-61.00	
		B02	-70.00	-61.00	
		B03	-70.00	-61.00	

Figure 3.2-3.—Affiliated Sets and Service Area files structure.

FILE: TEST	DATA	A1
ERROR FLAG	=	N
DOWNLINK FREQUENCY (GHZ)	=	11.200
UPLINK FREQUENCY (GHZ)	=	13.000
RECIEVER NOISE BANDWIDTH (MHZ)	=	1.000
AFFILIATED SETS FLAG	=	Y
RAIN OUTAGE PERCENTAGE OF YEAR	=	0.100
MAXIMUM RAIN ATTENUATION LIMIT	=	8.00
GROUPING CRITERION (DEGREES)	=	1.000
CONSTANT C1: C1*(N-1)*CRIT	=	1.000
CONSTANT C2: C2*BUFARC	=	1.000
CONSTANT C3: C3*N	=	0.000
CONSTANT C4: C4	=	0.500
SCENARIO IDENTIFIER	=	01/23/89 12:30
COMMENT:	EXAMPLE NASARCO INPUT DATA SET	
COMMENT:	FOR NASARC VERSION 4.0	

Figure 3.2-4.—Example Input Data file.

C 2

### 3.2.5.3 Percent of Year Outage Due to Rain Attenuation

As has been stated, the NASARCO program reads from several files to gather selected data, in part to determine appropriate prompts to issue to the user. If the rain attenuation flag in the Service Area file is set to Y, indicating that rain attenuation is to be included in appropriate calculations, the NASARCO program prompts the user to supply an annual percent-of-time outage for the link due to rain attenuation.

The selected percentage should lie within the following interval:

$$0.001 \leq \text{RNOUT} \leq 1.0$$

### 3.2.5.4 Maximum Rain Attenuation Limit

If the rain attenuation flag in the Service Area File read by NASARCO is set to Y, the program first queries the user regarding whether or not the rain attenuation to be taken into consideration is to be limited to a maximum value. If the user responds in the affirmative, a prompt is issued for a value (in dB) that expresses the maximum rain attenuation to be taken into account.

TABLE 3.2-2—INTERACTIVE PROMPTS/USER RESPONSES FOR NASARCO MODULE

PLEASE ENTER THE DATE AND TIME OF THIS RUN. ENTER THE DATE AS: "MONTH/DAY/YEAR" (EG. 03/09/88). ENTER THE TIME AS: "HOURS:MINUTES" (EG. 08:25).

ENTER DATE  
(Response:date)

ENTER TIME  
(Response:time)

If an Input Data file already exists, the existing input data will be displayed as follows:

THE AVAILABLE INPUT DATA IS THE FOLLOWING:

SCENARIO IDENTIFIER = 01/20/88 14:30  
COMMENT:  
COMMENT:  
DOWNLINK FREQUENCY (GHZ) = 4.650  
UPLINK FREQUENCY (GHZ) = 6.500  
RAIN OUTAGE PERCENTAGE OF YEAR = 0.050  
MAXIMUM RAIN ATTENUATION LIMIT = 10.00

WOULD YOU LIKE TO CHANGE ANY OF THE DATA ENTRIES AT THIS TIME? (IF SO, YOU WILL BE REPROMPTED FOR ALL ENTRIES.) ENTER Y OR N

(Response: One character, Y or N)

If the user's response is N, NASARCO will terminate.

If the user's response is Y, the following prompt will be issued:

YOU MAY NOW ENTER UP TO TWO LINES OF COMMENTS RELATED TO THIS SCENARIO. EACH LINE IS LIMITED TO 60 CHARACTERS. DO YOU WISH TO ENTER A COMMENT? ENTER Y OR N

(Response: One character, Y or N)

If the user's response is N, NASARCO will prompt for the next succeeding input.

If the user's response is Y, the following prompts will be issued:

ENTER LINE 1 OF COMMENT (60 CHARACTERS MAX)

(Response: descriptive text, 60 characters or less)

DO YOU WANT TO ENTER AN ADDITIONAL LINE OF COMMENT? Y or N

(Response: one character, Y or N)

TABLE 3.2-2.— Concluded.

If the user's response is N, the program will proceed to prompt for the next input.  
If the user's response is Y the following prompt will be issued:

ENTER LINE 1 OF COMMENT (60 CHARACTERS MAX)  
(Response: descriptive text, 60 characters or less)

The program will now begin prompting for parameter values.

SPECIFY INPUTS AS REAL NUMBERS UNLESS PROMPTED OTHERWISE.

INPUT DOWNLINK FREQUENCY IN GHZ.

(Response: real number, range 4.5 to 4.8 GHz, 10.7 to 19.95 GHz, or 11.2 to 11.45 GHz)

INPUT UPLINK FREQUENCY IN GHZ

(Response: real number, range 6.425 to 7.075 GHz or 12.75 to 13.25 GHz).

ENTER THE PERCENT RAIN OUTAGE IN TERMS OF PERCENT OF THE YEAR.

THE DEFAULT VALUE IS 0.050 PERCENT OF THE YEAR.

DO YOU WISH TO RETAIN THIS VALUE? (ENTER Y OR N)

(Response: one character, Y or N)

If the user's response is Y, the program will issue the next prompt.

If the user's response is N, the following prompt will be issued:

ENTER NEW VALUE

?

(Response: real number, range 0.001 to 1.0)

WOULD YOU LIKE TO LIMIT THE MAXIMUM RAIN ATTENUATION? (ENTER Y OR N)

(Response: one character, Y or N)

If the user's response is N, the program will proceed.

If the user's response is Y the following prompt will be issued:

ENTER THE MAXIMUM RAIN ATTENUATION LIMIT.

THE DEFAULT VALUE IS 10.00 DB.

DO YOU WISH TO RETAIN THIS VALUE? (ENTER Y OR N)

(Response: one character, Y or N)

If the user's response is Y, the default value will be assigned and the program will proceed.

If the user's response if N, the following prompt will be issued:

ENTER NEW VALUE

?

(Response: real number, dB)

THE AVAILABLE INPUT DATA IS THE FOLLOWING:

SCENARIO IDENTIFIER	= DATE, TIME
COMMENT:	= USER SUPPLIED COMMENT 1
COMMENT:	= USER SUPPLIED COMMENT 2
DOWNLINK FREQUENCY (GHZ)	= USER SUPPLIED VALUE
UPLINK FREQUENCY (GHZ)	= USER SUPPLIED VALUE
RAIN OUTAGE PERCENTAGE OF YEAR	= USER SUPPLIED VALUE
MAXIMUM RAIN ATTENUATION LIMIT	= USER SUPPLIED VALUE

WOULD YOU LIKE TO CHANGE ANY OF THE DATA ENTRIES AT THIS TIME?

(IF SO, YOU WILL BE REPROMPTED FOR ALL ENTRIES.) ENTER Y OR N

(Response: one character, Y or N)

If the user's response is Y, the entire sequence of prompts will be reissued.

If the user's response is N, the NASARCO program will terminate.

### 3.2.6 Ellipse and Rain Attenuation Data

As stated in section 2.3.1.8, the Ellipse file is composed of blocks of three records. The first record of each set of three contains an eight-character service area code, the orbital longitude at which the ellipse covering the service area was calculated, the longitude and latitude of the beam aimpoint, the ellipse major and minor axis beamwidths, and the orientation angle of the ellipse. Any ellipse calculation procedure may be utilized so long as the output of the ellipse calculation is placed in the correct format to be utilized by the NASARC modules (see table 2.3-5).

For any ellipse calculation procedure used to construct an ellipse file for use by the NASARC modules, it is important that the ellipse calculations for a service area be performed utilizing the same set of service area polygon points that the user intends to use in the NASARC Point Sets file. This will ensure maximal accuracy and consistency of the NASARC program calculations.

Ellipse data for service areas must correspond to the ordering of service areas within the Service Area file; within each block of ellipse data, longitudes for which the ellipses have been calculated must range from the westmost longitudinal limit of the service area's visible arc to the eastmost limit of that arc. Thus, in blocks of data for service areas whose arcs cross the 180° meridian, the record containing the ellipse calculated at 180° east longitude must be immediately followed by the record containing the ellipse parameters calculated at -179° east longitude. As may be inferred from the preceding, ellipse records should reflect ellipse parameters calculated at 1° increments for integral (whole degree) longitudes.

Rain attenuation data are contained in the subsequent two records of each block of three. The two records correspond to two sets of uplink and downlink frequencies (e.g., C-band and Ku-band). Each of these records contains attenuations calculated for each of up to 10 polygon points for the downlink frequency followed by attenuations calculated for each of the points for the uplink frequency. For the sake of consistency with certain portions of the NASARC software, it is suggested that the attenuations be calculated at 0.01-percent annual outage, in accordance with the attenuation model currently adopted by the Consultative Committee for International Radio (CCIR).

## 3.3 Using the NASARC (Version 4.0) Software Package

### 3.3.1 Invoking NASARC Programs

To utilize NASARC (Version 4.0) for a planning exercise, the NASARC procedure described in section 2.2.3 must be invoked by the user. The procedure first loads and executes the NASARCO modules. The NASARCO module verifies input data files for accuracy and prompts the user interactively for further input. When the user's responses have been gathered, the Input Data file is generated.

The NASSEP module is then executed and calculates a matrix of required orbital separations for all possible pairs of systems. This information is stored in the Separation Matrix file.

The NASARC1, NASARC2, NASARC3, and NASARC4 modules are executed in sequence for as many segments to be examined as there are specified within the Segments file. Therefore, if the user's system does not allow DO-loop constructs within user-created procedures, the NASARC1, NASARC2, NASARC3, and NASARC4 modules must be loaded and executed as many times as necessary by the user.

When all the segments specified have been examined, the NASARC4 module produces the NASARC Report file, the Condensed Report file, and the Predetermined Arc file.

### 3.3.2 Error Messages and Their Meanings

Table 3.3-1 contains a complete list of error messages generated by the NASARC modules. Information is also included on subroutines that produce the messages and suggested sources of error. This information is intended to



allow the user to quickly and easily identify causes of execution errors. The error messages are written to the logical unit defined for error messages—unit 19. The messages also appear on the user's screen; FORTRAN logical unit 10 should be defined as the user's terminal. The user is advised to examine the Error Message file if the expected results are not achieved (see section 2.3.3.4). The errors described generally result in premature termination of the module in question, with the exception of those indicated in the table. Errors, which result in necessary program termination, trigger the setting of an error flag in the Input Data file so that subsequent program modules are not executed on invalid data. The occurrence of various error messages might be eliminated by modifying the value of a parameter and recompiling to achieve a successful program run if the user has sufficient memory. All parameter names, the programs and/or subprograms in which they occur, and their current values are listed in the appendix.

TABLE 3.3-1—ERROR MESSAGES AND THEIR MEANINGS

Message	Program/subprogram producing message	Potential source of error
"ERROR—THE CONSTANTS USED IN DETERMINING PDA LENGTH HAVE ALL BEEN SPECIFIED AS 0.0 OR LEFT BLANK. PLEASE CHECK THE FIRST RECORD OF THE SERVICE AREA FILE."	NASARCO	1. Self-explanatory. All constants cannot be set to 0.0 at same time.
"ERROR—THE SEGMENT FILE BOUNDARIES DO NOT PROVIDE CONTINUOUS PROGRESSION OF CUMULATIVE ORBITAL ARC. CHECK THE SEGMENT WITH BOUNDARIES XXX.XX, XXX.XX."	NASARCO	1. A record of Segments file does not adjoin any previous segment. Correct the record indicated.
"ERROR—THE SERVICE ARC SPECIFIED FOR AAA EXCEEDS THE MAXIMUM POSSIBLE VISIBLE ARC FOR POSITIVE ELEVATIONS, OR THE WEST AND EAST BOUNDARIES FOR AAA MAY BE REVERSED. CHECK THE SERVICE AREA FILE."	NASARCO	1. Self-explanatory; correct the record indicated in the Service Area file.
"ERROR—MEMBERS OF THE AFFILIATED SET WITH CODE NUMBER N DO NOT INTERSECT A COMMON PORTION OF THE ORBITAL ARC. CHECK SERVICE AREA FILE FOR THE WEST AND EAST BOUNDARIES OF AFFILIATED SET MEMBERS WITH CODE NUMBER N."	NASARCO	1. Incorrect Service Area may have been indicated as member of set with code number N. 2. A service arc for member service area may have been incorrectly specified.
"ERROR—THE SPACE STATION ANTENNA CODE SPECIFIED IN THE SERVICE AREA FILE FOR AAA IS NOT ONE OF THE AVAILABLE CODES. PLEASE CONSULT THE NASARC MANUALS FOR AVAILABLE CODES, THEN MAKE THE APPROPRIATE CHANGES TO THE SERVICE AREA FILE."	NASARCO	1. Self-explanatory.

TABLE 3.3-1—Continued.

Message	Program/subprogram producing message	Potential source of error
<p>“ERROR—AN ILLEGAL ANTENNA DATA ENTRY HAS BEEN MADE IN THE SERVICE AREA FILE FOR SERVICE AREA AAA. PLEASE BE SURE THE VALUES FOR DIAMETER, SPACE STATION PARAMETER, AND THE EFFICIENCIES ARE ALL POSITIVE.”</p>	<p>NASARCO</p>	<p>1. Self-explanatory.</p>
<p>“ERROR—THE EARTH TERMINAL TRANSMIT ANTENNA CODE SPECIFIED IN THE SERVICE AREA FILE FOR AAA IS NOT ONE OF THE AVAILABLE CODES. PLEASE CONSULT THE NASARC MANUALS FOR APPROPRIATE CODES, THEN MAKE THE APPROPRIATE CHANGES TO THE SERVICE AREA FILE.”</p>	<p>NASARCO</p>	<p>1. Self-explanatory.</p>
<p>“ERROR—THE EARTH TERMINAL RECEIVE ANTENNA CODE SPECIFIED IN THE SERVICE AREA FILE FOR AAA IS NOT ONE OF THE AVAILABLE CODES. PLEASE CONSULT THE NASARC MANUALS FOR APPROPRIATE CODES, THEN MAKE THE APPROPRIATE CHANGES TO THE SERVICE AREA FILE.”</p>	<p>NASARCO</p>	<p>1. Self-explanatory.</p>
<p>“ERROR—THE NUMBER OF MEMBERS IDENTIFIED IN THE AFFILIATED SETS FILE FOR AFFILIATED SET N DOES NOT AGREE WITH THE AFFILIATED SET FLAGS IN THE SERVICE AREA FILE.”</p>	<p>NASARCO</p>	<p>1. Incorrect number of members in Affiliated Set file for set N. 2. Incorrect number of service areas have been identified as members of set N within the Service Area file</p>
<p>“ERROR—THE SPACE STATION ANTENNA PARAMETERS INDIVIDUALLY SPECIFIED IN THE SERVICE AREA FILE FOR MEMBERS FROM AFFILIATED SET AAA ARE NOT THE SAME. ALL MEMBERS OF THE SAME AFFILIATED MUST HAVE IDENTICAL SPACE STATION PARAMETERS. PLEASE CORRECT THE PROBLEM AND RERUN.”</p>	<p>NASARCO</p>	<p>1. Self-explanatory. Check all Service Area file entries belonging to affiliated set AAA.</p>
<p>“ERROR—THE NUMBER OF AFFILIATED SETS SPECIFIED IN THE AFFILIATED SETS FILE DOES NOT AGREE WITH THE NUMBER OF FLAGS IN THE SERVICE AREA FILE. PLEASE CORRECT THE PROBLEM AND RERUN.”</p>	<p>NASARCO</p>	<p>1. There are more/less unique affiliated sets identified in the Affiliated Sets file than are identified in the Service Area file.</p>

TABLE 3.3-1—Continued.

Message	Program/subprogram producing message	Potential source of error
"DATA ENTRY ERROR—PLEASE ENTER A POSITIVE REAL NUMBER." <sup>a</sup>	NASARCO	1. User has entered a response of incorrect type to interactive prompt by NASARCO.
"YOU HAVE SPECIFIED A FREQUENCY OUTSIDE OF THE BANDS ALLOCATED TO THE DOWNLINK FOR ALLOTMENT PLANNING PURPOSES. PLEASE CHECK YOUR DESIRED VALUE AND RE-ENTER." <sup>a</sup>	NASARCO	1. User has specified a downlink frequency that is outside the range: (a) 4.5—4.8 GHz (b) 10.7—10.95 GHz (c) 11.2—11.45 GHz
"THE UPLINK FREQUENCY SPECIFIED IS NOT IN THE COMPANION FREQUENCY BAND WITH THAT OF THE DOWNLINK FREQUENCY. PLEASE RE-SPECIFY THE UPLINK FREQUENCY IN THE RANGE 6.425 to 7.075 GHz."	NASARCO	1. Self-explanatory.
"THE UPLINK FREQUENCY SPECIFIED IS NOT IN THE COMPANION FREQUENCY BAND WITH THAT OF THE DOWNLINK FREQUENCY. PLEASE RE-SPECIFY THE UPLINK FREQUENCY IN THE RANGE 12.75 to 13.25 GHz."	NASARCO	1. Self-explanatory.
"YOU HAVE SPECIFIED A FREQUENCY OUTSIDE OF THE BANDS ALLOCATED TO THE UPLINK FOR ALLOTMENT PLANNING PURPOSES. PLEASE CHECK YOUR DESIRED VALUE AND RE-ENTER."	NASARCO	1. User has specified an uplink frequency that is outside the range: (a) 6.425—7.075 GHz (b) 12.75—13.75 GHz
"PLEASE ENTER YOUR PREFERENCE AS Y OR N." <sup>a</sup>	NASARCO	1. The user has supplied a response inconsistent with a required Y or N response.
"NO POINT SET FOUND FOR AAA"	NASSEP/RDPTS2	1. Point Sets file does not contain point set for a service area contained in Service Area file. 2. Point set corresponding to service area has code that does not match service area code.
"ERROR READING POINT SET DATA WHILE LOOKING FOR KEY: BBB. LAST KEY READ BEFORE ERROR OCCURRED: AAA"	NASSEP/RDPTS2	1. Point Sets file contains error in one or more records that causes error in FORTRAN READ.
"WESTERN ARC LIMIT FOR AAA IS INCONSISTENT WITH ELLIPSE FILE."	NASSEP/CREAT2	1. Ellipse file incorrectly constructed. 2. Service arc for service area AAA incorrectly specified.

<sup>a</sup>Does not terminate program execution.

TABLE 3.3-1—Continued.

Message	Program/subprogram producing message	Potential source of error
"EASTERN ARC LIMIT FOR AAA IS INCONSISTENT WITH ELLIPSE FILE."	NASSEP/CREAT2	<ol style="list-style-type: none"> <li>1. Ellipse file incorrectly constructed.</li> <li>2. Service area for service area AAA incorrectly specified.</li> </ol>
"THE ELLIPSE PARAMETERS FOR SERVICE AREA AAA AND S/C LONG. XXXX.X COULD NOT BE FOUND. INSTEAD THE ELLIPSE FILE WAS POINTED AT SERVICE AREA AAA AND S/C LONG. XXXX.X."	NASSEP/CICLK2	<ol style="list-style-type: none"> <li>1. Ellipse array incorrectly constructed; check Ellipse file.</li> </ol>
"NO POINT SET FOUND FOR AAA"	NASARC1/RDPTS	<ol style="list-style-type: none"> <li>1. Point Sets file does not contain point set for a service area contained in Service Area file.</li> <li>2. Point set corresponding to service area has code that does not match service area code.</li> </ol>
"ERROR READING POINT SET DATA WHILE LOOKING FOR KEY BBB: LAST KEY READ BEFORE ERROR OCCURRED: AAA"	NASARC1/RDPTS	<ol style="list-style-type: none"> <li>1. Point Sets file contains error in one or more records that causes error in FORTRAN READ.</li> </ol>
"WESTERN ARC LIMIT FOR AAA IS INCONSISTENT WITH ELLIPSE FILE."	NASARC1/CREATE	<ol style="list-style-type: none"> <li>1. Ellipse file incorrectly constructed.</li> <li>2. Service arc for service area AAA incorrectly specified.</li> </ol>
"EASTERN ARC LIMIT FOR AAA IS INCONSISTENT WITH ELLIPSE FILE."	NASARC1/CREATE	<ol style="list-style-type: none"> <li>1. Ellipse file incorrectly constructed.</li> <li>2. Service arc for service area AAA incorrectly specified.</li> </ol>
"THE ELLIPSE PARAMETERS FOR SERVICE AREA AAA AND S/C LONG. XXXX.X COULD NOT BE FOUND. INSTEAD THE ELLIPSE FILE WAS POINTED AT SERVICE AREA AAA AND S/C LONG. XXXX.X."	NASARC1/CICLK	<ol style="list-style-type: none"> <li>1. Ellipse array incorrectly constructed; check Ellipse file.</li> </ol>
"A GROUP EXCEEDS MAX NUMBER OF MEMBERS AND IS TRUNCATED. THE ARC LOCATION IS XXX.XX: CURRENT SEGMENT IS XXX.XX TO XXX.XX."*	NASARC1	<ol style="list-style-type: none"> <li>1. A compatible group of service areas has more than MAXMEM members. Redistribute arc segments in Segments file.</li> </ol>
"THE MAXIMUM NUMBER OF GROUPS HAS BEEN EXCEEDED WITHIN THE SEGMENT XXX.XX TO XXX.XX AT THE LOCATION XXX.XX. ADJUST SEGMENT LIMITS WITHIN THE SEGMENTS FILE."	NASARC1/ACCUM	<ol style="list-style-type: none"> <li>1. The total number of compatible groups of service areas has exceeded MAXGRP. Redistribute arc segments in Segments file.</li> </ol>

\*Does not terminate program execution.

TABLE 3.3-1—Concluded.

Message	Program/subprogram producing message	Potential source of error
"ERROR IN INPUT PARAMETERS. NASARC2 RUN TERMINATED."	NASARC2/INPARG	1. Error flag in Input Data file has been set to Y as result of previous error; check Error Message file for source.
"ERROR: THERE ARE MORE GROUPS IN THE INPUT LIST THAN THE ARRAYS CAN HOLD. INCREASE THE VALUE OF MAXGRP IN THE NASARC2 SOURCE CODE, RECOMPILE, AND RE-EXECUTE."	NASARC2/INGRPS	1. There are too many groups contained in the NASARC1 module output Groups file. Adjust parameter as suggested or reduce list by other means.
"ERROR: THERE ARE MORE GROUPS IN THE INPUT LIST THAN THE ARRAY CAN HOLD. INCREASE THE VALUE OF MAXRMN IN THE NASARC2 SOURCE CODE, RECOMPILE, AND RE-EXECUTE."	NASARC2/INRMN	1. There are too many groups in Unallotted Groups file that adjoin current segment. Adjust parameter or reduce list by other means.
"NO POINT SET FOUND FOR AAA"	NASARC3/RDPTS	1. Point Sets file does not contain point set for a service area contained Service Area file. 2. Point set corresponding to service area has code that does not match service area code.
"ERROR READING POINT SET DATA WHILE LOOKING FOR KEY BBB: LAST KEY READ BEFORE ERROR OCCURRED: AAA"	NASARC3/RDPTS	1. Point Sets file contains error in one or more records that causes error FORTRAN READ.
"THE ELLIPSE PARAMETERS FOR SERVICE AREA AAA AND S/C LONG. XXXX.X COULD NOT BE FOUND. INSTEAD THE ELLIPSE FILE WAS POINTED AT SERVICE AREA AAA AND S/C LONG. XXXX.X."	NASARC3/CICLK	1. Ellipse array incorrectly constructed; check Ellipse file.

<sup>a</sup>Does not terminate program execution.

### 3.4 Interfacing the NASARC and ORBIT Programs

While the NASARC software package identifies common, overlapping arc segments that are shared by compatible groups of satellite systems, the NASARC software does not identify specific orbital locations for individual satellites. Also, while the NASARC software bases compatibility assessment of pairs of systems on a target single-entry *C/I* that is calculated from an aggregate criterion, the software does not perform an aggregate interference analysis. Aggregate interference analysis may only be performed when specific satellite positions are known.

The ORBIT program, originally developed in Japan and now residing on the computer at the International Frequency Registration Board, employs optimization techniques to determine satellite placements that allow a

given aggregate C/I to be achieved for all systems. These operations are performed under constraints imposed by service arc limitations and other technical parameters that are common to both the NASARC and ORBIT programs. In fact, the input data file for the ORBIT program is the Requirements Data file discussed in section 2.3.1.2 of this *User's Manual*. In conjunction with the satellite positioning process, ORBIT also performs a full aggregate interference analysis for the input scenario.

The preceding discussion indicates that it is desirable to dovetail the capabilities of NASARC and ORBIT via an interface to allow the arc limitations determined by NASARC to be superimposed on the appropriate inputs of the Requirements Data file. Then ORBIT may be run to determine precise satellite locations within predetermined arcs found by NASARC and to demonstrate that aggregate interference criteria may be satisfied.

For purposes of allotment planning of the Fixed Satellite Service at the 1988 Space World Administrative Radio Conference, an automated interface program was constructed to perform the function described previously—i.e., superimpose predetermined arc limits for each administration, found by NASARC, onto the appropriate fields of the Requirements Data file. This interface uses the Predetermined Arc file (discussed in section 2.3.3.3 of this *User's Manual*) and the Requirements Data file (see section 2.3.1.2) as input files; the output is a modified copy of the Requirements Data file.

Since the NASARC/ORBIT interface was developed for the specific purpose of allotment planning at the 1988 Conference, it is not included as part of the NASARC software package. The program is also only useful if the user possesses a Requirements Data file (see section 2.3.1.2 herein) and the ORBIT software. The interested user is urged to contact the International Frequency Registration Board in Geneva, Switzerland, if further information on the ORBIT software is desired.

## REFERENCES

The Orbit Spacing Minimizer (ORBIT-II) User's Manual. Kokusai Denshin Denwa Co., LTD. Apr. 1984.

## APPENDIX—NASARC PROGRAM PARAMETERS

The NASARC program parameters described in the following table largely affect array dimensions within one or more NASARC modules. Thus, they also affect the storage requirements of the modules in which they occur. The values listed in the table were carefully selected to provide the programs with maximum capability to accommodate a variety of scenarios, while still permitting each module to be loaded within the 12-megabyte memory limitation of the IFRB computer system.

The user is reminded that if a parameter value is changed within the NASARC source code, the appropriate module must be recompiled prior to use.

NASARC PROGRAM PARAMETERS

Name	Definition	Locations	Value*
MAXITU	Maximum number of service area records that may be contained in the Service Area file	NASINTRF: MAIN NASARCO: MAIN NASSEP: MAIN RDPTS2 CREAT2 CICLK2	300

\*Values are those that meet the 12-megabyte memory limitation of the IFRB computer.

Name	Definition	Locations	Value <sup>a</sup>
MAXITU (cont.)	Maximum number of service area records that may be contained in the Service Area file	NASARC1: MAIN CREATE RDPTS NASARC3: MAIN RDPTS REPORT NASARC4: MAIN REPORT CNDREP	
MAXCOD	Maximum number of service areas to be included in affiliated sets	NASINTRF: MAIN NASARC0: MAIN NASARC4: REPORT CNDREP AFFINT	99
MAXSEG	Maximum number of segments to be examined, within the Segment file	NASARC0: MAIN NASARC1: MAIN NASARC2: INSEGS NASARC4: MAIN REPORT CNDREP	40
MAXTER	Maximum number of affiliated sets of service areas within Affiliated Sets file	NASINTRF: MAIN NASARC0: MAIN NASSEP: MAIN NASARC1: MAIN NASARC3: MAIN NASARC4: MAIN REPORT CNDREP	25
MAXMEM	Maximum number of service areas that may be included in a compatible group	NASARC0: MAIN NASARC1: MAIN NASARC2: MAIN INGRPS INALLT LSTALT CRTGRP	15

<sup>a</sup>Values are those that meet the 12-megabyte memory limitation of the IFRB computer.

Name	Definition	Locations	Value*
MAXMEM (cont.)	Maximum number of service areas that may be included in a compatible group	UPDATE UNPACK GRPBUF XTRACT PULL INDEX2 SUBLST MAXSEP UPDAT2  NASARC3: MAIN NASARC4: MAIN UNPACK	
MAXELL	Maximum number of ellipse records that may be contained in Ellipse file	NASSEP: MAIN CREAT2 CICLK2  NASARC1: MAIN CREATE	35,000
MAXGRP	Maximum number of compatible groups and group arcs that may be produced by NASARC1 within a single segment of the orbit	NASARC1: MAIN ACCUM CHK180 OUTLST  NASARC2: MAIN INGRPS JOINER CRTADM SUBLST OUTRMN	90,000
MAXPT	Maximum number of polygon points for each service area	NASINTRF: MAIN  NASSEP: MAIN  NASARC1: MAIN CREATE RDPTS CICLK  NASARC3: MAIN RDPTS CICLK	10
MAXTEM	Maximum number of groups, group arcs in temporary list	NASARC1: MAIN ACCUM CHK180	10,000
NUMR	Number of groups, individual arc locations processed at one time, in creating temporary list of groups, group arcs	NASARC1: MAIN ACCUM CHK180	10,000

\*Values are those that meet the 12-megabyte memory limitation of the IFRB computer.



Name	Definition	Locations	Value <sup>a</sup>
MSGELL	Maximum number of ellipse records to be utilized in single segment of the orbit	NASARC1: MAIN CREATE CICLK NASARC3: MAIN CICLK	16,000
MSGITU	Maximum number of service areas to be examined for compatibility within single segment of the orbit	NASARC1: MAIN CREATE RDPTS CICLK OUTLST NASARC2: MAIN INGRPS PARTIT CRTADM MISSPI PRIOR ITUARC GRPBUF SACHK CRTGRP NASARC3: MAIN RDPTS CICLK	100
MAXALT	Maximum number of allotted groups (over all segments of orbit)	NASARC2: MAIN INALLT CRTADM LSTALT SEGCHK PTACHK ALLOT NEIGH PDASEP UPDAT2 PUSH ARCCHK FINSEP NASARC3: MAIN	150
MAXALT	Maximum number of allotted groups (over all segments of orbit)	NASARC4: MAIN SWAP FEASIN REPORT CNDREP TEMPOR PUSH PTACHK ARCCHK	
MAXSUB	Maximum number of groups containing critical service area	NASARC2: MAIN GRTGRP	10,000

<sup>a</sup>Values are those that meet the 6-megabyte memory limitation of the IFRB computer.

Name	Definition	Locations	Value*
MAXRMN	Maximum number of unallotted groups that adjoin either edge of current segment of orbit	NASARC2: MAIN INRMN JOINER	10,000
MAXREC	Maximum number of records in NASARC2 Intermediate Selection file, Unallotted Groups file	NASARC2: MAIN INRMN OUTRMN NASARC4: MAIN	1,000,000
MAXF	Maximum number of aggregate arcs for subset arc extensions	NASARC2: COMBIN	100
MAXX	Maximum number of groups in sublist of groups containing critical service area	NASARC2: MAIN CRTGRP	10,000
MAXZ	Maximum number of groups in sublist for which given group is a sublist	NASARC2: SUBLST XTEND	10,000
MAXD	Maximum number of groups in critical groups sublist for which duplicates or subsets exist	NASARC2: XTEND	18,000
MAXMAT	Maximum number of entries in satellite separations file	NASARC2: MATRIX MAXSEP	20,000
MAXPTA	Maximum number of potential temporary allotments within group's group arc	NASARC4: TEMPOR	180
NGROUP	Maximum number of allotted groupings	NASARC4: PUSH1	150
MAXPDA	Maximum number of allotted groupings	NASARC4: PUSH2	150

\*Values are those that meet the 12-megabyte memory limitation of the IFRB computer.

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16. Abstract <p>The information contained in the <i>NASARC (Version 4.0) Technical Manual</i> (NASA TM-101453) and <i>NASARC (Version 4.0) User's Manual</i> (NASA TM-101454) relates to the state of Numerical Arc Segmentation Algorithm for a Radio Conference (NASARC) software development through November 1, 1988. The <i>Technical Manual</i> describes the NASARC concept and the algorithms used to implement the concept. The <i>User's Manual</i> provides information on computer system considerations, installation instructions, description of input files, and program operation instructions. Significant revisions have been incorporated in the Version 4.0 software over prior versions. These revisions have further enhanced the modeling capabilities of the NASARC procedure and provide improved arrangements of predetermined arcs within the geostationary orbit. Array dimensions within the software have been structured to fit within the currently available 12-megabyte memory capacity of the International Frequency Registration Board (IFRB) computer facility. A piecewise approach to predetermined arc generation in NASARC (Version 4.0) allows worldwide planning problem scenarios to be accommodated within computer run time and memory constraints with enhanced likelihood and ease of solution.</p>					
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