N94-23898

NASDA Knowledge-based Network Planning System

K.Yamaya[1], M.Fujiwara[1], S.Kosugi[1], M.Yambe[2], M.Ohmori[3]

[1]Tracking and Control Center /
National Space Development Agency of Japan
[2]Fujitsu Limited, Tokyo, Japan
[3]Fujitsu Social Systems Engineering Limited, Tokyo, Japan

ABSTRACT

One of the SODS (space operation and data system) sub-systems, NP (network planning) was the first expert system used by NASDA (national space development agency of Japan) for tracking and control of satellite. The major responsibilities of the NP system are: first, the allocation of network and satellite control resources and, second, the generation of the network operation plan data (NOP) used in automated control of the stations and control center facilities. Up to now, the first task, of network resource scheduling, has been done by network operators. NP system automatically generates schedules using its knowledge base, which contains information on satellite orbits, station availability, which computer is dedicated to which satellite, and how many stations must be available for a particular satellite pass or a certain time period. This paper introduces the NP system.

Key words: NP system, knowledge base, flexibility, conflict solving, expert systems

1. INTRODUCTION

This paper introduces the NASDA network planning (NP) system. Since NP system is a Type-1 SODS sub-system we start with a brief explanation of SODS.

1.1 Development of SODS

The type-1 SODS, which is the ground-station-based tracking and control system, has been in partial operation since the launch of JERS-1 (Japan earth resources satellite-1) in 1992. NASDA started to develop a SODS long-ranged tracking and control system, in 1987. The type-1 SODS is the first step in the development. In the early stages, we expected two new requirements for satellite operation. One is for simultaneous operation of more than three sun-synchronous sub-recurrent polar satellites (JERS-1, MOS-1: marine observation satellite-1 and MOS-1b), MOS-1 and MOS-1b were launched in 1987 and 1990. The other requirement is for double launch operations for use with the H-II rocket to go into opration in 1995. NASDA automated ground network control to meet these needs. NASDA also automated the scheduling of the ground network and planning file transmission.

1.2 Network Planning System

The NP system allocates network and satellite control resources for each satellite. NP then generates data for the network operation plan (NOP) used in the remote control of the stations and in configuration of control center facilities. The NOP flow chart is shown in Fig.1. NOP data, which based on the operation requests sent from network users through the NM (network management system) referring to the station event data (such as visibility information and periods when operation is under constraints), is transferred to TC (tracking network control system) and LC (communication line control system). This data is used by TC for the station control and by LC for the communications line control.

1.3 Developing NP policies

We considered several requirments when developing the NP system. One was the store and inheritance of know-how on network planning from experts in the field. More complicated and more frequent operations make it more difficult to store and inherit the

C-6

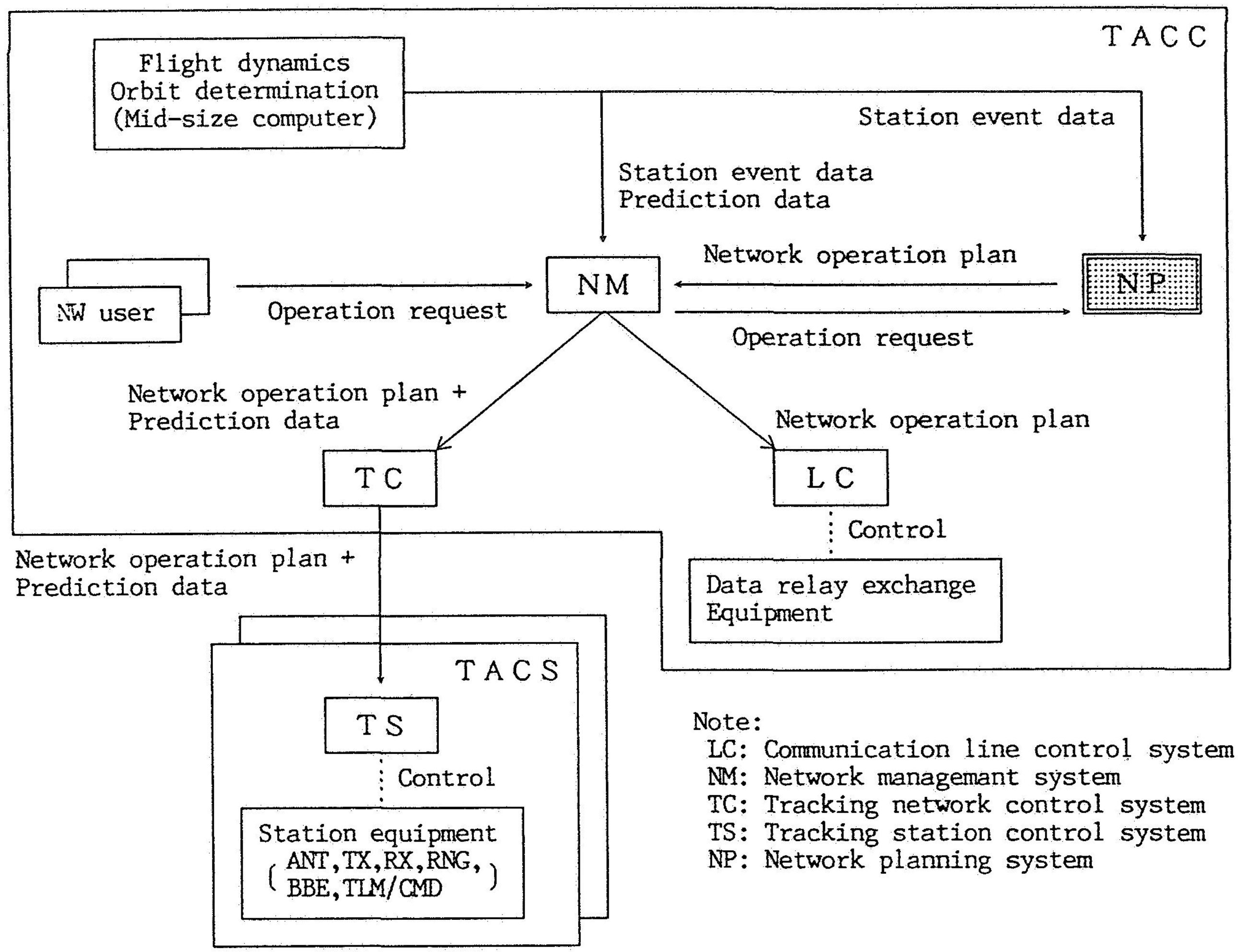


Fig.1 Data flow for the network operation plan

know-how. Another consideration was that scheduling could be simulated in some situations. Combining these factors, we introduced an expert system to NP.

1.4 Computer Technology

Type-1 SODS used a variety of new equipments, including engineering work stations (EWS), and a local area network (LAN). The NP system is the first expert system introduced in NASDA's tracking and control operations. Recently, expert systems have proven capable of using their inference capability for judgement and reducing part of the workload of an operator. Generally, expert systems can be classified into four groups: diagnostic, for medical patients or machine troubles; forecasting, for financial affairs analysis; control, for factory automation or fuzzy systems; and design and planning, for electric circuit design, construction of computer systems, and planning travel courses. The configuration of the NP system corresponds to the planning type.

2. FUNCTIONS OF THE NETWORK PLANNING SYSTEM

2.1 Knowledge Base

The NP system relies on a knowledge base data constructed from the know-how of human experts. We divide this knowledge base into 'definitions' and 'tables'.

2.1.1 Definitions

Definitions are of resources (satellites in operation, network facilities, etc.), operation priorities, and satellite priorities. The NP system uses these definitions for scheduling. The operator must define the resources to be used before scheduling an operation. Definitions contain the following information.

(1) Priority

The NP system's knowledge base uses two forms of priority: operation (launch, maneuver, usual, ...) and satellite. Each plan is established in the order of operation priority. When operation priorities are equal, each plan is established according to satellite priority.

(2) Satellite

Information is included for each satellite (ID, name, type of orbit, time margin of equipment preparations). This Definition is important for scheduling. The NP system changes the scheduling method in accordance with satellite orbits. Operation time is also decided by the required time for the station facility set-up.

(3) TACS (tracking and control station)

TACS information containing TACS name, TACS ID, and TACS type (domestic or foreign).

(4) TACS Antenna

TACS antenna definitions including antenna name and antenna type (X-Y or AZ-EL).

(5) TACC (tracking and control center) facilities

Contains TACC facility name and ID.

(6) SOCS (satellite operation and control system)

Includes SOCS name and ID.

(7) Station/pass combination definition

For sub-recurrent polar orbit. Defines station/pass combination pattern in detail. Some examples of this pattern are showen in Fig.2. More patterns are used in actual operation.

2.1.2 Tables

Tables indicate how to use resources, which computer is dedicated to which satellite, and how many stations must be available for a particular satellite pass or a certain time period. Each table has 'flexibility' for an optimal schedule where flexibility is expressed as the preferred order of facility allocation which are defined above. Using flexibility, when a facility

ex.1) 2 pass operation

	Pass 1	Pass 2	Pass 3
Station A	■	■	

ex.2) 2 station / 2 pass operation

	Pass 1	Pass 2	Pass 3
Station A	■	■	
Station B	■		

ex.3) 2 station / 3 pass operation

	Pass 1	Pass 2	Pass 3
Station A	■	■	■
Station B		■	

Fig.2 Station/pass combinations

cannot be used due to conflicts, alternate facilities are assigned. A table is constructed for each satellite. Tables are constructed for the following information.

(1) Preferred operation day

Prioritizes scheduling days for geostationary orbit.

(2) Preferred operation time

Prioritizes operation times for geostationary orbit.

(3) Preferred ranging time

Prioritizes ranging time. One ranging unit is a quarter for each one hour, for geostationary orbit.

(4) Preferred facilities

Gives TACS antenna preferences for geostationary orbit.

(5) Preferred SOCS

Prioritizes SOCS for geostationary and sub-recurrent polar orbits.

(6) Station/pass combination & activitie

Prioritizes 'station/pass combinations definition' for sub-recurrent polar orbits.

(7) Sub-recurrent orbit nominal pass

Defines TACS antenna and pass preferrences, where pass information fits in to visible patterns for sub-recurrent polar orbit satellites.

(8) Request code table (executive parameters & activities)

This table serves two purposes: user services and facilitating the knowledge base. Users can request satellite

operations simply by using numbers from this table. Users are not required to choose the operation time or revolution number, these are established from other tables. This table also provides information for the knowledge base. When a request and other requests conflict, optimal plans are determined by this table.
The request code table contains detailed request parameters and numbers from some of the above tables concerning request flexibility. The two orbit types considered are geostationary and sub-recurrent polar orbit. Table combinations are shown in Tab.1 and Tab.2. Since many table ID combinations are possible, numerous request code table preferrences are possible.

2.2 Scheduling By Network Planning System

As memtioned, the NP system establishes plans for knowledge database use. Requests are sorted by operation and satellite priority. NP system has three different planning modes for a variety of approaches for solving request conflicts.

2.2.1 Scheduling Modes

The NP system has three planning modes.
(1) Rejection mode
When a request conflicts with an already established plan, the request is just rejected. The request is regarded as 'NG,' and is unavailable for operations.
(2) Solving selection mode
When a conflict occurs, operators can select the conflict solving method. The methods are 'cut & try,' 'priority exchange,' 'backup code' and 'rejection.' These methods are explained in 2.2.2. Method selection allows efficient planning and can produce a tight fitted schedule.
(3) Automatic solving mode
Unlike the solving selection mode, this mode needs no operator intervention. Conflicts are solved by a fixed procedure. First, cut & try is tried. Second, if a request becomes 'NG' by cut & try, backup code is attempted. Lastly, if both cut & try and backup code fail, the request is put into rejection mode.
The solving selection and automatic solving modes make the most of the flexibilities for solving request conflicts, and for improving schedules.

Tab.1 Geostationary orbit

Request code table
- Preferred operation day table
- Preferred operation time table
- Preferred ranging time table
- Preferred facilities table
- Preferred SOCS table

Form of request (lesser items)

		Examples
Term of operation	...	Nov. 12 to Nov. 20
Request code ID	...	01 (2 TACS RNG operation)
Operation class (referring to operation priority)	...	04 (Usual operation)
Backup operation code ID (Cf. 2.2.2 conflict solving)	...	03 (1 TACS operation)

Tab.2 Sub-recurrent polar orbit

Request code table
- Preferred SOCS table
- Station/pass combination & activities table —
  - — Station/pass combination definition
- Sub-recurrent orbit nominal pass table

Form of request (lesser items)

		Examples
Day of operation	...	Nov. 12
Request code ID	...	01 (3 TACS operation)
Operation class (referring to operation priority)	...	02 (Maneuver operation)
Backup operation code ID (Cf. 2.2.2 conflict solving)	...	05 (2 TACS operation)

2.2.2 Conflict Solving Methods

This section explains the conflict solving methods used by the solving selection and automatic solving modes.
(1) Cut & try process
We assume NP is processing "Request X." NP seeks available network facilities and operation time within the flexibility of "Request X." Conflict then occurs.
① The group of already scheduled requests which conflict with "Request X" are cancelled.
② "Request X" is scheduled.
③ Available network facilities and operation times within the flexibilities of the cancelled requests are searched for.
④ If cancelled requests cannot be scheduled, NP cancels "Request X" and recovers the cancelled requests.
(2) Priority exchange process
The difference between cut & try and priority exchange is how they are done if a cancelled request cannot be rescheduled (as in ④ below). By priority exchange, cancelled requests become 'NG.'
① Already scheduled requests which conflict with "Request X" are cancelled.
② "Request X" is scheduled.
③ Available network facilities and operation times within the flexibilities of the cancelled requests are searched for.
④ If the cancelled requests cannot be scheduled, NP does not recover the cancelled requests. "Request X" plans are left.
(3) Backup code
If a request cannot be scheduled, the NP system schedules using this backup code. For example, we suppose that the usual code designates 3 TACS operations and backup code designates 2 TACS operations. If 3 TACS cannot be established, then 2 TACS are scheduled. Of course, users are not always required to use the backup code.
(4) Rejection
Requests are rejected.

2.3 Environment

The NP system runs on an engineering work station (Fujitsu A-80). The operating system is UNIX (SX/A) and the principally used languages are C, LISP, and FORTRAN. The NP environment is shown in Fig.3.

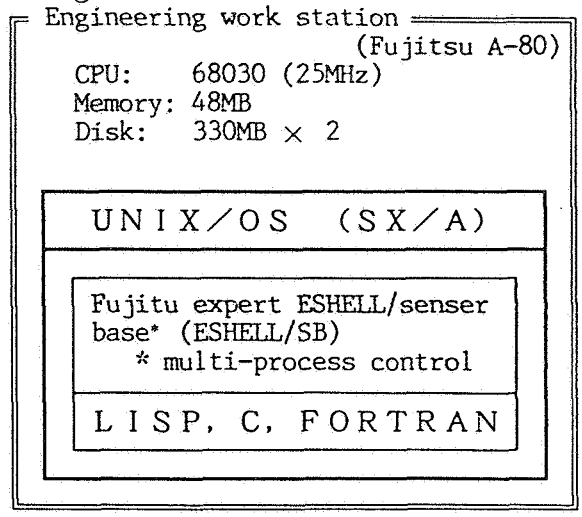


Fig.3 Operating environment

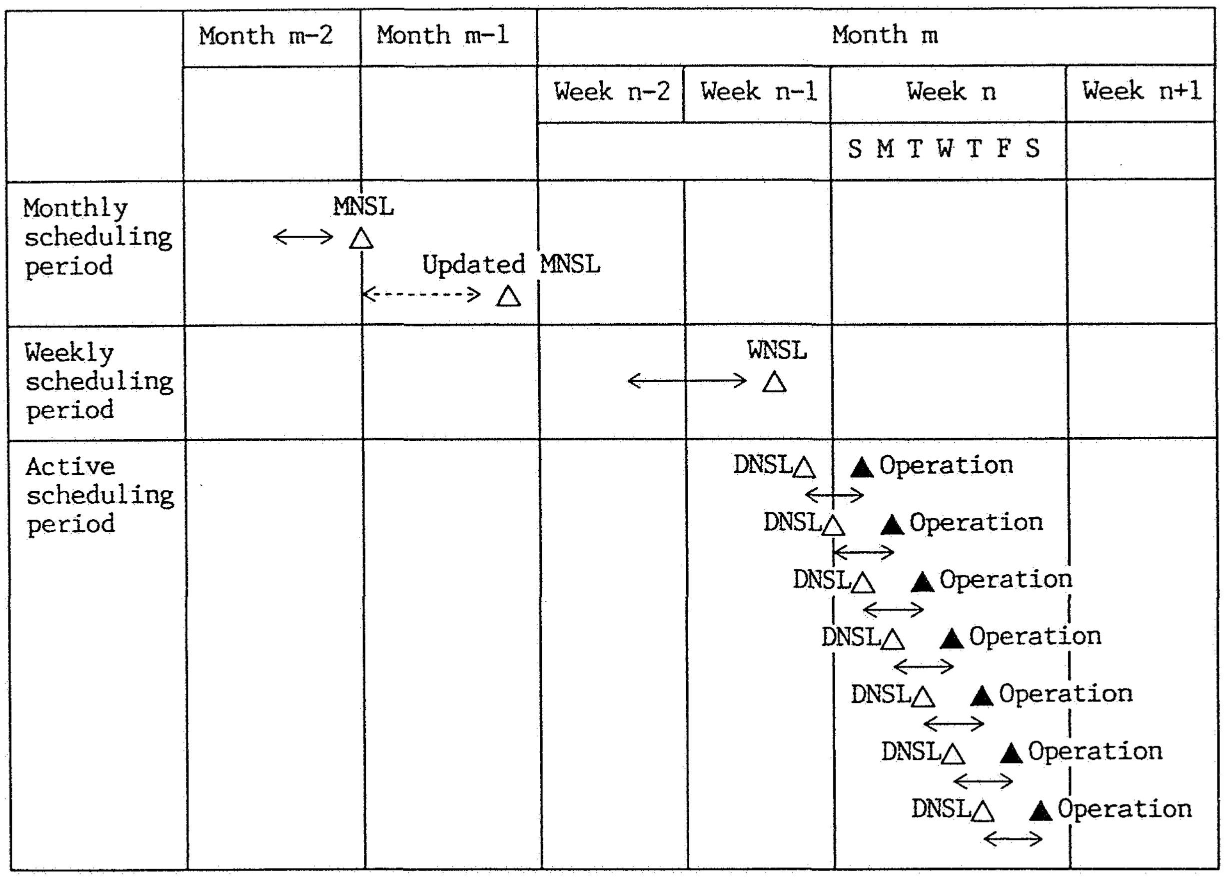
3. APPLICATION TO OPERATION

NP operates according to the timeline of Fig.4
(1) Monthly scheduling period
In this phase, the operator schedules activities such as facility maintenance, launches, and the operation plans for each satellite's nominal orbit. This schedule is a base of weekly and emergency scheduling. Monthly network schedule lists are printed out.
(2) Weekly scheduling period
In this phase, the operator reconsider the monthly schedule in more detail for the given week. If problems occur, scheduling is executed again. Weekly network schedule lists are printed out.
(3) Active scheduling period
If a problem happens during this phase, the operator updates the schedules as emergency scheduling. A daily network schedule lists is printed out.

4. CONCLUSION

4.1 Evaluation of NP System Operation

The NP system may be applied to a maximum of 28 satellites and 12 antennas with up to 99 operation codes per satellite. Results for scheduling three sub-recurrent polar orbit satellites were satisfactory. Before the launch of JERS-1, there were only two polar satellites whose visible time had very little overlap. However, the visible time of JERS-1 overlaps theirs so



Note: MNSL, WNSL, and DNSL are monthly, weekly, and daily scheduling lists.

Fig.4 Timeline of NP operation

heavily that the scheduling becomes much difficult. The NP system needs only about two hours to schedule a monthly plan. If manually, such a scheduling would require about one day. The NP system improves work efficiency and makes schedule list generation easy. This NOP allows timely scheduling and automated functions.

4.2 Expert System Effects

By using the change information in the knowledge base, users can make the most efficient use of the facilities. Moreover, by accumulating change information in the knowledge base, operating satellites, expert know-how is left and used successively. Scheduling simulations can be done easily for satellites or new facilities.

4.3 End-User Services

The monthly network schedule list includes the facility maintenance plan while the daily network schedule list gives information of backup passes. End-Users can use these lists for making requests.

4.4 Improvement

At now, the knowledge base of the NP system is updated according to the suggestions and requirements from the operators and the users. We hope to continue the effort to improve the NP system so that it can schedule more complicated requests including international cooperations.