DATA PROCESSING FOR THE EOLE PROJECT

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1. THE EOLE/CAS-A PROJECT - Data Processing at CNES.

1.1. Preliminary :

The EOLE project, either known as Cooperative Application Satellite-A (CAS/A) consists of a meteorological data collection experiment. It has been lead by CNES (Centre National d'Etudes Spatiales-FRANCE) and NASA, since 1965, and the experiment has been running from last days of August 1971 through June 1972.

1.2. Brief description of the EOLE project :

The main purpose of this experiment was to determine, for as long a time as could be, a chart of the winds in South hemisphere, between 20° South latitude and 70° South.

EOLE is a French satellite, which has been launched on August 16 th 1971 by NASA from WALLOPS ISLANDS (Virginia). The main orbit parameters are :

Period	: about 100 minutes
Inclination	: 51°
Apogee	: about 900 km
Perigee	: about 680 km

Its function is to interrogate a fleet of balloons, launched in South hemisphere, at a constant 200 millibar level (12 km).On a satellite call, these balloons transmit 2 meteorological parameters (local pressure and temperature) and 2 housekeeping informations. At the same time, the satellite measures the balloon range and its relative velocity. The whole set of data, as well as time of satellite call, are written into the satellite core memory. The satellite memory will be emptied when the spacecraft passes over a CNES tracking station. Let us notice that all these-data allow an effective location of each balloon.

1.3. Data processing at CNES

CNES was concerned with data processing for two main purposes

1.3.1. Initial data reduction, in order to deliver data tapes to scientists, including positions of balloons and balloon parameters.

1.3.2. Operations management, for which a fast knowledge of positions of balloons was required :

a) in order to deliver in time the satellite working program

b) in order to insure of security with respect to airlines

Generally speaking, a 12 hours to one day delay between balloon interrogation and balloon location seemed to be correct

2. DATA COLLECTION AND PROCESSING SYSTEM.

2. 1. Physical configuration :

CNES has developped a data transmission net between its overseas tracking stations and its main technical center-in Brétigny (near Paris).

The data lines are connected, throug ha concentrator, to an industrial processing computer (CDC 1700), which main function is to check and sort data messages.

All effective data processing is performed on a powerful computer (CDC 6600), which belongs to CNES computing center, so that EOLE data processing is just a part of its activity, and should not interfere witch other users. The 2 computers are connected, so that data transfer requires no human action.

All Control over the acquisition computer and programs running on the processing computer belongs to an operator which can send orders and receive messages or warnings from programs through a typewriter. Witch such an organisation, all data processing can be autonomous from normal computing center activity.

2.2. General organisation of the processing System :

This system comprises two parts.

2.2.1. a general support which consists of :

- a basic set of programs for the connection of the two computers.
- a specialized monitor on CDC 1700, running under standard Mass Storage Operating System (MSOS 2.1) which insures all control and data acquisition functions.
- a specialized monitor on CDC 6600, running under normal SCOPE 3.3 operating system, which insures normal sequencing of programs and linking witch CDC 1700, under CDC 1700 control.

2.2.2. a set of application programs :

These programs, written in Fortran language, are organized as fonctional units. Each program consists in one or some modules, i.e. sets of subroutines; each module has generally one or two specific functions which constitute a step in the program. This modular structure enables a great flexibility in programs, especially for tests and modifications.

3. ORGANISATION OF PROCESSING PROGRAMS.

All programs run as independent units which are linked only by a set of permanent files, so that programs can be considered as steps in data processing, and files as statuses of the program set.

The reader should refer to Annex I which describes the set of programs. Programs are listed below and some description is given.

3.1. Synchronisation program.

This program recognizes and separates the frames of the 2 telemetries sent by EOLE. Both scientific and housekeeping telemetries are sent on separate files (n° 19 and n° 13).

3.2. Housekeeping program.

This program processes all housekeeping telemetry frames and displays all housekeeping values and statuses on a listing. A diagnosis is given on satellite status. All information can be obtained in a conversational mode on the typewriter.

3.3. Scientific data decoding.

Data from scientific telemetry frames are decoded. Tests are

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made to check their reliability. All corrections are applied. Final data are sent on a file (n° 11).

3.4. Balloon location.

The principle of the location is this :

a) from the satellite orbit and time of interrogation, the position of satellite is known
b) the balloon is on the 200 millibar, level, i.e. on the 12 km altitude ellipsoid

c) the balloon is on the sphere centered on the satellite which radius is the balloon satellite range

d) the balloon-satellite relative velocity defines a cone which axis is the space craft speed vector, and which angle is easily computed.

Intersection of these three surfaces consists of 2 points, which are symetrical with respect to the projection of the satellite track on earth surface. Doubt has to be eliminated between these 2 ambiguous positions.

In a first pass of the program, the geometric method upper described is applied to each interrogation of a satellite pass (there are generally 2 or three). This leads to a set of 2 symetrical mean locations during the pass. Each of it is used as a trigger for a mean square reduction process over all measurements in the pass. Test of values of residues generally give a good discrimination of the false location. Let us notice that a later check of the balloon trajectory continuity can eliminate all remaining bad ambiguity checks. This later check is of the scientist responsibility and is not included in the location program.

Location values are sent on to 4 different files.

- file n° 14 is for operation purpose, and contains only the last computed location of each balloon; this file will be used in conjunction with prediction program.

- file n° 22 is for scientific use; it contains fully detailed location results, and is the source file for scientific data tapes; scientists use it for a fast on-line analysis of preliminary results.

- file n° 1 contains data for some special experiments which came after the balloon experiment, such as message transmission or buoys tracking; it contains, for each of these special objects, computed locations and all rough data associated with them, in order to allow any future analysis or reprocessing.

- file n° 3 was just designed for track drawing of balloons (charts and slides ware produced).

Let us notice that orbit parameters come from file n° 15 and rough data from file n° 11.

3.5. Prediction program.

This program computes from the motion of the satellite (orbit parameters-file n° 15) and from last known position of every balloon, the future meetings of satellite and balloons. Results are sent to file n° 16.

This program is the first of the three operations programs.

3.6. Operation management program.

Data from file 16 are sorted in order to propose an optimized working program for the satellite. Results are sent to file 17, and displayed on listings for examination.

3.7. Telecommand program.

This program updates, in a conversational mode from the typewriter, the working program proposal (file 17) according to operational constraints. Main result is a telecommand tape, which content will be sent to satellite by one of the CNES tracking stations. This tape contents, in a coded format acceptable to spacecraft, the hours and nature of calls it will emit towards balloons during next orbits. This program is stored on board the spacecraft in a specialized memory, and will be run automatically.

4. MAIN PROBLEMS ENCOUNTERED AT PROCESSING.

Three unexpected problems have arised since the beginning of experiment and had to be solved rapidly.

First two problems are related to the intense human activity in the 400 MHz range which is used for communication between spacecraft and balloons. A probable erratic failure in the satellite logic has enhanced this problem.

4.1. Synchronisation.

Scientific telemetry frames consist of eight numbered “sentences” of 128 bits and a synchronisation pattern plus time information (32 bits long). Each sentence contains the information from one balloon answer.

Some sentences have happened to be longer than 128 bits, by elements of 16 bits, containing irrelevant information. The synchronisation scheme, based on frames, had to be replaced by another one based on search for synchronisation patterns (now the beginning of an unknown-lengthed frame) and examination of each sentence time and number. Gain may be up to 20 per cent sentences more.

4.2. Noise elimination.

Some sentences in the telemetry result in incoherent or impossible informations at decommutation. Since there exists no other information on telemetry quality at this step, experimental criteria had to be developped to eliminate these noisy interrogations (there may be up to 90 per cent of these). These criteria now allow to build a chart of noises in the 400 MHz range and to locate some power ful sources.

4.3. Ambiguity check in location.

The principles of the location program lead to find 2 possible solutions, symetrical with respect to the satellite track. This ambiguity is primarily resolved by examination of the residues in the mean square method. This ambiguity could be in error, due to the fact that, during computations, balloon velocity was supposed null, since it is unknown. Even in case of a good check, a 20 kilometers error on the position was likeable. The introduction of a simple model of winds parallel to the Equator seems to have been a great improvement; a error matrix (balloon coordinates derivatives from the wind) is given to the scientists for later corrections. Location precisions tor balloons is thought to be now better than 5 kilometers in most cases.

Le t us notice that there remain two problems related with location precision, which can’t be solved by any method.

- lack of raw data : the mean squace method needs at least 2 calls of the balloon; in case of unique interrogation, only the first pass in the location program is run, and precision is poor (there are no correction terms)

- when the spacecraft passes at the zenith of the balloon, the principle of location program fails down, and no ambiguity check is possible.

5. RESULTS AND CONCLUSIONS.

There are mainly 2 classes of resultats: scientific ones and technical ones.

5.1. Scientific results.

CNES was not involved in analysis of meteorological experiment, and this will not be discussed here.

On the other hand, first results about location precision may be pointed out, though a deep analysis of this problem is still in progress. This analysis processes all results relative to the only fix balloon payloads which were in some CNES tracking stations. General results are those :

- all locations found are grouped; half locations are in a 1 km radius circle centered on the barycenter of the group; 80 per cent at least are in a 2 km radius circle.

- the barycenter may be at 2 a 3 km of the theoretical point; part of this difference can probably be explained by geodetic problems (coherence of the various systems of axises used). This seems a good result , with respect to tke simple method used and the small number of measures at each pass

- the first results of the deep analysis seem to point out that, for this type of satellite, position can’t be known with less than 500 m to 1 km doubt; this figure looks quite coherent with those at previous paragraph.[1]

5.2. Technical results.

It was first time that CNES used an on line data reduction process. This problem can be considered as successfully solved.. Minimum delay between balloon call and balloon location is 6 hours, mean delay is about one day, and maximum delay is 3 days. It must be noticed that data transmission lines are slow ones (200 bauds) and are shared with normal

[1] (we mean satellite’s position along its track).

transmission net of CNES. A fair improvement should be the use of fast specialized lines. A second problem is that the processing computer is running only 16 to 18 74oure a day and presently supports a large computing center. This delay is generally thought as correct by most users (scientists or operations staff). CNES intends to use similary systems with the same technical support for future satellites (1973). Faster: and larger data acquisition and processing systems look interesting and are presently being studied for the 75's.

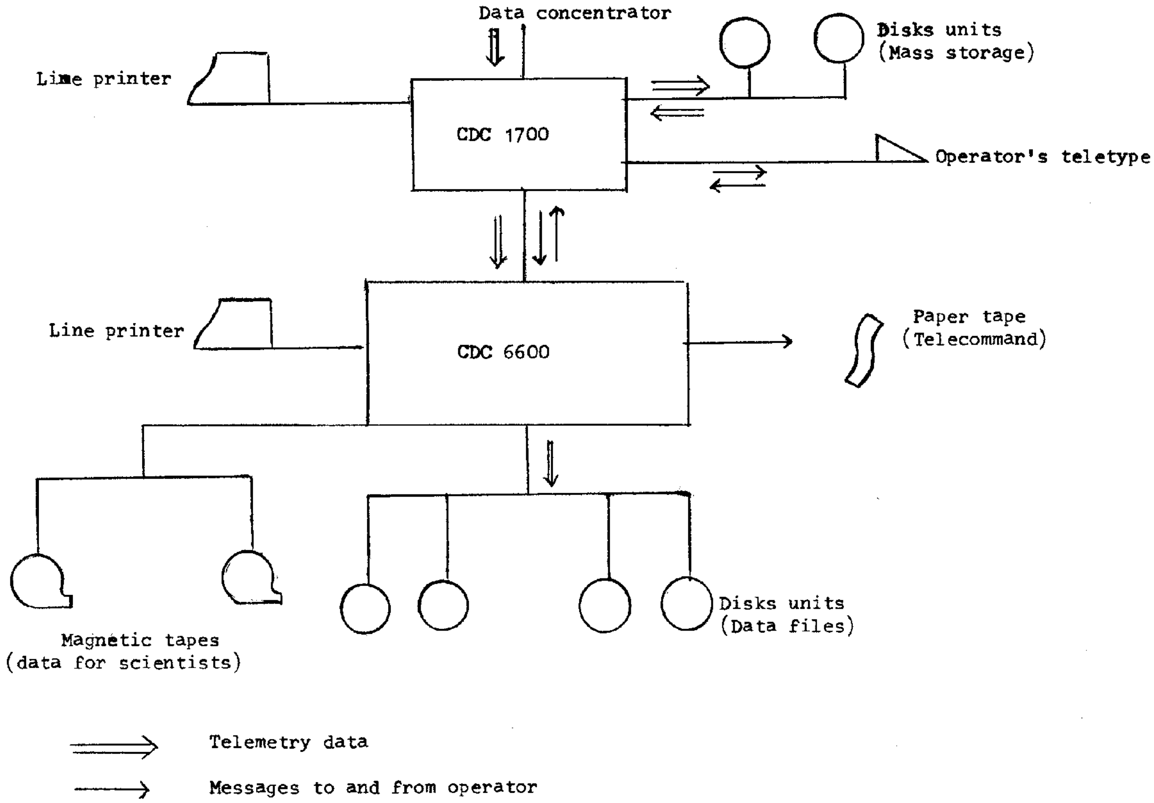
ANNEX I

PROCESSING ORGANIZATION

Processing organization is displayed on next page.
Numbered circles are files, data flow is shown by arrows.
Files contents is bisted below.

File 1 : Data for special experiments.
File 3 : Balloons locations, for display purpose
File 11: Decoded scientific data.
File 13: Synchronized housekeeping telemetry frames.
File 14: Later location of every balloon.
File 15: Orbit parameters (these are replaced, every day, from outside).
File 16: Future balloons-satellite meetings.
File 17: Optimized working program for the satellite
File 18: Ballon payloads characteristics.
File 19: Synchronized scientific telemetry frames.
File 22: Main file for scientists - Balloon locations

ANNEX II
PHYSICAL CONFIGURATION



PROCESSING ORGANIZATION

Processing programs and main files