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USS — the project of a complex for automatization of preparing and making observations at the radio telescope RATAN–600

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Abstract. Main tasks and principles of organization and methodology of construction of an automatization complex for preparation and conduction of observations at RATAN–600 are described. The complex USS (United Supporting System) is regarded to be a system that integrates key subsystems of the radio telescope and ensures their qualitatively new and interrelated development. The first results of the work done on the project are presented.

Key words: methods: observational: automatization – techniques: image acquisition – techniques: image processing

1. Introduction

The present day technology of obtaining astrophysical results with any large telescope is expected to use a set of functionally oriented systems to provide preparation for observations, control of the telescope, acquisition of information, archiving of data and their subsequent reduction (Verkhodanov et al. 1996; Kononov 1996). The main characteristic feature of RATAN–600 as compared to other radio telescopes is the diversity of observational methods and multifrequency mode of experiments done with it. RATAN–600 is a complex observing tool which incorporates a variable profile antenna (main mirror) and feed cabins equipped with various detectors for broad-band observations, spectral investigations and studies of radio emission of the Sun. The overall efficiency of the instrument in performing any astrophysical tasks depends, first of all, on the performance of its principal subsystems: the antenna automatic control system and the data acquisition systems. An important role is also played by the system preparing observational jobs and the system of experimental data archiving. The complexity, versatility and inhomogeneity of these systems, especially under the condition of their independent creation and development, pose a number of problems that frequently arise when the instrument is used for specific observational programs.

As experience of the last few years has shown, the importance of coordinated interaction of individual technological links is increasing. This is caused by a number of interrelated factors, the basic of which are as follows.

- Constant upgrading of observational methods, including introduction of new modes of control of the antenna and radiometers.
- Enhancement of capabilities of the radiometric complexes of the feed cabins.
- Parallel control of both the antenna resources and the resources of different receiving–measuring complexes in the case of execution of observational programs with different feed cabins.
- Considerable growth of observational information which has resulted from placing in service new generation automatic control system of the RATAN–600 antenna and additional radiometric channels.
- Application of a large number of original program products frequently duplicating one another and maintained by the authors independently enough.
- Necessity for preserving an ever increasing number of parameters reflecting the state of the radiometers, antenna geometry, meteorological conditions etc., which will make it possible to provide for many factors affecting the quality of observations.

New capabilities of the radio telescope, as well as new requirements to the instrument operation, lead to a considerable extension of scientific programs being carried out and to complication of the observing process. The consequence of this is an extra load on individual subsystems of RATAN–600, leading sometimes to extreme conditions of their performance because of insufficient coordination. At the same time, the proportion of manual operations increases, especially at the stage of preparing observational jobs, and also for the maintenance services directly at the stage of observations.

All this made it necessary to develop a new approach in the field of automatization of the radio astronomical experiment. This new approach was formulated as a concept of USS (United Supporting System) complex, which is a complex of automatic preparing and making observations at the radio telescope RATAN–600 (Zhekanis et al. 2002). The project USS provides for the use of common technology of preparation and control of observations for the most complete implementation of all capabilities of the tool on the basis of an up-to-date computer base. Since 2002, the USS project has been supported by the RFBR.

2. Development and integration of the systems

The USS project concept assumes the development and, in the end, the integration of 4 types of systems:

1) antenna automated control system;
2) experimental data acquisition system;
3) observational Databank of RATAN–600;
4) system of preparing observational jobs.

The development of each specific system must take account of its own functional orientation and potentially necessary connections with the rest of the components. In other words, the building up of capabilities of any of the systems has to be co-ordinated with other systems and conform to the general principles of construction and functioning of the complex USS as an integrated system.

The integration implies formalization and establishment of links between the enumerated components on the basis of system interfaces specially developed for this purpose and ordering the interaction between individual subsystems in the processing chain based on the general schemes of data exchange as astrophysical experiments are being prepared and done. An important point here is the organization of a real-time feedbacks with the systems of control of the antenna and radiometers for prompt correction of the conditions of performing any experiment at RATAN–600.

The creation of the integrated USS complex provides for gradual, step by step, development of the specialized systems incorporated in it and consequent introduction to service of their next versions without any violation of the current observational process. The whole project may be based on the already partially introduced hard-and-software developments, which are contemplated to be complemented considerably with new components to realize complex approach in creating a logically complete multifunction system supporting observations at RATAN–600.

3. Primary base

As a primary base for doing work over the project, the systems that had already existed by 2002 have been used, which, with a certain extent of automatization, supported round-the-clock observations with the instrument. An analysis of their state made it possible to work out effective criteria of integrating individual components in a unified automatization system of radio astronomical experiment USS.

3.1. System of antenna automatic control

The variable profile antenna (VPA) of the main reflector of RATAN–600 consists of 895 reflecting elements of the Circular and 124 elements of the Flat reflector. The setting of the reflecting panels is accomplished with the aid of the automatic control system (ACS) which realizes the method of a digital open-loop system of automatic adjustment with organization of the batch job formulation. The VPA ACS is a 3-level hierarchical hard-and-software system having distributed computational resources connected with each other by the local computer network (Zhekanis 2002). All the equipment of the VPA ACS is dispersed over an area of $0.5\,\mathrm{km}^2$ with conventional perimeter more than 2.5 km. The number of channels for movement control in two directions with a constant velocity is 2809, while the number of position measurement channels is 17000. The system ensures the designed for RATAN–600 surface setting precision of 0.17 mm.

At the present time, control of the Circular reflector is exercised by a *third* generation ACS, which had been made before 1995 on the basis of domestic mini- and microcomputers of class PDP-11 and LSI (Golubchin et al. 1995; Zhekanis et al. 1995). A total of over 100 thousand antenna settings to conduct observations has been accomplished with its aid.

In 2001 the Flat reflector was equipped with a new VPA ACS of the *fourth* generation, which was based on computers of class IBM PC with new hardware for measuring the panel positions of the antenna and with external net access. In the process of using the new control system of the Flat reflector, about 20 thousand observations with a maximum density of settings up to 180 during 24 hours were made. In the nearest future it is planned to control part of the Circular antenna by the *fourth* generation VPA ACS.

3.2. Experimental data acquisition system

The receiving complex of the continuum radiometers, which is an elaborate multifrequency instrument capable of solving a wide range of astrophysical problems, is the leader as to the amount of output information (up to 90%) (Berlin et al. 1995; Nizhelsky et al. 1999). The multichannel structure and the great number of operation modes of the detectors, as well as the need for control of the mechanisms and the systems of the feed cabin as a whole, require adequate hard-and-software support of the entire complex by the data acquisition and control system (DACS).

The DACS of the feed cabin No.1 of RATAN-600 after the introduction of its new version in 1994 (Chernenkov, Tsybulev 1995) has undergone a number of changes as regards its hard- and software. These changes are connected with the expansion of the set of radiometers, increasing number of radiometric channels, and appearance of new engineering and program solutions in the sphere of acquisition, control, and digital reduction of signals.

The introduction into operation of an antijamming system of the decimetre range radiometers in 1995 (Berlin et al. 1997) showed the prospects of using digital signal processors (DSP) for high-speed reduction of signals in real time, in particular, for the task of demodulation of radiometer signals. However, the transition to this technology for all the radiometric channels has not been completed yet. The completion of this stage of updating will enable creation of a flexible homogeneous acquisition system, which can be duplicated for the DACS of other sets of continuum radiometers (feed cabins No.5 and No.6) and also recommended it for use in the rest of the feed cabins of RATAN-600.

Since the middle of the 1990s, a self-documented format based on the standard FITS extension — Binary Table — has been used for representation of output data of the feed cabin No.1 acquisition system. This made it possible to considerably enhance possibilities of experimental data parameterization and organize more flexible links with the FADPS reduction system (Verkhodanov et al. 1992, 1993; Verkhodanov 1995) extensively used at RATAN-600. The acquisition systems of the receiving-measuring complexes of the feed cabins No.2 and No.3 employ their own formats for representation of output information, which are the local standards for the corresponding types of data — spectral and solar.

3.3. Observational Databank

At the present time the observational Databank ODA-R (Observational Data Archive — RATAN-600) is in operation at RATAN-600. This is an integrated multibase distributed information system intended for accumulation and storage of experimental data and also for providing automated access to the archive information for different categories of users. The concept of the system was formulated in 1998 on the basis of analysis and generalization of the experience of the previous developments at SAO in the field of archiving astronomical data (Kononov, Evangeli 1991; Kononov 1994, 1995a,b; Kononov, Mingaliev 1996, 1998). The first version of the Bank was realized step by step in 1999–2001 under the support from the RFBR and continued to develop (Kononov et al. 2001, 2002).

The system is oriented to different types of standardized radio data, each being related to a specific receiving-measuring complex of the radio telescope. Currently, the Bank ODA-R supports three types of data: the data of the broad-band radiometers of the feed cabins No.1, No.5 and No.6, the spectral radio data of the feed cabin No.2 and the solar data of the feed cabin No.3.

The permanently expanding main archive base included, as of 2002 January 1, results of more than 140000 multifrequency observations amounting to a total of 22.3 Gb with a recent 5–50 Mb daily information flow and a number of observations of up to 170–180.

The ODA-R, as one of the technological links, supports in an automatic mode a raund-the-clock observational cycle of RATAN-600, organizing communication with the acquisition system by means of a two-level network system of buffering ODA/BS-2L under the control of the archive server of the radio telescope — *oda.ratan.sao.ru*. The network buffering system is a part of the Databank, its input interface shell, which exercises on-line reception and check of all output information of the acquisition system (Kononov 2002).

Since 1995, to present the output data of the acquisition system of the feed cabin No.1 continuum radiometers, the registering RFLEX format has been used (Verkhodanov et al. 1994, 1995; Verkhodanov 1995), which is based on the standard extension Binary Table of the international FITS format (Cotton et al. 1995). We consider this format to be the first working version of the unified FLEX format, which is contemplated to be applied as standard to creating the USS complex with allowance made for the concept of the structure of the ODA-R Databank. Despite certain shortcomings, the stability of the format has long favored the introduction of a fully automatized chain "acquisition–archiving" that has been functioning without the interference of the Bank administrator for about 3 years.

The joining of the ODA-R Bank with other acquisition systems to receive other types of data (spectral and solar) accounting for 10% of volume is implemented in a less automatized mode. First of all, this is due to the specific character of representation of data of these types, as well as to organizational matters.

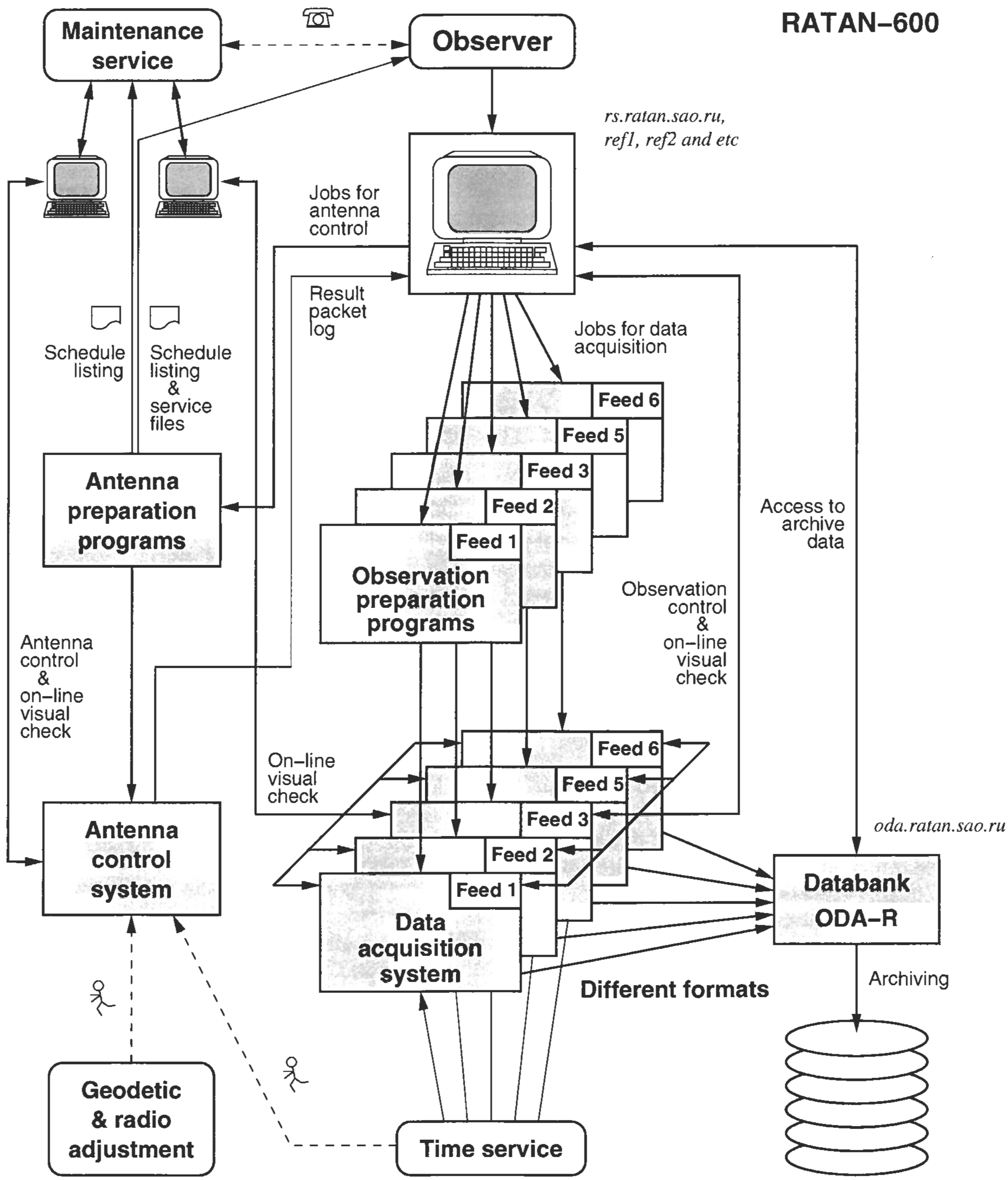

Figure 1: *Maintenance of the observation cycle of RATAN–600 in 2001.*

3.4. Observational job preparation

Fig. 1 displays a general block diagram of functioning and interaction of the radio telescope systems when maintaining the observing cycle in 2001. The preparation of jobs and data for observations, that is for the organization of the observing process itself, is rather labour-consuming. In view of the earlier experience of independent development of the basic systems of the radio telescope in this field, we had poor intersystem links (and in a number of cases they were lacking altogether), the great number of manual operations and the need for application of tens of heterogeneous program products of both general and individual use, which performed three basic tasks in the overwhelming majority of cases:

• computation of ephemerides of the object under observation;

• computation of the VPA positions in different modes of observations;

• preparation of data for the control and acquisition systems.

Such program products were created at different times by different authors, they frequently duplicate one another, and some of them are no longer supported. A great number of problems arise in this situation, both in the preparation and conduction of observations. Within the frames of the project USS it is supposed to create a united system of preparation of jobs for observations, which has to ensure the majority of modes of using the radio telescope with minimum expenditures of time, intelectual and physical effort. The most developed system in this field, and, in some matters, the only one of its kind, is the data preparation system CS (Compute Setting) designed for preparing data to control the RATAN-600 antenna (Zhekanis, Zhekanis 1997). This system makes use of the language of parametric description of input data in a relatively simple and convenient for the user system and computer-independent text NVT format (Name–Value Table) and includes:

1. Computation of ephemerides of fixed cosmic objects.
2. Computation of positions of the antenna and feed cabins in the main observing modes (passage across the azimuth).
3. Dispatching and making a schedule at a level of one continuous box of observations (1–7 days).
4. Preparation of job packages for the antenna automatic control system.
5. Databases for storage and maintenance of a set of parameters (more than 100 names) used by the system.
6. Programs of text visualization of the results of computation and the results of antenna setting.

In this connection we have discussed the system CS as the primary base for the creation of a unified system of observational job preparation.

3.5. Main problems

As experience of intensive use of individual systems has shown, their functional capabilities are still limited, and the configuration and character of their interaction present in the end a whole number of problems which manifest themselves in:

• bulkness and inconvenience of the entire procedure of observational data preparation;

• plurality and discrepancy of program maintenance components;

• absence of flexible unified links between individual systems;

• absence of the necessary check procedures of on-line operation of the systems;

• failure to exercise the fullest and prompt control of all the necessary resources by the astronomer in the process of observation;

• insufficient standardization of information outputs of different acquisition systems;

• insufficient parameterization of output experimental data.

The creation of the USS complex is to eliminate all these problems.

4. Principal tasks of the project

Enumerate the main tasks which are to be performed in creating the project USS.

1. Development and reduction of a cardinally new system of observational data preparation ensuring for the radioastronomer the entry of the required parameters, their testing, performing the necessary precalculations, distribution of the called-for resources of the radio telescope and global check of their correct use.
The job preparing system is integrated with the antenna control and data acquisition systems by means of transmission to them of strictly parameterized job packages, which, in the aggregate, define the real schedule of the telescope operation.

2. Development and inclusion into the antenna automatic control system of new external interface shells, processing the antenna setting job packages and implementing real-time feedback with the data acquisition system at the stage of observations.
The antenna control system is integrated with the observation preparation system, receiving from it packages of jobs, and with the acquisition system by means of transmission by the latter of strictly parameterized packages that reflect the actual settings — the state of resources used.

3. Development and placing in service of a new-generation multifunctional data acquisition system exercising control of the radiometric complexes, recording of digital data, and also multilevel journalizing of all astrophysical experiments.
The acquisition system is integrated with the antenna control system and with the job preparation system, receiving from them and storing the information about the actual states of the antenna resources and the required configurations of the radiometric complexes, and with the observational Databank, transmitting to it observational results and files of logs of experiments parameterized as much as possible in all respects.

4. Development and reduction to practice of new unified local standards on the basis of the requirements and recommendations of the universally accepted standards in the field of astronomy concerning the identification of data and their presentation.
Use of the FITS Binary Table format supported by the IAU as the base.

5. Elaboration and connection to the observational Databank of external input and output interface shells supporting the new local standards of structuring, identification and representation of data. The Databank is integrated with the acquisition system on the basis of the unified FLEX interface (FLexible EXchange) which is also used to connect the Bank to the processing systems.

It is important to note that the enumerated principal tasks of the project suggest three more essential points:

- development of general schemes of data transmission within the whole technological chain "job–control–acquisition–archiving";
- creation and maintenance of specialized data bases containing information about observational programs, radio telescope operation schedules, statistics of setting the antenna elements, parameters of the radiometric complexes etc.;
- work-out of user's interfaces for input of observational jobs, and also procedures of visualization (monitoring) of the state of all the key units of the observing complex with the aim of prompt checking the quality of observations.

The general scheme of interrelation of the systems of the complex USS, which corresponds to the problems formulated above is presented in Fig. 2.

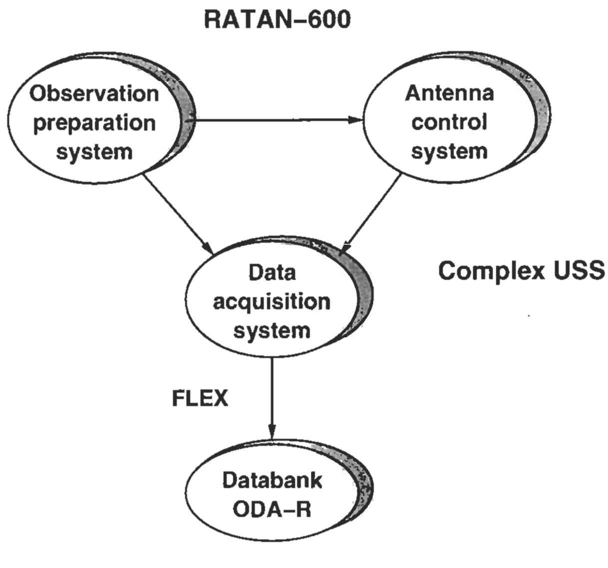

Figure 2: *General scheme of integration of USS complex systems.*

5. Methodology of construction of the complex USS

Let us dwell upon the principal aspects of construction of the integrated complex USS, the block diagram of which is displayed in Fig. 3.

5.1. Principles of organization

The design of the complex of automatized preparation and making observations at the radio telescope RATAN-600 is based on the following main principles.

1. The complex USS is the aggregate of interrelated soft/hardware systems each of which is a separate part of the system of astrophysical experiment automatization.

2. The systems incorporated in the complex are functionally oriented and correspond to individual links of the technological chain maintaining continuous operation of the radio telescope.

3. The rules of interaction of the systems reflect the requirements of the general information model of the complex ensuring optimization of the entire observational process.

4. Each system has rigorously formalized input and output.

5. The interrelations of the systems are realized on the basis of the interfaces unified at maximum.

6. The scheme of operation of the systems ensures in the end a maximum degree of parameterization of output experimental data.

7. The rules of passage of information through individual units of the complex allow for the possibility of flexible check of data transformation at all key stages.

8. The complex USS is oriented to different categories of users (observers, maintenance service workers, designers of the systems etc.) giving them respective authority.

9. Step-by-step and co-ordinated introduction of individual parts of the complex ensures a higher degree of automatization of astrophysical experiment and reduction of all manual operations to a reasonable minimum.

In the process of operation the complex USS is supposed

- to make it uniformly possible for all observers, irrespective of the contents of observational programs and receiving-measuring complexes of the feed cabins used, to prepare and carry out observations;
- at the stage of observational job preparation to

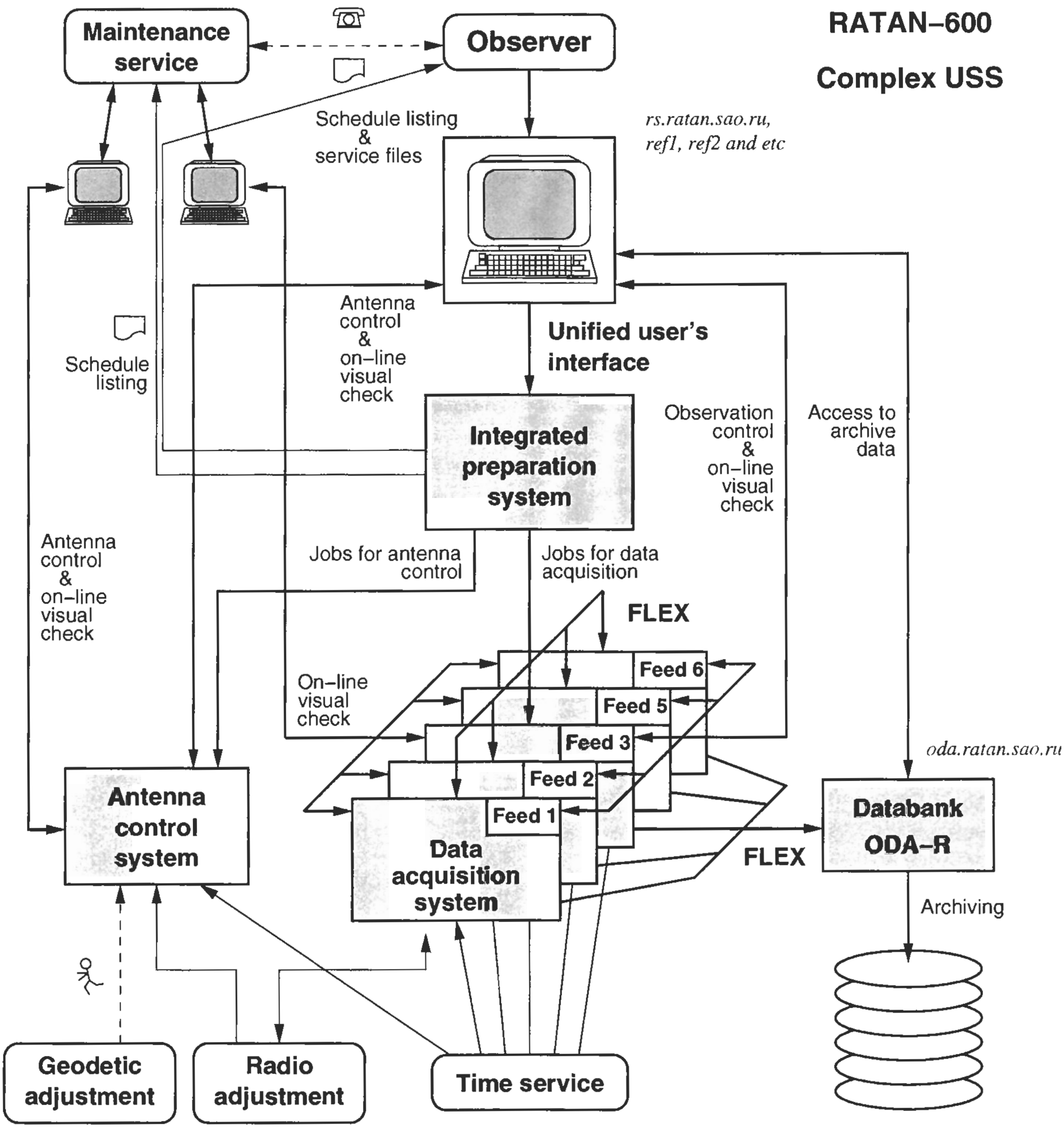

Figure 3: *Maintenance of the observational cycle of RATAN–600 by means of the USS complex.*

realize convenient and flexible user's interfaces taking account of the particularities of using certain radio telescope resources called for;

- to maintain in the process of observations additional on-line communications to obtain the necessary reference information and ensure possibilities of prompt correction of the observational process both on the part of the maintenance service and the observer;
- to ensure the journalizing of passage of information through individual systems of the complex;
- to create and maintain the intersystem specialized databases;
- to give the users supplementary information on the basis of the logs and specialized databases;
- to prevent unauthorized interference in the operation of individual system components.

5.2. General information model

The complex USS embraces three stages of obtaining and transformation of information (Fig. 3):

1) observational job preparation;
2) making observations;
3) experimental data archiving.

The **first** stage is maintained by the integrated observational job preparation system. To input the information, the common user's interface is granted to the astronomer, which is unified in respect to the receiving-measuring complexes, types of feed cabins and antenna resources appearing in the request. The job preparation may be executed by one or several instrument users independently with merging the input packages in a single one or without it, depending on the modes of observations and the used radio telescope resources. The preparation and preliminary testing of the jobs or their constituents can be exercised in a remote mode. After the reduction of the input jobs, check of their correctness, accomplishment of the necessary precalculations, output data packages form. These are intended for operation of different automatized radio telescope control systems and the acquisition systems of the radiometric complexes. They also contain the information about the radio telescope operation schedule for a certain time interval. To present the output data and transmit them to the automatized systems of the complex, preferable use of the unified FLEX format is supposed.

The **second** stage, a stage of the observations proper, is realized with the aid of co-ordinated operation of the VPA ACS and individual aquisition systems on the basis of the schedule prepared earlier. The next antenna setting at the desired time is accomplished by the ACS from the data formed on the basis of the common package of jobs. After the completion of the antenna setting and positioning of the feed cabin, the DACS of the specific receiving-measuring complex, which performs preparatory operations using the corresponding parameters from the common package, is activated and executes the recording and acquisition of observational data during the given time interval with the parallel journalizing of the experiment.

The co-ordinated operation of the ACS and acquisition system implies to establish dynamical links between them allowing fast obtaining of information of whether the antenna is prepared to carry out the current observation and of the actual configuration of the reflecting elements. This information arrives not only in the internal ACS archive, but is included into the output data of the acquisition system in a certain form, for instance, logs of observations. Besides, at the stage of observations, a visual on-line check of acquisition is realized by the astronomer and, which is of special importance, the observer can interfere in the scheduled process of antenna control, for instance to exclude a certain setting. At the same time, similar on-line communications with the ACS and the acquisition system are also kept up for the appropriate maintenance services.

As a result of operation of the acquisition system, flows of digital experimental data and logs of observations form, which are reduced to the system of FLEX standards corresponding to a concrete type of observational data and sent to the buffer area for subsequent transmission to the Bank ODA–R.

The **third** stage is controlled by the observational Databank. The flows of output data of any acquisition systems are received by means of the unified input interface shell of the Bank, which realizes the unified FLEX interface. The transmitted standardized data are automatically identified on the basis of a fixed set of rules and centralized descriptions and archived in an ordinary manner in the appropriate divisions of the ODA–R. Thus, the support of the FLEX interface from two sides, by the Databank and the acquisition systems, ensures uniform interaction of the two types of systems with all ensuing advantages: use of the common software, unification of the methods of access to the archive data of any type, possibility of creating a common user's interface, the same organization of the Bank divisions, application of unified procedures of data check, collection of archive statistics etc.

The described scheme of formation and direction of data flows is the foundation of the general information model of the complex USS, which is, naturally, to be complemented and detailed at subsequent stages of designing and introductions.

5.3. Architecture aspects

The integration may touch on not only the means of data preparation for making observations but also immediately the software of the systems of data acquisition and control of the radio telescope, and not only at the level of formats of input and output data but also at the level of structural and architectural solutions in creating distributed and rather elaborate systems. Consider the structure of a unified distributed modular data acquisition and control system presented in Fig. 4.

The overwhelming majority of elaborate acquisition and control systems incorporate interface facilities of interaction of the users and the system, with the help of which such operations as formulation of the job, control of the job, check of its fulfillment, promt meddling, system testing, change of the configuration, etc. can be done. In this version the operations of interaction of the users with the system are suggested to be performed by means of application programs which make use of distributed remote network access to the resources of the system in the mode client-server. When necessary, these programs may be united in command files or in integrated window shells (concept of UNIX) and may be of both general use and personal, developed by the user himself. The connection of the application programs with the acquisition systems must be executed via the universal net interface based on the standard network

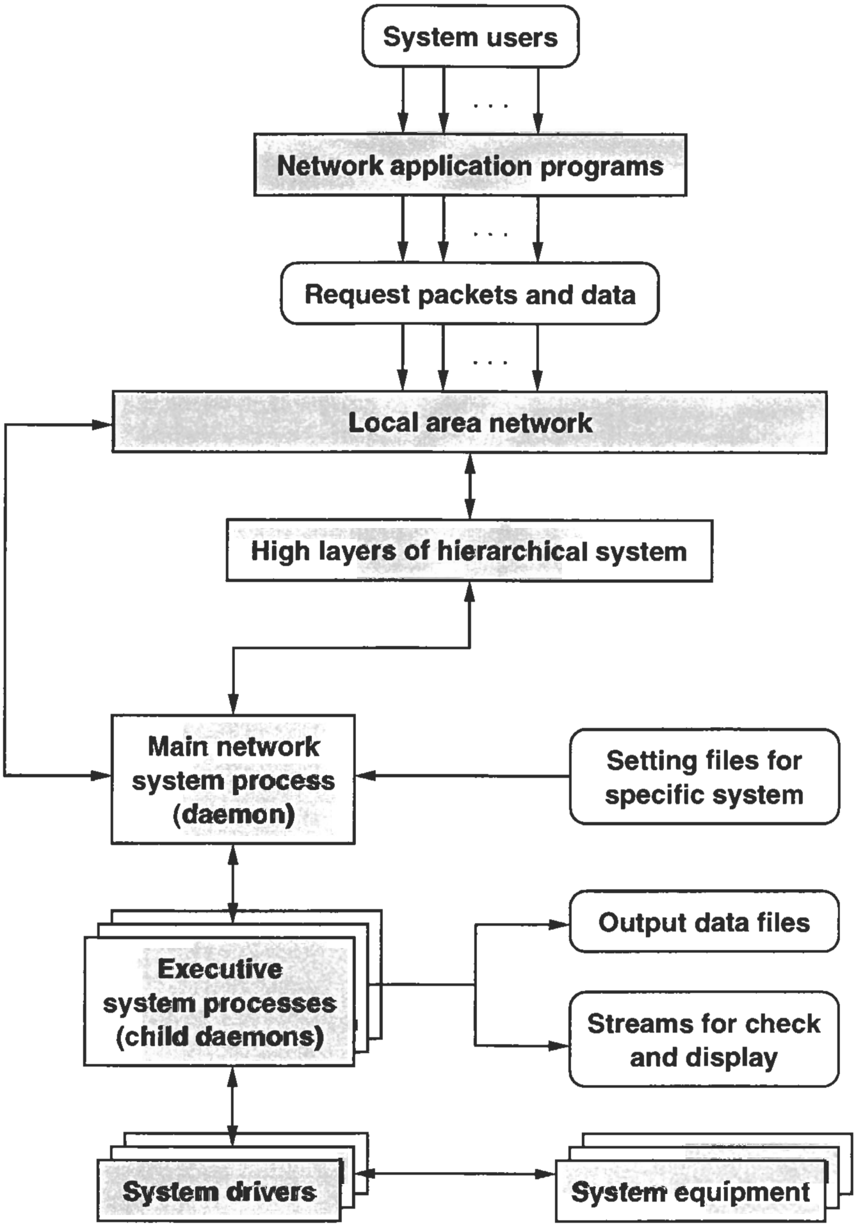

Figure 4: *The structure of the unified distributed modular data acquisition and control system.*

protocols TCP and UDP.

The application programs must form and transmit to the network standardized packages of jobs and requests. The package formats may be different in various systems. However, within a great number of like systems, such, for instance, as the acquisition systems of RATAN–600, it is desirable to use the common internal format, for this is associated in the end with the common archive system and, possibly, with the common data processing system. As has already been noted, it is planned to use for acquisition systems the unified FLEX format for the representation of observational data, which is an upgraded version of the international FITS format. Thus, the FITS format will be used not only for the output data representation but also for network access to the acquisition and control systems, having come to be a universal and quite convenient means of transport and storage of data. The headers of the FLEX files must be strictly standardized in fields of general purpose to ensure intersystem compatibility.

The packages formed at any point of the network come to the input of the main network process of the acquisition and control system. The main process is the network server operating in the mode of the monitor resident permanently in the system (daemon). It starts when loading the operation system (OS) and ensures operations of primary adjustment of the system for a given configuration, network access to the system resources of the client's application programs, protection against unauthorized access (in part), general check of operation of the system. The executive processes are generated by the main process with different network requests and do the immediate work for maintenance of connection with the application client-program, for formulation and removal of jobs, for recording and primary reduction of data, for control of the system equipment, for formation and distribution of output files, etc.

Any developed acquisition and control system includes a lot of operations and functions which can be unified at the level of libraries and processes. It is practically always that rather complicated and, as a rule, multivariant operations must be performed, such as organization of network access, elimination of unauthorized access, work with data flows and formats, the system's resources quoting and control of fulfillment of the schedules (possibly, parallel), on-line control, check and graphic vizualization, transmission of information to the archive server, etc. All these areas mainly of system programming can be subjected to complete unification and standartization preserving a possibility of their development. It is natural that all the acquisition and control systems are based on unique equipment, that is not subjected to complete unification as to the software. This problem can be solved by the development of the necessary set of different drivers and also specialized application and executive processes. Here too, the high level of unification will be provided for by thought out conventions on data formats and methods of access to the drivers. It is in this manner that all operation systems work with different peripheral equipment.

Thus, the main idea consists in the creation of a universal basic kernel for the acquisition and control systems constructed on the modular principles at the level of processes, drivers and libraries, with the use of powerful versatile instrumental facilities for designing and maintenance. The basic principles, characteristics and methods of using such systems must be standardized, well documented and easy of access to other designers of acquisition and control systems. All this, is to reduce sharply time expenditures for the creation of new acquisition and control systems, for development and reconstruction of the already existing systems, and to improve considerably the reliability of operation of all these systems.

The architecture described above, except for individual details and data formats, was used in the creation of the software for the new system of automatized control of the RATAN–600 Flat reflector.

5.4. Basic software

Against the background of numerous discussions of the merits and demerits of competing operation systems or the means of elaboration of different acquisition and control systems, the authors consider it necessary to express their opinion concerning the operation environment in which systems like those proposed above must be created and function.

To date, the most suitable operation system, which is powerful vigorously developing and satisfying a great number of requirements, is Linux (Taket et al. 2000) made entirely on the basis of UNIX. This is quite a high-speed stable, protecting to advantage the information against virus, unauthorized access, failures of the equipment and "bad" user's programs. Mechanisms of the virtual memory and mechanisms of shared libraries and context of the same processes are provided for in it, which save memory, thus increasing the transmission of the system. The multiprocess property borrowed from UNIX, the developed system of command languages, the structure of the file system, the protection of the resources, with the system being opened for the system programmer, powerful means of development, etc., when properly applied, improve many times the efficiency of the developments and ensure the reliability of using especially elaborated systems.

The creation of the basic programs and libraries is preferred to fulfill in the object-oriented language *C++*, since it, preserving all capabilities of the language *C*, ensures a great deal of possibilities which reduce the time of development and the number of errors, and also brings the designer to a higher and more refined level, which meets the requirements to the development of multipurpose, complex information structures and systems. Moreover, the distributors of Linux began to include in their packages quite a successful graphic library *Qt* of the Troll Tech company, written in the *C++*, which is also to speed up the work with obtaining products of higher quality. The drivers in the OS Linux are worked out solely in the language *C* with the immediate inclusion in the kernel or in the modular version — connected automatically to the kernel as the device is addressed to. The facilities of real-time operation are being built up and upgraded.

It is because of this that we consider the OS Linux to be the basic operation environment in which program development for the creation of all the components of the complex USS must be carried out.

5.5. FLEX interface

The FLEX interface (FLexible EXchange) was elaborated in 1992–1995 for the purpose of unification of interaction of different type systems in the technological chain "acquisition–archiving–processing" (Kononov 1995d). Its ideology is based on the system of *general* and *local* standards which are developed, fixed and maintained in all the systems, the interaction between which must be ordered.

The unification of intersystem communications on the basis of the FLEX interface determines concrete directions of developments of information integration of the systems:

- detailing the rules of structurization of output data of the acquisition systems;
- issuing conventions on identification of observational data;
- solution of matters concerning the forms of data representation on the computer media.

In this respect it is planned to introduce *general* standards in three areas:

FLEX–I	—	data interpretation;
FLEX–N	—	data identification;
FLEX–F	—	data representation.

The data interpretation (naturally, not astrophysical) is executed on the basis of the hierarchical model of descriptors of the generalized acquisition system that makes it possible to treat any output file as a descriptor file of the corresponding level (Kononov 1995c).

The data identification is provided by a common system of conventions on observational data identification — unified rules of file names (Kononov 1995f).

The common flexible FLEX format allowing taking account of specific features of any type observational data is used as the data format (Kononov 1995e). The format is based on the standard extension Binary Table of the international FITS format for exchanging observational data between astronomical centres. This is why the FLEX format is FITS-like, and, without violation of principal conventions, allows taking more detailed account of peculiarities of different type systems. Essentially, the FLEX format is a system of rules of interpretation of certain objects under the FITS environment. One of the main advantages of this format is the selfdocumentability and that it is open to entering changes in the case of correction of the internal structures of data.

A natural continuation of the *general* FLEX standards is the *local* FLEX standards which reflect specific features of information outputs of the concrete acquisition systems. For each data type, the local standards are also introduced in three areas. Any local standard is application of a certain general standard in the appropriate area of application. It is the local standards that determine in the end all logically complete centralized descriptions of observational data and must ensure automatic adjustment of the program component of the Bank ODA–R to fulfill its certain functions.

Within the frames of the USS project, the FLEX interface received further development as regards the data representation. To expand the area of unified interaction of heterogeneous systems, generalization of the FLEX format was accomplished.

5.6. Data parameterization methods

Under the data parameterization is implied the maintenance of output digital arrays of the acquisition system by sets of parameters which are considered as certain methacharacteristics that describe different aspects of observations carried out. These sets of parameters play an important part, especially in location of observational results into the Bank ODA–R and are associated with the idea of information completeness of the archive data. The higher the degree of parameterization of data the more possibilities are offered the astronomer for further use of the stored information since not only the set of potential keys of search in the archive is extended, but also the set of data reduction procedures itself.

To ensure a maximum parameterization of output experimental data, a methodology is used which provides:

- definition and fixation of sets of parameters for individual types of data;
- definition of groups and status of parameters from the manner of their formation;
- fixation of types of values of parameters;
- development of detailed schemes of transmission of sets of parameters from system to system at different stages.

All this is part of the process of unification of intersystem communications and in the final form must be expressed in the system of FLEX standards.

6. First results

The work over the project USS was started in 2002. At the first stage we were mainly focused on both the development of all the components of the future complex, especially of the acquisition system of the feed cabin No.1, and formalization of intersystem communications. The following results of the work done should be regarded as the main ones.

1. Refinement of the model of information integration of all the subsystems of the complex USS was carried out. The schemes of circulation of data flows within the technological chain "job–control–acquisition–archiving" were detailed.

2. Updating of the hardware of the upper level of the VPA ACS of RATAN–600 was fulfilled. A temporary working version of the VPA ACS server was

designed on the basis of the general purpose server of the radio telescope — *rs.ratan.sao.ru*. It incorporates the database and ACS software, which are used both for execution of operations of job preparation for the antenna control and immediately for the antenna control in observations.

3. Parametric databases were elaborated for the continuum radiometers of the feed cabins No.1 and No.5 in the NVT format compatible with the database of the VPA ACS. Conventions were worked out on simple methods of inclusion of the set of characteristic features of the radiometers into the package of data preparation for observations, which is integrated with the VPA ACS. Autonomous programs of operation with the databases for the detectors were created.

4. Development was initiated of the multilevel software provision designed for the network dispatchening of observational programs, that is, for the distribution of jobs between individual units of the ACS and co-ordination of these jobs with the quotes for using the antenna resources, and also for protection of the system and for network access of the observers to the VPA ACS.

5. The receiving-measuring complex of the feed cabin No.1 is furnitured additionally with new devices of acquisition and reduction of signals based on the facilities of the companies Analog Devices and Altera, including that on the basis of digital signal processors SHARC ADSP-21062. Software was created for programming the DSP under the OS Linux. The new equipment and the programs of its support are reduced to regular service.

6. A terminal server of data acquisition and control of the radiometers — *ref1.ratan.sao.ru* was purchased and put into operation at the feed cabin No.1. The equipment of the server is presented in the standard of Industrial PC to operate the feed cabin under complicated conditions. The computer operates under OS Linux and the first version of the new generation acquisition system (Tsybulev et al. 2002), which includes the resident monitors (daemons) of acquisition of information, compensation and control of the radiometers, databases of the radiometers, programs of network formulation of jobs for observations, programs of primary buffering of experimental data and network transmission of the accumulated information to the Bank ODA–R for its subsequent archiving.

7. Concept of the generalized FLEX format was worked out, which extended the area of unification of intersystem communications as regards the representation of data. This resulted in a possibility of extending the intersystem exchange standard to the antenna automatic control system, the acquisition system of the feed cabin No.1 and the job preparation system. To work with FLEX files and also with FITS files, as a particular case, a basic set of classes was developed in the *C++* language, which includes many methods of reduction of FITS structures of the type *name* = *value* and methods of reduction of any FITS headers. The elaborated software of support of the generalized FLEX format was reduced to test service and continues to develop.

8. Partial updating was performed of the RATAN–600 archive server — *oda.ratan.sao.ru* — on which the centralized Bank of observational data ODA–R was developed. The Databank functions in a raund-the-clock mode and maintains on-line communication with the acquisition systems. For more efficient buffering of continuously arriving experimental information, additional Ultra320 SCSI equipment was installed on the archive server and the disk storage was completely reorganized with the creation of the RAID array for the operative buffers. A scheme of intercomputer network exchange of data with the feed cabin No.1 acquisition system was optimized.

7. Conclusions

The elaboration of the complex USS at RATAN–600 will ensure qualitatively new interrelated development of individual subsystems of the radio telescope on the bases of present-day computer facilities and integration of these subsystems in a united technological chain with maximum parameterization of output experimental data and support of the universally accepted standards in the field of astronomy. We believe that under the conditions of intensive development of the receiving-measuring complexes of the radio telescope, the methods of control of variable profile antenna and diversity of observing programs, the methodology of creation of the complex USS and the first obtained results described in the paper reflect the optimum way of solution of the accumulated problems in the sphere of automatization of astrophysical experiment at RATAN–600. The formulated new approach will lead not only to essential improvement of the reliability and operation efficiency of the instrument as a whole, but also simplify essentially the work of the radioastronomers in the preparation of observations, carrying them out, and using the obtained results.

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