PLANNING AND MANAGEMENT OF THE EXPERIMENTS («System» Project)

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PLANNING AND MANAGEMENT OF ON-BOARD EXPERIMENTS AT THE SCIENTIFIC ORBITAL LABORATORY IN THE STRUCTURE OF THE ISS

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Introduction. Various research modules (RM), i. e., scientific orbital laboratories, are assumed to function as the components of the ISS. It is also assumed that a considerable number of simultaneous experiments should be completed at every RM, while a relatively small number of astronauts are participating aboard. In addition, a RM operating term is supposed to be long in orbit, and long-term experiments are intended to be carried out by astronauts in accordance with a program, which is quite complicated and changes periodically.

These features show that planning and implementation of experiments should be arranged in a new way. The possibility to create a mode of virtual on-board presence of the authors of these experiments at the RM, in order to provide efficient control of the experiments up to implementation of a telecontrol mode, is of importance.

The problem of the virtual presence of an expert close to the experimental installation, which may be located at a long distance from a researcher for some reason, and the problem of an expert's ability to be involved in an experiment, are urgent. The users and designers of experimental installations are just beginning to realize this importance. The virtual presence of the authors of the experiments means in many cases a possibility to revise the conditions, under which these experiments are carried out, and to essentially broaden the scientists' abilities. In this case, a space crew, working at the RM, seems to become more numerous, including ground-based experts, whose virtual presence during the experiments staged by themselves, may make the scientific level of these experiments substantially higher and may increase their efficiency. There is every reason to believe that creation of virtual systems used for management of space experiments is now emerging as a new field of science.

At present, the activities aimed at creation of the systems performing telecontrol of scientific investigations and technological processes already take place in the majority of the space-faring countries. For instance, the Levis Research Center of NASA has now created the Telescience Support Center, in order to support scientific on-board experiments at the ISS. In addition, the telecontrol mode (telescience) is supposed to be implemented practically in all the experimental installations, created within the framework of ESA Columbus Program (European part of scientific and technological on-board experiments at the ISS, including a biolaboratory, laboratories, studying the features of solids and liquids, and a module, studying physiological effects) [3].

PLANNING AND MANAGEMENT OF SCIENTIFIC AND TECHNOLOGICAL ON-BOARD EXPERIMENTS: SYSTEM DESIGN

Specialists working at the Space Research Institute, NASU — NSAU, and at the NSA of Ukraine have developed the design of the system for planning and management of scientific and technological on-board experiments, performed at an assumed Ukrainian Research Module (URM) of ISS [2].

According to a preliminary estimate, about 8-10 simultaneous on-board experiments are planned to be conducted at the URM. The hierarchical control system designed is shown in Figure 1. The URM is assumed to contain the workplaces of the researchers with local control systems, which comprise the lower hierarchy level (Level 1). The upper hierarchy level (Level 2) includes a central experiment control system, a space communication channel (CC) of the URM and a space crew. The workplaces of researchers, where the authors of experiments are present, are on the ground. The mission and experiment control center (MECC) creates their virtual on-board presence, when respective experiments are carried out at the URM, and this is done by the ground-based part of experiment planning and management system through the MECC CC or through its own CC. This paper proposes creation of such a database system, which would contain the results of the total set of on-board experiments performed at the URM. This may be realized, for instance, on the basis of the Redundant Array of Inexpensive Disks (RAID) technology in the form of the shared data RAID-repository, accessible to Scientific Information Processing Center, to Space Research Institute and to the international scientific community.

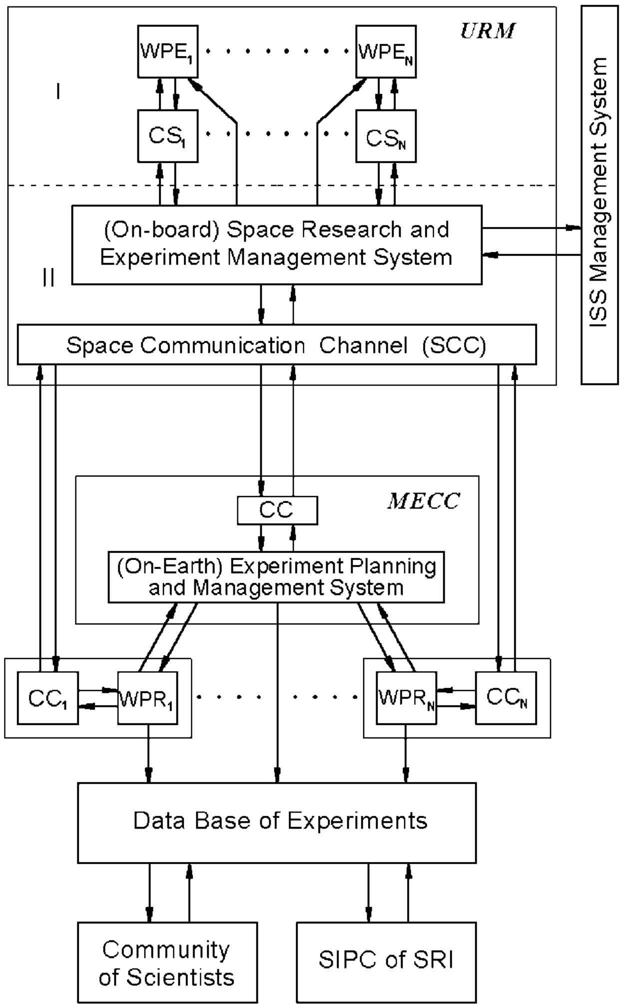

Fig. 1. WPE_i — (on-board) workplace of experimentalists, CS_i — (on-board) local control systems, CC — communication channel, MECC — mission and experiment control center, WPR_i — (on-Earth) workplaces of researchers, SIPC — Scientific Information Processing Center, ISS — International Space Station, SRI — Space Research Institute, URM — Ukrainian research module

CONDUCTING A SET OF ON-BOARD EXPERIMENTS: PLANNING METHODOLOGY

The Program, concerned with scientific and technological experiments, carried out in the URM, includes 6 priority areas. First of all, the Program considers 15 integrated projects, which include, in their turn, almost 100 separate experiments. For example, Section 1 of the Program, i. e., «Space Biology, Biotechnology and Medicine» consists of 4 integrated projects («Greenhouse», «Zoomodule», «Biolaboratory», and «Biomedcontrol») and «Greenhouse» project consists of about 20 experiments.

The specific feature of the onboard experiments conducted at the URM is that a set of experiments is to be simultaneously performed in the single orbital laboratory. Various scientific installations and instruments should be mounted and should operate in parallel to perform these experiments. Therefore, when an initial experiment set structure and a further current renewal are planned then restrictions imposed onto the volumes, weights, energy and information exchange intensity should also be taken into consideration. In addition, it is necessary to provide a compatibility of experiments during their performance with the ISS technological operation modes and between the experiments themselves. For instance, when the solar batteries of the ISS are reoriented, vibrations are probable, and a level of microaccelerations caused by them, may exceed a level admissible for separate types of experiments. Thus, planning the experiment duration the possibility of simultaneous performance of the technological mode of reorientation should be eliminated, or, to realize an experiment, the vibration level should be measured and an appropriate protection from vibration should be envisaged in an installation. Much the same situation is probable during parallel operation of scientific installations and instruments, because of electromagnetic radiation, irradiation, thermal or other flows, which take place in this case and which may have a great influence on performance of a separate experiment. Therefore, appropriate means should be provided for protection from these influences and their intensity should be measured.

Experiments will be conducted at special workplaces of specific design, accommodating the main and auxiliary equipment for performance of these experiments. The number of these workplaces, R, is limited, and the number of experiments, N, is much higher than R. Hence, a nontrivial problem emerges here concerned with the choice of top-priority R experiments out of N experiments, as well as the problem concerned with ordering the rest of these experiments.

The main criterion of selection of R experiments consists in their scientific value and technological novelty. Proceeding from this criterion, such a selection is performed by experts and, first of all, by the members of the CCOSS and by the experts working at the NSA of Ukraine. In this case, those research areas are highlighted, in which top-priority experiments should be performed, and natural restrictions are introduced which are imposed on their number. The experts will have to select a number of candidates for top-priority experiments, which is larger, than a number defined by the introduced restriction, and this selection is made for each area. Therefore, we have $N_1 < N$ experiments, from which R experiments are to be selected. It is necessary to make up N_2 combinations from N_1 selected experiments for R different experiments. In this case, upper constraints should be taken into account in each research area. In this case, the experts may also introduce the lower constraints on a number of workplaces in every area, for example, in order to locate no less than two on-board research installations at the URM, which are to support the experiments, carried out in one of these areas. Thus, the procedure of choosing the possible combinations becomes easier.

Further selection of the said combinations, pretending to their top priority as to performance, is to be made by means of a computer program. The abovementioned restrictions imposed onto a possibility to perform the considered set (combination) of R experiments should be taken into account.

When experiments are planned at the URM, the human factor should also be taken into consideration. If an astronaut serves the set of R experiments, then he must be checked for his ability to do this, as well as for his professional level for each experiment, i. e. the extent to which they are computerized, duration required for their performance, fatigue and different factors (in particular, microgravity) influencing the efficiency of his work. All these factors can allow making the set of possible top-priority experiments even smaller.

It should be noted that when scientific and technological investigations are planned and performed at the URM, one should be fully aware of the fact that a specific human-computer system is in place here. The problem related to construction of high-performance human-computer systems is not solved yet despite the rich history of the investigations carried out in this area. It is only evident that, in view of the specific conditions of the astronaut's activity, one should try to avoid as much as possible, entrusting him with execution of those operations, which can more or less successfully be carried out by computer-aided control systems. He should perform only those operations, which, for certain reasons, are rather complicated for implementation or which cannot be realized by technical means. In addition, his main function should be participation in the case when problems are to be solved in an emergency.

The state-of-the-art of information technologies and telecommunication systems allows implementation of the mode of virtual presence at the URM of a ground-based scientist who is an author of an experiment, and the distribution of duties in such a human-computer system becomes substantially modified. There is every reason to believe that when every constraint, both purely technical and associated with the human factor, is taken into account, a computer-aided selection will result in a relatively small number of sets of R experiments, pretending to their top-priority performance.

METHODOLOGY OF COMPUTER-AIDED SELECTION: VOLUME AND POWER RESTRICTIONS FOR A SET OF EXPERIMENTS

Problem Statement. Let there be N on-board experiments (projects), which are to be realized at the URM.

Let us assume that an equipment (instrument) set, consisting of σ_i units, is necessary for realization of each i-th project. A qualitative composition of equipment for each i-th project is characterized by a vector X^i, where $\dim X^i = \sigma_i$. Vectors X^i consist of a number of unique components, required only for realization of some i-th project, as well as of a number of the components, participating also in the realization of other projects. The total set of equipment components x_k, $k = 1,...M$, participating at least in one project out of N projects, is characterized by the vector:

$$\mathbf{X} = ||x_k||_{k=1}^{M}, \tag{1}$$

where x_k is the number of some k-th instrument. Therefore, vectors X^i, $i = 1,..., N$, may be considered as selections from σ_i components of $\mathbf{X}$, i. e.

$$X^i = S^i X,\ S_i = ||s^i_{ln}||_{l,n=1}^{l=M,\ n=\sigma_i}, \tag{2}$$

where S_i is some $(M\times\sigma_i)$-dimensional matrix. One element of this matrix is equal to a unity in each row, i. e., this condition means that the l-th component of $\mathbf{X}$ is used in the i-th project, and all the other elements of the same row are equal to zero. S^i are the exhaustive characteristics of an equipment set, needed for implementation of some i-th experiment.

Let us assume also that a volume ν_k is required to accommodate each k-th instrument. Then, to realize some i-th project, the volume

$$V^i = \sum_k \nu_k,$$

is needed, where the index k runs through every value of the vector X^i.

Suppose, that a total volume

$$\overset{o}{V} = \sum_{i=1}^{N} V^i,$$

required for location of the entire equipment, when all the N projects are realized simultaneously, exceeds a given volume $\overset{*}{V}$, i. e.:

$$\overset{o}{V} > \overset{*}{V}.$$

If inequality (3) exists, it is impossible for all the N experiments to be realized simultaneously. Hence, the following problem: it is necessary to establish such a parallel-serial schematic for delivery of equipment and for its arrangement on board the URM, and to perform such a combination of experiments that an amount of equipment is involved at every moment of time t, for which the inequality

$$\widetilde{V}_t \le \overset{*}{V},\quad t \in [0, T] \tag{3}$$

is met during the whole time interval $[0,\ T]$, providing for performance of a specified number of experiments.

In this case, $\widetilde{V}_t$ is the total volume, i. e., an amount of equipment used at a moment of time t.

Let us suppose now, that p_i energy units are needed to perform each i-th experiment. In this case, to simplify the solution to the problem, concerned with the definition of the required experiment realization scheme, let p_i = const, $i = 1,..., N$, i. e., the power consumed during some i-th experiment does not vary in time. Denote the amount of energy, available for consumption, by $\overset{*}{P}$. Then, the scheme for which a total consumed energy $\widetilde{P}(t)$ does not exceed P, i. e.

$$\widetilde{P}(t) \le \overset{*}{P},\quad t \in [0; T], \tag{4}$$

is considered to be a serial-parallel experiment realization scheme, admissible by the power indices.

Such a parallel-serial experiment performance scheme, for which inequalities (3) and (4) are met simultaneously, is hereafter referred to as an admissible scheme. To solve the problem of experiment performance scheme definition, the experiment performance conditions should be clarified and some cost considerations should be pointed out. Let us assume, first of all, that to prevent the equipment duplication, it is necessary to consecutively use the same equipment unit x_i for performance of different experiments. Those instruments that were already used to realize a project and which are not needed for realization of the remaining projects, are «annihilated», and, therefore, a place, where new instruments must be mounted, is free for the latter.

Let each i-th experiment be realized during a time interval τ_i. To simplify the solution of the problem of definition of an admissible experiment performance plan, let there be no space-time constraints, imposed onto experiments, i. e., they can be realized at an arbitrary moment of time $t \in [0; T]$ and in any position of the ISS with respect to the Earth. Let us take the totality of experiments and consider such a group of them equal to $\overline{N}$, for which $\tau_i = T$.

The structural and energy resources ($\overset{*}{V}$ and $\overset{*}{P}$, respectively) are specified. Then, consider their portions $\Delta\widetilde{V}$ and $\Delta\widetilde{P}$, needed for experiments, realized during the whole time interval T under consideration, i. e., for an experiment, when $\tau_i = T$, and reject them from further consideration. Let us introduce the following denotations:

$$\overline{P} = \overset{*}{P} - \Delta\widetilde{P};\ \overline{V} = \overset{*}{V} - \Delta\widetilde{V} > 0 \qquad (5)$$

for the remaining resources. Let us denote a number of experiments, remaining for consideration, as $\overline{M} = M - \Delta M$. The scheme definition problem, when $\overline{M}$ experiments are accomplished and for which resources $\overline{P}$ and $\overline{V}$ are provided, is dealt with further on.

Defining an Experiment Performance Plan: Problem Solution Scheme. The experiments X^i, repeated in a cyclic manner q_s^i times are considered to be q_s^i independent experiments that need the same equipment structure. Each i-th experiment in the 3D-space $\{t, v, p\}$ is characterized by its triad («generalized volume») $\omega = \tau_i \times V^i \times p_i$. Therefore, at contents level, the problem, related to checking how inequalities (4) and (5) are met, is similar to the known problem of «box packing» into a specified 3D box $W = T \times \overline{V} \times P$. However, there is the following essential difference between these two problems: a group of triads ω_i that are to be packed into W, is not specified in advance, but it is to be determined. The number of possible combinations of instruments in N projects is

$$C_\sigma^N = \frac{N!}{\sigma!(N-\sigma)!}.$$

The value of C_σ^N is equal to 10^5 — 10^7 at $N = 50...100$ and at average $\sigma_i = \sigma = 4...5$, and, evidently, the problem of definition of an admissible experiment performance scheme is a complicated combinatorial problem that is rather difficult to be solved «manually». It is also evident that this combinatorial problem has no single solution. Therefore, for excluding this non-singularity and for reducing the number of variants analysed, which are further on checked for satisfying inequalities (4) and (5), let us introduce one more characteristic, i. e., the project priority degree. Without losing the generality, let us assume that, when a project ordinal number is decreased, a project priority degree increases. Then the following problem solution scheme may be proposed.

Starting from the first project, characterized by the matrix S^1, the projects, compatible with the first one are stated according to the matrices S^i and to the order of their numbers increase, and the volumes V^i and energy resources P^i, which are needed for their implementation, are determined and summed up. This process of increasing the number of simultaneously realized projects, goes on until a violation of one of inequalities (4) and (5) is observed. After this, the last project, the addition of which for forming the group of simultaneously realized projects has resulted in violation of one of inequalities (4) and (5), is rejected, and the set of projects, derived in this way, is admissible.

Then, when a project with a minimum duration is terminated, the equipment, already used for its realization is annihilated, if it is not used in the rest of the projects. For filling up an extra volume formed in accordance with the already described methodology, let us determine those additional projects in the order of decreasing numbers, which are compatible with the rest of the projects, not completely realized yet. The project compatibility is checked by the lack of elements not equal to zero, in the respective rows of S^i.

Then, when some next-shortest project is terminated, the above procedure is repeated until the answer is provided as to whether a specified time interval $[0; T]$ is sufficient for realization of the total number of projects or not. It should be admitted in the latter case that a proposed project totality is not realizable within the provided resources and that the number of projects must be made smaller.

Some Generalizations. Consider now some generalizations for the above method, in which an admissible parallel-serial experiment performance scheme is defined. It was assumed above that each experiment can be realized at some arbitrary moment $t \in [0; T]$. Generally speaking, however, if a set of N experiments is planned, space-time restrictions may be imposed onto some of them by virtue of many reasons, ultimately requiring these experiments to be performed, starting at the time moments $t^j \geq 0$ during the time τ_j. Take the highest priority for this experimental portion and combine these experiments with the ones, performed during the entire time interval T. Denote the resources, needed for realization of the experiments with time restrictions, as $\hat{V}(t)$ and $\hat{P}(t)$. Then, the reserve of the resources, necessary for realization of all the remaining experiments in $\tau_i < T$ is

$$\overset{\circ}{V}(t) = \overset{*}{V} - \Delta V - \hat{V}(t), \tag{6}$$

$$\overset{\circ}{P}(t) = \overset{*}{P} - \Delta P - \hat{P}(t), \tag{7}$$

Therefore, instead of checking inequalities (4) and (5) with the constants in their right sides, in the case under consideration one should bear in mind that the right sides of inequalities (6) and (7) are the specified functions of time. Much the same situation is also in place, when either initial energy resources depend on time for some reason, or if the energy resources, required for realization of some experiments, vary in time.

For simplicity sake, everywhere above it is assumed that when a volume, needed for the realization of some experimental totality, is determined, this volume is equal to the sum of volumes required for performance of each such experiment. The actual situation, however, is different, since for a number of structure-related reasons, the total RM volume falls into a certain number s of standard racks of equal volumes, and each such rack consists, in its turn, of a specified number q of standard cells of a volume equal to Δv. Thus, the total module volume is discretized at two levels: at an upper level and at a lower level, i. e., at a level of racks and a level of cells, respectively. Therefore, if total volume V_σ, necessary for realization of a set of experiments, consisting of σ experiments, is determined, it should be not the sum of the volumes V^i for each i-th experiment, but the sum of the values

$$\overset{*}{V^i} = \mathrm{Ent} V^i, \tag{8}$$

where Ent$X$ is the nearest larger integer number of the scale of volumes Δv.

A SYSTEM FOR TELECONTROL OF AN EXPERIMENTAL ON-BOARD INSTALLATION

Another important function, performed by the system of planning and management of scientific and technological on-board experiments at the URM of the ISS, consists in realization of the experiment telecontrol mode. The co-executor of the Space Research Institute in the sphere of experiment telecontrol design and implementation is the Physical Engineering Teaching-Research Center (PETRC) of the NAS of Ukraine, which took part in the International Project on design of MIGMAS, an on-board space ion microanalyzer jointly with the Austrian Research Center (Seibersdorf) and «Energia» Russian Space Corporation [4]. To control MIGMAS, PETRC has developed SIMSCAN [5], the hardware-software system, which by means of a computer enables performance of all the instrument adjustment operations, testing its condition and carrying out information acquisition, processing and documenting.

The main idea of telecontrol is to share control functions between several systems with different levels of intelligence, interconnected by communication facilities, and to minimize data flows between these systems.

In the majority of the present-day analytical instruments, a considerable number of the analysis process computerization operations are executed by a computer or by an instrument controller. The man's task is to generate a sequence of macrocommands for this computer or controller. Evidently, such a macrocommand sequence can be generated also at a distance from this analytical instrument, if a man has complete information about an instrument state at the decision-making moment.

It has become possible to solve this problem due to development of the communication means, capable of providing a sufficient data transfer rate. The examples here may be Internet, telephony, video conferences in the Internet. Nevertheless, considering the distance from the Earth to the ISS and the continuous motion of the ISS with respect to the Earth, the information flows should be minimized, the high speed and integrity of control

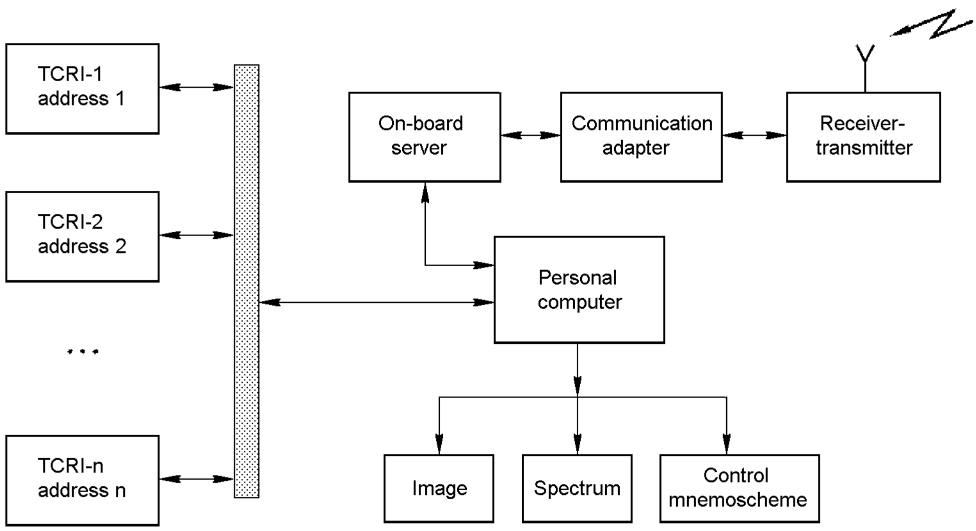

Fig. 2. ABEL — Automatic On-Board Experimental Laboratory: A Flowchart

programs transfer aboard the ISS should be provided, as well as transfer of the system state parameters and measurement results to the flight control center (FCC).

In contrast to commercial analytical instruments, where measurement processes and measurement procedures are strictly standardized, a scientific instrument, created as a separate specimen, must readily allow making changes in the hardware configuration and analysis procedures. Therefore, those systems, which are aimed at computerization of such instruments, should also be universal and not developed for a particular instrument.

Figure 2 shows a flowchart of an automatic on-board experimental laboratory (ABEL). This control system level is constructed on the basis of a computer, which controls the operation of several telecontrolled research installations (TCRI), connected to it in one of the usual ways, for instance, by the USB- or IEEE 1394 (Firewire) buses. A really multiproblem operation system, for example, Windows NT or UNIX, should be installed in this computer. Control programs should always be present in the computer memory and provide a continuous monitoring of the parameters of every TCRI. The software should enable entering the control instructions and displaying the experimental results and current information on the operational modes of the selected instrument. The computer must be connected to the on-board information network of ISS, in order to send data to the Earth.

The upper (ground-based) telecontrol system level in the ABEL (Figure 3) is based on the standardized

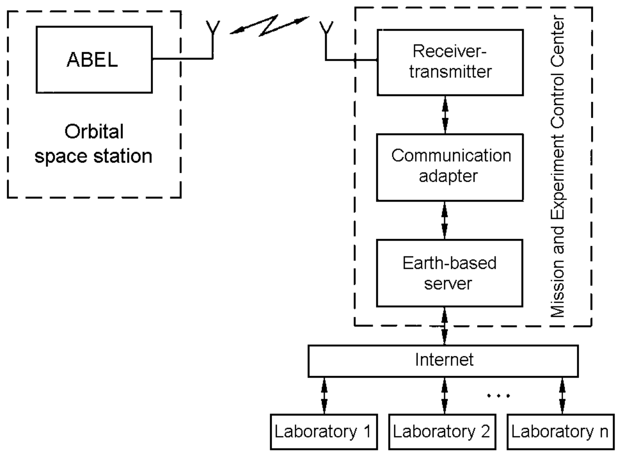

Fig. 3. Telecontrol System: A Flowchart

Internet technologies. The FCC incorporates the system server, which envisages the following:

— transfer of the instrument control commands;

— receiving all the operational and analytical information from the ABEL;

— making protocols of ABEL instrument operation;

— structuring and storing the obtained information;

— proving authorized scientists' access to the obtained information;

— providing virtual contact between the experts.

Since the analog sensor signals must be digitized

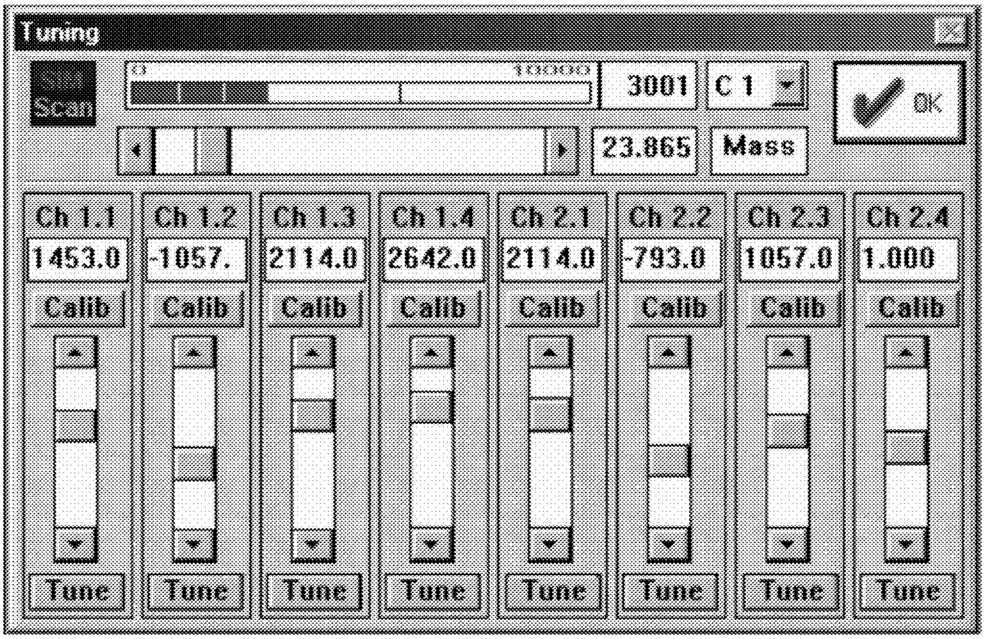

Fig. 4. A Displayed Virtual Instrument

during performance of an experiment, the system must be supplied with a set of AD converters. The control analog signals must be generated by a set of DA converters, whose capacity and operating speed are determined by the measurement and control system features.

The concept of construction of remote control of an experiment is based on the client-server methodology. A server exports some resources (equipment access in our case), and clients use these resources. A server communicates with clients through a computer network, to be created via Internet and Intranet. A client provides a transfer of queries and control from a researcher to a server, which converts these data into instructions of installation control, of reading the output data of physical measurements, as well as of sending them to a client. A client visualizes these data for a researcher. It is rational to construct the software using Java that is simultaneously a medium and an execution environment, supported by every operation system and now also supported by the hardware [1].

The system of telecontrol of scientific and technological experiments, performed at the URM of the ISS, has passed its ground-based pilot design stage, and has been tried out in the case of remote numerical control of the secondary-ion mass-spectrometer. SIMSCAN-3, the mass-spectrometer computerization system, performs complete parameter control and instrument adjustment, records the primary and secondary mass-spectra, ion and electronic images, and conducts the depth profiling. It is a Eurostandard crate of a half-height, containing a set of functionally independent modules and connected to an IBM PC computer by a specially designed parallel interface, incorporating a bi- directional 8-bit data bus, an 8-bit address bus and a control bus. The maximum data exchange rate is about 500 Kbytes/sec. SIMSCAN consists of the following modules:

— A high-voltage operational amplifier module. It consists of 4 amplifiers, used to control a system of deflection of a primary ion beam. Maximum output voltage is ± 130 V; bandwidth is 200 kHz.

— A deflection system DA converter module. It contains the following converters: two 13-bit DA converters (12 bits + a symbol) and one 11-bit DA converter (10 bits + a symbol). It is used to control the high-voltage operational amplifier module.

— A module for Wiener filter control. It incorporates one 16-bit precision DA converter and is used to control the power supply unit of Wiener filter magnet.

— An AD converter module. It contains one 13-bit DA converter with a switch for 8 channels (12 bits + a symbol). Conversion time is 100 mcs. It is used to measure the current at different column points, the source temperature and so on.

— A timer-counter module. It incorporates one 32-bit timer and two counters (a 32-bit counter and a 16-bit counter). It is used to register the pulses from a secondary-electron and secondary-ion channel outputs.

— A DA converter module. It contains four 12-bit DA converters. It is used to control the high-voltage power supply units of accelerating, extracting and focusing voltages, as well as the source temperature, energy and type of secondary ions.

Such a set of modules, used for control and monitoring purposes, makes the system flexible for adaptation to performance of any experiments on microanalysis and/or microprocessing. The information basis of the whole instrument is special-purpose software that allows implementation of all the functions of this instrument, namely:

1. Generating control signals for the analyzer beam scanning (deflection) over the surface of the object being analyzed, to provide a raster allowing a broad variation of the raster dimensions, scanning amplitude, number of pixels, contrast gradation, scanning time, choice of sectors or scanning lines. These systems are typical for raster electronic microscopes, electronic and ion microprobes, scanning tunnel microscopes, microscopes of atom forces, acoustic and laser microscopes.
2. Generating a control signal for analyzer scanning. Such a signal usually varies in time by a linear law and is formed by DA converters with a high resolution (16 bits).
3. Registering an output signal in analog or counting modes in the frequency band of $1...10^7$ Hz.
4. Control of the main circuits providing the analyzer operability through DA converters.
5. Display of the main parameters characterizing the system state.
6. Analyzer calibration for scale linearization purposes.
7. Recording the derived images, spectra and current parameters.

The instrument software, namely the control program called SIMSCAN.EXE, functioning in the MS Windows environment, is developed using the object-oriented approach and implemented in the C++ and Assembler languages. The software module is created, which directly controls the system in a computer-aided operational mode and in the virtual instrument mode. The instrument controls are displayed as mouse-controlled potentiometer slides, with indication of the current values of the controlled parameters. The program allows calibration of each channel. Measured signals are displayed as a bar indicator and as an intensity meter (see Figure 4).

The results of testing the mock-up of the system for remote control of the secondary-ion mass-spectrometer demonstrate the system operability and efficiency. This opens up the possibilities for development of other systems on its basis, which are capable of performing telecontrol of other sophisticated on-board experimental installations and instruments in the orbital scientific laboratory within the ISS.

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