The Integrated Information Display System for the Soyuz-TMA and the Integrated Console of Manual Control Loop for the Russian Segment of the International Space Station

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The paper presents the Neptune-ME information display system (IDS) as a spaceman console (SC) of the descent module of the Soyuz-TMA piloted transport spaceship, and the integrated console (IC) of manual control loop for module equipment in the Russian segment of the Alpha international space station. The Neptune-ME is an upgraded version of the Neptune-M console of the Soyuz-TM spaceship. The upgrading has been performed using the up-to-date computing techniques and methods of man-computer interface (MCI) design. This is the IDS of the fifth generation in piloted cosmonautics. The instrument interface of the new SC corresponds to the instrument interface of the earlier one. The MCI of the console under consideration is principally other than the Neptune-M MMI. The IC replaces the "Pluton" and "Merkurii" command consoles which are widely used in the MIR orbital station. The facilities and methods of console design proposed in the paper can find wide use in different application systems.

Information Display Systems for Soyuz Spaceships

The control systems of the "Soyuz-7K", "Soyuz-A8" (Soyuz-Apollo program) and the Salyut station designed by the Energiia Russian Space Corporation used the Sirius IDS. Fig. 1 shows the general view of the main instrument panel spaceship consoles. This was the third generation system based on the concepts of command information compression and the techniques of programmed temporal information presentation. The system had high technical and economic characteristics. For the first time in the worldwide practice multifunctional displays based on CRT and electroluminescent tubes were used in this system. The main console was a electromechanical display. For the first time a video monitor displayed television and measurement information in individual and combined modes. The information displayed on the CRT was transmitted to the Earth over a television channel.

Fig.1

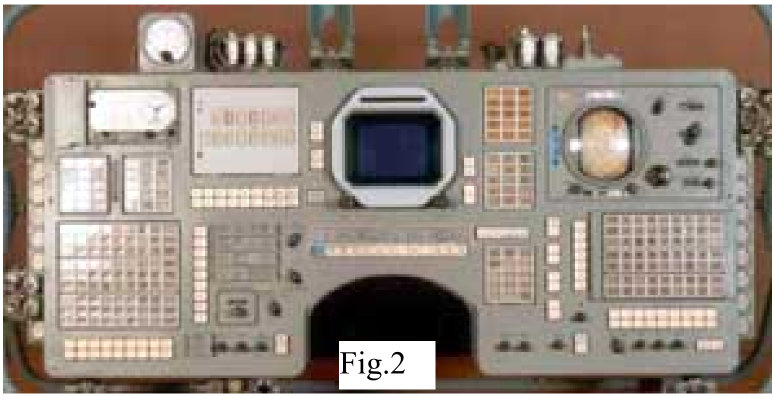


Fig.2

However, while the problems of information support were solved for the Sirius IDS, the recommendations of ergonomic research and the features of the contingent of space system test personnel were not considered to the full. As a result, the Sirius IDS was replaced by the Neptune IDS during the first upgrading of the Soyuz spaceship.

The general view of the main console of the Neptune IDS is shown in Fig. 2. The tasks of the spaceship IDS are provided by the Simvol and KL-110 display systems. The "Soyuz-T" spaceship demonstrated the return to the IDS of the earlier generation in onboard equipment control and the transition to the fourth generation IDS in the maintenance of spaceship computing equipment, and to the spaceship movement control.


Fig.3

The principles implemented in this system were widely used later on in developing the IDS for all home-produced spacecraft and space stations, including the Buran space aircraft. Then, the system console was upgraded again. The analog information conversion and presentation system was replaced by a monitor. The monitor had no scale means. Scales were generated electronically. The cosmonaut console in this design (see Fig. 3) had been in operation on the "Soyuz-TM" to 2002 year.

Purpose of "Soyuz-TM" IDS

The information display system is designed:

- to control spaceship systems;
- to display flight and navigation information;
- to interface to the onboard computer to perform the tasks of spaceship navigation and movement control during rendezvous, docking, maneuvers, orientation, descent, and landing;
- to display the main system parameters, propulsive mass margins, atmosphere parameters in the spaceship modules, etc.;
- to control radios;
- to generate and output key commands;
- to output emergency and warning information using light and audio signals;
- to display television, measurement and indication information on a television monitor in individual and combined modes.

The spaceship is controlled by two cosmonauts as a minimum.

Design and Structure of the Soyuz-TM Console

The console is designed as a riveted framework. Displays and controls are located on the front panel. Electronics units are installed inside the framework. The "Simvol" and KL-110 display systems which are not incorporated into the console, are found in the domestic module, and accordingly, in the DM. Electroluminescent signal and character-synthesizing displays and CRT monitors are the basic display means of the console.

The input signals include:

- parallel two-position signals on the condition and the modes of operation of units and systems to be displayed in the console signal fields;
  - parallel two-position emergency and warning signals;
- television signals from the television cameras and the Simvol and KL-110 display systems. During docking the signals of the television cameras and the "Simvol" display come in a combined form. The signal timing and mixing is provided by a television system;
- parallel signals from system analog sensors to process and display measured parameters on the CRT screen of the console monitor (Strelka console subsystem);
- a sequence of pulses to monitor fuel consumption on a electromechanical counter. The counter provides for the manual setting of fuel load ;
- seconds marks on the onboard clock and control command for a seconds counter;
- seconds marks to provide the operation of a combined navigation display;
- analog voltage and current signals to display the main parameters of the electrical power system on a stand-alone display;
- a parallel BCD code to be displayed on a stand-alone manual information input (MIID) display in the onboard central computer system.

The output signals include:

- signals like dry contact closing which enter the command matrices of the onboard computer control system;
- signals from the buttons of key commands;
- signals from the decimal keyboard of set point input to the onboard computer;
- a television signal from the analog parameter converters to display information on the monitor.

All the signals, except a TV-signal, are transmitted over three-wire communication lines.

Thus, the communication between the console and the onboard systems is a parallel, parallel-serial (BCD) and serial count and TV interface. The implementation of such an interface requires a large number of wiring and connectors. 47 connectors with 1809 contacts are used to provide the communication to the onboard complex.

Tasks of "Soyuz-TM" Console Upgrading

The main tasks of the console upgrading are as follows:

- Reduction of the console depth and height to provide the flights for cosmonauts of a larger size than that accepted for the "Soyuz-TM" spaceships.
- Replacement of instruments that are no longer produced.
- Spaceship control from one workstation, namely the commander workstation.

Information Display Systems of the MIR Station and the Service Module of the International Space Station

Fig. 4a

Fig. 4b

Fig. 4c

According to the Russian program of manned cosmonautics development, the basic module of the International Space Station (ISS) is built using the basic module of the MIR-2 station. The MIR station employed the IDS which include the following main components (see Fig. 4a, b, c):

Fig.5

- display systems Simvol, STEK, Svet,
- a multi-channel emergency warning system,
- manual control loop with the hierarchical method of control object selection and the expanded form of information presentation,
- panels of direct system parameters measurement (see Fig. 5),
- a television system.

The "Merkurii" IDS (see Fig. 6) which was used in the manual system control loops of the Quantum, Spectrum and etc. modules, was planned to be utilized in the manual control loop of the MIR-2 basic module. However, the production of the instruments incorporated in this IDS was ended. The resumption of their manufacturing is not profitable.

Fig.6

Thus, the objective need in IDS upgrading arose during the development of such systems for the modules of the Russian segment (RS) of the ISS.

Selecting the Way of IDS Upgrading

The proposal based on some investigations in the synthesis of the IDS for the automatic control systems of complex installations /1,2,3/ has been made to apply the integration of display units using ground computing and information techniques as the principal way of upgrading.

Fig.7

An integrated control console (ICC) which is hardware and software compatible with a IBM PC, is suggested as a basic console for the manual control loop. The console is shown in Fig. 7. The console comprises an electroluminescent color panel which is designed together with the electronics as a stand-alone VGA monitor. The computing section is built using micro PC modules. The console has embedded interface units to interface to the onboard systems and the matrix system of control object selection. The number of commands transmitted through the matrix switchboard of the onboard control complex (OCC) is 18*9 /4,5/. The number of received two-position signals is 192.

The ICC provides the registration of operator's commands and the transmission of this information to the telemetry system for further drop to the Earth. The two ICCs are installed in the service module. Similar consoles are suggested to be used in the other systems of the ISS RS. The ICCs of all the modules of the ISS RS are integrated in a manual remote control system (MRC). They are connected to a common multiplexed bus with the GOST 18977-79 (ARINC429) interface. The loop structure is shown in Fig. 8. Such a configuration provides the possible MRC extension during the operation of the station on an orbit.

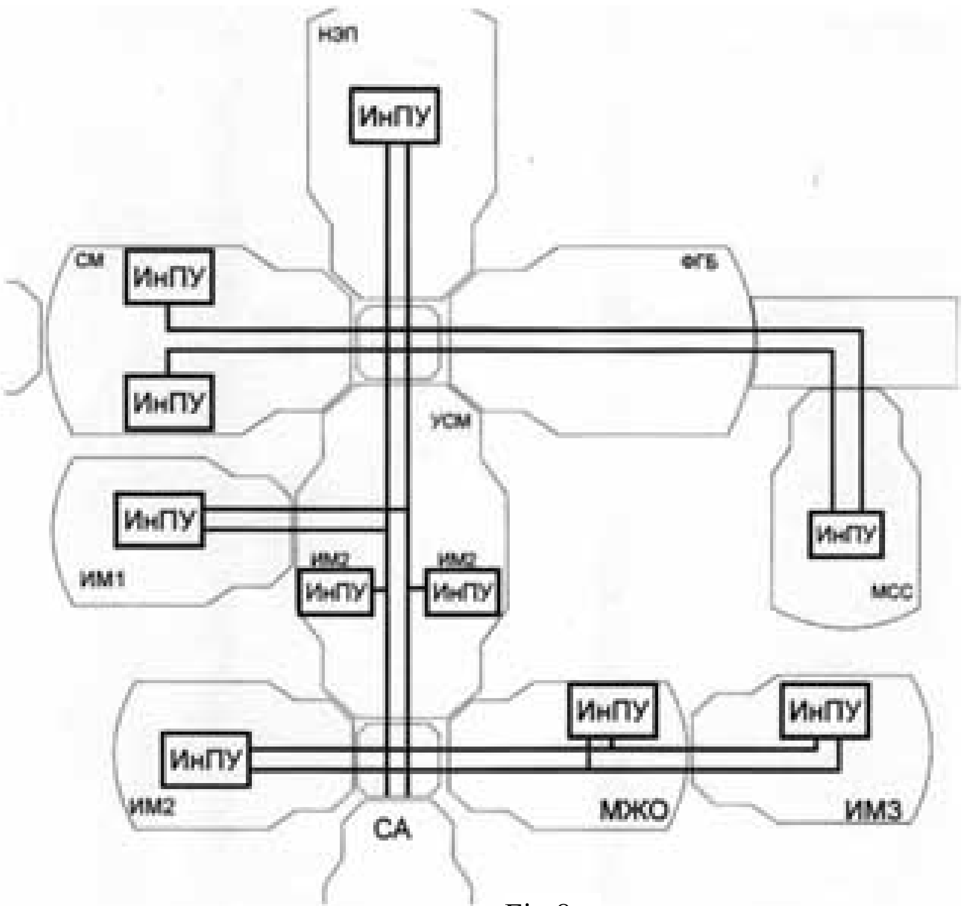


Fig.8

The man-computer interface (MCI) is based on a hierarchical design using a menu. The first format of the MCI is given in Fig.9. The ICC implements 14 Russian formats and 14 English formats. Considerable reserves are available to grow the number of display formats. The format selection and the command selection and transmission is provided by a marker which is controlled from the keyboard similar to that used in standard personal computers. The software is built so that after a new module is delivered to the ISS, the ICC formats of this module are loaded in the ICC of the service module. This provides the opportunity of controlling the onboard systems from both the service module and directly the ICC of the appropriate station module.

The results obtained in developing the ICC for the ISS RS were used to solve the problems of IDS upgrading for the "Soyuz-TMA" intended for crew rescue from the ISS.

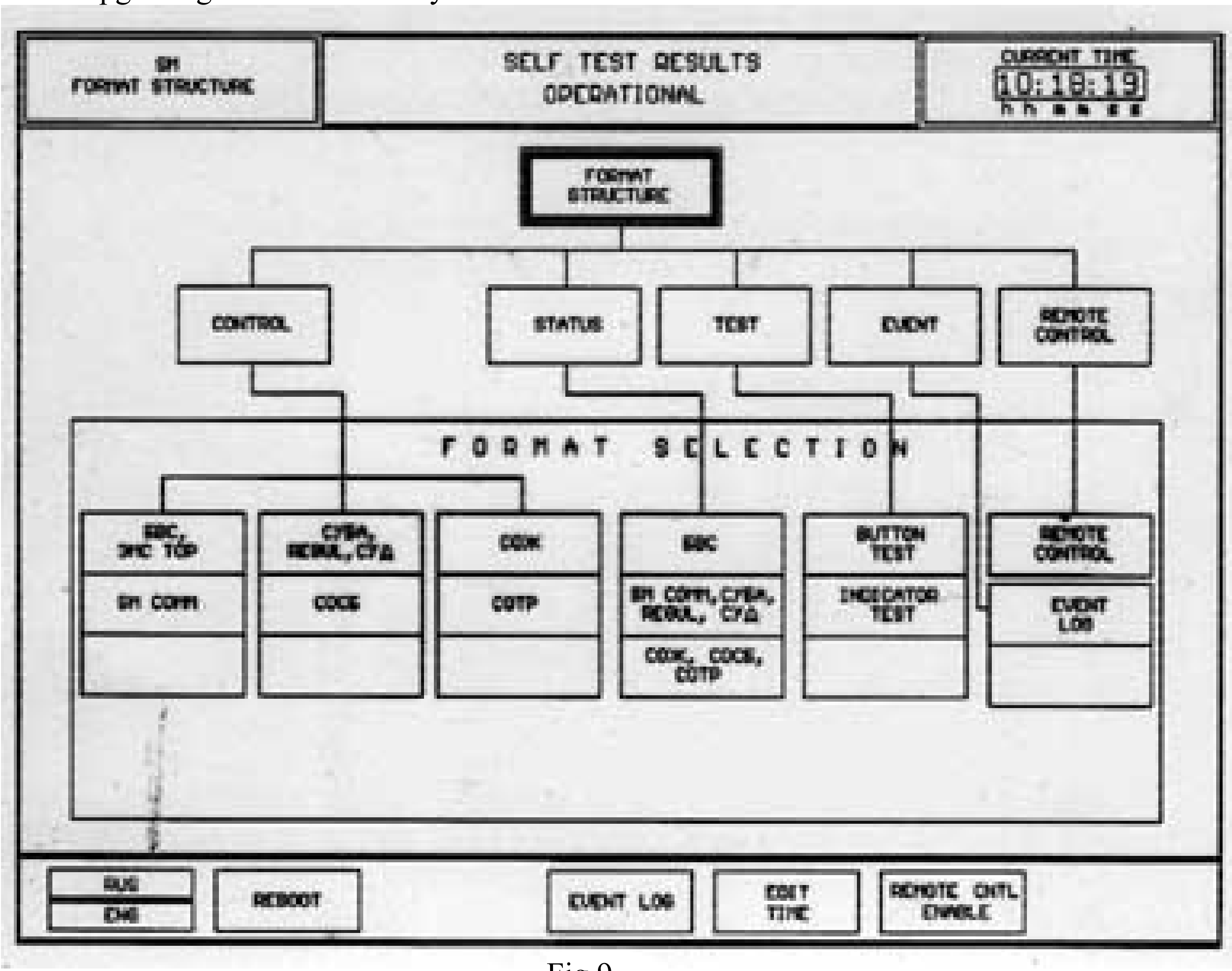


Fig.9

Features of Neptune-ME IDS for "Soyuz-TMA" Spaceship

According to the "Soyuz-TM" upgrading program for the ISS tasks, the "Soyuz-TMA" information display system should provide control and monitoring to the same extent as the earlier system with the same hardware interface to the onboard systems. The analysis of upgrading problems show that they can be solved only by utilizing flat displays and up-to-date computers. Two-screen IDS based on CRT video monitors have been developed within the Almaz and Energiia-Buran Space Programs.

However, the change to an electronic IDS integrated on the basis of two screens reduces the IDS survivability for the "Soyuz-TMA" spaceship. It is possible to improve the survivability by providing the redundancy of the screens and accordingly all computing units and input-output units. The problem is not solved in this way for given dimensions and weight.

For the first time in the practice the project proposes and implements the concept of a one-screen IDS. The feasibility of such a system is founded on a basically new approach to the design of a man-computer interface (MCI). The proposed approach to the MCI design is based on:

- the concept of possible hierarchical presentation of object systems;
  - the concept of possible hierarchical presentation of goals and tasks of the complex system activity;
- the concept of possible programmed presentation of goals and tasks of the complex system activity and of a finite number of such programs;

- the principle of necessity and adequacy of information displayed in a one-screen format to solve an individual task;
- the activity management by using the principles implemented in interactive computer systems such as the Windows environment.

Fig. 10 presents the general view of the new console in the reusable vehicle. The "Simvol" and "KL-110" display systems and, as mentioned above, all the links to the onboard control complex are retained and used at the first stage of upgrading the IDS and the onboard complex control system (OCCS). A new MIL-STD-1553B link is included to the new computer system. The console includes /6/:

- two ICCs one of which contains VGA video monitors: a color monitor (8 colors with no gradation) and a monochrome monitor (16 grey levels); two marker control units (MCU) (See Fig. 11);
- three computer modules (CM) which are software and hardware compatible with an IBM PC. The two CMs together with the video monitors and the marker control unit form two ICCs, i.e. two onboard personal computers. The third CM is designed to receive, process and transmit analog information to the ICC CM;
- information input-output units of the onboard computer system via the interface similar to that of the "Soyuz-TM" Neptune IDS;
- communication interface module using a MIL-STD-1553B bus to a KSO20 computer which is incorporated into the "Soyuz-TMA" DM onboard equipment;

Fig.11

- video processors to input television information to the ICC and to transmit information from the ICC to a TV system for further transmission to the Mission Control Center;
- ICC communications with telemetry;
- signal input from the console controls and the emergency warning system;
- a light/audio emergency warning system;
- command output with mechanical protection from occasional switch-on;
- spaceship power protection from short-circuits in the console and some other components.

The hardware is developed and selected to satisfy the requirements for operations under weightlessness and DM depressurization conditions, i.e. the operations of suited cosmonauts.

The system base contains system computing facilities, screens, information support (IS) and software (SW). The system IS and SW provide the man-computer interface (MCI) /7/.

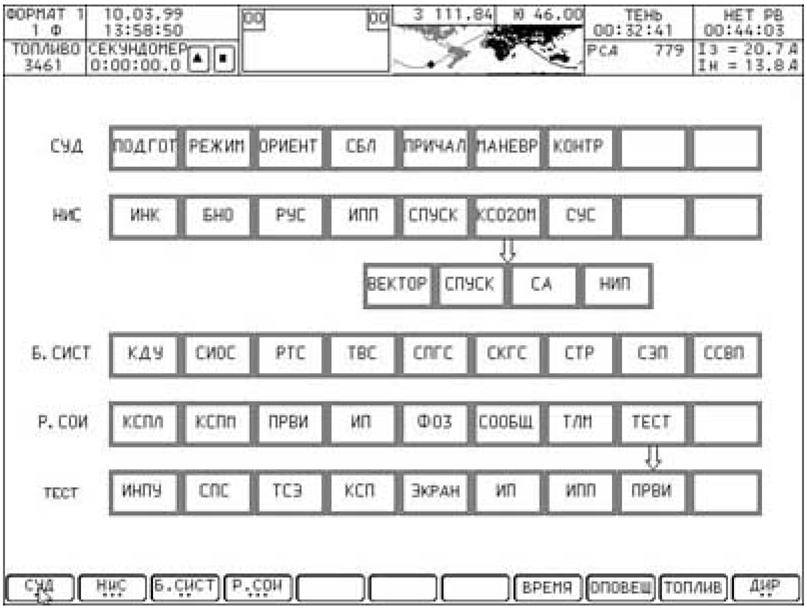


Fig.12

At the first stage of the upgrading the actions are taken to retain the interface of the earlier console to the maximum extent. The new console implements no programmed temporal control that significantly reduces the effectiveness of cosmonaut activities. The IS consists of 58 information display formats. The first format given in Fig. 12 is basic. A field is assigned for constant displayed information in the format structure. This is a field where the information on the spatial attitude relative to the Earth, the time and the main safety parameters is presented to the cosmonauts. The format displays the menu of the dialog system. The actions with the menu are provided by the ICC and MCU keyboards.

Fig.13 shows an example of the control and test format for one of the onboard systems and Fig.14 an example of the OCCS interface format for set point input. The information of the "Simvol" display system is displayed in the window.

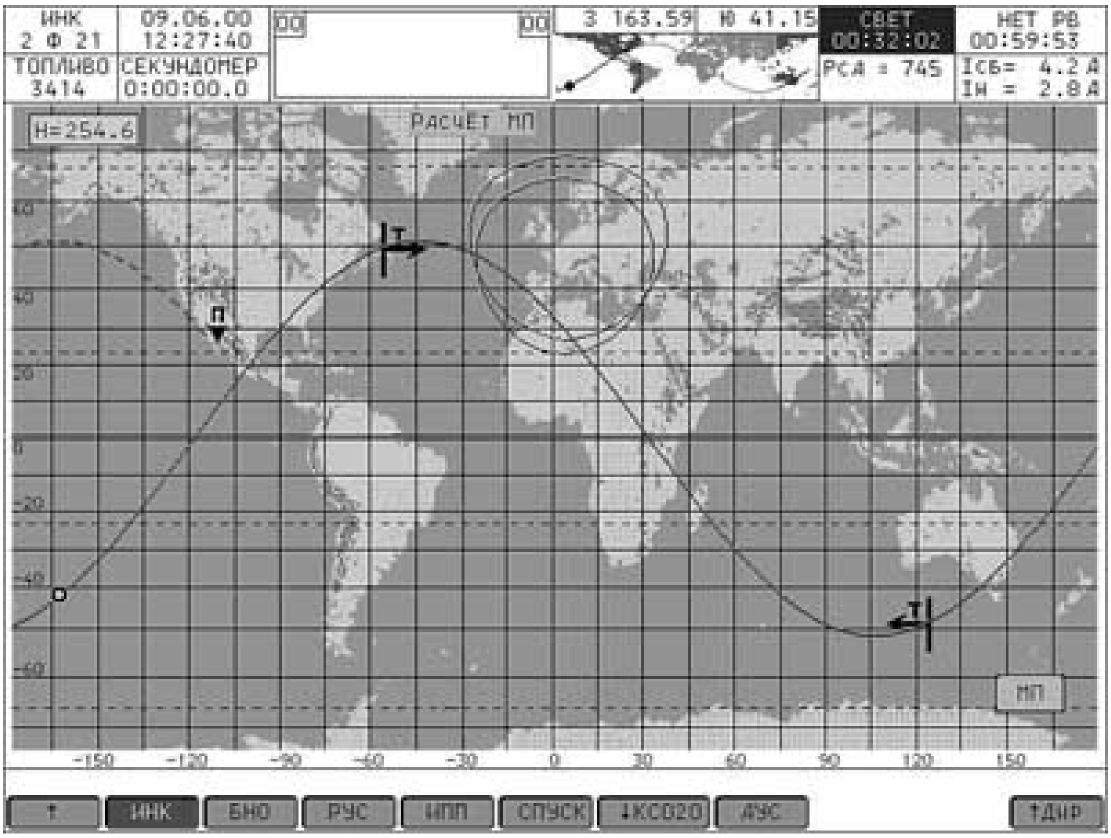


Fig.13

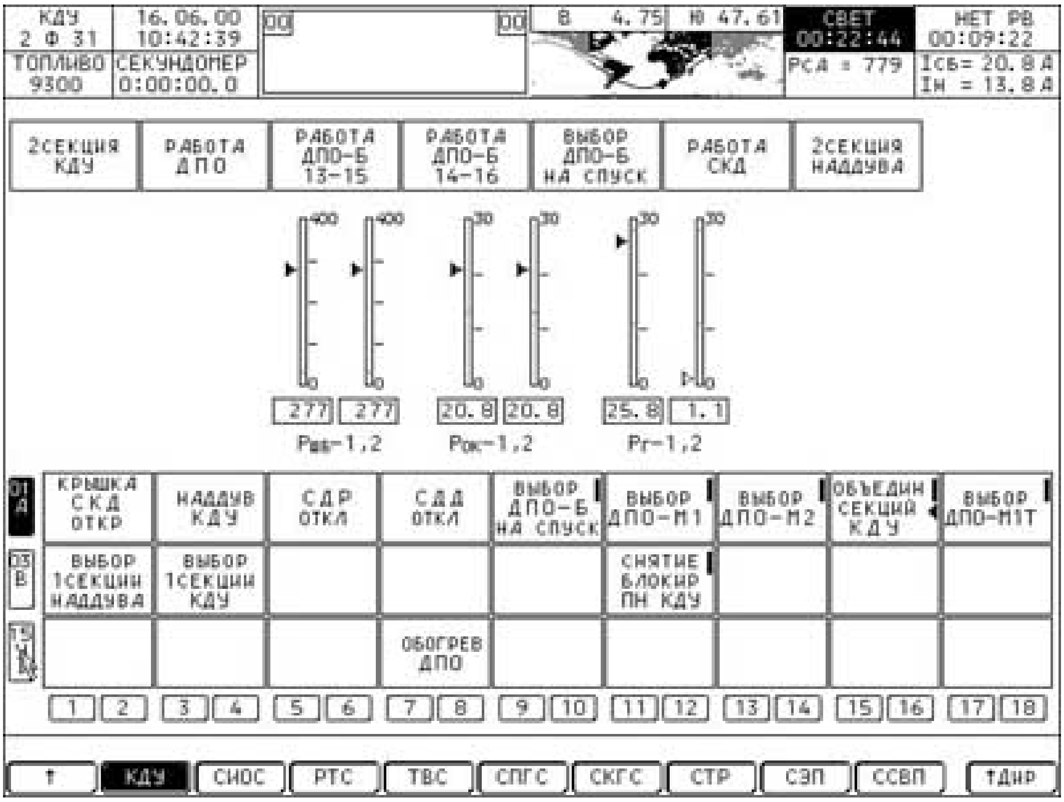
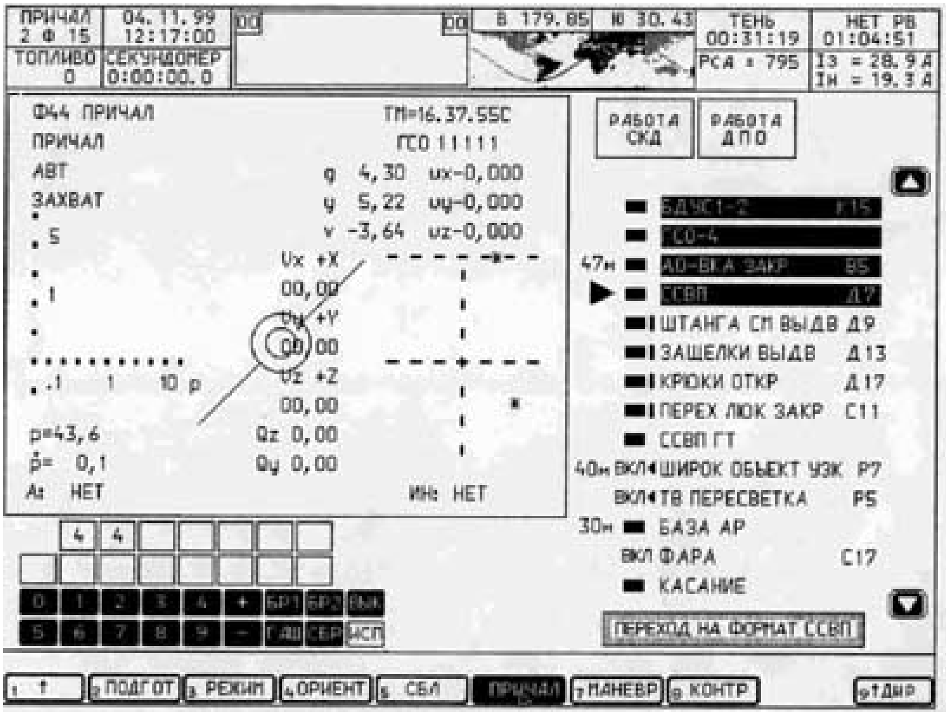


Fig.14

Fig.15 shows a navigation format.



The principal functions of the software are:

- programmed generation of display formats;
- continuous scanning of signals and analog information and control of display elements on the formats;
- registration of signals longer than 10 ms that is especially important during ground tests and checks of the object;
- registration and transmission of the information on signal receipt from the onboard systems and the console controls to the telemetry system, i.e. the monitoring of both onboard systems operation and cosmonauts actions with the console. The SW allows a cosmonaut to look through recorded information;
- management of the interactions between the Argon-16 OCCS and the KSO20 computer installed in the DM (in-transit operation) during set points input and check;

- management of the interaction with the KSO20 in the navigational mode of the IDS;
  - input and updating of initial data (time, propulsive mass margin, alarm-clock, spaceship weight and moments of inertia, etc.).

The onboard SW includes a number of service programs:

- adjustment of the analog information processing system using real sensors;
- tolerance generation for analog tolerance check (not used at the first stage of the upgrading);
- interaction with an external personal computer;
- elements of the automatic display format design within a given class of symbols, procedures, etc.;
- other programs which facilitate trouble-shooting during the tests of the console installed on the object.

The SW contains 100 thousand text lines in Pascal and 30 thousand lines in Assembler.

Conclusions and Recommendations

1. For the first time in the domestic and worldwide practice a one-screen onboard IDS of a complex object has been developed on the basis of the ground technologies.
2. A basic design of the integrated console is proposed for the IDS of the complex object.
3. Software has been developed for the electronic IDS which can be accommodated and used in designing the IDS of other complex objects.
4. The accepted IDS architecture allows the MCI to be further improved to provide the tasks of spaceship motion control at all flight stages and the weight of the IDS hardware to be reduced.
5. The management of the man-computer interface is a difficult scientific and practical problem which requires the considerable changes in the design approaches to an automatic control system, comprehensive ergonomic research, etc.
6. The practice shows that the significant upgrading of the IDS of a complex object is possible , with its hardware interface retained.

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