The Land-Onboard Complex of a Control Flight Balloon

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***Abstract* — Necessity of carrying out of experiments for real time by means of use of operated flight of a balloon it is caused by a number of the reasons. We name some of them: the research of the physical phenomena, such as studying of a spatial magnetic field of the Earth; monitoring of the terrestrial surface, for example, for the purpose to test of a state of gas and oil lines; the research of terrestrial and a cosmic space. For the purpose of the task in view decision the ground-onboard complex of a balloon including is offered: 1. On-board part, including: - The onboard Computer, what is intended for working off of functional tasks of flight control and interaction with actuation mechanisms of a balloon and devices; - The module of definition of a site of a balloon, what works on the basis of satellite navigating system; - The complete set of radio transferring equipment consisting of transceivers and radio-controlled of communication; - The complete set of target devices. 2. Ground part (control command point), what provides working off of functions of flight control of a balloon by the operator from stationary or portable command control point, check and testing of all functions and possibilities of management of a balloon. On the basis of the developed complex four flight experiments on measurement of a spatial magnetic field of the Earth are executed.**

***Index Terms* —forecasting of flight balloon, land commanding post, navigating system, onboard computer complex, radio system.**

I. INTRODUCTION

The use of automatic balloons (AB) for surface monitoring, over ground and space research and solving other problems for long flights is a very important direction. Thus, it is necessary to create a control system of flight AB. In the present work the experience of working out of universal complexes for controlling AB of different types is presented.

AB flight control is carried out by choosing a starting point and selecting the height of the flight to achieve the demanded direction and speed of AB movement taking into consideration the wind for arriving to given point. It is known reaching the set height is provided by throwing down the ballast or gas releasing.

The works were carried out in the following directions:

1. Working off of structure of the united set of onboard equipment for the balloon (BEB) flight control.
2. Working out and realization of the flight control commanding post.
3. Working out the system of forecasting the working capacity of the complex of onboard and land control flight facilities.
4. Working out the algorithms of high-altitude and horizontal flight control AB.
5. The analysis, choice and program realization of the protocol concerning the command-telemeter information exchange between board and land equipment.

II. THE STRUCTURE OF THE EQUIPMENT OF FLIGHT CONTROL BY AUTOMATIC BALLOONS

The equipment of flight control by balloons (EAB) consists of the land commanding post (CCP) which is single for the set of simultaneously operated AB and the onboard equipment of the balloon (OAB). The generalized scheme of EAB AB is presented on (Fig. 1).

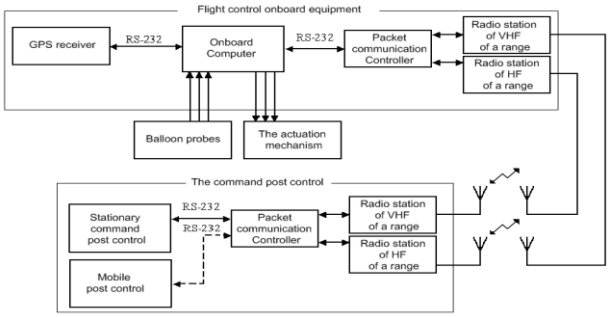

Figure 1. The scheme of EAB AB

Flight control is carried out by EAB on the basis of the data about the environment and parameters of the balloon movement that get to BEB from the navigating system and onboard gages, and also on commands and taking into account the data which can be transferred from CCP.

Land commanding post CCP carries out the formation flight control AB commands by means of processing the information from external gages (pressure, temperature, navigating etc.). The signals from the gages arrive at the computer complex (CC), where they are processed by various algorithms according to the demanded flight program. CC sends signals of AB flight control (ballast dump, gas release). CC forms the telemeter signal containing the information of the parameters of onboard equipment work, the coordinates of AB location, its speed, pressure, quantity of the let out gas and the dumped ballast, the condition of mechanisms etc. This information is transmitted through the package communication controller by radio station and for other realization by GlobalStar.

The telemeter information received by the transceiver which is a part of onboard equipment BEB goes through the package communication controller to the stationary or portable CCP. The Software of CCP processes the information and displays it.

The equipment of flight control EAB is intended to solve some functional problems onboard AB, to control the balloon AB flight from CCP, to receive the navigating data about the location, speed and course of AB, from the receiver of satellite navigating system, and to exchange the telemeter information with the earth on a radio channel, according to the specialized protocol of data packet transmission.

The commanding post CCP is intended for working off the functions of AB flight control by the operator from the stationary or portable command post, checking and testing all functions and possibilities of control the commanding post CCP, and forecasting of balloon AB movement. The portable command post of control provides checking the equipment of AB before the start and carries out the local operating control of AB, providing decentralized AB control. The Software of AB allows carrying out forecasting of operated AB flight over territory the Russian Federation or other country in the real or accelerated time scale.

III. FORECASTING AND CHECK OF WORKING CAPACITY OF AB

Equipment of AB allows to predict balloon flight, simulating of flight AB, working of onboard and land control facilities of the flight that are close to real conditions. The forecasting system is a built in function of software CCP.

Basic purposes of system of forecasting are:

1. Imitation of processes of flight and flight control of AB at all stages in real time in interaction with CCP;
2. Checking AB flight control algorithms intended for work of software AB;
3. Debugging of functional tasks of AB;
4. Working off of the principles of horizontal flight control on the basis of the average and real meteodata;
5. Preflight forecasting of real balloons flight.

The imitating models are realized within the limits of forecasting system engineering: model of a balloon movement of, model of atmospheric processes, model of onboard gages, and model of onboard navigating system. The result of work of mathematical model of flight of a balloon is presented on fig. 2.

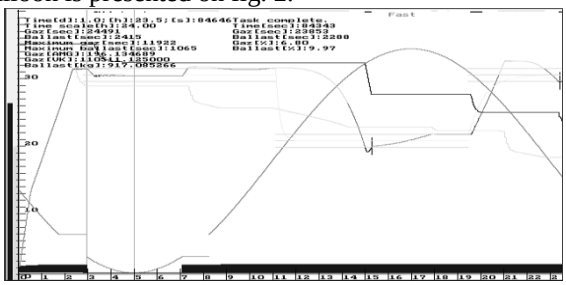

Figure 2. Result of model of flight of a free balloon

The methodic of the trajectory characteristics calculations allows calculating the key parameters of AB flight, on the basis of the meteo data and AB technical characteristics.

The model of atmospheric processes allows connecting the base of the meteorological data which defines the direction and speed of movement of a wind. In case of absence of the meteo data it is possible to use the preset area an average map of winds in the preset area. It allows predicting AB trajectory, the direction and speed of its movement.

The onboard gages data is formed according to «Standard atmosphere» and get into the algorithm of vertical control as input parameters. The onboard navigating system is realized by means of model of atmospheric processes and model of flight of a free balloon.

On the basis of the forecast data of the balloon flight it is possible to make a conclusion about possibility of the flight task.

IV. THE PRIMARY GOALS OF AB

The main tasks of EAB AB during a real flight are:

- providing with autonomous control (program-time, high-altitude-speed, navigating) and radio channel flight control of high-rise and stratospheric AB (from 6 km to 50км at flight time duration till 15 days with possibility of repeated compulsory change of height of the flight;
- giving commands on operating of fulfilling mechanisms and dumping of cargoes according to the established program on time and height, the navigating information, according to radio commands from CCP with preliminary or real time set variants and dump intervals;
- automatic and radio control of special equipment work;
- definition of AB flight location;
- transferring radio telemetering information from AB board to the land (air) CCP;
- radio designation of AB in flight and its suspension brackets after the landing;
- providing radio control of AB flight on KB and VHF ranges;
- diagnostic check of working capacity of AB equipment.

V. STRUCTURE AND SETTING OF ONBOARD EQUIPMENT OF FLIGHT CONTROL

The onboard equipment of flight control of an automatic balloon (Fig. 3.) represents the combination of computing means both functionally and informational connected.

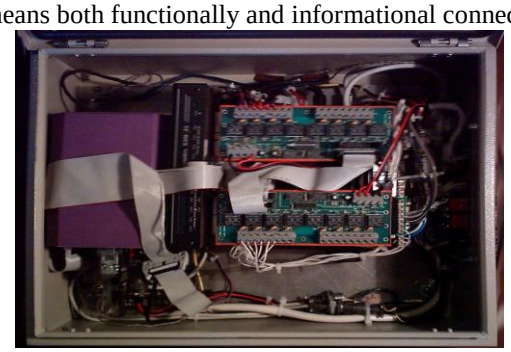

Figure 3. The onboard equipment of automatic balloon

The structure of the equipment of an automatic balloon includes the following functional modules:

- The onboard computer complex (CC);
- Navigating system;
- The radio sending device;
- The block to control the fulfilling mechanisms.

CC is made on the basis of the industrial computer according to PC/104 standard. It possesses the expanded system of data gathering including analog inputs, analog conclusions, digital input and outputs. It allows connecting a considerable quantity of gages and controlling facilities. It possesses the full isolation of all inputs and outputs overheat protection, don't need an external source of cooling, and also possess means of visual monitoring of the device condition. The expanded BIOS function improves the system adaptability to various aspects of hardware-software surroundings.

The subsystem of discrete input-output of general purpose with 24 lines of external signals on the basis of microcircuit which lines are equipped with resistive terminators, and analog-digital input-output with 16 channel ADT of 16-digital accuracy. Subsystems can work in inquiring modes, on interruptions or through DMA channel. The synchronization of measurements can be both external, and internal.

For module work the power supply which forms 4 channels having protection against an overload. The power supply provides high degrees of reliability. The power supply has added supplemented the control block allowing putting on and off power device in the established intervals of time. This block represents microcontroller programmed in specialized language, with a serial port for loading of programs.

The navigating module is universal 12-channel the GPS or GLONAS receiver allowing defining with the big accuracy of coordinate and a vector of speed of object on which it is located. In onboard BEB it is used for information delivery in a control system of flight AB about current position and about components of a vector of speed AB. Thanks to universality of the interface of data transmission and software OAB, it is possible using any other navigating module with similar parameters.

Universal complete set of firm ICOM is used for data transmission on a communication radio channel between CCP and BEB. The protocol of AX.25 provides multistation (plural) access.

The control unit is intended by executive mechanisms for switching scheme of power chains variable and a direct current by means of electromagnetic relays.

VI. THE SOFTWARE OF ONBOARD EQUIPMENT OF FLIGHT CONTROL

Control functions of balloon OAB are carried out by the specialized software computer working under the control of real time operating system RT-Linux and solving the following functional tasks:

- Receiving of control commands from the earth from a radio receiver and checking the integrity of their delivery;
- Decoding of control commands of AB and their processing;
- Definition of parameters AB by checking onboard gages;
- Forming commands on mechanisms:
- Producing vertical control
- Data transmission parameters of the condition of AB, and sending messages on the earth through a radio transmitter.
- Receiving the data from navigating system about parameters AB and their processing according to the given algorithms of control.
- Coding and decoding of the accepted data, check of integrity of the package.

The numerical modeling of processes of vertical flight control was carried out. It is shown that algorithms of vertical control provide the demanded trajectory of flight (stabilization of height of flight, program transition from one height to another).

VII. COMMAND POST OF FLIGHT REGULATION

Specialized software CCP is intended for flight and real time control by one or more flying automatic balloons.

Software CCP provides:

- The multipurpose window interface;
- Screen display of a map with scaling possibility;
- Possibility of efficient flight control of one or more AB;
- Possibility of flight AB according to the set trajectory, efficient change of height and testing any parameters AB;
- Showing horizontal profile of flight (trajectory) of all traced AB on the map;
- Showing a high-rise profile of flight of any AB, chosen by the user;
- Showing in a separate window the parameters AB, chosen by the user;
- Having a local database of all user commands and commands of AB control with possibility of their viewing and choosing;
- Receiving of the data from the controller of package communication;
- Checking of integrity of delivery of data packages coming through the communication channel;
- Gathering and registration of the data coming through the communication channel, its decoding and presentation of the received information the form suitable for the user for the purpose of its further analysis.

The present program complex works under control of multitask multiuser OS.

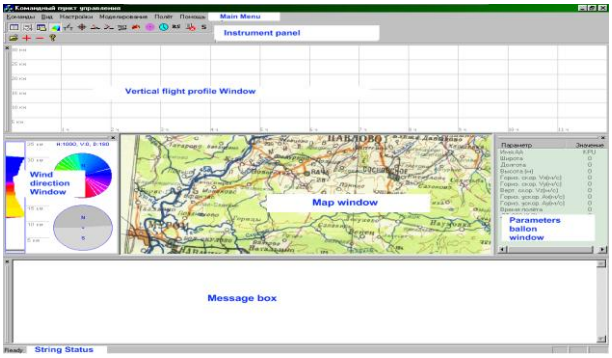

Figure 4. The main window of "Command point of management»

The user interface CCP (fig. 4) allows adjusting the appearance depending on the task or according to the operator wish.

AB flight is displayed on the screen of a map with possibility of dynamic scaling. The current location of the balloon and the schedule of its flight can be seen on the screen.

During the balloon flight the operator can control the flight of one or more AB: check the set trajectory, change the height and control the condition of parameters of any AB, dump of cargoes, control the external devices, etc.

A change of height of balloon flight is carried out by formation of the flight task directly on CCP or on OAB during preflight preparation. The flight task consists of set parameters allowing precisely the trajectory of balloon flight at the set height and quality of transient from one height to another. Also it is possible to change the trajectory of AB movement by the direct influence on executive mechanisms, opening the gas valve or ballast for the set time.

The data is sent directly through a radio channel, CCP conducts gathering and registration of the data coming by the communication channel, their decoding, and check of integrity of delivery of data coming by a communication channel and representation of the received information in a form comfortable for the user for the purpose of its subsequent analysis.

VIII. THE INTERFACE OF CCP

The interface of CCP consists of:

1. Keys of tools line
2. The message window for diagnostic and commands messages.
3. Route window for indication of the current AA position.
4. Window of parameters for indication of parameters of active AB.
5. Window of wind direction and speed of a current AB on height.
6. Window of the vertical profile of AB flight
7. Dialogue window «the Flight task»
8. Window of the mode of the flight forecast
9. Window of mode of testing of equipment
10. Window of mode Flight mode
11. Window of Formation of the flight task
12. Giving of signals on executive mechanisms
13. The flight termination

IX. REALISATION

In process of the realization it is created:

- The experimental sample of onboard equipment of flight control AB;
- Command point of management AB;
- The design documentation on the experimental sample of onboard equipment of flight control AB.

At carrying out land and flight tests it is shown that the experimental sample of the equipment of an automatic balloon of flight control by automatic balloons is efficient, flight tests has sustained, corresponds to appointment.

On the basis of the developed complex four flight experiments on measurement of a spatial magnetic field of the Earth are executed.

Figure 5. Prepare to Flight

X. CONCLUSION

Necessity of carrying out of experiments for real time by means of use of operated flight of a balloon it is caused by a number of the reasons.

With this aim the ground-onboard complex of a balloon is offered.

The equipment of an automatic balloon is designed on the basis of computer PR-32Z-EA, and allows making data transmission and control in HF/VHF communications, control of devices, switching of executive mechanisms, reading of indications of various gages, definition of current coordinates.

The software of the equipment of an automatic balloon is developed in system of real time Diamond RT Linux. It allows controlling of an automatic balloon and provides delivery of commands on operation of actuation mechanisms and dump of cargoes according to the established program, automatic and radio control by work of special equipment, transfer of the radio telemetering information from board AB on land (air) CCP, to spend diagnostic check of working capacity of equipment AB.

The software of CCP is developed in system Windows, allows to carry out flight and operational control by one or more automatic balloons being in flight, provides the multipurpose window user interface, possibility of conducting flight AB on the set trajectory, operative change of height and control over a condition of parameters AB.

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