Simulation of the Control Processes of the Automatic Spacecraft for Observation in the Regimes of the Target Functioning

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Abstract: In the process of automatic spacecraft (AS) design it is necessary to estimate the characteristics of space system target effectiveness depending on such the factors, as parameters of AS orbital flight, operating condition, supply system design characteristics, onboard service systems actigrams and others. The bundled software have been developed under Delphi-7 environment in order to solve the problem. It has user-friendly interface and can be exploited even by inexperienced users.

Keywords: automatic spacecraft, target effectiveness characteristic, observation periodicity, simulation, Delphi..

1. INTRODUCTION

In the initial stages of the automatic spacecraft (AS) design it is necessary to evaluate periodically the influence of changes in the ratings to the characteristics of space system target effectiveness.

Basic target effectiveness characteristics are the indices of photographs resolution, observation periodicity, productivity of survey, effectiveness of the delivery of video information to user, etc. All these characteristics are essentially influenced by a large quantity of the factors: the parameters of AS orbital flight, the ratings of target equipment, operating condition, electric power supply system design characteristics, onboard service systems actigrams, control of AS motion relative to the center of masses and others. The simulation of AS target functioning, taking into account the factors indicated, is the important stage of design analysis and synthesis of AS appearance.

2. MODELS AND ALGORITHM

In order to evaluate the target effectiveness characteristics of complex technical systems the method of simulation is used (Kurenkov et al., 2006). While it's usage AS flight and onboard systems functioning are simultaneously simulated. In this case through the specific time intervals the parameters, which characterize the state of target equipment and onboard service systems, are tracked, and effectiveness characteristics of space monitoring system are evaluated periodically. Are considered:

flight time (turns, twenty-four hours, months, years);

the types of orbits (circular solar-synchronous, elliptical);

orbital parameters;

the conditions for the survey of objects subject to the angle of the Sun above the horizon, the cloudiness and others;

the standard actigrams of AS work (periodic turnings of AS hull in the process of target work and in the process of preparation for it);

the angle between the surface of solar panel and the direction to the Sun;

the actigram of the work of the service equipment;

the reserve of electric power in the buffer batteries;

the influence of the reliability of the elements of onboard systems on reduction in the effectiveness characteristics of automatic spacecraft, etc.

Models for evaluating the parameters, which characterize the states of the system being investigated, consist of the particular models totality, these ones areunited into the complex model with the aid of the special program. In the process of program work particular models "are connected" at the specific moments of time. With each new "connection" of particular models are used, as a rule, the initial data, which are changed depending on the current (in the process of calculation) time and the states of various elements of system, and also depending on the random factors, which influence the system being investigated.

Mathematical models for the evaluation of AS target effectiveness characteristics include:

- the model for organizing the simulation of AS orbital flight;
- the model for evaluating the indices of the observation resolution;
- the model for evaluating the indices of observation periodicity;
- the model for evaluating the factors of survey productivity;
- the model for evaluating the indices of the effectiveness of delivery video information to the Earth;
- the model for evaluating the conditions of application (angle of the Sun above the horizon) and others.

On the basis of the models proposed are developed algorithms and software for the evaluation of AS target effectiveness characteristics depending on the parameters of orbits, characteristics of target equipment, actigrams of the work of the target and service equipment, conditions of application and indices of the reliability of onboard systems.

This software can be used for the operational evaluation of the influence of AS target effectiveness characteristics.

Are developed models, algorithms and software for the selection of the optimum route of the survey of the objects of observations (OO), which include the particular models:

- the model for formation of initial data on OO by the direct task of the coordinates of known objects or generation of random coordinates taking into account the nonuniformity of OO distribution with respect to the continents and the regions of the Earth (Figure 1);

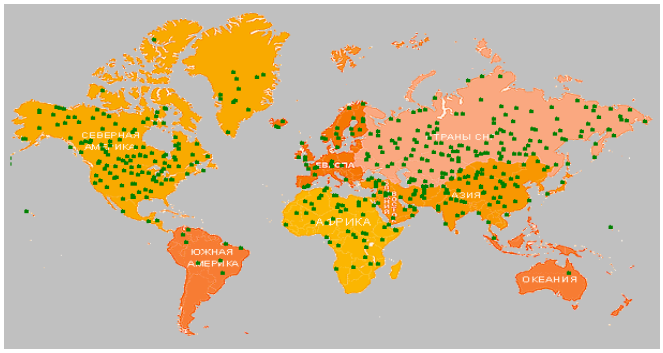

Figure 1. Formation of the massif of OO random coordinates

- the model for selection of OO, which enter “light spot” and AS swath, during the given number of turns of flight (Figure 2);

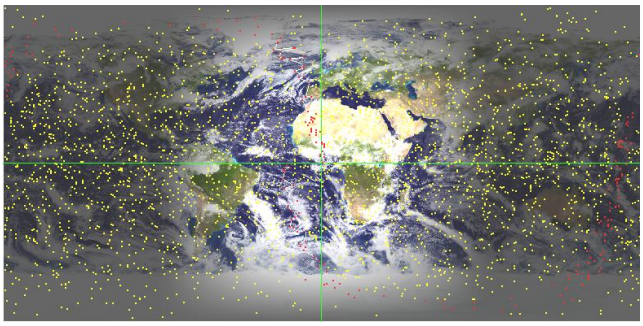

Figure 2. OO entering “light spot” and swaths

- the model for control of AS retargeting in the process of conducting the route of survey;

- the model for selection of the route of survey on the criterion of a maximum quantity of photographed objects taking into account limitations on the retargeting angular velocity.

As showed experience of AS designing and operating, the most critical from the point of view of available resources, appears the electric power supply system, on which it depends the fulfillment of the preset parameters of AS target effectiveness.

Therefore are developed models, algorithms and software for evaluating the balance of the electric power on board AS taking into account the complex action of the basic factors of operation and special features of the actigrams of target work, for example, while realizing long route of survey with the large angles of deflection of the optical axis of monitoring equipment from the nadir. These models include the particular models:

- the model for evaluating the orientation of solar panels in the process of survey conducting and retargeting from one object of observation to another;

- the model for evaluating the replenishment of supplies of electricity in the storage batteries taking into account the orientation of the solar panels and redistribution of some quantity of the energy for onboard equipment work directly from the solar battery;

- the model for evaluating the expenditure of electric power with the work of onboard equipment;

- the model of control of connection and turning off basic instruments of relatively grate power in the correspondence with the assigned actigram.

Each group of the represented particular models, in turn includes the individual models, which are used in the specific sequence for the solution of the problems, for which are intended these particular models. Such individual models are intended to account for various factors, which influence the results of calculation. For example, particular model for evaluating the current and average cosine of the angle between normal to the surface of solar panels and direction to the Sun both in the oriented flight and in the disoriented flight, contains individual models, intended for:

- calculation of the coordinate systems, connected with AS and versions of the layout of optical equipment for observation;

- accounting for a change of orienting the coordinate system, connected with AS in the process of satellite insertion and its transfer in operating status;

- determination of the coordinates of unit vector to the surface of solar panel in the base coordinate system;

- calculation of the coordinates of the vector of direction to the Sun in the fixed geocentric coordinate system depending on the time (number of twenty-four hours) elapsed from the moment of the passage of the vernal equinox point;

- conversion of the coordinates of the unit vector of direction to the Sun from the fixed geocentric coordinate system into the geocentric orbital coordinate system, connected with the pericentre of orbit;

- transformation of coordinates of the unit vector of direction to the Sun from the geocentric orbital coordinate system, connected with the pericentre, into the barycentric orbital coordinate system;

- determination of the coordinates of the unit vector of direction to the Sun from the barycentric orbital coordinate system, into the coordinate system, connected with AS center of masses and the center of the Earth;

- calculation of the coordinate of the unit vector of direction to the Sun from the coordinate system, connected with AS center of masses and the center of the Earth, into the base coordinate system;

- determination of the cosine of the angle between direction to the Sun and normal to the surface of solar panel in the base coordinate system;

- determination of the instantaneous value of the cosine of the angle between direction to the Sun and normal to the surface of solar panel in the process of retargeting while realizing of route sketch.

With the aid of developed software can be evaluated the average-daily power of electric power supply system and the power of electric requirements of target equipment and onboard service systems in the flight conditions, close to the real, and the energy consumption of equipment of onboard systems with the actigrams close to the real (Figure 3).

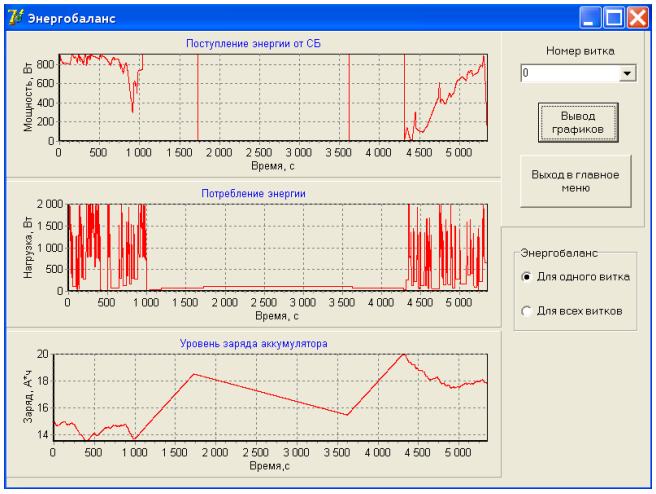

Figure 3. On-board energy balance changes in the process of AS target functioning

Aggregative algorithm of simulation for the evaluation of effectiveness characteristics of space observation system is given below.

1. User interface for the work in conversational mode is formed.

2. Necessary initial data are assigned, then is formed the window for representation AS routes against the background of the map of time zones, arrangement of the objects of observation and earth-based data reception center, as well as windows that display the results of calculation according to the current values of basic AS effectiveness characteristics.

3. Are formed initial data on the objects of observation by introduction of the assigned coordinates or randomly.

4. Is achieved selection of objects of observation, which fall into the strips of survey and selection of the route of survey.

5. The subprogram for flight simulation and AS target functioning with assigned initial data is included.

6. Are calculated the parameters of AS orbits taking into account secular variations because of the second zonal harmonic in geopotential decomposition (current values of the orbit ascending node longitude and orbit perigee argument, true anomaly angle, AS radius-vector).

7. Geographical coordinates of AS subsatellite point are calculated and transferred into the screen coordinates with the aid of the appropriate scale factors, sub-satellite point tracing is displayed.

8. The subprogram for control of AS turnings while it's track is connected.

9. The subprogram for determination the indices of observation periodicity is connected.

10. The subprogram for determination the indices of observation resolution is connected.

11. Is connected the subprogram for determination the indices of information delivery effectiveness.

12. The subprogram for determination of capacity factors is connected.

13. Subprograms for determining the cosine of the angle between normal to the surface of solar panels and direction to the Sun are connected. (If it is necessary, subprograms for determining the average cosine of the angle between the normal to the solar panel and direction to the Sun in disoriented flight are used).

14. Are connected subprograms for determining the energy balance on board of AS, taking into account programmed rotations and actigrams of onboard equipment work.

15. All current parameters and design characteristics are displayed in appropriate forms for visual monitoring, they are also written down in corresponding files.

16. Time is incremented and items 6- 15 are carried out cyclically.

17. Is formed the protocol of calculation, which can be printed, accompanied by appropriate graphs.

In order to expand the software capabilities, models for evaluation the influence of cloudiness and AS onboard systems reliability at the target effectiveness characteristics of space observation system are developed. With the help of these models, it is possible to normalize AS and onboard systems indices of reliability in the process of design in order to guarantee the tolerance level of space observation system output effect loss, taking into account actual operation conditions.

The developed models, algorithms and software may be developed, taking into account various AS effectiveness characteristics.

3. SOFTWARE

The bundled software has been developed under Delphi-7 environment. It has user-friendly interface and can be exploited even by inexperienced users.

In Figure 4 is represented the window of the bundled software, in which AS orbital motion and program turnings on its survey route are demonstrated.

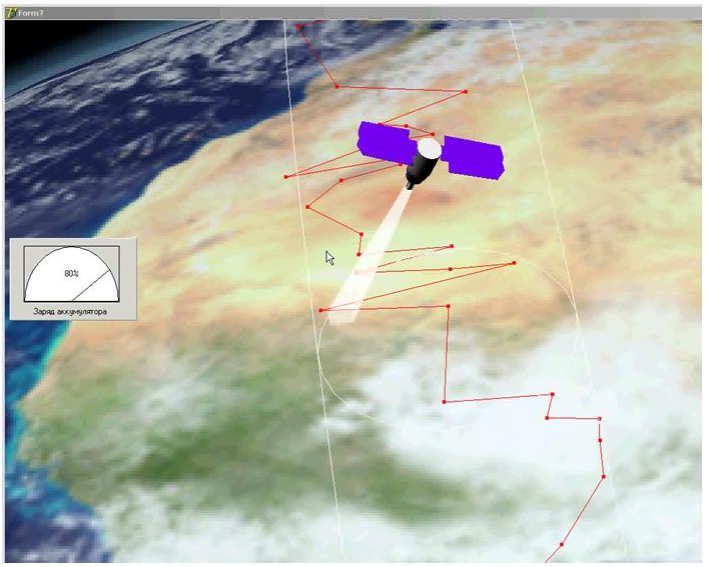

Figure 4. Window of bundled software for illustration of AS orbital motion and program turnings during realizing of the route of the survey

4. CONCLUSIONS

Models and algorithms for simulation automatic spacecraft target operation and bundled software have been developed. It is planned to improve the models by taking into account some more AS systems characteristics as well as operation conditions.

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