Automation system of communication satellite designing

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Abstract. The selection of efficient alternative design of communication satellite architecture is impossible without solving the problem of Computer-Aided Design. The authors have offered the structure and the functions of communication satellite and data relay satellite. The prospects for further development have been defined as well.

1. Introduction

Solving the problem of selecting efficient alternatives of communication satellite architecture is impossible without solving the problem of Computer-Aided Design. The reason is obvious: the main tendency of the modern system-cybernetic field is the integrated study of sophisticated and supersophisticated engineering systems such as communication satellites and data relay satellites. It allows to synthesize systems that are more advanced; constantly complicating means of production are necessary for their creation. Meanwhile over the last years in the organization of designing of communication satellites we can observe a clear tendency to the automation of the design process. This tendency is characteristic not only for regular technical parts of project activities, but for intellectual aspects of design as well [1].

One of the directions of the intellectual project activity dealing with the creation of communication satellites is implementation of dialog man-machine procedures of decision-making process. In this case, the basis represents a multicriteria method of decision-making in conjunction with wide use of discrete model and simulated model. Using man-machine procedures allows the designers of all levels to control the project performance handle the situation objectively and make management decisions efficiently. For this reason, while designing communication satellites more and more attention is paid to the Computer-Aided Design (CAD). Nowadays CAD allows to operate not only regular operations, but organizational design structure and life limit of communication satellite as well. Besides, CAD contributes to more efficient solution of other tasks, which were solved by designers intuitively before, each mistake could cost much during the flight operation.

However, creating CAD of the satellite of communication and data relay requires not only structuring the design process, but using new ideas and achievements of system analysis in the field of designing complicated systems as well. One of these ideas is the approach based on multi-faceted multilevel description of complicated systems. The metastructure of the communication satellite received as a result is the basis of formalization of numerous processes while designing...
communication satellite; it allows to develop functional and convenient instrumentation for a design manager to manage the project design.

2. Conceptual backgrounds of the creation of computer-aided design of communication satellite

The issues of creating CAD of communication satellite and requirements to this automation system have been discussed in details in the previous section. Let us consider the Computer-Aided Design as a sophisticated developing system. In the widest sense, CAD has to realize managerial duties connected with satellite design. These functions are the following:
- formation of the design metastructure;
- drawing the plan of project work;
- operating control of the satellite development.

The metastructure of communication satellite design represents one of the elements of amalgamated metastructure of the enterprise–developer since the latter performs diverse projects simultaneously. Herewith many organization units take part in the design of satellite onboard system, but they use common technical, programming and other tools.

The metastructure of communication spacecraft design contains the following elements:
- the structure of the technology of project decision making;
- the structure of the technology of planning and operational control of project design;
- the structure of mathematical and data base organization and management of project work;
- the technical structure of design;
- the organizational structure of design including the cooperation of providers.

The structure of the technology of decision making defines the order and the content of interaction of all primary processes of decision-making in distributed system described in the previous sections.

The structure of the technology of planning and operational control of project design reflects the specificity of decision-making techniques and the methods of multilevel coordination while drawing a plan of project works, the methods of correction of a plan and operational replanning. The planning of project works should be made using multi-criteria methods of decision-making. Herewith performance indicators for assessment of the plan are made according to the methods described in the previous sections and the alternatives are different programs of project designing. The operational control of the design process is aimed to achieve planned project work condition due-by-date due to redeployment of resources among providers. Besides, it presumes the possibility of correction of reference design in the course of creation of the communication satellite taking into account new developments.

While realizing all the functions of control of project design mathematical methods and models are being used; these methods and models are being realized in the man-machine algorithms of decision-making and they play an important role in modern CAD.

At the enterprise dealing with the development and manufacture of communication satellites, it is necessary to create a team of designers who are able to define the strategy of design and modernization of satellites performing their tasks as part of different satellite communications systems taking into account all conjuncture conditions [2]. The base of the strategy is polystructural representation of spacecraft being designed and the design metastructure choice that should be done taking into consideration all system environment in the amalgamated structure of the enterprise. The design metastructure creation has to be realized simultaneously with the generation of communication satellite metastructure. On a formal level all mentioned metastructures have to be presented using one graph with three types of curves: curves reflecting the sequence of spacecraft structure generation at system forming and choosing communication satellite architecture; curves characterizing the interaction of the elements of design metastructure and, finally, curves reflecting the relationship of the elements of design metastructure of the communication satellite.

In the broadest strokes it is the conception of modern CAD of communication spacecraft; this conception includes the most perspective directions of creation of systems of a like nature. In the
following sections, we consider the structure of perspective CAD of communication satellite; as well as stages of creation and development of Computer-Aided Design of communication satellite.

3. Structure and functions of cad of communication satellites

Being an integral part of an enterprise, the system of automated design of communication spacecraft has to realize the metastructure of satellite design and fit in CAD of satellite communication system and, as a matter of course, combine with the metastructure of communication satellite design in whole. As noted above, the metastructure of communication satellite design belongs to amalgamated types of structure, which are the most difficult to analyze from the point of view of management activity. To carry out the analysis it is necessary to study in details the system environment of CAD of communication satellite.

Figure 1 shows the place of design of communication satellite in the general process of development of space communication and relay systems. As we can see in the figure, requirements and source data get onto the communication satellite design from several contours:

- requirements and source data from the part of the space communication system including the satellite being developed;
- requirements and source data from the part of constituent parts and elements of space segment and particularly means of its orbital injection;
- requirements and source data from the part of automated control system of communication satellite;
- requirements and limitations from the part of ground-based technological, operating and experimental base of enterprise-developer and its cooperation;
- available nomenclature, technical and qualification level of constituent parts and elements of communication satellite, developed both in Russia and abroad.

![Figure 1. Designing of communication satellite in the overall process of developing space communication systems.](image-url)
In other words, the design of any communication satellite is performed hand in hand with the developers of constituent parts and elements of satellite communications system, space segment and automated system of spacecraft control.

Designing any communication satellite is an integral part of the designing process of satellite communication system and it includes the aspects: external design and internal design. The main functions of external design are the following:
- providing the competitiveness of the satellite on the market of space communication service (for civil satellites: commercial satellites and national economy communication spacecraft);
- providing by the developed spacecraft required communications capacity, taking into account tasks of interference protection of communication radio line (for the satellites created in the interests of Russian Strategic Missile Forces of the Ministry of Defense of Russian Federation);
- carrying-out the requirements from consumers (users) of data relay channels of spacecraft and earth segment of satellite telecommunication system;
- carrying-out the requirements to the control of communication satellite;
- creating the logic of satellite operation in the frame of satellite telecommunication system (order and the duration of removing of spacecraft from the satellite constellation to carry out ground-handling operation connected with the blackout according to the intended purpose);
- carrying-out of requirements from existing (or defining them in the performance specifications of a customer) infrastructure ground operation aid (technical and launching areas, fuel service units, transport shipping material, supportive tools for room conditions, etc.)
- coordination with the existing launch vehicles;
- providing satellite working capacity under the conditions of external influencing factor affecting spacecraft in its ground and flight operation, as well as its maintenance;
- providing the counterwork of programmable adjusted of a potential enemy;
- cost minimization for experimental designing and further operation of the satellite according to the designated purpose;
- preparing communication satellite to launching, final orbit launching and bringing into flight service within required time intervals;
- and others.

Unlike the external spacecraft design, we consider that the main functions of the internal design are the following:
- forming and the choice of the architecture of the design-layout scheme of communication satellite;
- defining tools of communication satellite;
- defining main design characteristics of onboard systems and a satellite in whole;
- forming the logic of satellite operation; this logic provides carrying-out of external requirements to the creation of spacecraft;
- providing necessary resources of spacecraft to solve the tasks of data relay, operation (realization of built-in logic of satellite operation, orientation and stabilization of spacecraft, navigation and control of motion, correction of orbit parameters of spacecraft, receive-transmit array of command and programming data, extraction of telemetric information set, etc.), power distribution, maintaining necessary temperature conditions of onboard equipment, providing strength characteristics of structural elements, counteraction to programmable tracking of a potential enemy;
- survivability of onboard systems, their equipment and elements in operation being a part of a satellite.

The enumerated functions of external and internal design of communication satellite are performed in CAD; the structure of CAD is shown in figure. 2. The basis of the technical structure of CAD are local data-processing networks providing automation of different aspects and stages of satellite development. These local data-processing networks are united into the inner net that allows methods of modern informational technology to perform the mechanisms of interlayer and intralayer
communication among all the processes of making design decisions included in the distributed structure of communication satellite design [3].

Local networks have to contain several superpersonal machines. Spacecraft design manager's automated workplace is connected to the united inner net as well; the united net has to have access to the inner net of the enterprise.

4. Perspectives of developing cad of communication satellites
In the development of CAD of modular packaged unit of spacecraft, we can see definitive analogy with the implementing of CAD in mechanical engineering, where it all started with the automation of merely rote designing. Hereafter it turned out that designing process of some separate units and subsystem was getting more and more complicated, it was becoming intellectually advantaged on the side of CAD, but herewith there were difficulties in designing the system in whole [4]. We can see similar situation in the design of communication satellite. As spacecraft became more sophisticated, the logics and functioning processes of both external and internal design of satellite started to face stones of stumbling connected with the increase of finalization and approval, mismatch, associativity.

![Diagram of Computer-Aided Design Structure](image)

**Figure 2.** Computer-Aided Design Structure.

In that context, specialists are optimistic about CAD in terms of solving managerial tasks. First, we are talking about formation of the net of decision making for all levels of design with the development
of appropriate mathematical support in the form of expert systems and decision-making support systems. This tendency of intellectualization of decision-making procedures is rather considerable; it appears that in the nearest time this tendency will be significative in the development of CAD of communication satellite. In accordance with it, mathematical support of CAD of spacecraft will become more complicated; this mathematical support will provide solving the tasks of design management in the broadest sense.

At present the armory of means included in the mathematical support of CAD of communication satellite contains the complex of net models based on the apparatus of Petri net; this apparatus is used combined with elementary whole-numbered models for the choice of satellite architecture, atomic Boolean models of choosing spacecraft structure and control technology, decision-making models.

The complication of the functional structure of modern communication satellites especially with the application of multicomputer systems, the availability of parallel processes makes it impossible to design decisions using traditional analytic methods not to speak of the choice of optimum alternative. In its turn, it causes the necessity to simulate design spacecraft in whole, some modes and some constituent units.

It is obvious that efficient design of perspective communication satellites is becoming impossible without the application of automated workplace of a projecting engineer [5]. Besides, the application of computers as part of automated workplace allows to automate considerable part of work in documenting and other procedures, used in the designing process; it allows to create unified pervasive technology of designing, gaining and conservation of pooled experiences in the data bank of the system. Let us consider overall character of the actions of automated workplace users while designing communication spacecraft.

At the phase of the design of feasibility assessment, specialists set and formalize goals of designing; they analyze appropriate initial data; they develop preliminary proposals about achieving specified technical characteristics; they perform the primitive description of designing object. Prevalently it is a creative process carried out by highly qualified design engineers. Their work using automated workplace consists in the access to the data of the system of selecting information dealing with the set of requirements to the future product, existing and prospective means of achieving assigned goals of designing, opportunities and perspectives of manufacturing and operating of spacecraft.

While forming the initial description of an object performed on the morphological level, design engineers are using interactive programming techniques of computer graphics that allow to create and adjust the structure of a future product in convenient pictorial representation. This work is performed in the frames of automated workplace, if it is necessary, with automated handling to the informational resources of the central data bank. At this stage, specialists use procedures of dialogue organization, informational search, exchange and output of information in alphanumeric and graphic forms. The results of this stage are registered in the system data bank and, if it is necessary, they are documented at appropriate technical tools of the automated workplace. They represent initial data for the selection and construction of mathematical models.

After defining initial data, design engineers face the task of selecting and forming of the functional models required in the designing process. In general, this stage has a constructive character and it requires from design engineers clear vision of the possibilities of mathematical models used in automated workplaces. Upon the availability of the information about the models being used as part of data bank of the system, information system is used; upon the request of design engineers, this system sends out suitable mathematical models with necessary descriptions onto the data display device of the automated workplace. Using appropriate dialogue tools, design engineers have a possibility to correct models, composition of several models to one general model [6]. Design engineers have to select two models: the first one is for synthesizing design decisions; the second one is for their analysis. In the absence of suitable models in the system, design engineers develop missing models; they do it by themselves or engage software engineers. After the selection of the models being used, relevant
information is memorized in the data bank of the system and it is used in the context of setting a design task and choosing a method of its solution.

Forming of the design task represents formalization for the purposes of designing desired characteristics, quality parameters and conditions that the product being designed has to correspond to. These operations are performed by design engineers with using dialogue tools of the automated workplace. Having described a design task, projecting engineers turn to its solution using almost all software and hardware of the automated workplace. The results of the task solution are memorized in the design data bank of the system.

One of the overriding priorities of the spacecraft design process is simulating its operation, provided that the depth of the simulation increases when passing each subsequent stage.

Thus, by applying successive approximation of the considered overall character of projecting engineer’s work on the tools of automated workplace, specialists carry out coherent transition from the stage of technical proposals to the Front End Engineering Design and further to the engineering development. Including supporting information about the results of development and testing of spacecraft in the database, at later stages integrate knowledge will be cumulated; it gives the opportunity to use this knowledge in the context of new development, as well as in the context of carrying out the analysis of spacecraft work in the process of its operation.

Conclusions
At any enterprise dealing with the development and manufacturing of communication satellite it is necessary to create the team of design engineers that are capable to define the strategy of designing and modernizing satellites performing their tasks as part of different satellite communications systems taking into account all conjunctural conditions. The base of this strategy is polystructural representation of spacecraft being designed and the selection of the design metastructure, this selection should be done taking into consideration all the system environment in the amalgamated structure of an enterprise. Building the metastructure of designing should go in parallel with the generation of communication satellite metastructure.

We have offered a developed structure and functions of CAD of communication satellite. We have shown that CAD of communication satellite, being a constituent part of CAD of an enterprise, has to realize the metastructure of satellite designing and intrinsically fit in CAD of satellite communications system, and as a matter of course be congruent with the metastructure of designing satellite communications system in whole. Main functions of external and internal designing of communication satellite have been developed.

We have presented development prospects of CAD of communication satellite. We have shown that efficient designing of perspective communication satellite is becoming impossible without the application of the automated workplace of a projecting engineer. Besides, using high-performance computers as part of the automated workplace allows to automate a considerable part of work dealing with documenting and other activities in the designing process, as well as it allows to create unified pervasive technology of designing, cumulating and conservation of team experience in the central data bank of the system.

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