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ORCID 629.764.7

B.T. Suimenbayev[1], V.I. Trushlyakov[2],
G.T. Yermoldina[1], Zh.B.Suimenbayeva[1], A.M. Bapyshev[1]

([1]Institute of Information and Computational Technologies SC MES RK, Kazakhstan,
[2]Omsk State University MES RF, Russia)
ako-bapyshev@mail.ru

BUSINESS-PROCESS DEVELOPMENT OF THE INFORMATION-ANALYTICAL SYSTEMS OF THE BAIKONUR COSMODROM AND LAUNCH VEHICLE DESIGN FOR ECOLOGICAL SAFETY IMPROVINGIN THE IMPACT AREAS OF THEWORKED-OFF STAGES

Abstract. The analysis of the existing information-analytical system (IAS) of the Baikonur cosmodrome (IAS_{cd}) and the launch vehicles design (IAS_{lv}) are carried out. The main sources of the technogenic impact of LV launching with the main liquid propulsion engines in the impact areas of worked-off stages (WS) are shown. The concept of modernization of the existing IAS_{cd} and IAS_{lv} is proposed, which provides for the reduction of the technogenic impact for none rasable expendable worked-off stages, based on operational recommendations of the created IAS_{lv} andIAS_{lv}^{es} on the fire-explosion safety of the worked-off stages, reducing the size of theimpact areas of the worked-off stages, and the possibility of theworked-off stagesmaneuvering to change the impact area. Proposals for the modernization of the existing IAS_{cd} and the design concept for non-reusable LVs, based on the conditions for improving ecological safety, have been developed.

Key words: technogenic impact, falling areas, information analytical system, purposed medium rocket step, components of rocket fuel.

Introduction

The development of advanced LVs with the main liquid propulsion engines (LPE), in accordance with the accepted recommendations of such organizations as the UN's Technical Subcommittee on the Peaceful Uses of Outer Space [1], the Inter-Agency Space Debris Coordination Committee (IADC) [2] provides a significant reduction in the technogenic impact of LV launches with mainLPE on the environment, including:

- prevention of pollution of the near-Earth space by the upper WS with the main LPE which are large explosive space debris;
- a drastic reduction in the number and areas of impact areas on the surface of the Earth for the lower WSs, which are fire hazardous and toxic objects, leading to the chemical contamination of soil with residues of liquid toxic propellant components such as unsymmetrical dimethylhydrazine, nitric acid, kerosene.

Developers and operators of LV with LPE are interested in applying technologies, schematic and designsolutions aimed at increasing the ecological safety of LV to modern requirements, while the technical solutions should not worsen the achieved performance in terms of tactical and technical characteristics, reliability, use of proven technologies for the LV production, ground tests and operation.

The location of the Baikonur Cosmodrome is such that considerable areas of the impact areas of the lower WSare located on its own land territory of Russia and Kazakhstan. During the LV launches from the Baikonur cosmodrome, 28 impact areas(IA) are deployed in Russia (4.5 million hectares, including 0.12 million hectares in the Omsk Region, 0.96 million hectares in the Novosibirsk Region, 1.96 million hectares in the Tomsk region, 0.4 million hectares in the Tyumen region, 0.53 million hectares in the Altai Republic, 0.15 million hectares in the Republic of Sakha (Yakutia)), 52IAs in the Republic of Kazakhstan (4.6 million hectares), 4 IAs in the Republic of Turkmenistan (1.19 million hectares), 2 IAs in the Republic of Uzbekistan (0.17 million hectares) [3].

The impact areas of the lower WS in the USA, the European Union, Japan, India, Brazil are located in the waters of the World Ocean, therefore, the issues of ensuring ecological safety in the impact areas in comparison with Russia and Kazakhstan are virtually absent.

Of considerable interest are the works carried out in the United States on reusable lower WS, for example, launches of the rescued lower WS of LV"Falcon-9" [4], LV "Sheppard" [5], in which an attempt is made simultaneously to solve two basic problems arising in the rocket and space activities:

- reducing the cost of the payloads insertion due to the multi-use of the most expensive part of the LV with the main LPE (lower WS);

- reducing the technogenic impact of LV launches with the main LPE in the impact areas of the WS due to the return of the lower WS to the launch site, which is more important for Russia with its location of cosmodromes than for the USA.

In terms of the economic efficiency of such LVs (the ratio of the cost of the payload insertion into thespecified orbit to the cost of the total payload insertion), we can refer to the experience of operating the Space Shuttle reusable transport space system (RTSS) using technology, schematic and designand construction solutions based on a manned aerodynamic (airplane) landing scheme. Operational experience has convincingly shown that the economic efficiency of the non-reusable LV is much higher than the efficiency of RTSS [6]. The data on the economic efficiency for the LV with the main LPE using technologies, schematic and designand construction solutions applied at the Falcon-9 LV in comparison with the economic efficiency of traditional non-reusable LVs in open press have not been detected, although work has been known to analyze the effect of the flight scheme of the stage with a rocket-dynamic rescue system for the energy characteristics of a two-stage medium-range LV[7].

Similar studies are being conducted in Russia, for example, the projects "Rossiyanka" [8], "Baikal" [9], "Demonstrator" [10], using both a rocket-dynamic maneuver for the soft landing [7] and aerodynamic maneuver (airplane landing scheme type of RTSS Space Shuttle, Buran) [8, 9].

The shortcomings of the technologies, schematic and designand construction solutions used in the above developments are significant losses in the payload mass, complex technical solutions that lead to the large volumes of ground testing and, accordingly, the high cost of the LV launch due to its multi-use [6].

The study [11, 12] formulated the main factors of the technogenic impact of the LV launches with the main LPE in the impact areas of lower WS and conceptual proposals for their cardinal reduction. Thesemainfactorsinclude:

- unused liquid propellant residues components in tanksof the WS after the mainLPE cut-off, which entails an increased probability of explosion of the fuel tanks both at the atmospheric section of the WS descent trajectory, and directly on the surface of the impact area, increasing the probability of fire hazard of vegetation cover inflammability;

- the presence of uncontrolled motion of the WS in the atmospheric section of the WS descent trajectory, which leads to a significant dispersion of the points of fall of the WS and its fragments, respectively, of the area of the impact areas with a probability of 10^{-4} of the non-reflection of a man [2].

Taking into account the conducted analysis, it is proposed to consider the concept of ensuring ecological safety (ES) based on the following postulates:

P1. The life cycle of the WS should not end, as it is implemented at the present time in the logic of the functioning of virtually all Russian launch vehicles launched from the Baikonur cosmodrome - achieving specified movement parameters, cutting-off the main LPE. Should still be implemented phase of the WS operating, by analogy with the spacecraft, providing for its transfer to the utilization orbit after the end of the active life. At this phase, the WS should ensure minimization of technogenic impact on the environment in the area of its expected fall.

P2. At the present stage of the study, it is not supposed to return the WS to the cosmodrome with its soft landing and subsequent reuse, similar to the first WS of the Falcon-9 LV.

P3. Ideal option - the fall of the WS with almost "dry" fuel tanks and fuel lines with a minimum deviation from the projected point of fall of the WS, located in the R-neighborhood from the energy-optimal point of fall of the WS.

Implementation of this concept involves:

1. The presence in the information and analytical system of IAS_{ia}, which is the part of the general IAS of the cosmodrome IAS_{cd} [13, 14], information on the ecological consequences of the WSfall to the initial predicted point of fall selected by the developer and operator of the launch vehicle, including:

a) meteorological conditions in the neighborhood of point of fall,

b) prediction of the possibility of vegetation fire taking into account climatic and meteorological conditions,

c) the spread of the vapor cloud of the fuel component,

d) alternative points of fall of the WS with the corresponding characteristics, etc. the above information must be generated

This information from the IAS_{ia} is necessary to make a decision by the LV developer for the purpose of developing technologies, schematic and design and construction solutionsfor improving the ecological safety of the LV in the impact area.

2. The presence in the IAS_{ia}information and analytical system, which is the part of the overall system for the design and exploitation of LV, the following information:

a) the possibility of changing the predicted coordinates of the point of fall of WSto the other recommended points in the impact area, where the ecological consequences due to the characteristics of the impact area [15, 16] will be significantly less;

b) options for changing the coordinates of the points of fall of the WS, for example, by changing the pitch program, yawing on the active section of the LVlaunching phase, [17] or by an additional autonomous on-board descent system (ABDS) installed on the WS [18], to implement the WS maneuver into other possible points of fall in the same designated impact area, but with more acceptable characteristics;

c) use of the energy optimal pitch program and the corresponding predicted optimal point of fall of the WS, while this point of fall must be in the R-neighborhood from the energy-optimal point of fall of the WS; The R-neighborhood is determined by the energy capabilities of the ABDS, the time of passive WS flight from the moment of separation from the LV to the moment of contact of the surface of the impact area.

In addition to the information received from the IAS_{ia}, which is necessary to improve the ecological safety of LV, the IAS_{lv}works on:

a) minimization of fuel residues in tanks after cutting-off of the main liquid propulsion engine;

b) assessment of the ABDS ballistic capabilities for the WS maneuvering on the trajectory of descent;

c) estimation of the possible spillages of residual fuel components from collapsed fuel tanks and WS lines in the predicted WS point of fall;

d) probability estimation of the WS explosion and the expected zone of fragment dispersion, etc.

1 Statement of the research problem

In accordance with the above analysis and the formulated concept, the general problem of improving the ecological safety of the LV with mainLPE can be decomposed into three interrelated sub problems:

- development of IAS_{ia} as a component of the IAS_{cd}, determination of a list of additional tasks, mathematical models and software products that implement them;

- development of IAS_{lv}^{es}, as an integral part of the IAS_{ia} of the existing system of design and operation of LV, determination of a list of additional tasks, technologies, schemes and design solutions aimed at improving the ecological safety of LV;

- determination of the optimal interaction, information flows between the IAS_{ia} andIAS_{lv}^{es}, the criterion of optimality and boundary conditions.

2 Development of IAS_{ia}

The system of ecological monitoring of Baikonur Cosmodrome (SEMC) conceptually includes three main systems: the information-analytical system, the geo-information system and the monitoring system.

A number of works have been devoted to various aspects of the construction of such systems, for example, [14-16], in which the system of ecological monitoring of the Baikonur Cosmodrome was considered as part of the overall monitoring system, which it was possible to distinguish the component of the technogenic impact of the rocket and space activities on the environment. Figure 1 shows the general structure of the ecological monitoring of the Baikonur cosmodrome.

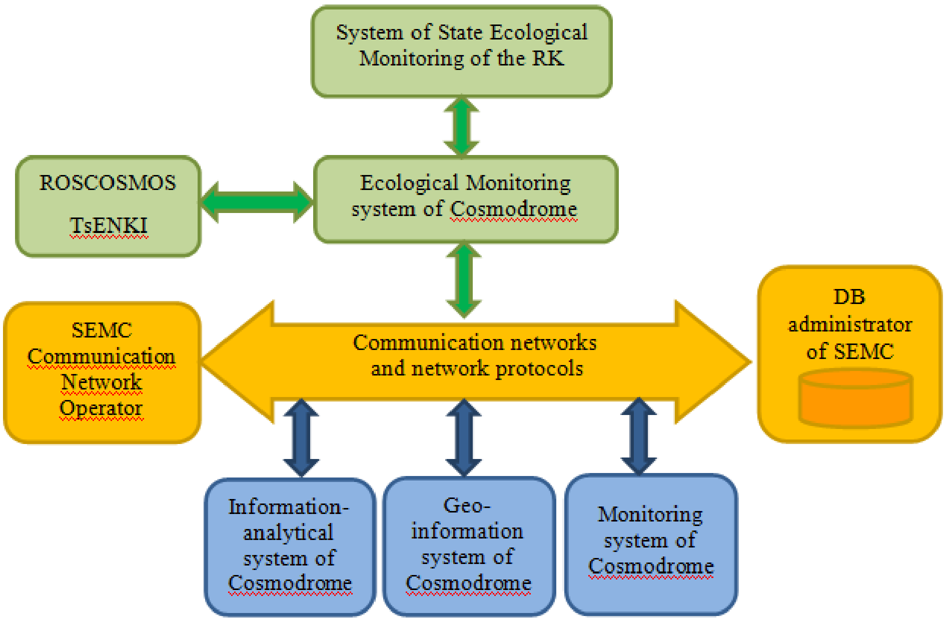

Figure 1 - System of ecological monitoring of Baikonur cosmodrome activity

The proposed approach is based on the separation of the IAS_{cd} functions into two parts: the basic IAS_{cdb} and IAS_{ia}.

The task of the IAS_{cdb} includes traditional assessments of the ecological monitoring of the Baikonur cosmodrome, based on obtaining information from the materials of the ecologicalcertification of the impact areas of the WS in accordance with the passport of the IA [15, 16, 19]. Theseassessmentsinclude:

- general information about the enterprise responsible for the operation of the IA;
- general information about the impact area of the WS and adjacent territories;
- characteristics of natural and climatic conditions in the impact area territory;
- information on economic activities in the impact area and in adjacent territories;
- characteristics of pollution sources of the IA, etc .;
- Calculation of ecological damage $E_i\,[\vec{R}_i(x_i, y_i)]$ and the cost of restoration work $C_i^{rw}[\vec{R}_i(x_i, y_i)]$ for each launch.

The task of IAS_{ia} includes:

a) from the received data on the upcoming LV launch from the IAS_{lv} (the initial aiming point of the WS fall in the assigned IA $\vec{R}^{in}_{aim}(x_i, y_i)$, the optimal aiming point at which the payload mass inserted to the specified orbit is maximal, dividing the area of the IA by N sections with Si areas (i = 1, ... N), so that $\sum_{i=1}^{N} S_i = S_\Sigma$;

b) in the chosen N areas, N possible predictable coordinates of the points of fall of the WS are selected;

c) distances $\Delta\vec{R}_i = \vec{R}_{opt}(x, y) - \vec{R}_{pr}(x_i, y_i)$ are estimated for assessing the possibility of WS maneuvering by shifting the point of fall of the WS to these values and transmitted to the IAS_{lv};

d) on the basis of the passport of this IA, the ecological damage $E_i\,[\vec{R}_i(x_i, y_i)]$ from falling into this i-th section and, accordingly, the cost of restoration works, is calculatedthe each predicted point of fall $\vec{R}_i(x_i, y_i)$;

d) the received information is transmitted to the IAS_{lv} for the calculation of the LV movement control programs in the active section of the launch trajectory and the WS control programs in the descent section to the selected point, which is determined from the analysis of the data array $\{C_i^{sa}[\vec{R}_i(x_i, y_i)]\}$, the estimation of the ballistic capabilities of the ABDS for maneuvering by changing the coordinates of the point of the fall by a $\Delta\vec{R}_i = \vec{R}_{opt}(x, y) - \vec{R}_{pr}(x_i, y_i)$ value.

In Fig. 2, as an example, the impact area for the Proton LV is given.

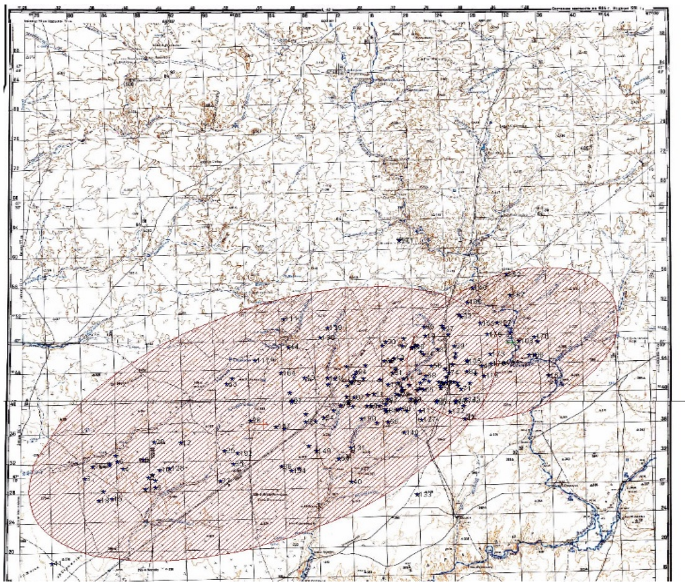

Figure 2 - The impact area for the "Proton" LV

As follows from Fig. 2, it is possible to ensure the fall of the WS into areas with significantly different landscape conditions. At the same time, it is assumed that an ABDS is installed on the WS, which provides control of the WS movement on the descent trajectory. As a result of this control, the accuracy of the WS fall is similar to the landing accuracy of the Falcon-9 LV WS when landing at a cosmodrome or a floating barge.

3 IAS_{lv}^{es} development

IAS_{lv}^{es} is an element of the existing IAS_{lv}, which includes information and analytical models of the LV, starting with the stage of formation of tactical and technical and technical tasks, including the choice of design and construction parameters for LV, design and construction, technological, production documentation including for testing at all stages of fabrication of the material part in the manufacturer), operational documentation (for work on the technical and launch complexes of LV), network schedules of the work plan for the various phases of the LVlife cycle.

As noted above, the life cycle and, accordingly, the technological,schematic and design and construction solutionsfor LV, equipment for LV testing and checking are oriented to complete the cycle with a command to cut off the main LPE after achieving specified movement parameters and the payloadseparation. Further operation of the WS is a different kind of risks: explosion in theorbit, collision with other orbital objects before fires and pollution by WS fragments in the impact areas [1-3, 19].

IAS_{lv}^{es} development within the framework of the concept of improving the ecological safety of LV with main LPE in the impact areas of the WS provides for the use of information from the IAS_{ia} in several areas:

a) to change the program for controlling the movement of the launch vehicle at the launchingphase (changing the points of aiming for the WS fall: the optimum point, an acceptable point from the condition of minimizing ecological damage, which is achieved by the adjusting the existing techniques for calculating LV launch programs);

b) to develop control of the WS movement with the ABDSuse while moving along the trajectory of descent to the selected point on the territory of the WS impact area;

c) for the ABDS creation, which requires to complete a full cycle of its development with the assessment of the impact of the ABDS inclusion in the LV onboard equipment on the tactical and technical characteristics, reliability, operational properties and LV functioning;

d) determination of the ballistic capabilities of the ABDS for the displacement implementation of the coordinates of the WS point of fall by the value $\Delta\vec{R}_i = \vec{R}_{opt}(x, y) - \vec{R}_{pr}(x_i, y_i)$.

If the first two items a), b) are realizable within the existing IAS_{lv}, then the implementation of positions c), d) will require certain costs and time for the ABDScreation.

It is assumed that the ABDS development and its installation on Russian LV, in accordance with the proposed concept is objectively necessary, since the existing concept of design and operation of Russian LV with LPE does not satisfy a number of modern requirements. This follows from the analysis of the development of the trend of world rocket construction [1-10], in particular, the continuous increase in the requirements for environmental safety by both international and Russian legislation, increasing competition in the market of launch vehicles [1-10].

In accordance with the formulated concept of improving the ecological safety of LV with the main LPE [10, 11, 20, 22], it is proposed to develop an additional ABDS, which is assigned the main part to ensure the specified indicators for the ecological safety of LV in the WS impact area:

- extraction of unused fuel residues in tanks and WS lines after cutting off the main LPE on the WS trajectory of descending based on the technology of their transfer from the gas-liquid phase to the gas-vapor mixture [20];
- use of energy resources in the recovered vapor-gas mixture from fuel tanks to solve the problem of controlled descent of the WS [17, 18];
- development of algorithms for controlling the gas-reactive system, ensuring the WS descent at the specified point in the impact area from the condition of minimum costs for compensation of environmental damage $\{C_i^{sa}[\vec{R}_i(x_i, y_i)]\}$.

4 Interaction of IAS_{cd} and IAS_{lv}

The interaction between IAS_{cd} and IAS_{lv}, like any information exchange between complex technical systems, has an iterative character, which can be divided into several stages and levels, both with the readiness of each of the IAS and the current tasks to be solved by each IAS.

1. At the current level, the primary task is to create an IAS_{ia} and to create a database for each impact area of the most acceptable WS points of fall from the condition min min$\{C_i^{sa}[\vec{R}_i(x_i, y_i)]$.

2. Stages of interaction IAS will be determined by the creation terms of both mathematical models, software products, and material systems that implement them, in particular, the IAS_{ia} database, the degree of readiness of the ABDS.

3. The received information is necessary for conducting research within the framework of the IAS_{lv},IAS_{lv}^{es} for the following purposes:

a) the synthesis of various programs for the LV movement control in the launching phase, without taking into account the limitations on the WS impact areas (calculation $\vec{R}_{opt}(x, y)$);

b) an estimate of the distance $\Delta\vec{R}$ between $\vec{R}_{opt}(x, y)$ and the recommended WS points of fall, obtained in the IAS_{ia}, from the condition min $\{C_i^{sa}[\vec{R}_i(x_i, y_i)]\}$;

c) development of proposals for changing the design and construction parameters of the WS for the maneuver implementation on the trajectory of descent.

4. The hierarchy of each IAS, the levels of interaction of the IAS_{ia} and IAS_{lv}

In Fig. 3 shows a general schematic diagram of information flows between the IAS_{ia} and IAS_{lv}

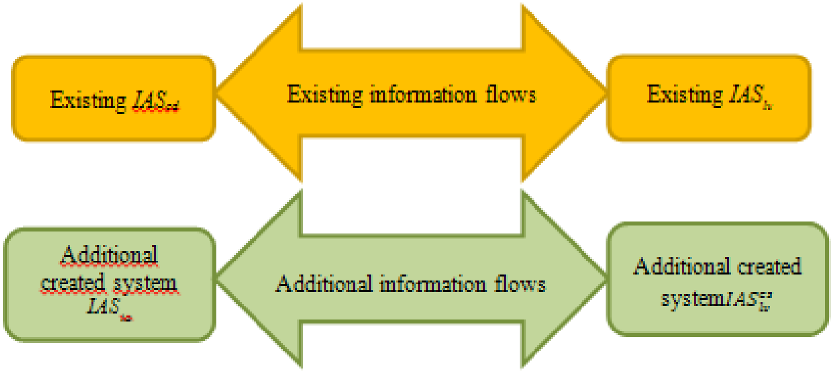

Figure 3 - The general schematic diagram of information flows between IAS_{cd}, IAS_{lv}, IAS_{ia},IAS_{lv}^{es}

Realization of the presented concept of increasing the ecological safety of the launch vehicle with the main LPE will significantly reduce the ecological load on the environment in the impact areas of the Baikonur cosmodrome due to a drastic reduction in the areas of impact areas (controlled descent of the WS), a significant reduction in the probability of vegetation fires (due to the almost complete recovery of liquid residues fuel), the choice of the safest (from the ecological point of view) points of the WS fall on the territory of the designated impact area. The volumes and costs of the IAS_{ia},IAS_{lv}^{es}creation will be determined at the next stages of the research.

5 Conclusions

1 The analysis of modern tendencies of increase of ecological safety of LV with LPE is carried out. The main factors affecting the level of environmental damage in the impact area of of the WS are given.

2 The concept of reducing the technogenic impact in the impact areas of the Baikonur Cosmodrome for non-reusable non-escaped WS is formulated, based on the operational recommendations of the IAS_{ia} to the IAS_{lv}, the composition of the information for exchange between the IAS_{ia} and IAS_{lv} is determined.

3 Proposals have been developed for the development of the design methodology for IAS_{ia} to assess the technogenic impact of LV launching on the selected fall area integrated into the general information analytic system of the Baikonur cosmodrome.

4 Proposals for theIAS_{lv} creation to improve the ecological safety of LV with main LPE in the impact areas are developed on the basis of upgrading the control programs for LV launches at the active phase of the launch trajectory, the programs for controlling the movement of the WS at the atmospheric portion of the descent trajectory, and the use of ABDS.

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Б.Т. Суйменбаев[1], В.И. Трушляков[2], Г.Т. Ермолдина[1], Ж.Б. Суйменбаева[1], А.М. Бапышев[1]

[1]Институт информационных и вычислительных технологии, Алматы, Казахстан
[2] Омский государственный технический университет, Омск, Россия

РАЗРАБОТКА БИЗНЕС-ПРОЦЕССА ИНФОРМАЦИОННО-АНАЛИТИЧЕСКИХ СИСТЕМ КОСМОДРОМА БАЙКОНУР И ПРОЕКТИРОВАНИЯ РАКЕТЫ-НОСИТЕЛЯ ДЛЯ ПОВЫШЕНИЯ ЭКОЛОГИЧЕСКОЙ БЕЗОПАСНОСТИ В РАЙОНАХ ПАДЕНИЯ ОТРАБОТАВШИХ СТУПЕНЕЙ

Аннотация. Проведён анализ существующих информационно-аналитических системы (ИАС) космодрома Байконур ИАСкд и проектирования ракет-носителей (РН) ИАСрн. Показаны основные источники возникновения техногенного воздействия пусков РН с маршевыми ЖРД в районах падения отработавших ступеней (ОС). Предложена концепция модернизации существующих ИАСкд и ИАСрн, обеспечивающая снижение техногенного воздействия для одноразовых неспасаемых ОС, основанная на оперативных рекомендациях создаваемых ИАСрп и по обеспечению пожаровзрывобезопасности ОС, снижения размеров площади падения ОС, возможности манёвра ОС для изменения района падения.Разработаны предложения по модернизации существующей ИАСкд и концепции проектирования одноразовых РН, исходя из условий повышения экологической безопасности.

Ключевые слова:техногенное воздействие, районы падения, информационная аналитическая система, отработавшая ступень ракеты-носителя, компоненты ракетного топлива

Б.Т. Сүйменбаев[1], В.И. Трушляков[2], Г.Т. Ермолдина[1], Ж.Б. Сүйменбаева[1], А.М. Бапышев[1]

[1]Ақпараттық және есептеу технологиялар институты, Алматы, Қазақстан
[2] Омбымемлекеттік техникалық университеті, Омбы, Ресей

«БАЙҚОҢЫР» ҒАРЫШ АЙЛАҒЫНЫҢ АҚПАРАТТЫҚ-ТАЛДАУ ЖҮЙЕЛЕРІ ҮШІН БИЗНЕС-ҮДЕРІСТІ ДАМЫТУ ЖӘНЕ ҚҰЛАУ АЙМАҚТАРДА ӨТЕЛГЕН САТЫЛАРДЫҢ ЭКОЛОГИЯЛЫҚ ҚАУІПСІЗДІКТІ ЖАҚСАРТУ ҮШІН ЗЫМЫРАН ТАСЫМАЛДАУШЫЛАРДЫ ЖОБАЛАУ

Аннотация. Байқоңыр ғарыш айлағының қазіргі заманғы ақпараттық-талдау жүйелерін (АТЖ) және $АТЖ_{га}$ ұшыру аппараттарын жобалауды талдау жүргізілді. Зымыран қозғалтқыштары бар ұшыру аппараттарының өтелген сатылардағы (ӨТ) антропогендік әсерінің негізгі көздері көрсетілген. АТЖ-мен жасалған жедел ұсыныстарды негізге ала отырып, ОС-ның өрт және жарылыс қауіпсіздігін қамтамасыз ету, ОҚ-ның құлау аймағының көлемін азайту, құлау аймағын өзгерту үшін ӨС-ты маневр жасау, бір реттік қауіпсіздіктегі ӨС-ға антропогендік әсерін төмендетуді қамтамасыз ететін қолданыстағы $АТЖ_{га}$ және $АТЖ_{зт}$ жаңғырту тұжырымдамасы. Қолданыстағы $АТЖ_{га}$ жаңғырту және экологиялық қауіпсіздікті жетілдіруге негізделген бір реттік бірліктерді жобалау тұжырымдамасы бойынша ұсыныстар әзірленді.

Түйін сөздер: технологендік әсерлер, құлау аймағы, ақпараттық-талдау жүйесі, зымыран тасымалдау-шының өтелген сатысы, зымырандық отын компоненттері

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A.T.Assanova[1], A.A.Boichuk[2] , Z.S.Tokmurzin[3]

[1] Institute of Mathematics and Mathematical Modeling, Almaty, Kazakhstan;
[2] Institute of Mathematics NAS Ukraine, Kyiv, Ukraine;
[3] K.Zhubanov Aktobe Regional State University, Aktobe, Kazakhstan
assanova@math.kz; boichuk.aa@gmail.com; tokmurzinzh@gmail.com;

ON THE INITIAL-BOUNDARY VALUE PROBLEM FOR SYSTEM OF THE PARTIAL DIFFERENTIAL EQUATIONS OF FOURTH ORDER

Abstract. A initial-boundary value problem for system of the partial differential equations of fourth order is considered. We study the existence of classical solutions to the initial-boundary value problem for system of the partial differential equations of fourth order and offer the methods for finding its approximate solutions. Sufficient conditions for the existence and uniqueness of a classical solution to the initial-boundary value problem for system of the partial differential equations of fourth order are set. By introducing of a new unknown functions, we reduce the considered problem to an equivalent problem consisting of a nonlocal problem for the system of hyperbolic equations of second order with functional parameters and the integral relations. We offer the algorithm for finding an approximate solution to the investigated problem and prove its convergence. Sufficient conditions for the existence of unique solution to the equivalent problem with parameters are established. Conditions of unique solvability to the initial-boundary value problem for system of the partial differential equations of fourth order are obtained in the terms of initial data. Separately, the result is given for the initial-periodic in time boundary value problem.

Keywords: system of the partial differential equations of fourth order, initial-boundary value problem, nonlocal problem, system of the hyperbolic equations of second order, solvability, algorithm.

1. Introduction. Currently, the problems of mathematical physics connected with the description of wave motion of liquids of different nature are drawn by great attention. This interest is caused not only by big applied importance of these problems, but their new theoretical and mathematical content often do not have analogues in the classical mathematical physics. One of the important classes of such problems are the initial-boundary value problems for fourth order partial differential equations. To date, various methods for researching and solving the initial-boundary value problems for fourth order partial differential equations of hyperbolic and composite types are developed in [1-12]. In order to investigate various boundary value problems for fourth order partial differential equations along with the classical methods of mathematical physics (the Fourier method, the method of Green's functions, Poincare's metric concept) we apply the method of differential inequalities and other methods of qualitative theory of ordinary differential equations. Based on them, the conditions for solvability of considered boundary value problems are obtained, and the ways for finding their solutions are offered. Fourth order system of partial differential equations began to be studied relatively recently.

In the present work we consider system of the partial differential equations of fourth order at the rectangular domain. Boundary condition for time variable are specified as a combination of values from the partial derivatives of required solution on third orders by spatial variable. We investigate the questions of existence and uniqueness of the classical solution to initial-boundary value problem for system of the partial differential equations of fourth order and its applications.

2. Methods. For solve to considered problem we use a method of introduction additional functional parameters [13-29]. The original problem is reduced to an equivalent problem consisting of nonlocal problem for system of the hyperbolic equations of second order with functional parameters and integral relations. Sufficient conditions for the unique solvability to investigated problem are established in the terms of initial data. Algorithms for finding solution to the equivalent problem are constructed. Conditions of unique solvability to initial-boundary value problem for system of partial differential equations of fourth order are established in the terms of system's coefficients and boundary matrices. Separately, the result is given for the initial-periodic in time boundary value problem.

Note that, in [30, 31] a similar approach has been applied to the initial-boundary value problem and nonlocal problem for the system of partial differential equations of third order.

2. Statement of problem. At the domain $\Omega=[0,T]\times[0,\omega]$ we consider the initial-periodic boundary value problem for system of the partial differential equations of fourth order in the following form

$$\frac{\partial^4 u}{\partial t\partial x^3}=A_1(t,x)\frac{\partial^3 u}{\partial x^3}+A_2(t,x)\frac{\partial^3 u}{\partial t\partial x^2}+A_3(t,x)\frac{\partial^2 u}{\partial x^2}+A_4(t,x)\frac{\partial^2 u}{\partial t\partial x}+A_5(t,x)\frac{\partial u}{\partial x}+$$

$$+A_6(t,x)\frac{\partial u}{\partial t}+A_7(t,x)u+f(t,x), \qquad (t,x)\in\Omega, \tag{1}$$

$$\frac{\partial^3 u(0,x)}{\partial x^3}=K(x)\frac{\partial^3 u(T,x)}{\partial x^3}+\varphi(x), \qquad x\in[0,\omega], \tag{2}$$

$$u(t,0)=\psi_0(t), \qquad t\in[0,T], \tag{3}$$

$$\frac{\partial u(t,x)}{\partial x}\Big|_{x=0}=\psi_1(t), \qquad t\in[0,T], \tag{4}$$

$$\frac{\partial^2 u(t,x)}{\partial x^2}\Big|_{x=0}=\psi_2(t), \qquad t\in[0,T], \tag{5}$$

where $u(t,x)=col(u_1(t,x),u_2(t,x),...,u_n(t,x))$ is unknown function, the $n\times n$-matrices $A_i(t,x)$, $i=\overline{1,7}$, and n-vector function $f(t,x)$ are continuous on Ω, the $n\times n$-matrix $K(x)$ and n-vector-function $\varphi(x)$ are continuous on $[0,\omega]$, the n-vector-functions $\psi_0(t)$, $\psi_1(t)$ and $\psi_2(t)$ are continuously differentiable on $[0,T]$. The initial data satisfy the condition of approval.

A function $u(t,x)\in C(\Omega,R^n)$ having partial derivatives $\frac{\partial u(t,x)}{\partial x}\in C(\Omega,R^n)$, $\frac{\partial u(t,x)}{\partial t}\in C(\Omega,R^n)$, $\frac{\partial^2 u(t,x)}{\partial x^2}\in C(\Omega,R^n)$, $\frac{\partial^2 u(t,x)}{\partial t\partial x}\in C(\Omega,R^n)$, $\frac{\partial^3 u(t,x)}{\partial x^3}\in C(\Omega,R^n)$, $\frac{\partial^3 u(t,x)}{\partial t\partial x^2}\in C(\Omega,R^n)$, $\frac{\partial^4 u(t,x)}{\partial t\partial x^3}\in C(\Omega,R^n)$, is called a classical solution to problem (1)--(5) if it satisfies system (1) for all $(t,x)\in\Omega$, and boundary conditions (2)--(5).

We will investigate the questions of existence and uniqueness of the classical solutions to the initial-boundary value problem for system of the partial differential equations of fourth order (1)--(5) and the approaches of constructing its approximate solutions. For this goals, we applied the method of introduction additional functional parameters proposed in [13-31] for solving of various nonlocal problems for systems of hyperbolic equations with mixed derivatives. Considered problem is provided to nonlocal problem for the system of hyperbolic equations of second order including additional functions and integral relation. The algorithm for finding the approximate solution of the investigated problem is proposed and its convergence proved. Sufficient conditions of the existence unique classical solution to problem (1)--(5) are obtained in the terms of initial data.

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