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The Methodology of Variable Management of Propellant Fuel Consumption by Jet-Propulsion Engines of a Spacecraft

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Abstract—Traditionally, management of propellant fuel consumption on board of a spacecraft is only associated with the operation of jet-propulsion engines (JPE) that are actuator devices of motion control systems (MCS). The efficiency of propellant fuel consumption depends not only on the operation of the MCS, but also, to one extent or another, on all systems functioning on board of a spacecraft, and on processes that occur in them and involve conversion of variable management of propellant fuel consumption by JPEs as a constituent part of the control of the complex process of spacecraft flight.

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When considering the problems of the efficient propellant fuel consumption by jet-propulsion engines (JPE) on board of a spacecraft, there are to be solved ballistic problems on minimization of the value of the characteristic velocity that provides execution of the program of spacecraft flight in the process of controlling the motion of the center of mass of a spacecraft. Propellant fuel consumption for controlling the motion about the center of mass of the spacecraft is optimized. Control of the processes is carried out by means of the motion control system (MCS). When it happens, the processes that occur in other systems of the spacecraft are considered from the standpoint of propellant fuel consumption merely as processes that provide an attainment of rated parameters of the JPEs.

Propellant fuel consumption depends on all systems operating on board of the spacecraft and on the processes that occur in these systems, and involve conversion of various kinds of energy, with this dependence becoming manifested for both operative and inoperative JPEs. Using the flight of the Yamal geosynchronous spacecraft as an example, it will be shown that, to a certain degree, propellant fuel consumption depends on the processes which occur in electric power supply systems, thermal control systems, systems of solar array orientation, on-board computing systems, on-board equipment control systems, etc.

During flight of the Yamal spacecraft management of propellant fuel consumption by JPEs was considered an integral part of the continuous complex process of flight control of the spacecraft. In this case the term "fuel consumption management" represents not only a reduction in the propellant mass on board the spacecraft, but also prevention of propellant mass consumption, i.e., "consumption-free motion control" when solving the same goal-oriented tasks of a spacecraft flight.

The variability of the complex process of motion control of the spacecraft gave rise to the emergence of variants (variability) of efficient management of propellant fuel consumption by means of energy conversion in a single energy cluster involving on-board and external forms of energy [1] of the spacecraft, while its systems were regarded as regulators of the occurring processes.

Prior to ignition of the JPEs, consumption-free motion control of the spacecraft and the control that provided retention of propellant fuel in reservoirs filled by it, were carried out (propellant leak prevention). In addition, before ignition of JPEs, management of propulsion fuel consumption was aimed at the preparation of initial conditions of the process of flight control of the spacecraft that provides the efficient operation of the JPEs. During the operation of the latter, control of processes occurring inside the engines and in engine control systems, was carried out. Concurrently the problem of creating initial conditions with respect to the sum vector of the angular momentum of the spacecraft at the end of maneuvers for the subsequent consumption-free control of spacecraft flight while maintaining the predetermined orientation was being solved.

The methodology of the variable management of propellant consumption by JPEs is the single complex of common principles and methods, terminology, indicators, and criteria of estimations of results that are used for different variants of managing propellant fuel consumption with due regard for the current state of the complex process of flight control and choosing a variant that would provide attainment of prearranged current goals of the flight with the highest possible efficiency with respect to propellant fuel consumption. Minimization of propellant fuel consumption when executing the program of spacecraft flight is the single indicator of the maximum efficiency as to the selected