Abstract of the MSc Thesis by Mr. Maksim Trifonov

Statistical analysis of launch vehicle motion at the max-q flight part taking into account random atmospheric disturbances

The attitude control system of angular motion of the launch vehicle (LV) is the subject of study in this work. The problem of the statistical analysis of a vehicle angular motion of the LV taking into account a horizontal wind as a correlated in altitude random function is solved in the work. The second order shaping filter is used for the wind description as a correlated random function of the vehicle flight altitude. Statistical characteristics of this process have to be taken into account in the analysis of normal accelerations experienced by the LV during its flight in windy atmosphere, both at the structural design of a new LV or during modification of existing LV.

Purpose is to develop technique of the statistical analysis of controlled motion of the 1st stage LV in presence disturbances due to horizontal wind in an atmosphere with the use of moments equation method.
The technique provides calculation of statistical performance indicators of stabilization system by use the moments equation method. To simply the method it is necessary to obtain the differential equations for the augmented state vector describing angular motion of LV in Cauchy's normal form. Augmented state vector also includes two variables of the second-order shaping filter describing the wind as a random process. The mean vector and covariance matrix of the augmented state vector are estimated by integration of quasi-linear ordinary differential equations for these characteristics.
Statistical characteristics of all state variables of the attitude control system, as well as characteristics of output of interest and variance range, are results of calculations. The proposed technique is implemented in a calculation program development in Matlab&Simulink environment.
Statistical characteristics of output of interest -normal acceleration and all component of a state vector of LV are obtained as the results of calculations. The results obtained with the use of proposed techniques are compared with the similar results calculated by the Monte-Carlo simulation and the approximate «enveloping» methods.

It is shown that the methods of equation moments and Monte-Carlo give similar results, although the Monte-Carlo method is significantly more computing time-consuming. Easy for implementation method of «envelops» can lead to receiving the underestimated estimates of possible values of normal accelerations of LV.
Relevance of the work is determined by the dynamic development of space research, which require creation of various satellites, which differ both in weight- dimension characteristic and design-layout scheme. In addition, a number of space research projects requires a simultaneous insertion into orbits of several spacecrafts that places specific requirements to design of head part of LV, in particular, leads to the use of large head fairing (nose cone). It is known that the normal g-force experienced by LV increases with the increasing of fairing volume of a nose cone. In that case it is necessary to take into account all the disturbing factors as accurately as possible, and the major disturbing factor for the 1st stage of LV is the wind.