

ANALYSIS OF THE OPERATION OF THE CONTROL JET ENGINES OF THE CYCLONE-4M LAUNCH VEHICLE UPPER STAGE AT SUSTAINER ENGINE STARTUPS AND SHUTDOWNS

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The aim of this work is to study the effect of disturbances from startups and shutdowns of a restartable sustainer engine on the operation of control jet engines in their continuous and pulse operation with account for the integration of the engine feed lines. Abandoning the traditional feed of control engines from individual tanks increases the payload mass by eliminating the need for a gas displacement system and offers a more complete use of the onboard propellant. The main objectives of the system of control engines as actuators of the launch vehicle upper stage flight control system are roll, pitch, and yaw control in different operating regimes of the sustainer engine, the acceleration of the stage before sustainer engine restarts, and the removal of the stage to an utilization orbit with remaining propellant burn-up. Because the feed lines of the sustainer engine and the control engines are hydraulically connected, at sustainer engine startups/shutdowns the propellant component pressure at the control engine inlets is subject to disturbances in the form of surges and dips, in response to which the rocket stage flight control system must generate additional control actions. The control engine operation under disturbances from the sustainer engine was studied using the authors' comprehensive mathematical model, which describes the propellant component flow in the feed lines, electrically operated fuel valves, and combustion chambers of control engines, and the time profiles of disturbances recorded in full-scale ground tests of the Cyclon-4M launch vehicle upper stage. Calculations were conducted for the most strenuous combinations of the control engine operation under disturbances from sustainer engine startups and shutdowns. The calculated data show that the control engine thrust is within the limits specified in the requirements specification for the development of the control engines as a part of the liquid-propellant jet system.

Keywords: *sustainer engine, control engine, feed system, comprehensive mathematical model, pressure disturbances, thrust, calculated data.*

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