

# ARRANGEMENT AND RESULTS OF THE PHOBOS-GRUNT EMERGENCY FLIGHT MONITORING AND ITS RE-ENTRY IMPACT WINDOW ESTIMATION IN RUSSIAN MISSION CONTROL CENTER

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As a result of a failure of a mid-flight engine which should have inserted the Phobos-Grunt in an interplanetary trajectory flight to Mars this spacecraft (SC) was left in a reference low earth orbit where it was put on the night 09.11.2011 by the launch vehicle «Zenith-2SB41».

Despite all attempts to restore functionality of the Phobos-Grunt, it remained to be an uncontrollable object which orbit constantly lowered due to perturbing forces, and after a while this SC had to re-enter. Having a total weight (together with fuel) ~ 13.5 tons, the Phobos-Grunt could create a real risk situation at destruction in the dense layers of atmosphere and falling of its survived fragments to the Earth. Whereas the SC could theoretically deorbit over any point of the Earth' surface in a range of latitudes  $\pm 51.4^\circ$ , the forthcoming re-entry event of this space vehicle drew a wide response all over the world.

For implementation of more accurate operative maintenance of the Phobos-Grunt flight and its de-orbit monitoring the special operative group (OG) was formed by Roscosmos. The flight dynamics experts from the Mission Control Center of the Central Research Institute of Machine Building (TsUP TsNIImash in Russian abbreviation) constituted the backbone of this OG. The designers of the Phobos-Grunt and the other experts from different organizations competent of problems of a SC flight control were involved in the activity of OG as well. The procedure of the operations' sequence and informing of the interested state structures on SC flight conditions and a predicted of its re-entry impact window were determined.

At the same time the Inter-Agency Space Debris Coordination Committee (IADC) initiated carrying out the international test campaign for the control of the Phobos-Grunt re-entry (IADC test campaign 2012\1).

The Russian Mission Control Center (TsUP TsNIImash) on behalf of Roscosmos always actively participated in similar international experiments on the re-entering space objects. In this case the capability of joint efforts both Roscosmos and other space agencies was used at the solution of a problem of the Phobos-Grunt re-entry prediction.

In the paper the results of activities on navigation and information maintenance of the Phobos-Grunt flight and its re-entry prediction executed by the Russian TsUP experts within the framework of the Roscosmos OG as well as within the framework of the IADC test campaign are presented. The information on the arrangement, the procedure of carrying out this work, software and methodology (including models of SC motion, models of atmosphere, methods of trajectories propagation, orbit determination parameters, etc.) used at the solution of considered problems are given. The results of the Phobos-Grunt orbit determination (OD) and the re-entry parameters (time and location coordinates) prediction obtained during its flight are outlined.

To estimate the most probable time and impact area of the Phobos-Grunt re-entry a special post-flight analysis on the basis of realization of a considerable quantity of the Phobos-Grunt OD variants at using of different types of data representing various tracking sensors and different atmospheric models was fulfilled in TsUP. The final results of the estimation of a possible impact area of the Phobos-Grunt obtained in TsUP TsNIImash as well as the results of other participants of the IADC test campaign 2012/1 allowing to compare them to each other are represented.