

# EXPERIENCE OF THE RUSSIAN SPECIALISTS IN THE AREA OF SPACE DEBRIS MITIGATION. FLIGHT DYNAMIC'S ASPECTS OF THE COMMUNICATION SATELLITE EXPRESS-AM4 FLIGHT TERMINATION FROM OFF-NOMINAL ORBIT

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Questions of organized termination of “Express-AM4” spacecraft’s flight are considered. The spacecraft was launched in order to provide a telecommunication service at geostationary orbit (at the point 80° east latitude).

As a result of off-nominal functioning of reboot block “Breeze-M” the spacecraft remained at orbit with the following parameters: inclination 51.1°, maximum altitude 20400 km, minimum altitude 650 km. At this orbit the spacecraft was in flight mode “injection to geostationary orbit”, onboard control system worked nominally, fuel amount of apogee engine was about 2800 kg.

In this case the spacecraft should be a “risk object” for a lot of functioning spacecraft: navigational satellites GPS and GLONASS at altitude 19000÷20000 km, satellites of various purposes at altitude 700÷6000 km. It was declared, that “Express-AM4” couldn’t be used as a telecommunication satellite at geostationary orbit. Specialists of EADS Astrium predicted, that onboard control system in this off-nominal situation could work nominally not longer than to the middle of 2012 year.

So, the task of organized flight’s termination was formulated. The task was very complicated due to a lot of features of onboard control system in given flight mode and limitations for ground control segment. Mission control center of TSNIMASH (Korolev, Moscow region, Russia) was asked to perform a flight dynamic’s investigations for selection of flight termination’s scenario and to be as a back-up ballistic center. It was a decision of ROSKOSMOS.

As possible variants of organized termination of the flight were considered:

- deorbitation and splash down of structure elements in ocean (favorable variant);
- transfer to so called “safe” orbit, where the spacecraft could be as a “risk object” for minimum amount of spacecraft.

During project-ballistic investigations various scenarios of flight termination were considered. Features of onboard control system and the apogee engine’s fuel amount were taken into account. The possibility of monoimpulse deorbitation was shown. The scenario of spacecraft’s transfer to “safe” orbit with complete fuel amount termination was proposed. The analysis of “safe” orbit parameters’ evolution for long time interval (100 years) was performed, stability of selected orbit taking into account lunar-solar disturbances was shown.

The recommendations obtained in MCC were taken into account for realization of spacecraft flight’s termination procedure.

The deorbitation of the spacecraft with splash down of structure’s elements in northern part of Pacific ocean was successfully performed on the 25<sup>th</sup> of March 2012 year. The specialists of Russian Mission control center provided a complex checking and verification of command information for deorbit manoeuvre prepared by EADS Astrium. Also estimation of the splash down zonecenter’s coordinates using tracking data after nominal deorbit manoeuvre was performed.

As a result of the work is the fact that the spacecraft’s splash down took place at nominal zone. So, organized flight termination provided the decreasing of debris in the near-Earth space.