

# **COMMERCIAL OPERATIONS OF THE ROCKOT LAUNCH VEHICLE FOR SMALL AND MEDIUM PAYLOADS INTO LOW EARTH ORBIT**

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## **HISTORY/LV DESIGN**

ROCKOT, is a three stage all liquid fuelled vehicle with proven heritage. The SS-19 ICBM, which provides ROCKOT's first two stages, has been flight-proven more than 140 times, without a failure in the last 16 years and over 80 flights. Additionally the three stage version ROCKOT with the BREEZE stage has a 100% record with 4 flights to its credit.

The ROCKOT vehicle is marketed to the LEO satellite industry by EUROCKOT Launch Services GmbH, Germany which is jointly owned by Astrium GmbH, Germany, and Khrunichev State Research and Production Space Center, Russia. EUROCKOT offers commercial launch services to LEO from 48° up to SSO by offering two launch sites, Plesetsk and Baikonur. Inclined GTO and earth escape missions can also be served with an additional commercial solid stage.

To maintain this impressive capability and to provide world class commercial launch services EUROCKOT has made substantial capital investments in modernizing and refurbishing the Rockot related ground infrastructure at the Plesetsk Cosmodrome and improving the Breeze upper stage while retaining the impressive heritage of the vehicle. This has resulted in a modern vehicle with a large usable payload volume and unique flat payload interface plane suitable for multiple payloads. Brand new state of the art payload processing facilities, mission control center, lodging facilities and transport infrastructure has been built up. Rockot has a dedicated launch pad with a mobile service tower and its own integration facilities. For payload preparation, integration and encapsulation a closed clean area is provided consisting of three compartments including two class 100.000 clean rooms for payload and upper stage integration and a class 100.000 airlock as well as an area for cold gas fuelling.

Rockot, with its unique payload interface plane comprising a flat surface combined with the largest payload volume in its class allows a variety of payload attachments to be provided. These can include multiple satellite launches of a mix of mini- and microsatellites with main payloads as well as dedicated missions. EUROCKOT provides a wide choice of flight-proven adapters and multi-satellite platforms to the customer to allow such payloads to be accommodated.

One of the baseline interface options is the Russian Single Pyro Point Attachment System (SPPA) which to date has provided 23 successful satellite separations including

the CDF launch. As an option for primary payloads, EUROCKOT offers classic clamp band and equivalent systems using well known suppliers such as SAAB-Ericsson and CASA. Also offered are Khrunichev or Astrium supplied multi-satellite dispensers (MSD), both for primary payloads as well as for piggybacks. The ASTRIUM system for piggybacks can accommodate standard type mini- and microsatellites contained on a ring around the central main payload. Such a MSD could be mated with the piggyback payloads at the ASTRIUM facilities and hence would be shipped pre-integrated to the Plesetsk launch site to be mated to the main payload and launch vehicle. Other attachment/separation systems as 300 mm and 600 mm Clamp Band System as well as point attachment with pyrolocks are described below.

## COMMERCIAL DEMONSTRATION FLIGHT (CDF)

To demonstrate and verify this commercial capability, a Commercial Demonstration Flight (CDF) of ROCKOT was undertaken and the new dedicated EUROCKOT launch facilities at Plesetsk were commissioned. ROCKOT simulated a commercial mission by successfully deploying two satellite simulators SIMSAT-1 and SIMSAT-2 into a circular 547 km, 86.4° inclined orbit. The payload injection revealed a high accuracy well within the values defined in ROCKOT's User's Guide: The dispersion in altitude was less than 1 km. Acoustic noise levels were significantly below the values indicated in EUROCKOT's User's Guide. Pre-launch defined and attained CDF mission values as well as some flight results in the field of operations, performance, mission analysis and payload pre- and in-flight environment will be presented and assessed in the article.

## LAUNCH MANIFEST

EUROCKOT's launch manifest for 2001 includes the launch of two DLR/ NASA GRACE scientific satellites. EUROCKOT's order backlog presently shows 13 launches.

## THE NEXT LAUNCH: GRACE MISSION

The GRACE mission was selected as the second mission under the NASA Earth System Science Pathfinder (ESSP) Program in May 1997. Near the next solar maximum, the two identical GRACE satellites will be launched in tandem formation from Plesetsk Cosmodrome in Northern Russia into a polar orbit by a Rockot-KM (Commercially Modified) launch vehicle. Launching in October of 2001, the GRACE mission will accurately map variations in the Earth's gravity field. The GRACE satellites will fly about 220 kilometers apart with an initial altitude of 500 kilometers above the Earth. They will decay near the solar minimum with an estimated mission life of approximately five years.

GRACE will be able to map the Earth's gravity fields by making accurate measurements of the distance between the two satellites, using GPS and a microwave ranging system. It will provide scientists from all over the world with an efficient and cost-effective way to map the Earth's gravity fields with unprecedented accuracy. The

results from this mission will yield crucial information about the distribution and flow of mass within the Earth and its surroundings.

GRACE is a joint US-German project between the National Aeronautics and Space Administration (NASA) in the United States and Deutsche Forschungsanstalt für Luft und Raumfahrt (DLR) in Germany. Dr. B. Tapley of the University of Texas Center for Space Research (UTCSR) is the Principal Investigator (PI), and Prof. Ch. Reigber of the Geo-Forschungs-Zentrum (GFZ) Potsdam is the Co-Principal Investigator (Co-PI). Responsible for satellite development and test are Astrium GmbH and Space Systems/Loral Inc., USA. Astrium Friedrichshafen provides the bus and flight software of the two flight satellites based on an existing small satellite designed for the CHAMP mission. SS/L provides the attitude control system design and microwave link electronics.

At Astrium facilities in Friedrichshafen, Germany, the Fit Check of the Multi-Satellite Dispenser (MSD) with the Flight Model Satellites was successfully concluded in September 2000. The MSD is an aluminum structure that allows the two GRACE satellites to be side-mounted to the Rockot launch vehicle for launch and is designed and manufactured by RST Rostock Raumfahrt und Umweltschutz GmbH, an Astrium subsidiary under contract to EUROCKOT.

The acceptance tests of the MSD were performed at the Moscow facilities of the Russian Khrunichev Space Research and Production Center (KSRC). The tests confirmed the correctness of the mathematical model predictions for stiffness of the MSD structure. The MSD structural model is used as an input into the Coupled Loads Analysis (CLA) performed by Khrunichev as part of the standard package of services provided by Eurockot during mission integration of satellites.

In December 2000, the Critical Design Review (CDR) was held at EUROCKOT in Bremen, Germany. Multiple CDR objectives as thermal analysis, CLA, cleanliness analysis, telemetry system, EMC, electrical interfaces, reliability, quality and test results, prelaunch servicing & operations were successfully reviewed and approved.

## PIGGYBACK CAMPAIGN: "LAUNCH-A-PIGGY"

With its program "Launch-a-Piggy" EUROCKOT Launch Services intends to attract operators of micro and mini satellites for dedicated launches on Rockot starting in 2001 from Plesetsk. On the EUROCKOT website a homepage „LaunchaPiggy.com“ has been set up. Further launches of this type are scheduled for the next five years, in particular a flight into Solar-Synchronous-Orbit of 700km – 900km altitude in the second quarter of 2002 (LAP-2). With the max. capability of up to 1100 kg into SSO, a group of mini- and micro satellites can be carried in addition to the Russian spacecraft, room is still available. The Rockot launch vehicle EUROCKOT can provide this opportunities as comparable low costs from dedicated launch facilities at the Russian Cosmodrome of Plesetsk

A specific User's Guide for piggy-back satellites will be released by EUROCKOT at the beginning of the year 2001. Technical Services for piggy-backs by EUROCKOT will cover mission management and mission integration activities.

## SMALL SATELLITE INTERFACES

Depending on the satellite launch configuration, a standardized dispenser located under the fairing can support a group of 2 to 7 mini satellites weighing from less than 50 kg up to around 300 kg. The aimed applications are science experiments, earth observation and telecommunication missions. The launches are scheduled for different inclinations following the orbit of the core satellite as well as arrangements between the mini- and microsatellites.

The Breeze upper side is provided with a standard attachment hole pattern. A large number of holes allows multiple arrangement of payload adapters depending on the choice of satellites to be transported commonly on one launch.

The main Breeze components for the piggy-back system are the adapter and the separation system. The adapter supports the satellite during launch, releases the spacecraft upon command and ejects the payload from the launcher. The adapter system consists of a load carrying structure with a bolted launch interface in the lower part attached to Breeze' standard hole pattern and a satellite interface in the upper part.. The adapter can be suited to the spacecraft from case to case. The adapter system also includes brackets for the pusher system and brackets for the satellite umbilical connectors, if desired by the Customer

The separation system developed and fabricated by Khrunichev State and Research Production Center, Moscow (KSRC) is either a clamp band type offered in two sizes, 300mm or 600mm consisting of a clamp band, a retention set and a separation spring set or a point attachment system with pyrolocks and a separation spring set. Redundant separation commands and separation confirmation signals from the launch vehicle to the spacecraft will be provided as per Rockot User's Guide. The separation systems are either fully flight qualified like the pyrolock system or at least on component level.

As usually with co-passenger payloads, no electrical links are provided from the launch vehicle to the payload in the standard configuration. Nevertheless, these services can be offered on Customer's demand as optional service. All of the electrical links as battery trickle charging, commands, housekeeping data etc. can be provided with the same quality and as outlined in EUROCKOT's User's Guide provided that not all of the 200 transit wires between the EGSE and the payload zone are reserved for the main payload.

The environmental loads for piggies can be taken hundred percent from EUROCKOT's User's Guide. Nevertheless, environmental tests will be performed for all payloads of each dedicated flight configuration. All Piggy-backs will be separated simultaneously in different directions to avoid any collisions with other payloads or the upper stage. Some very rough dimensions in satellite length, width and height must be kept, the center of gravity misalignment has to be within an acceptable tolerance. Thus, EUROCKOT offers a wide flexibility in the selection of the arrangement of spring pushers and their characteristic features individually for each flight.

EUROCKOT's dedicated class 100 000 clean rooms are provided for core payloads and co-passengers as well as an area for cold gas and/or monopropellant fuelling (optional service).