

# **MAIN TRENDS OF SMALL SATELLITES DEVELOPMENT AND CAPABILITIES FOR THEIR PIGGY-BACK INJECTIONS BY LAUNCH VEHICLES OF KHRUNICHEV SPACE CENTER**

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The field of small satellite development is of more and more increasing interest in the world's astronautics. The technological preconditions influencing on a creation of small satellites are analysed in the paper. The conclusion is made on a foregoing broad application of small satellites for solving of various tasks concerned with scientific purposes and of tasks concerned with practical using of space vehicles. There are marked the problems regarding injections of small satellites. Taking into a consideration these features, a piggy-back injection of small satellites is obtaining still more application. The specific versions of piggy-back injection by the Khrunichev's launch vehicles, such as the 'Proton' and 'Rockot', are estimated.

A large attention began to be given during recent years to a testing of new technologies with using small satellites having masses from one up to several hundreds kilograms.

Missions of these satellites still are limited and have a narrow-specialized nature. Most spread parameters of their orbits are: altitudes of 400÷1000 km, inclinations in the broad range up to 98°.

The breakdown structure of world space market in 1998 and forecast for 2005 confirm the increased role that small spacecraft play (from 4.3% to 43%).

The progress in small satellites creation is provided by achievements in a solving of technological problems range in such the directions like:

- means for on-board data processing, power supply and communications thank to:
  - enhancing of on-board data processing means due a progress in computer technology;
  - enhancing of efficiency of solar arrays approximately 1.5 times as much;
  - using of advanced fly-wheels in high-resource control systems.
- using of pressurized structures in solar array panels, antenna reflectors, solar radiation concentrators and large mirrors in optic instruments, using of optic or laser means for inter-satellite communications with large speeds of data transmission (tens of Mbit and more)
- applications of electric thrusters permitting to decrease stocks of propellant in a comparison with traditional thrusters
- other.

In a turn, these achievements generated possibilities for changes in a range of absolute technical parameters of satellites.

The given data confirm a transition in the nearest years to a use of spacecraft miniaturization in low and middle orbits. For example, this is illustrated by spacecraft for Earth observation.

The important factor is also that about 50 (47) countries have own national space programs at the present. They are provided by a national financing permitting to solve complexly the problems of satellite creation and their injections into orbits.

However, numerous small states, laboratories, universities and commercial organizations, aspiring to take part in developments of advanced space technologies, are solving modest tasks in frames of limited financing.

A smallest launcher being available for commercial launches is too large and economically disadvantageous one for a launch of small satellite.

On the other hand, small weights of satellites and a disconnection of their developers lead to the problems which complicate their group injections.

The way out of this situation is a piggy-back injection of secondary payload simultaneously with an injection of prime payload.

Such the practice is used with the “Ariane-4”, “Delta-2”, “Pegasus”, “Taurus”, “Molniya-M”, “Cosmos-3” and other launch vehicles. As much as 50 small spacecraft were just injected.

An analysis of these launches permits to make some conclusions:

- Number of piggy-back spacecraft is determined by a reserve of launch vehicle's payload mass or by a reserve of prime payload mass
- Required orbital parameters of small piggy-back spacecraft can be realized only under the condition of end parameters providing for an orbit of prime payload
- Implementation of small spacecraft piggy-back injections is most acceptable for launch vehicles having upper stages with the capability of numerous restarts. In this case, it is most simple to carry out a separation of piggy-back spacecraft in transfer orbits of prime payload
- Launch vehicle is up-graded, as a rule, for an arrangement of piggy-back payload fastening or by an introduction of special adapter.

Taking into account a consideration these features, the Khrunichev is investigated an implementation of piggy-back injections by the “Proton-M” and “Rockot” launch vehicles.

The given schemes permit to accommodate small spacecraft as secondary passengers either at specialized structural spots or at special adapters.

The concrete proposals may be determined in a process of agreement taking into account the program of launches for prime payloads and design solutions for accommodation of secondary passengers.