SOME ISSUES ON DEVELOPMENT OF SPACE DEFENSE FACILITIES AGAINST ASTEROIDS AND COMETS

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Realization and scientific support of the actuality of asteroid and comet danger appeared in the end of last century. A very vivid evident of such danger was the fall of comet Shumeiker-Levi fragments unto Jupiter in summer 1994. Bright demonstration of such space danger were, in particular, four events, that took place in 2002. The first one was on July 14th, when an asteroid sized 100 meters had flown by Earth in a negligible, in terms of space, distance – only some 120 thousand kilometers. Two other events occurred in the night of July 5th. One was in the sky of Ukraine nearby Dnepropetrovsk, when Israeli Boing-757 pilots thought to be attacked by anti-aircraft missile, which in actuality turned out to be the entry into Earth atmosphere of bright fire-ball. The other one was American scientists discovery of asteroid 2002-NT7, with the diameter of about two kilometers, which shall be passing dangerly close to Earth in 2019. And, finally, the burst of a celestial body on September 24th, fortunately above Taiga region, in the area of Vitim river, what resulted in cut-down of about 100 km^2 of forest.

In a short period of time nature had introduced to us a full scope of dangers from space: a rock, sized of a soccer ball, able to light up international conflicts including those involving nuclear weapons; an asteroid sized of hundreds meters, which can wipe off a megapolis or a state; and also a multi-kilometer sized asteroid, a crash with which might end life on the Earth itself.

It is obvious, that we have to be ready beforehand to face a situation in which it shall be necessary to make fast and sure decisions about rescuing of millions and even milliards of people. In other case with shortage of time, governmental separation and other factors we won't be able to take adequate and effective terms of protection and rescue.

In line with this it would be unforgettably careless not to take any protective actions against such outbreak. It is even more true, when we consider that the asteroid and comet danger is one of those few ones, which could be noticed and worked out beforehand, with proper preparatory actions taken.

The conclusion fro the above said is such, that asteroid and comet danger is one of the main risk factors for our civilization and the development of means to solve it should be one of the main tasks for humanity in the 21st century.

Planetary defense system "Citadel"

As results of our research and development activities show, present level of technological development of Russia, CIS and leading world states enables to start with development of Planetary Defense System (PDS) from asteroid and comet danger [1-5]. As a basis for this we take a fact, that back in previous days in Soviet Union alone there were developed and undergone all ground-testing programs almost all main components of PDS or prototypes of such.

As example of such one can mention many samples of space-rocket techniques, nuclear weapons, communication, navigation and operation means, etc. Some of these do not have any analogy anywhere in the world. And today there is a unique opportunity to use these means, many of which were developed for military use, not for destruction, but for protection of humanity in a whole.

One of possible options of functioning and operational schemes of such System could be "Citadel". It shall include global control space-and-ground system and regional segments of instant interception.

PDS project foresees creation of short-notice PDS reaction echelon, which shall be in a fully prepared mode. It shall be used for protection from relatively small (10 to some hundred meters) asteroids and nuclei of burned comets, which often enough collide with Earth and might be detected only some twenty-four hours, weeks, or months before collision.

Basis of interception service shall be made of space-rocket, nuclear, and other means of Russia (CIS), USA, European and other states. It shall include reconnaissance and interceptor spacecrafts (S/C)

Possible scheme of the echelon of PDS short-term reaction components and functioning of its components are given on figure 1.

It shall be functioning in a following way.

After detecting a dangerous celestial object (DCO) all ground and space monitoring mean around the world which shall be able to detect it will start tracing it. Based on the data received from them in the Planetary Defense Center (PDC) the analysis on the danger level (place and time of collision, expected loss) shall be performed and a set of preventive actions shall be established. The proposals shall be issued towards the government of the state and after settling of the operations plan at governmental level, an order for the launch of at least two S/C-reconnaissance and S/C-interceptor shall be issued. The launch of S/C-interceptor and first S/C-interceptor must be performed no later than 12 hours after detection of DCO. This is considering a possible launch window. As for the second spacecraft it must be launched no later than 24 hours after detection.

S/C-reconnaissance must approach the object as fast as possible, and come up to a minimum distance from DCO. It must examine and define its trajectory, velocity of rotation, define its mass, mineralogical content and dimensions, acquire detailed panorama of its surface and download these data to Earth. Based on the data acquired in the institutes of the Russian Academy of Sciences and in Planetary Defense Center and engineering model shall be developed, which shall allow a more effective interference of intercepting–spacecrafts by usage of nuclear devices or other means. Upon operating these means DCO shall be diverted from its trajectory or destroyed.

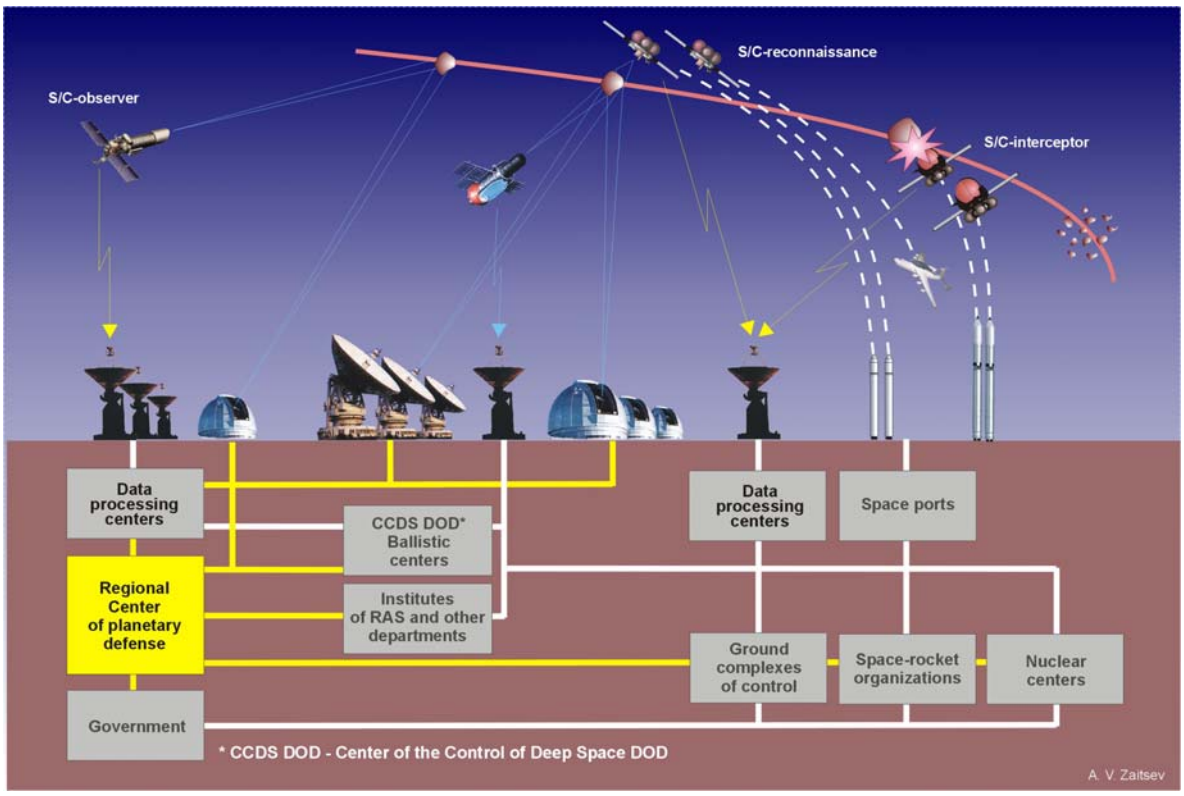

Fig. 1

S/C-reconnaissance

A major task when developing a S/C-reconnaissance is to make as small as possible all on-board operation systems and other units of S/C. This is also true for on-board scientific equipment. In line with energy consumption properties of Launch Vehicle (LV) and diminishing the time necessary for launch preparation, shall provide for a maximum time interval between the launch of S/C-reconnaissance and the approach of S/C-interceptor towards a dangerous object.

It is foreseen to include two panchromatic cameras of high and medium (with larger field of view) resolution, tree multispectrum cameras of visible, ultraviolet, and infrared ranges, video spectrometer, laser distance measuring device, gravity measuring tool, on-board radio system for downloading of scientific data are planned to be part of S/C-reconnaissance scientific equipment.

Technical properties of on-board scientific equipment are given in Table 1.

Table 1.

Name of equipment	Properties		
	Angular field of view, deg	Range of observation, mkm	Resolution (from 1000 km), m
High resolution camera	2.5x2.5	0.5…0.8	8
Medium resolution camera	5x5	0.5…0.8	70

Ultraviolet range camera	4.2x5.6	0.5…0.8	250
|Broad-angle camera	25x25	0.5…0.89	350
Infrared range camera	5.6x5.6	1.1…2.8	400
Video spectrometer	5x5	0.4…0.9	100
Laser ranger	1/120	1.06	4

Structure of S/C-reconnaissance is developed based on the heritage of the Lavochkin Association. Non-hermetic space platform on which scientific equipment shall be mounted, including also on-board service systems: on-board processing unit, set of high quality navigate measuring and operational tools, on-board radio-navigate system, power system, thermal mode system, antenna-feeder system, two component correcting propellant engine.

At development of on-board systems of the S/C-reconnaissance most up-to-date inventions and achievements of Russian electronic manufacturing are being used. This is done with the usage of presidios video devises.

Mass and energy properties of on-board systems of S/C-reconnaissance are given in table 2.

Mass of S/C-reconnaissance is 233 kg, energy consumption – 300 Watt.

Table 2.

Name	Mass, kg	Power consumption, Watt.
On-board scientific equipment	**94**	**140**
Optical electronic set	24	60
Platform with stable dimensions	15	
Video spectrometer	25	40
Laser distance measuring device	30	40
Space platform	**139**	**170**
On-board control set	36.8	
Power system	17	
Receiving equipment and data download system	42.5	130
Thermal system	3	20
Correcting engine: including fuel	13.2 9.2	20
Shell	15	
Antenna-feeder system	1.5	
On-board cable network	10	

Outer appearances of S/C-reconnaissance in operational mode and the mounting of scientific equipment is given in figure 2. On figure 3 one may find S/C being placed on "Dnepr" LV with "Lift" booster.

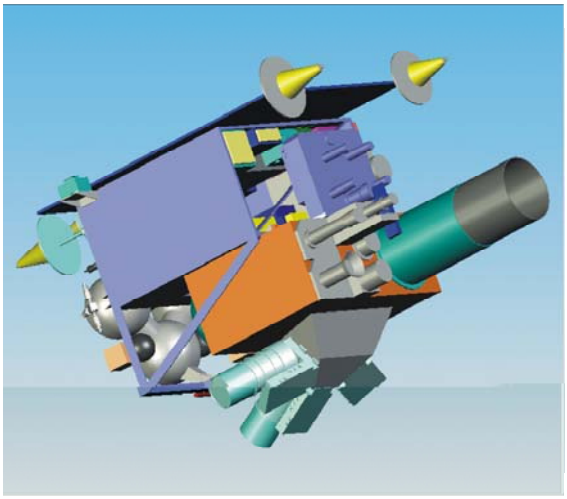

Fig. 2

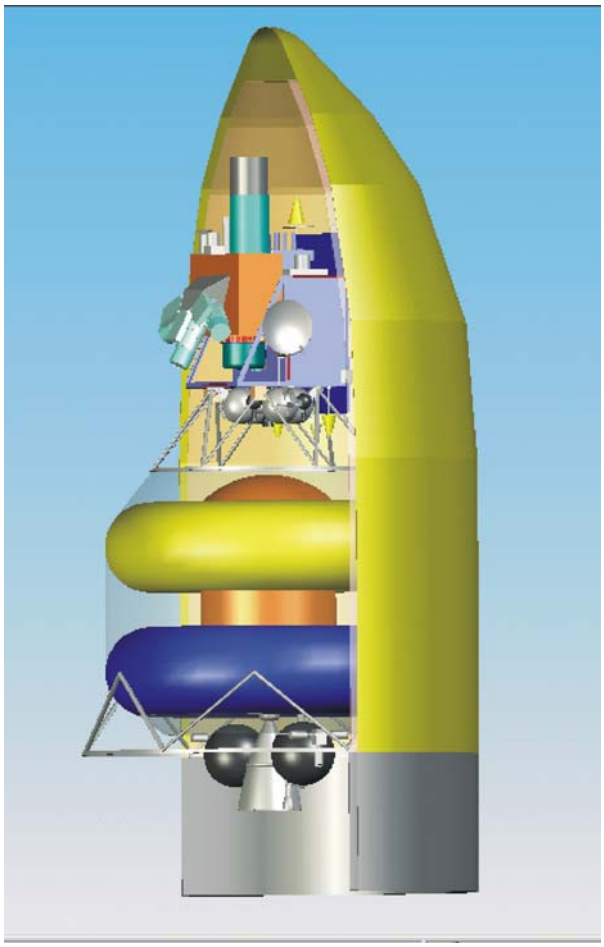

Fig. 3

Launch means

In order to provide for timely reaction on DCO, intercepting means, in particularly the launch vehicles, must meet quite high requirements of time necessary for launch preparation, weight of payload, which they can carry, etc. At different levels these requirements are met by "Dnepr", "Souz", "Zenith" and some other LVs. For example "Zenith", which has quite high capabilities on mass lift, has unique properties in terms of launch preparation period. It takes only 1.5 hours to prepare it for launch after it has been mounted on the starting position, and the consequent launch from the same starting position is possible in 5 hours [6]. Not a single space-rocket complex in the world does have such abilities. It's obvious, that for "Dnepr" time for launch readiness can be counted by minutes. All of this makes LV unique means for launching intercepting spacecrafts, particularly S/C-reconnaissance.

Main properties of above mentioned LVs are given below.

"Dnepr" LV

"Dnepr" LV is a converted option of strategic missile SS-18 ("Satan"), used for injecting S/C into different orbits.

In accordance with START-1 AND START-2 treaties these missiles shall be converted into "Dnepr" LVs as it shall be necessary.

SS-18 is a two stage. Its take-off mass is ~240 tons. Mass of payload, launched on this LV from "Baikonur" launch site into circular orbit with altitude of ~200 km and slope 51,8 degrees is 4900 kg.

For S/C insertion into interplanetary trajectory, along with booster, developed by "Uzhnoe" Design Center, "Lift" booster may also be use. Maximum fuel mass of the booster is 5700 kg, and final mass 1100 kg.

"Souz-2"Launch Vehicle

Launch Vehicle "Souz-2" has three stage system. Launch sites for "Souz-2" LV shall be created in 2005 using as a base already existing launch sites for "Souz" LV at "Plesetstk" and "Baikonur". Apart from it there shall be also a launch site built in 2008 in French Guinea.

LV take-off mass is ~320 tons. Payload mass, which it can take from "Baikonur" into a circular orbit with altitude of ~200 km and inclination of 51.8 degrees reaches up to 8300 kg.

For inserting a spacecraft into interplanetary trajectory "Fregat" booster, developed at Lavochkin Association is being used. Such booster had already performed six successful launches in period 2000 to 2003 as a part of "Souz" LV ("Souz-Fregat") Maximum mass of booster fuel is 6200 kg, and final mass – 980 kg.

"Zenit-2SB" LV

Two stage "Zenit-2SLB" LV constitutes of "Zenit-2SB" LV and head-cone, developed by Lavochkin Association.

"Zenit-2SB" is being developed now for project "Ground start". Launch pad for this LV is located at "Baikonur".

Take-off mass of LV is ~460 tons. Payload mass, inserted into a circular orbit with altitude of ~200 and inclination of 51.8 degrees reaches up to 15000 kg.

"Fregat-SB" booster shall be ready for nominal usage as a part of "Souz-2" and "Zenit-SB" in 2006. This booster is being developed on basis of "Fregat" booster by supplying it with additional jettison fuel tank set. Maximum fuel filling of booster is 10700 kg.

Power capabilities of LV for launching spacecrafts

Power capabilities of LV (maximum character velocity, m/s) for launching spacecrafts with mass of 300 kg with a launch fro "Baikonur" are given in Table 3.

Table 3

Launch-vehicle	Booster		
	«Lift»	«Fregat»	«Fregat-SB»
	Vchar, m/s		
«Dnepr»	≤ 4600	-	-
«Souz-2»	-	≤ 5800	≤ 6100
«Zenit-2SБ»	-	-	≤ 7200

Provided the velocity of DCO is about 50 km/s, which is a maximum velocity for asteroids, power capabilities of "Dnepr" LV enable to set up the approach of spy-spacecraft to it at a distance of about 950 thousand kilometers from Earth (in case of detection of DCO forty eight hours before collision.

It must be highlighted, that since most of asteroid orbits are inclined against elliptic plane, their interception, due to limited power capacities of todays LVs, shall be performed, mainly, on relatively small distance from the border of gravisphere of Earth, which had the radius of about 1 million kilometers.

Missions with usage of spy-spacecrafts

"Space patrol" project [7] foresees development and launch of a spacecraft towards asteroids passing close to Earth as well as towards objects moving in meteorite flow. The following projects may be carried out: "Flight", "Strike", "Diffusion" and "Interception".

In frame of "Flight" project methods and means of distant examining of DCO shall be tested, and well as studies of asteroid properties from fly-by trajectories, testing of S/C-reconnaissance and other components of PDS.

In frame of "Strike" and "Diffusion" projects properties of space objects at high-velocity strike (up to 70-90 km/s) will be studied. For penetration into the surface of asteroids special penetrators might be used.

In frame of "Interception" project it is foreseen to perform interception of an aster-

oid. Some types of missions in some cases might be combined (for example “Flight” +” Strike” and so on).

Development of a spacecraft for the mentioned above missions shall take from 2 to 5 years.

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