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Committee on the Peaceful Uses of Outer Space

Information on research in the field of near-Earth objects carried out by Member States, international organizations and other entities

Note by the Secretariat

Addendum

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II. Replies received from Member States

Russian Federation

[English and Russian]

Planetary Defence Centre

Review of activities of the Planetary Defence Centre

1. The Russian Federation and the countries of the Commonwealth of Independent States (CIS) have accumulated significant scientific and technological capabilities. These could be used to develop a planetary defence system to protect the Earth from the threat posed by asteroids and comets.[1-7] One of the main reasons for this is that the former Soviet Union alone produced virtually all the basic components, or prototype basic components, of a planetary defence system and subjected them to full-scale testing. Those components include many models of launchers and spacecraft, nuclear weapons and means of communication, navigation and control. For a number of them, no similar models exist anywhere else in the world. There is now a unique opportunity to use those resources—many of which were developed for military purposes—for the protection, rather than the destruction, of all of humanity.

2. However, activities in this area are carried out in a piecemeal fashion and, to a large degree, as separate initiatives. In this connection, a number of Russian and Ukrainian organizations founded the Planetary Defence Centre in 2002 as a non-profit-making partnership, with a view to combining the efforts of organizations and experts working in various fields towards the establishment of a planetary defence system.

3. The main activities of the Planetary Defence Centre are as follows:

(a) Design of a planetary defence system to protect the Earth from the threat posed by asteroids and comets;

(b) Elaboration of possible space threat scenarios and methods and means of countering such threats;

(c) Participation in the preparation and conduct of simulation and demonstration experiments to test the components of the planetary defence system;

(d) Conduct of public awareness campaigns and other activities.

4. The activities of the Planetary Defence Centre are based on the conceptual design for the Citadel planetary defence system, which has been approved by the Centre's member organizations.[4, 5]

The Citadel planetary defence system

5. The Citadel system will consist of an Earth- and space-based service for the global monitoring of outer space and regional segments for rapid interception.

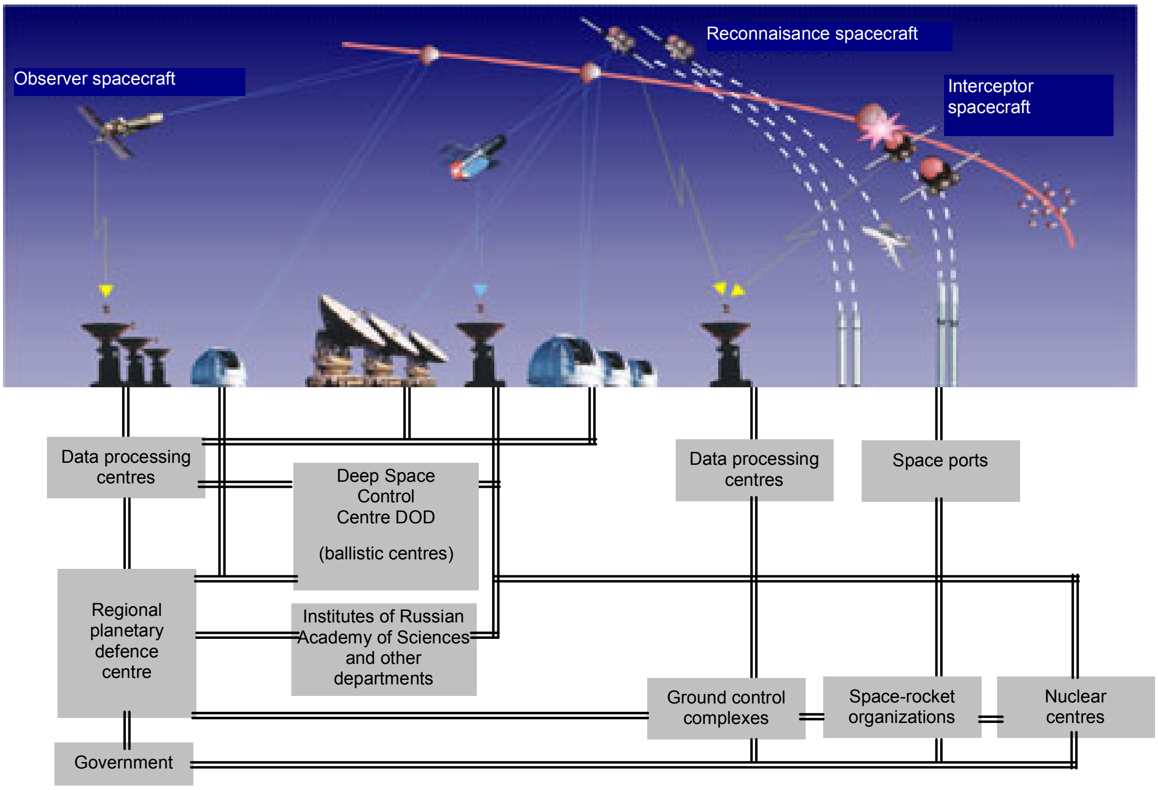
6. The design of the planetary defence system envisages, in the first instance, the establishment of a rapid response echelon, which will be in a state of permanent readiness. This is intended to protect against the relatively small asteroids (measuring tens to hundreds of metres) and extinct comet nuclei that collide with

the Earth quite frequently and can be detected only a few days, weeks or months before a collision.

7. The interception service will make use of space rockets and nuclear and other resources from the Russian Federation (CIS), the United States of America and European and other countries. These resources will include reconnaissance and interceptor spacecraft.

8. Figure I shows the possible structure of the planetary defence system's rapid response echelon and the interaction of its components.

Figure I
Diagram of the structure of the planetary defence system's rapid response echelon



Reconnaissance spacecraft

9. Reconnaissance spacecraft are one of the main components of the planetary defence system.

10. In the manufacture of reconnaissance spacecraft, it is of prime importance to miniaturize the on-board support systems, the spacecraft hardware and the on-board research equipment. In addition to meeting the energy requirements of launch vehicles and reducing the time needed to prepare them for launch, this will ensure the maximum time interval between the fly-by of the reconnaissance spacecraft and the interceptor's approach towards a dangerous object.

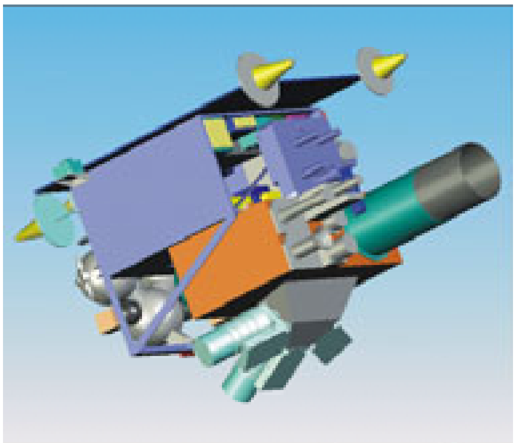
11. The design for the reconnaissance spacecraft was developed jointly by the Planetary Defence Centre and the Lavochkin Association and is based on one of the projected small spacecraft.[6]

12. The research equipment is to include two panchromatic cameras with high and medium (wide field of view) resolution, three multispectral cameras (visible band, near-ultraviolet band and infrared band), an imaging spectrometer, a laser ranging sensor, a gravity-gradient meter and an on-board radio system for transmitting scientific information.

13. The reconnaissance spacecraft has a mass of 230 kilograms and energy consumption of 300 watts.

14. Figure II shows a view of the exterior of the reconnaissance spacecraft in the operating position and the location of the on-board research equipment.

Figure II
Overall view of the reconnaissance spacecraft



Missions using reconnaissance spacecraft

15. The Space Patrol project[7] provides for a spacecraft to be built and launched towards asteroids passing near the Earth and, in particular, objects moving in meteor showers. The following missions could also be carried out: Prolet (fly-by), Udar (impact), Vnedrenie (penetration) and Perekhvat (interception).

16. During the Prolet mission, methods and equipment for the remote sensing of dangerous celestial bodies will be tested, research will be carried out on the properties of asteroids from fly-by trajectories, and tests will be performed on reconnaissance spacecraft and on other components of the planetary defence system.

17. The Udar and Vnedrenie missions will involve the study of the properties of celestial bodies and of the physical processes that take place during a hypervelocity impact (70-90 km/s). Special penetrator probes could be used to penetrate the surface of asteroids.

18. During the Perekhvat mission, an asteroid interception is to take place. Certain types of mission could, in some circumstances, be combined (for example, the Prolet and Udar missions).

19. It will take between two and five years to build the spacecraft for these missions.

Institutional and legal issues

20. The establishment and operation of a planetary defence system will present humankind with a number of unusual problems, not only scientific and technical problems, but also organizational, political, ethical, juridical, legal, environmental and other problems.

21. The Planetary Defence Centre is also engaged in addressing these issues. The results of these and other activities have been presented at scientific conferences and workshops.

22. The Planetary Defence Centre would like to invite all those wishing to participate in the development of the Citadel planetary defence system to collaborate on the project. The address of the Centre is as follows:

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Notes

[1] A. V. Zaitsev, "Proposals for the establishment of a system to prevent asteroids and comets from colliding with the Earth (reorientation of work carried out under the Strategic Defense Initiative (SDI) towards peaceful purposes)", memorandum No. 629203 of 20 October 1986 to the General Secretary of the Communist Party of the Soviet Union, Babakin Space Centre, 1986.

[2] V. M. Kovtunenko and others, "Principles for designing a system to protect the Earth from asteroids and comets: technical note", Lavochkin Association, Babakin Space Centre, 1995.

[3] A. V. Zaitsev and others, "Use of the designs of the Lavochkin Association for the establishment of a planetary defence system to protect against asteroids and comets", Lavochkin Association collection, Collected Scientific Papers, issue No. 2, Moscow, 2000, pp. 204-207.

[4] A. V. Zaitsev, "The Citadel planetary defence system: a conceptual design", Lavochkin Association, 2000.

[5] A. S. Bashilov and others, "The Citadel planetary defence system: proposals", Planetary Defence Centre, 2001. [6] V. A. Asyushkin and others, "Some issues on development of space defense facilities against asteroids and comets", European Conference for Aerospace Sciences, Moscow, 4-7 July 2005.

[6] V. A. Asyushkin and others, "Some issues on development of space defense facilities against asteroids and comets", European Conference for Aerospace Sciences, Moscow, 4-7 July 2005.

[7] A. V. Zaitsev and others, "Impact experiments for project Space Patrol", *International Journal of Impact Engineering*, Proceedings of the Hypervelocity Impact Symposium, vol. 20, 1996, pp. 839-848.

United Kingdom of Great Britain and Northern Ireland

[English]

1. The United Kingdom of Great Britain and Northern Ireland is home to two centres providing information on near-Earth objects.

2. The first is the Spaceguard Centre, located at the former Powys Observatory, near Knighton in mid-Wales. It represents the Spaceguard Foundation as the International Spaceguard Information Centre. It has set up the nationwide Comet and Asteroid Information Network (CAIN) and has a well-established outreach programme. It currently liaises with Spaceguard organizations in 17 countries around the world and encourages the establishment of new ones (the latest being Spaceguard South America, Spaceguard Israel and the recently constituted Spaceguard India).

3. The Centre acts as the Primary Science Advisor for the Faulkes Telescope NEO project and has acquired private funding to set up a pair of 0.3-metre robotic telescopes for astrometric follow-up. The project is known as the Spaceguard NEO Astrometry Project (SNAP). One system will be located at the Spaceguard Centre (SNAP N), and the other will be located in Namibia (SNAP S). The status of the programme is that the equipment for SNAP N has been procured, and the robotic system is under development. It is anticipated that SNAP N will be fully operational in April 2006. Once commissioning is complete, SNAP S will be installed, thus representing a significant increase in the contribution of the United Kingdom to the global follow-up process.

4. The second is the Near Earth Object Information Centre (NEOIC) of the United Kingdom, which was established in response to recommendations 13 and 14 of the Report of the Task Force on Potentially Hazardous Near Earth Objects, established by the Government. NEOIC is operated by a consortium led by the British National Space Centre (BNSC), under contract to BNSC. The main centre is based at the National Space Centre in Leicester, which houses a near-Earth object (NEO) exhibition and provides a primary contact point for public and media enquiries. A network of seven academic institutions active in the field of NEOs advise the Centre: Queen's University of Belfast; the United Kingdom Astronomy Technology Centre, Edinburgh; the Natural History Museum, London; Queen Mary, University of London; Imperial College, London; and the University of Leicester. In addition there are three regional centres with linked exhibits and access to the NEOIC facilities. These are based in W5 Belfast, the Natural History Museum, London, and the Royal Observatory, Edinburgh. The NEOIC website (www.nearearthobjects.co.uk) provides a virtual exhibition, a resource section (for educators and the media) and the latest NEO news, including answers to frequently asked questions. The site also allows access to the Report of the Task Force on Potentially Hazardous near-Earth objects.

5. The Open University has just commenced an undergraduate course in which NEOs is one of the seven topics covered, including not just the science but the related themes of communication, risk, ethical issues, policymaking and decision-making. A study text has also been produced to accompany the course: A. J. Ball, S. P. Kelley and B. Peiser, *Near-Earth Objects and the Impact Hazard*, S250 Science in Context Topic 2, Open University, 2005. The Open University runs an active

programme of postgraduate and doctoral studies; recent doctoral examination titles have included "Thermal infrared and optical observations of near-Earth asteroids" and "Penetrometry of NEOs and other solar system bodies".

6. In addition to theoretical studies, a number of experimental programmes are under way, among them the development of a penetrometry rig, to simulate a high mass, low speed impact of a penetrometer fixed to a landing spacecraft. Penetrometers will be the key to enabling in situ measurements on an NEO surface, which are likely to be delicate in nature, to give structural and mechanical information on the body, essential to successful mitigation or negation of the body. The Open University has an interest in instrumentation for the in situ physical and geochemical investigation of NEOs.

7. The Open University anticipates partnering with industry for the European Space Agency (ESA) DQ Phase A mission study, providing input across a range of scientific and engineering-related fields. The Open University is also engaged in the assessment study led by the Centre national d'études spaciales of France for a rendezvous and landing mission to a primitive binary NEO. The Italian Space Agency (ASI) and the German Aerospace Center (DLR) are also part of the study team. The study, ending in March, is in competition with other missions in the CNES system to proceed to a Phase A study. Open University staff have also continued their ongoing membership of the ESA Near-Earth Object Mission Advisory Panel (NEOMAP) Committee.

8. QinetiQ continues to promote its Small Satellite Intercept Missions to Objects Near Earth (SIMONE) concept. The goal of SIMONE is to send micro-spacecraft, each to a different type of Earth crossing NEO. This would allow physical and compositional characterization observations to be made, in support of possible mitigation strategies. The concept arose as a response to the Report of the Task Force on Potentially Hazardous Near-Earth Objects. SIMONE was one of six studies commissioned by ESA for a possible NEO mission. SIMONE was a collaborative study between QinetiQ and the Open University's Planetary and Space Sciences Research Institute. Although SIMONE was highly regarded by ESA, of the six studies completed, only the Don Quijote mission was selected to go forward to Phase A, as it was assessed to be more strongly directed towards a mitigation experiment. However, ESA remains very interested in the SIMONE concept, and it is anticipated that elements of SIMONE will almost certainly be taken forward in some form. The SIMONE mission concept is based around a small (120 kg) spacecraft equipped with gridded-ion electric propulsion (QinetiQ T5), powered from an ultra-lightweight solar array. The spacecraft would carry a suite (13 kg) of miniaturized instruments to make the observations. The original concept envisaged five identical spacecraft each of which would rendezvous with a different object. The multiple build would be extremely cost-effective, and the five spacecraft, could be launched to Earth orbit simultaneously using the Ariane 5 Structure for Auxiliary Payloads (ASAP-5). The electric propulsion enables great flexibility on launch window and Earth orbit escape.

9. Research is under way at the University of Southampton to assess the global threat to Earth posed by small (less than a kilometre in diameter) NEOs. The many impact-generated effects resulting from a NEO impact each have an effect on the Earth's ecosystem and serious consequences for the human population. The primary challenge in the research is accounting for each impact-generated effect and

developing an adequate model to simulate it. To this end, a computer simulation tool is under development with the capability of modelling small NEO impacts. This tool tackles the hazard on both a local and a global scale, tracking the consequences of an impact on the human population. Each of the impact-generated effects will affect the human population and infrastructure to varying degrees. Therefore the analysis of mortality rates and infrastructure cost is the key feature of the simulation. Overall hazard assessment of a NEO impact event will be rated by the casualty figure and level of infrastructure damage.

10. The computer simulation tool first tracks the object as it enters the Earth's gravitational sphere of influence. Its path is then simulated through the atmosphere as it experiences ablation and aerodynamic forces. The object's energy is either fully spent in the atmosphere, resulting in an airburst, or it reaches a ground impact. The impact event is modelled using algorithms based on the current literature. Land impacts include the effects from seismic activity, shock waves, radiation generated by the developing fireball, and ejecta distribution. Ocean impacts require a tsunami wave to be modelled, which will then inundate coastlines across the globe.

11. The simulation output analyse how each impact-generated effect affects human populations worldwide. Casualty figure estimates will be complemented by an indication of the economic cost due to lost infrastructure. These two indicators will enable assessment of the NEO hazard on a global and country-by-country basis. Investigations can be carried out into the involvement of individual countries in any known NEO events. Furthermore, numerical modelling techniques will provide analysis of the threat, leading to a global understanding of each individual's risk due to potential NEO impact events.

12. The objective of work conducted by the University of Glasgow is to develop fundamental optimal control theory and apply it to the interception of hazardous NEOs. Different parameters, such as time, mass, orbital corrections and maximum deviation, will be optimized. A study of the robustness of the methods will also be performed to take into account the uncertainties on both the NEO dynamics and boundary conditions. A variety of propulsion methods, ranging from solar sails to nuclear propulsion, will be considered and the advantages and disadvantages of each will be assessed. Numerical simulations in a realistic scenario will be developed in order to investigate the performance of such methods, and the simulation data will be animated to evaluate the optimal trajectories and deviation methodologies. This is a three-year programme funded by the Engineering and Physical Sciences Research Council.

13. During November 2005, the Royal Aeronautical Society hosted a Workshop in London on NEOs to assess the current status of research into NEO characterization, detection and orbit determination, mitigation and policy. The Workshop was sponsored by the Office for Outer Space Affairs of the Secretariat, ESA, BNSC and the Rutherford Appleton Laboratory. Leading scientists from Europe engaged in NEO activities met to review how Europe could best contribute to and complement the existing activities around the world. The Association of Space Explorers (ASE) contributed a valuable insight to how policy might develop to address issues that could arise should a hazardous NEO be identified.