THE MAIN PROBLEMS OF DEVELOPMENT OF THE ORBITAL DEBRIS MODELS IN RUSSIA.

V.I. Lukiyashchenko, S.A. Meshcheryakov

Central Research Institute of Machine Building
4, Pionerskaya Str.
Korolev,
Moscow Region 141070
Russia

Abstract

Not so long ago space debris investigations were of a speculative nature in the main. There are theoretical estimations of amounts of fragments erupted at all explosions, future growth of collision danger, and the like. Marginal points (micrometer particles' data and catalog) were not so conclusive. The is new turn of the problem now: Goldstone and Haystack measurements [1] brought direct data of small but collision hazard particles. It was experimentally shown millimeter size particles are of the main collision danger for large systems.
This work was made in proper time. ISS Alpha works need good assessments of the collision hazard. In addition the deployment of great communication satellite systems seems to concern LEO in the nearest future. Also tether satellites are very vulnerable.
The great technique needs standard assessment methods. We should have norm engineering space debris model, exploring programs to calculate an evolution of debris populations of all kinds and regular observation data.

1. Introduction

In Russia there are several organizations fundamentally worked at space debris problem and its influence in the space systems. At first IAC "Vympel" and SRC "Cosmos" possess a large experimental data. According summarization [2] may be named as cataloged debris model and used in many applications. SRI of RAS (IKI) was pioneering in near-earth space debris investigations [3]. CPS made an effective model for space debris [4], carries a hard work at investigation of orbital explosions. Mathematical problems are worked out in MGU [5]. WSF organizations also give attention to our problem [6,7]. TSNIIMASH started to work under this problem a few years later. The main object of its work is providing of manned flight's safety, working out a concorded program complex for all sides of this problem.
The first question of this problem is solved by statistical code by A.I. Nazarenko.

2.A few generalities to statistical modeling

There is a row of experimental data that show the necessity for additional analysis of different assumptions in available statistical models.
1. It was found in on-board experiments (LDEF, SS "Mir" experiments) with micrometer particles, Goldstone and Haystack observations of millimeter particles that collision fluxes at the surfaces are statistically uneven.
2. The direct method [8] as compared to some statistical calculations yields different results. Unfortunately there is not averaging scheme used in this work.
We believe that the development of special exploring 4-d models would improve the situation.
But it should be noted that:
1) A.I. Nazarenko [9,10] showed his model gives nice results if to take account of collision objects' size;
2) The statistic of the work [8] is in question. One worked with Monte Carlo method knows that for instance 1000 tests yield rather poor result even for satisfactory dispersion, and accuracy grows very slowly (in proportion to square root of number of tests).
At all events one can say the statistical methods solve their own tasks more effectively then direct methods.

3. Some features of A.I. Nazarenko's model

In the model [4] one dimensional evolution problem is solved, the source of orbital particles assumes to be function of altitude and time. Author takes this function on the traced objects and observation data. Variables are separated.
The used method gives simplest and simultaneously correct account of particle orbit dynamic according to atmosphere conditions. It also gives automatic approach to cataloged objects.
Some points of controversy are following.
1. Connections between sizes, ballistic coefficients and mass of particles are given rather arbitrary.

Proceedings of the Second European Conference on Space Debris, ESOC, Darmstadt, Germany, 17-19 March 1997, (ESA SP-393, May 1997)

- It is difficult to give alternative. It is reasonable to suppose that the millimeter particles are the products of explosion of tanks for example -- in this case the task would be more certain.

2. The sources of orbital millimeter particles are space explosions, but the model doesn't use an explosion catalog.

-- The history of orbital explosions has too many blazes. At nearest future explosions' data will be rather defective to complete a space debris model. Again to include the individual explosions the model "tuning" may be changed.

3. The model does not account of eccentricity of orbits. As long ago as work [11] it was pointed out the influence of high eccentricity orbit particles to population in near-earth orbits. A considerable amount of explosions occurs in high elliptical orbits (Fig. 1). In any explosion the products have rather long orbits (Fig. 2).

- The accuracy of solving evolution problem in the model connected with correctness of the starting data today. Again to raise the mathematical accuracy one needs to account of eccentricity, argument of perigee and longitude of ascending node all together. The atmosphere is asymmetric also. It is not engineering problem, it is the task for exploring methods.

4. There are tasks needed most compact characteristics of space debris. For example the solving of telescope problem such as below needed to compute 6 multiple integral. For this purpose NASA's analytical model [12] was used.

- The model solves main problems. One model cannot comprise all events.

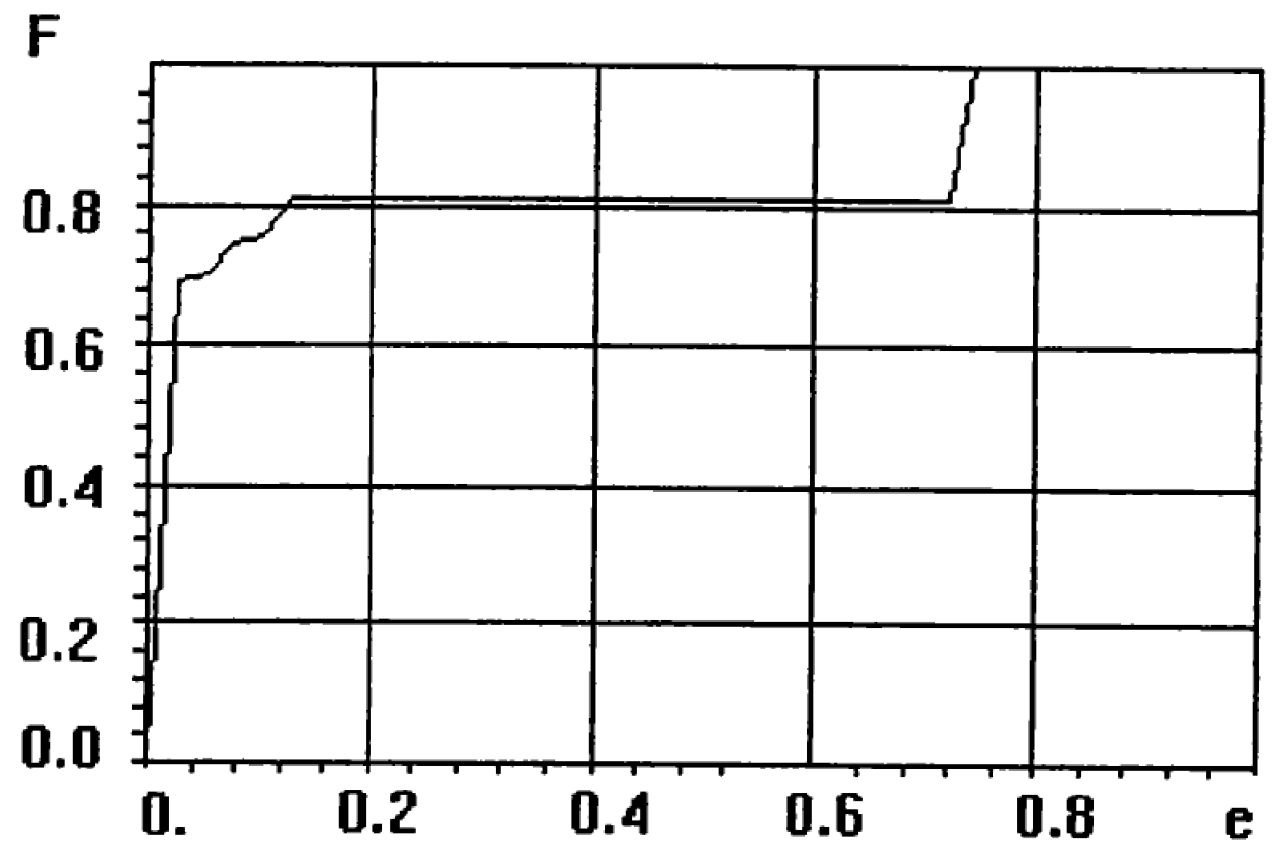

Fig.1 Cumulative distribution of orbit's eccentricities in the catalog of explosions.

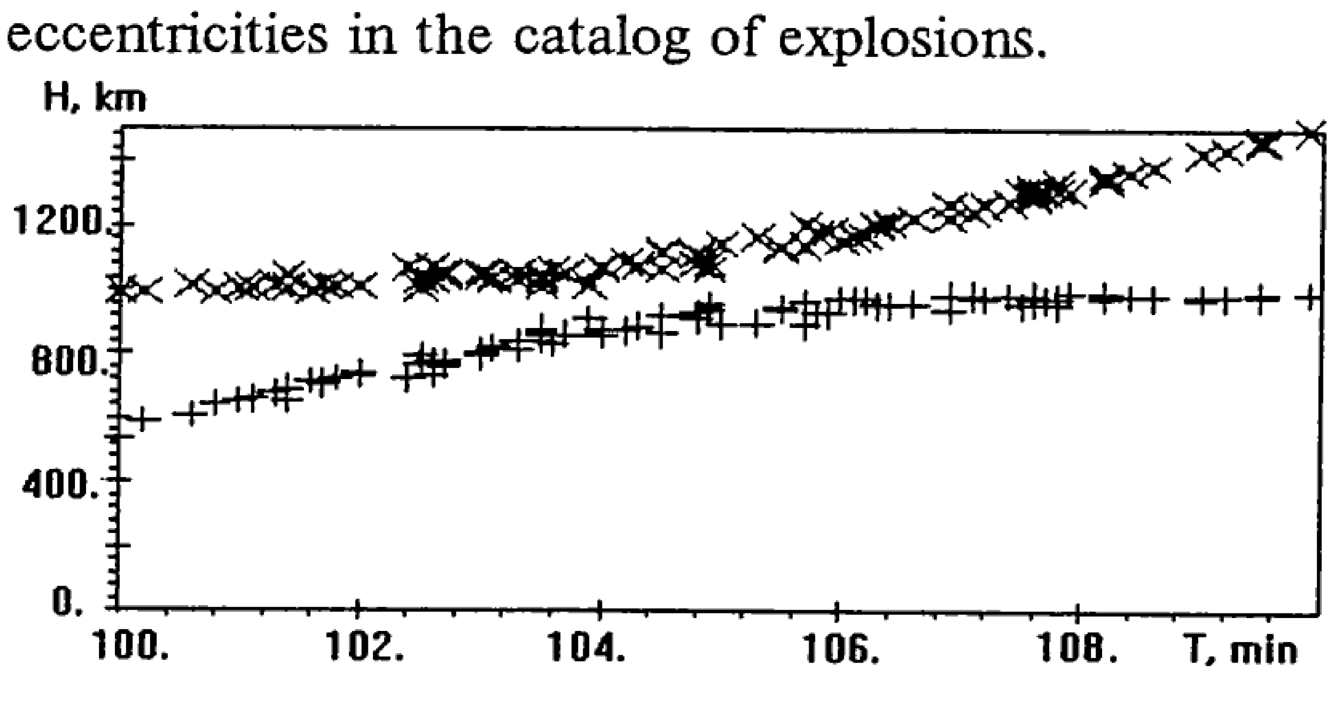

Fig.2 Common Gabard's diagram for millimeter fragments of an explosion.

4. <u>The alkali droplets in near-earth space</u>

The alkali droplets thrown under graving the nuclear plants [13] may be one of component of space debris. In early performed calculations [14] the solar flux was 10 as much and equilibrium temperature was overstated. There are more accurate data. The vaporization rate is insufficient for the fast vanishing, but it seriously affect droplets orbital dynamics.

It should be noted that the thermal balance is very sharp, every small variation of the parameters would lead to essential change in results, and these results are also preliminary. It is prematurely to isolate the droplets from the model because there are not their sufficient statistical characteristics. But one may go to the more deep theoretical and experimental investigations. It should be observed that there are many space factors that can imply alkali metal's lifetime, and natural on-board experiments on space physics of these droplets should be preferable.

The remainder part of coolant can be poured out the reactor bodies as affected by shocks of space debris small particles and meteoroids and it is potentially dangerous. The probability of this stochastic process is implied by particle flux and response function. The last is unknown. But the preliminary examination of a thin film on metal surface[15] showed that probability of large pollution of altitudes 900 - 1000 km as result of this process is very small.

5. <u>Observation of millimeter particles with a space-based telescope</u>

As mentioned above ground-based radar observations are of paramount importance for the last progress in space debris problem. But these observations are unique. One may hope that space-based apparatus will be common tools those permit to obtain a regular and complete information. At first plan there are infrared and visual band telescopes. There were computed the possible using of telescope IKON [16], that is similar to telescope IRAS, for observation of millimeter particles. It was supposed that the telescope will be operated in staring mode with minimal possibilities of detecting of the orbits.. It would be interesting to orbit such apparatus below the first peak of pollution that is of most interest. Frequency of registration of orbital particles seems to be rather low, on the verge of required statistics, but real. Perhaps a telescope in visual band will be more effective.

There are cumulative distributions of registrated numbers orbital particles with detector characteristic time equal 0.1 and 1 s and sensitivity in range of 10^{-14} - 10^{-16} J. It is appears, that one can obtain some information about the particle size and altitude

distribution by varying these parameters. To check the alkali hypotethis one may use simultaneous observations on several bands.
The interesting problem is using of space-based radars but this question needs initial studying.

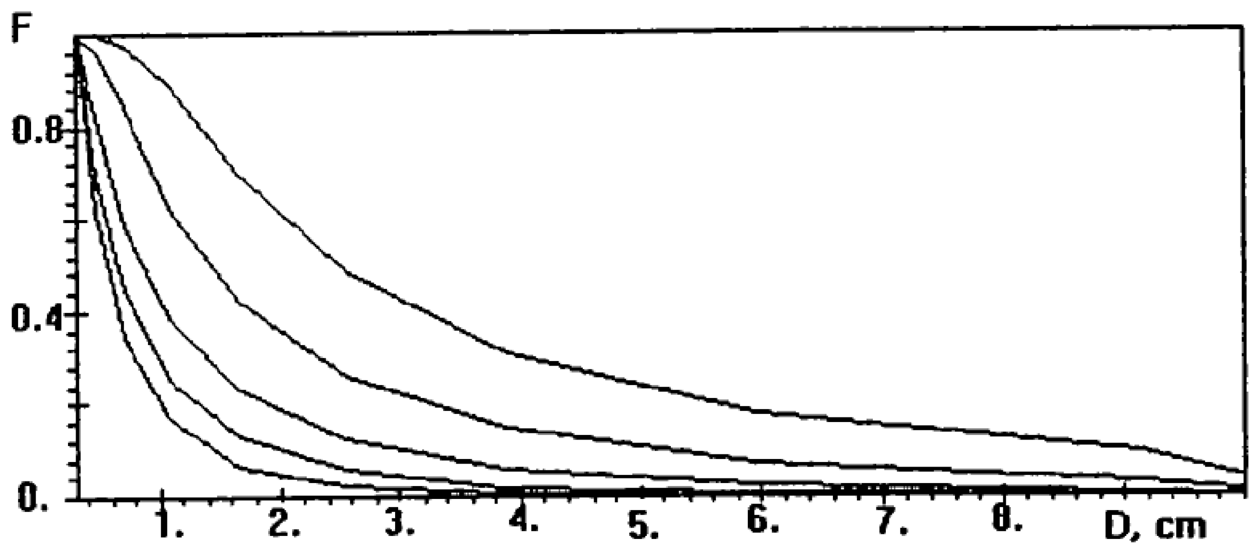

Fig. 3 Cumulative distribution of registrated particles. Detector's characteristic time equal 1 s.

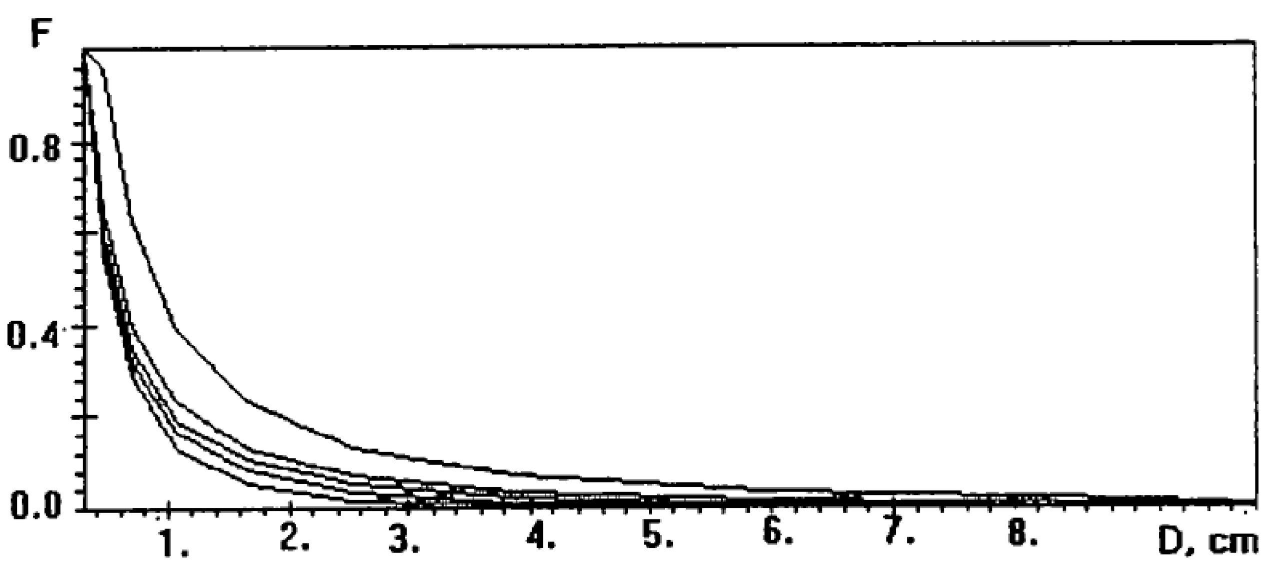

Fig. 4 Cumulative distribution of registrated particles. Detector's characteristic time equal 0.1 s.

6. Conclusion

We should solve the following problems in the first place.

1. To complete the validation of A.I. Nazarenko's model. To continue the work of checking one with another all methods worked out in different organizations that cover all questions from fragmentation to collision parameters' estimations. Space debris model means to be confirmed annually.

2. To analyze shares of individual explosions in millimeter and centimeter orbital particle's pollution. Each explosion has got its own characteristics. We should compute our explosions.

3. To analyse the evolution of debris population in 4-d phase space. It is possible that the statistical (or hydrodynamical) methods will be more effective for this purpose.

4. To work out methods of space-based optical observations. It is the nearest problem. Only on-board measurements will give the opportunity of regular estimation of near-earth space pollution.
It was interesting to account of MSX results and to continue and to add these investigations.

5. To go on the further theoretical and experimental investigations to make more exact estimation of share of alkali metals in pollution in the region of altitudes 900 --1000 km.

7. References

1. Stansbery E.G., Kessler D.J.. Tracy T.E., Matney M.J., Stanley J.F. Haystack Radar Measurements of the Orbital Debris Environment. *NASA, JSC-26655,* May 1994.

2. Khutorovsky Z.N., Boikov V.F., Kamensky S.Y. Direct method for the analysis of collision probability of artificial space objects in LEO: techniques, results and applications. 1st European Conference on space debris. Darmstadt, Germany, 5-7 April 1993.

3. Nazirov R.R., Sukhanov A.A. Method and results of prediction of orbital debris spatial density. 1st European Conference on space debris. Darmstadt, Germany, 5-7 April 1993.
4. Nazarenko A.I. Prediction and analysis of orbital debris environment evolution. 1-St European Conference on space debris. Darmstadt, Germany, 5-7 April 1993.

5. Smirnov N.N., Dushin V.R., Panfilov I.I., Lebedev V.V. Space debris evolution mathematical modelling. 1st European Conference on space debris. Darmstadt, Germany, 5-7 April 1993.

6. Pudovkin O.L., Pryakhina E.B. The distribution of technogenical bodies in near-earth space and estimation of their implying to space apparatus. Kosmicheskii issledovaniya, v. 32, N 4-5, 1994, 76-82.

7. Menjshikov V.A., Kusin A.I., Postovit I.A., Pchelinzev A.A. The probability of space apparatus collision with unobservable space debris. Moscow, VKS, ZNII im. N.K. Tikhonravova, 1996.

8. Khutorovsky Z.N., Kamensky S.Y., Boikov V.F., Smelov V.L. Risk of collision of space objects at low altitudes. In "Collisions in space" ed. A.G. Masevich, Moscow, Kosmosinform, 1995, 19-90.

9. Nazarenko A.I. Development of project of standard model of technogenical pollution of near-earth space. RSA, Center for Program studies, 1996.

10. Nazarenko A.I., Chernyavsky G.M. Modeling of near-earth space pollution. In "Collisions in space" ed. A.G. Masevich, Moscow, Kosmosinform, 1995, 104-130.

11. Kessler D.J., Anz-Meador P.D. Effects on the Orbital Debris Environment Due to Solar Activity. AIAA-90-0083, 1990.

12. Natural Orbital Environment Guidelines for Use in Aerospace Vehicle Development. NASA Technical Memorandum 4527, B.J. Anderson, Editor, R.E.Smith, Compiler, MSFC, Alabama,1994

13. Kessler D.J. A new source of debris: RORSAT's. 12th Inter-Agency Space Debris Coordination Meeting, Houston, TX, March 8-10, 1995.

14. Meshcheryakov S.A Critical time Periods for Collision Hazards of Spacecraft. 13th Inter-Agency Space Debris Coordination Meeting, ESA/ESOC, Darmstadt, Germany, 28 Feb -- 01 Mar, 1996.

15. Meshcheryakov S.A. Analysis of one line of evidence of orbital debris population bred by RORSAT satellites. 1st workshop on space debris. Moscow, Center of Program studying, October 9 -11, 1995.

16. Sholomitsky G.B., Maslov I.A., Arkhipova V.P. and others. Infrared survey of sky with large-angle cooled telescope on sun-synchronous satellite "Nika" (project IKON). Moscow, ISR RAS, 1995.