Space Objects Data Catalogue

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ABSTRACT

Question on the databases and catalogues creation for supporting various space debris issues was discussed in the STSC Technical Report on Space Debris (A/AC/105/720) presented at the UNISPACE III. It is the very actual problem to create such information tools which would be accessible for wide international science community.
The Space Council of the Russian Academy of Sciences (RAS) had proposed at the end of the 2000 to the President of the RAS to establish special Center on accumulation, processing and analysis of scientific information on various space debris issues.
According the special directive of the RAS President on Feb 28 the Center is to be based on existing infrastructure supported by the Ballistic Center of the Keldysh Institute of Applied Mathematics (KIAM).
Information core of the Center is the Space Objects Data Catalogue.

1. INTRODUCTION

Decision on creation of the Center logically follows of previous work by numerous institutes of the RAS in space debris related issues. The main problem was lack of coordination and almost absence of data exchange between researchers inside RAS as well as their collegues in Russian Aviation and Space Agency and Ministry of Defence.
It is clear that such wide field of studies as space debris requires a lot of tools to be permitting various scientists to avoid of equivocal understanding some information and results of it's analysis. As a result a lot of discussions it was decided that the primary such tool is commonly used Space Objects Data Catalogue. Here is some reasons why such catalogues was to be created as quick as possible

- *The extension of international cooperation in the field of an evaluation of space contamination by manmade objects causes the necessity of collecting, processing and systematization of a large information content presented originally in various formats, with various accuracy etc., and also creation of the software tools ensuring simpliest and at the same time fastest access to this information on the part of various organizations (including international) and separate contributors;*
- *The increase of number of actively functioning objects on orbits increases probability of origin of a various kind of conflict situations, as that use of intersected frequency bands, risk of collision of objects in the close located longitude positions on geostationary orbit etc. In spite of the fact that in the sanction of conflict situations a lot of organizations is engaged, the probability of their origin can essentially be lowered by supplying general access to the demanded reference information concentrated in one place;*
- *The sharp increase of computer's power, available to broad circle of the researchers, allows to decide many of problems connected to learning of evolution of whole set or separate groups of space objects of an artificial origin in near-earth space. But strict representation a lot of information is necessary for this;*
- *Despite of existence of special organizations engaging the collecting and storage of the information on activity of the man in space (first of all it concerns to the UN Secretary, executing management of the international Register of Space Objects, World Data Centre on Satellites and Rockets etc.), there are essential problems connected to occurrence frequently of the contradictory data on those or other aspects, complexity of adequate comparison of the information, in particular, orbital, presented in various models, formats and having various accuracy etc. At last, all these data by virtue of the circumscribed reasons are available while only to rather narrow circle of the experts, though all data doubtlessly represent all mankind value and should be available to everyone.*

2. INITIAL REQUIREMENTS AND STUDIES

Special methods of the Space Objects Data Catalogue (the Catalogue hereafter) construction were developed at the KIAM RAS. The logical model permitting to present in a formalized kind the description of any artificial space object on more than 200 parameters was put into the basis of the Catalogue. These parameters

characterize space object on the one hand as some material body (overall dimensions, weight, parameters of trajectory), and on the other hand - as some technical product or it's part (functionality, description of various onboard systems of space vehicles and stages of launchers, description of the reasons of fragments' formation and changes accompanying this in a condition of a payload etc.). Besides the concept of the description of continuous evolution of whole set of space objects of an artificial origin within the framework of this model for the first time is realized on the basis of two main concepts - the object and the event. The capability of data storage on just planned events (launches, landings, manoeuvers, separation of subsatellites, dockings etc.) is incorporated into the model apart of the description of the past states.

The circumscribed area of space was not limited in formal terms during initial studies, that allows to store in the Catalogue the information on objects located on orbits around other planets or on their surface. Objects are any payloads, rocket bodies, special upper stages, fragments, clouds of small particles etc., and events are understood as change of a condition of separate object or some group of objects (launching into orbit of new objects, docking, landing, fragmentation of object, manoeuver etc.) at some instant. Such approach has ensured a capability of a reconstruction of set of objects with a set of their characteristics at given time, and taking into account happening events for any specific instant, including some section in the future too. It allows to make, for example, preliminary simulation of phase of spacecraft launch with the purpose of detection of possible dangerous approaches with others space objects, to obtain an extensive statistical material at a construction of models of distribution of objects in near-earth space etc.

At a level of objects' identification the capability of storage of the designations and identifiers of the same object used in various sources (the UN Register, catalogue supported by the U.S. Space Surveillance System etc.) is supplied. It allows without additional costs of time to receive the required information on object, irrespective to the identifier used in the query.

One more important feature of the Catalogue is the capability of storage even of the contradictory data on values of same parameter for the same space object irrespective of the reason called this inconsistency (for example, quoting of weight of a geostationary spacecraft at the lift-off moment as relating to a working orbit time etc.). Moreover, in accordance with conflict resolution, the capability of correct attachment of the data to a particular instant is provided.

At last, one from important advantages of the Catalogue is the storage of the reference on a source of the data on each value of each parameter or logically connected group of parameters (for example, orbit parameters). Any information can not be brought in to the Catalogue without the indication of the reference on a source of the data. It allows at the analysis of the information to make correct comparison of the various data.

3. THE CATALOGUE STRUCTURE

The Catalogue structure in common form is presented at Fig.2 as well as structure of more general Space Debris Issues Data Catalogue at Fig. 1.

The structure shown is realizing the "objects-events" concept.

Each of shown boxes covers a large portion of various tools for working with data.

Orbital archive and all orbital/celestial mechanics tools are separated of data tools intentionally since they can be used in other tasks not related to space debris.

As to formats of data storage in the Catalogue, the capability of input and storage, in particular, of orbital information in the known forms of representation - state vectors (as in Russian science centers and NASA centres), Two Line Elements (as standard generated by the U.S. Space Command and everywhere used) is stipulated.

4. CURRENT STATUS

Experimental version of smaller part of the Catalogue covering administrative and some physical characteristics of objects as well as orbital and measurements archive (without powerful processing tools), primary events (launches, decays, fragmentations, dockings/undockings and subsatellites separation) and reference data library had been developed in 1994-1997.

It was filled with the every possible data on more than 28000 man-made space objects appeared in space since October 4, 1957.

Last year it was decided to start with development of the Catalogue on the basis of up-to-date computing technologies and programming. At present such version of the Catalogue is under development by the Russian *KIASystems* company.

Linux and Oracle 8.1 were choosen as operational system and RDBMS respectively. Database structure and all algorithms of data processing were reevaluated and significantly upgraded.

Currently structure of database is written and created in Oracle environment. Special procedures for data upload into the database and access to it from different tasks are undergoing intesive testing.

Large portion of real data (reference data, primary parameters of launches, objects, data for motion models, orbital archive) are loaded into the database.

To the most of them access is provided through user-friendly Web-interface.

For large orbital archive including data from various sources special task of orbital identification had been written and intensely tested. Following results were obtained by the date. Portion of around 2.3-2.4 millions orbits (approximately one year set for whole cataloged objects) is passing through identification task in nearly 7.5 hours at 650 MHz Pentium III. During the identification process following decisions are making:

- *whether an orbit relates to the proper number of object;*
- *whether an orbit is anomalous;*
- *whether the decay date stored in the database is correct;*
- *did the orbit of particular object perturbed by force not accounted by the motion model (i.e. did the object probably manoeuvered, fragmented, collided etc.);*
- *whether crosschanging of orbits within group of close objects took place;*
- *which different numbers relates to the same object (for example, which uncorrelated targets and cataloged objects forms the sequence of numbers of the same object).*

By the mid of March orbital archive for period of 1994-2001 had been used for intensive testing and tuning of the identification task for special groups of objects (like debris of recent fragmentation, clusters of controlled GEO sats, LEO constellations, objects with high drag or reflectivity etc.)

Accurate numerical model of motion also had been programmed.

One of significant results is development of the close approaches task similar to USSPACECOM COMBO and it's analogue using by the Russsian Space Surveillance Center. Current realization of this task permits to calculate close approaches between all orbiting objects included into the Catalogue (nearly 9000 objects) for period of one day just in 12-12.5 minutes on 800 MHz Pentium III. In other words, processing of one year period (archived data) takes about 73-76 hours. Such calculations were made for 1998-2000 years tacking into account results of identification task. Example of close approaches analysis results presented at Fig. 3.

5. CONCLUSION

Of course, the are some problems which should be resolved within near future. One of this is data comparing and exchanging with collegues from other organizations. It's very common problem tacking into account that we haven't yet developed any standards on such informational echange. The only commonly used and understandable data are Two Line Element sets producing by the U.S. Space Command. Also widely used, but of less known within space debris researchers community are datafiles in NAIF system developed by the JPL. So, it seems we need consolidate our efforts to solve the data exchange problem, at least, in formats and described parameters.

Other problem which requires participation of a broad circle of the experts, is the data acquisition for the Catalogue and drawing-up of the acceptable solutions concerning organization of broad access to it.

6. REFERENCES

References.

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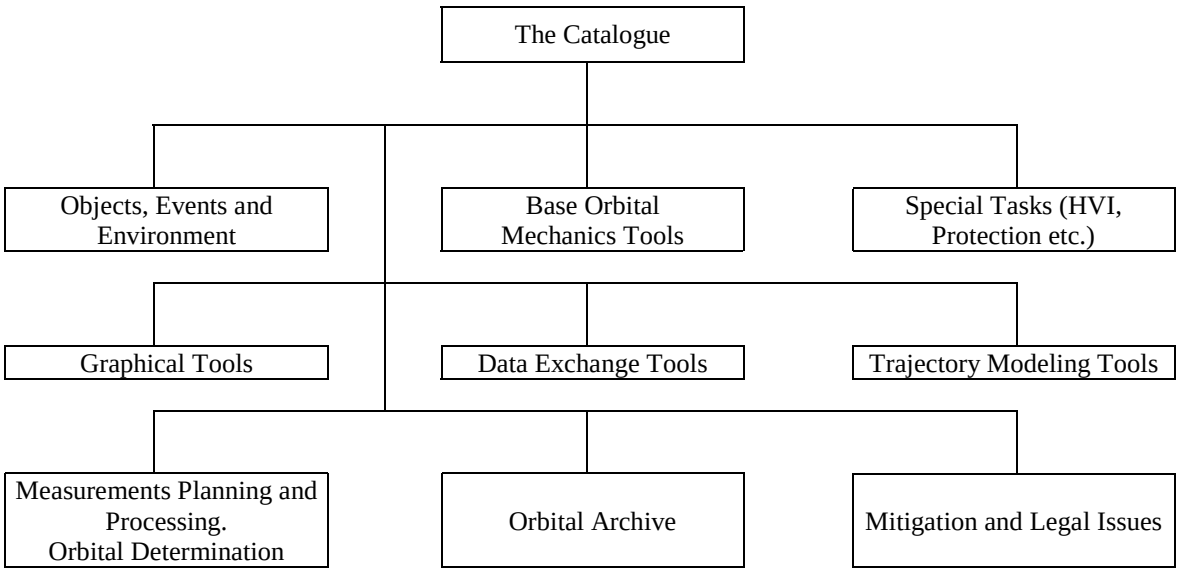

Fig. 1. Space Debris Issues Data Catalogue Structure

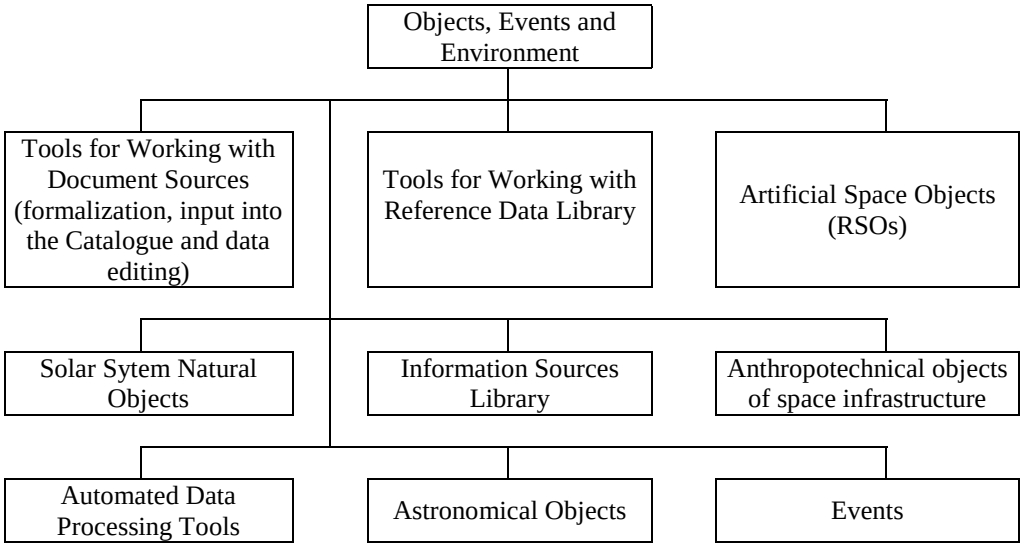

Fig. 2. Space Object Data Catalogue Structure

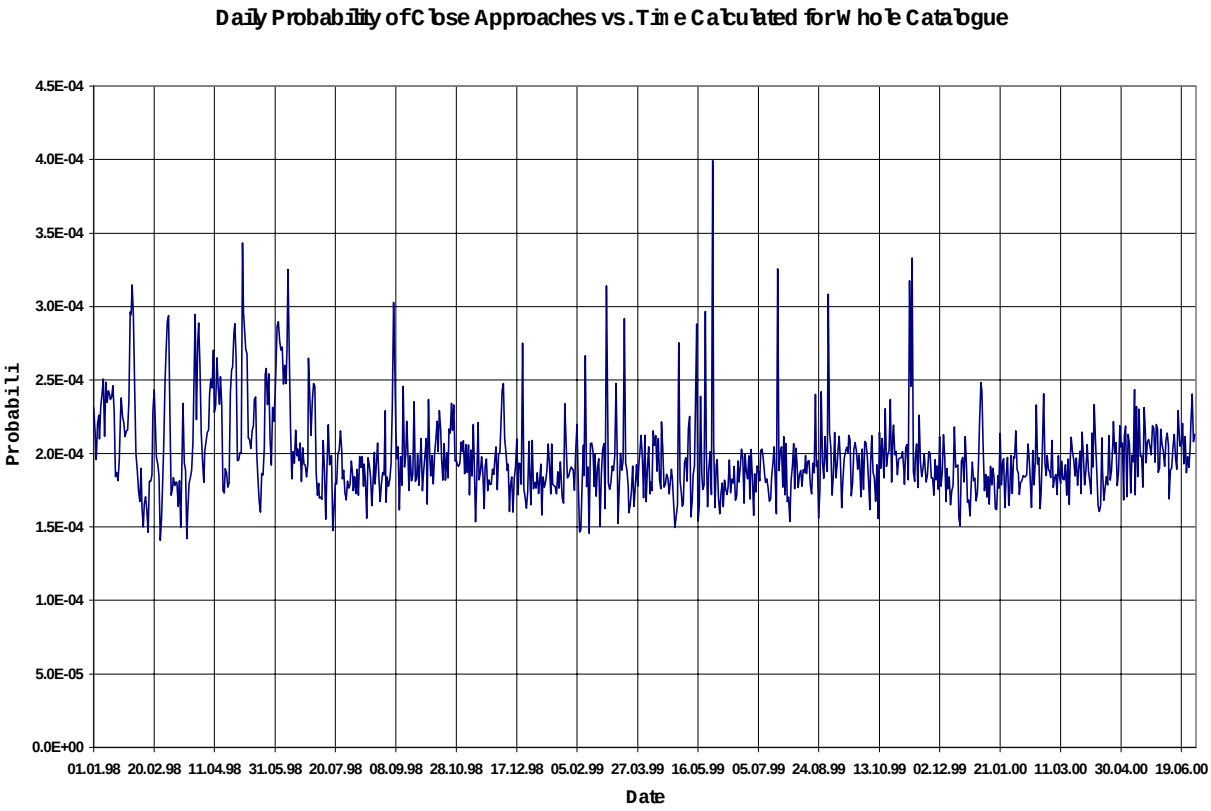

Fig. 3. Example of close approaches analysis results