SPACE DEBRIS END TO END SERVICE – PRESENTATION OF THE DLR WORK PLAN

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ABSTRACT

Resulting from the present effort on international regulations and the compilation of guidelines to handle the space debris problem in the future, the need consists to advise spacecraft manufacturer, suppliers and operators ideally in the form of a commercially useful End to End Service.

The competence of German institutions incl. research institutes and companies in the field of the space debris research and risk analyses is widely recognized and very well suitable to deal with all the corresponding aspects in Germany but also Europe-wide. It is the intention of DLR to concentrate and link all expertises and competences, available in Germany, in one coherent project. The space industry should contribute to risk analyses, reviews of guidelines and to proposals for space debris minimising design and operations of spacecrafts.

Preliminary proposals by several institutes and companies have been prepared and have been compiled to a consolidated work plan for a project named 'Space Debris End to End Service'. 'End to End' means the consideration of space debris mitigation aspects from begin of the design over the operational phase of a spacecraft up to the end of the mission and the following phase of the initiation of space debris avoidance measures (e.g. passivation, de- or re-orbiting). The effectiveness of such an End to End Service shall be demonstrated on a satellite project.

The work packages of the project shall cover in principle the following activities:

- Conception of an End to End Service
- Identification of national needs, the state of knowledge and information
- Spacecraft requirements and mitigation measures
- Re-entry analyses
- Application on a pilot project, incl. system review, meteoroid and space debris modelling, hazard analyses, recommendations of measures and a cost to benefit analysis.

This paper reports about the work plan and the status of the project.

1. INTRODUCTION

Spacecrafts are very expensive objects, of which the development, the launch and the operation need in most cases hundred of millions dollars - in the case of governmental contracts spent by the taxpayers. Therefore it is logical to reduce or better to avoid the risk of loss of a spacecraft but also to avoid the generation of space debris or at least to minimize it. At the same time all measures have to be taken to avoid damages of human life or objects, which could result from surviving re-entries and impacts on ground.

The space debris problem is becoming more and more complex. With the increasing number of spacecrafts and therefore the increasing population of space debris, the more detailed knowledge on the environment, the effects of space debris impacts, the potential mitigation measures, the effects of impact protection systems, the operational consequences and the effort to international regulations it is a need of support and advise to spacecraft manufacturers, suppliers and operators, idealized in the form of an also commercially usable End to End Service. With this project a concept shall be developed for such an End to End Service starting with the conceptual phase up to the end of life of a space project or programme, so that the hardware in orbit – hopefully - does not end as space debris.

This project starts as a national project but it is the intention of DLR to implement it in interna-tional cooperations. A first opportunity is the ESA 'Network of Centers on Space Debris', in which the Space Debris End to End Service project will be integrated. At the same time the project can also be considered as a contribution to the activities of the IADC (Inter-Agency Space Debris Coordination Committee) and to the initiative of the 37th session of the Scientific and Technical Subcommittee (STSC) of the UNCOPUOS to investigate the effectiveness and economical aspects of space debris mitigation measures.

2. PLANNING OF ACTIVITIES FOR 2001 TO 2003

On a national workshop in February 2000 the repre-

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industry have presented their activities in the field of space debris research. Furthermore it was discussed the possibility of the establishment of a single coherent project to keep the space debris related competence and expertise in Germany as well as to participate in international programmes or projects and to contribute to them, in particular in the framework of ESA and the IADC.

3. OBJECTIVES OF THE PROJECT

The objective of this project 'Space Debris End to End Service' is to create and establish a concept and the necessary tools to advise and support future users of the outer space in the treatment of the space debris problematic. This includes also the information on national and international agreements, guidelines and standards on space debris mitigation as well as support the achievement of design and operational requirements of spacecrafts in this respect

'End to End' means the consideration of all space debris aspects from begin of the design over the operation of a spacecraft up to the end of the mission and the following phase of space debris avoidance measures (e.g. passivation, de- or re-orbiting). This means for the potential user of the space that he will be informed on national as well as on international agreements, guidelines, regulations and standards - also they are not legally obliged – already in the planning phase and to consider them in his contribution to the space debris mitigation. He can take appropriate measures in advance in the spacecraft design as well as for the operational phase. But it will be shown also the possibilities how to estimate the risk of a space debris impact and how he can protect against – at least up to a certain order of magnitude of impact particle size. The user will get also an orientation for the expenditure of space debris mitigation measures, demonstrated by exemplarily performed cost to benefit analyses.

After end of mission, measures have to be taken to transfer the spacecraft into a mode (e.g. destructive re-entry, lifting on a 'disposal orbit') to exclude any risk of damage of other space objects or damages on ground. That closes the End to End Service, considered in the chronological course of a space project or programme.

There are many intensive international efforts to come to worldwide agreed regulations on space debris mitigation measures (IADC, UNCOPUOS, ITU). This project will contribute to these efforts.

The following results shall be achieved by this project:

- Presentation of a requirement specification for an End to End Service for the development of spacecrafts and the demonstration of the concept by a national pilot project
- Presentation of a catalogue of space debris measures including a cost to benefit analysis
- Tools for improved re-entry and damage analyses as well as for the optimisation of impact protection systems
- To contribute with the findings to international cooperations (ESA, IADC, UNCOPUOS)

4. WORK BREAKDOWN STRUCTURE

The activities are subdivided into 6 main work packages and corresponding subtasks or sub-work packages, which will be finally defined as individual work packages. Subsequent an overview of the preliminary work breakdown structure (WBS) is given (the final work breakdown structure will be composed after the evaluation of the final proposals):

<u>WP 1000 Concept for an End to End Service</u>

- Identification of requirements for an End to End Service under
  - consideration of operational constraints and
  - consideration of consequences on the design.
- Establishment of a requirement specification
- Establishment of a guideline for the implementation of space debris mitigation measures into the spacecraft design and operation

<u>WP 2000 Identification of National Needs & State of the Art</u>

- Questionaire and interviews to identify the national needs and the state of the art

<u>WP 3000: Mitigation Measures</u>

- Identification of design measures, including
  - Damage analyses
  - Optimization of protection systems
- Identification of operational Measures

<u>WP 4000: Reentry Analyses</u>

- Analyses of the destruction of a space objects during re-entry
- Radar analyses to support numerical analyses

<u>WP 5000: Application on a Pilot Project</u>

- Selection of a pilot project to prove the service concept

- System review of the selected object
- MD-modelling
- Risk analysis
- Recommendation of mitigation measures

WP 6000: Cost to Benefit Analyses

- Estimation of the cost to benefit ratio of space debris mitigation measures

5. DETAILED DESCRIPTION OF THE WORK PACKAGES

In the following the work packages (WP) and sub-tasks are described in more detail.

5.1 WP 1000: Concept for an End to End Service

In this main WP and the corresponding sub-work packages an End to End Service concept shall be established. Special attention shall be directed to its soundness in industrial space projects with respect to existing and future recommendations, guidelines and standards for the space debris safety and mitigation.

Therefore a specification for the End to End Service shall be prepared also under the specific consideration of the requirements from industry's and operator's point of view. In this specification existing recommendations, guidelines and standards as well as existing tools to support the End to End Service shall be integraed.

WP 1000 will be subdivided into further sub- work packages:

- Identification of the requirements for an End to End Service

  Existing and future recommendations, guidelines and standards shall be considered and investigated with respect to their compatibility with industrial requirements. Existing tools to support the End to End Service shall be identified and classified.

  This sub-work package shall also consider the operational boundary conditions as well as the effects on the spacecraft design.

  The mitigation measures, identified in WP 3000, shall be reviewed in this work package for implementation into a requirement specification.

- Requirement specification

  In this sub-work package a requirement specification for the implementation of space debris mitigation measures into future spacecraft design and operations shall be established.

- Guideline

  A guideline shall be established to support and give instructions to spacecraft designers, engineers and operators from the begin of a space project or programme over the operational phase up to the end of life or mission to transfer the spacecraft into a mode, in which the spacecraft does not represent longer more a space debris risk (e.g. by a de-orbit or re-orbit manoeuvre).

5.2 WP 2000: Identification of the National Needs and the State of the Art

In this main WP the following activities are foreseen:

- Identification of concerned companies and operators, research institutes, insurance companies and public institutions (authorities, governmental customers etc.)
- Preparation of a questionnaires to identify the national needs and the state of the art
- Interviews with industry, operators, insurance companies and concerned institutions
- Evaluation and analysis of the questionaires with the feed back to the End to End Service concept

For these activities contributions by research institutes, space industry, public institutions, insurance companies and operators of space vehicles are expected.

5.3 WP 3000: Mitigation Measures

This main work package will be subdivided into two further sub-work packages: one will address design related measures and the other one operational measures.

In the first mentioned sub-work package potential measures for mitigation and avoidance of space debris will be identified, which shall be considered already in the design and development of future space vehicles.

Damage analyses shall be performed to achieve effective design measures. There shall be developed - so far as possible – universal damage equations for impact protection systems under consideration of particle geometry.

The physical phenomenology of processes shall be described. The behaviour of the second wall under defined particle clouds shall be analysed. Numerical analyses and impact tests shall be performed for verification of the developed damage equations.

Furthermore in this work package Meteoroid and Space Debris Protection Systems (MDPS) shall be optimised. The influencing parameters to reduce the mass will be determined. The computer program MDPANTO (Meteoroid/Orbital Debris Protection Analysis Tool) used for the optimisation of MDPSs will be upgraded.

Much work in these areas has been done before in many studies and projects of ESA. The results shall be considered within this project to avoid duplications.

In the other sub-work package mitigation measures shall be identified, which have to be taken during the operation of a space vehicles before reaching their end of life to minimize or avoid the generation of space debris. The potential consequences on the spacecraft design shall be taken into account.

5.4 WP 4000: Re-entry Analyses

This main WP will be also subdivided in two separate work packages.

In one sub-work package the numerical analysis of the destruction or the burn up of a spacecraft during re-entry shall be performed. The object, suitable for such an investigation, shall be chosen in accordance with WP 5000. The activities cover the object selection, the compilation of the essential data for modelling, the modelization and the performance of the fragmentation analyses. This includes also the estimation of the risk of survivability of the re-entry of a spacecraft.

In the other sub-work package combined radar observation and motion analyses of a selected object (or several objects) shall be performed. The orbit and object parameters will be compiled. In the ideal case this radar analysis can be performed with the object, chosen for the fragmentation analysis with which the SCARAB computer simulation program could be verified.

5.5 WP 5000: Application on a Pilot Project

The usefulness of the End to End Service concept shall be demonstrated on a pilot project. From the current point of view a national satellite project as ROSAT, ABRIXAS, CHAMP, BIRD or DIVA will be chosen as result of discussions with the project contractors.

In a sub-work package the system and the mission of the selected pilot space vehicle shall be reviewed according the End to End Service concept of WP 1000. Further specific requirements have to be compiled. Sensitive components to be protected against space debris impacts must be identified.

In another sub-work package the meteoroid and space debris environment to be applied on the pilot object shall be identified.

Also in a sub-work package a hazard analysis shall be performed. The potential risk of damage of the pilot satellite as well as potential damages caused by the satellite itself (e.g. space debris generated by loosing components, survived atmospheric re-entry) shall be analysed. The probability of damage or destruction of the system or of components shall be determined. Also the potential of secondary or consequential damages has to be identified.

5.6 WP 6000: Cost to Benefit Analyses

The benefit of the space debris mitigation measures shall be identified and brought in relation to the expenditure. For this exercise an appropriate and by industry accepted cost model has to be chosen. So this work package requires direct collaboration with the space industry and the operators of spacecrafts.

6. STATUS OF THE PROJECT

The start of the project has been postponed several times due to some organisational and administrative reasons created inter alia by the complications arising with the effort to establish a coherent project to be agreed by all partners within the governmental regulations. At the time of the 3rd European Conference on Space Debris the requests for proposals are under preparation.

The activities shall be managed by one selected prime-contractor, who shall also contribute to the project by a significant share, at least by the responsibility for the work packages 1000 and 2000.

It is now expected to start the project mid 2001. With the planned period of 30 months, the project shall finish end of 2003.

This work plan of the ‘Space Debris End to End Service’ project has also been presented to ESA as the German contribution for implementation into the Integrated Work Plan of the ‘Network of Centers on

Space Debris', to the 19th IADC Meeting at DLR in Cologne and to the STSC of the UNCOPUOS.

7. CONCLUSION

The project 'Space Debris End to End Service' will form for the first time an integral concept for spacecraft designers, manufacturers, suppliers and operators to consider the space debris mitigation aspects from the begin of a space project or programme up to the end of mission. They will receive a guideline to be followed during the design, the development and the operational phases of a spacecraft from the requirement specification to be considered over recommendations for constructural measures up to operational measures, so that the spacecraft will – hopefully – not end as space debris or destructed by it.