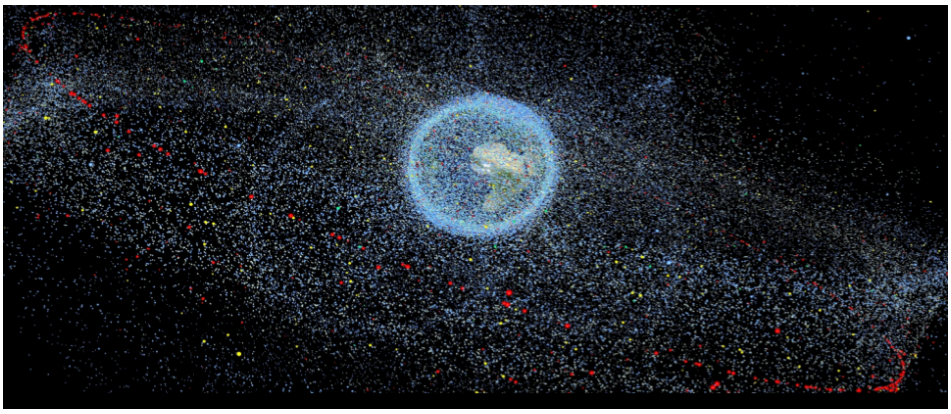
From Measurements to Understanding: MASTER Modelling Workshop

Tuesday 02 March 2021 - Thursday 04 March 2021

ESA/ESOC



Book of Abstracts

Contents

Talks - Day 3 / 5

DMF as support framework for impact risk applications

Author: Stijn Lemmens[1]

[1] *European Space Agency*

Corresponding Author: stijn.lemmens@esa.int

"Prediction is very difficult, especially if it is about the future", yet this is exactly the reality we face when we want to build the missions of tomorrow against the design requirements and licence requirements of today. Impact risks and the associated uncertainties in the untracked regime, caused by the uncertainties on the future launch traffic and adherence rates to space debris mitigation guidelines, can become unacceptably high when we have a pessimistic view of the future. On the other hand, we do not wish to underestimate risks of operating in a congested environment either.

Within the debris mitigation facility, a direct link with the work done on environment capacity and the tracking of current trends in space debris mitigation is envisaged. This link can be most clearly expressed under the form of regular MASTER population updates, based on direct data processing rules regularly applied to the measured environment. The aim is to have an automated extrapolation under modulated conditions with specific applications and community feedback in mind.

Talks - Day 2 / 6

From Measurement to Uncertainties to Understanding

Authors: Andre Horstmann[1]; Vitali Braun[1]

[1] *IMS Space Consultancy GmbH*

Corresponding Author: vitali.braun@esa.int

A major aspect in the upgrade towards MASTER-8 was to come up with a functionality to assess flux uncertainties for the artificial space debris. The methodology is based on the comparison between measurements and the model output, expressed via the error-ratio. Depending on that ratio it was possible to have certain metrics defined for the first time in MASTER's validation process that go beyond the qualitative assessment of the results by a trained expert. Those metrics give an indication of the model fit to what has been measured and pave the way for further automation in the validation process of the model. Due to very heterogeneous data sources covering size regimes from microns up to tens of metres in different orbital regions, a sensible weighting has to be applied. In this talk, the basics behind the methodology to derive flux uncertainties will be explained.

Talks - Day 3 / 7

FUTURE SPACE DEBRIS POPULATION STUDY

Author: Keiran McNally[1]

Co-authors: Alfredo M. Anton [1]; Hugh Lewis [2]

[1] *GMV*

[2] *University of Southampton*

Corresponding Author: kmcnally@gmvnsl.com

In the last two decades, a growing concern about the space debris population has been developed among the Space community as a result of the increase of the satellites launches particularly in the LEO regime due to proposed mega-constellations. Numerous studies and experiments have been conducted by ESA and other space agencies to determine the actual population of debris that is currently in orbit including, not only the catalogued ones, but also the sub-catalogue size objects.
This study was performed by GMV and the University of Southampton in 2018 for the UK's Defence Science and Technology Laboratory (DSTL)
In this study, MASTER population was used as the starting point in 2018 to provide DSTL with three plausible scenarios, short-term in the year 2023, mid-term in 2028 and long-term in 2043. Launches and fragmentation events in the last 3 decades were analysed in order to derive the trends on the different markets and regimes, e.g. earth observation in LEO, telecommunications in GEO, mega-constellations, etcetera… These trends were extrapolated to create a discrete population of new launches for the whole period considered.
Additionally, as requested by DSTL, the initial population and the launch trends were classified according to the operational mission, matching the population against the 18th SPCS catalogue.
The initial populations and the discrete launches populations were propagated using the software DAMAGE (Debris Analysis and Monitoring Architecture to the Geosynchronous Environment) developed by Dr. Hugh Lewis at the University of Southampton. DAMAGE is a three-dimensional computational model of the full LEO to GEO debris environment, capable of evolving populations of objects down to 1 mm. DAMAGE includes a semi-analytical orbital propagator, a breakup model, several collision prediction algorithms and a satellite failure model, which also accounts for mission failures resulting from the non-catastrophic impacts of small particles. For constellations, DAMAGE can apply a variety of post-mission disposal options, including the use of electric propulsion to adjust the post-service orbit of the satellites.
At the time of the study, there was a high uncertainty regarding the successful launch of the different constellations considered, such as Oneweb, SpaceX and Samsung. In order to manage this uncertainty, the output of the study includes four different simulations for the three scenarios, considering or not the Oneweb constellation, that was the most plausible at the time, and including or not fragmentations due to explosions. Additionally, each one of the simulations includes a Monte-Carlo like process in order to consider some stochastic processes during the simulations, such as collisions or the initial population randomisation on the MASTER objects. Finally, the obtained populations are compared against the MASTER populations provided by ESA for the scenarios at the selected epochs, in order to analyse possible differences on the launch trends and the effect of the fragmentations.

Talks - Day 1 / 8

ADLER-1 In-situ Space Debris Measurements

Authors: Gernot Groemer[1]; Willibald Stumptner[1]; Mario Lassnig[1]; David Smith[1]

[1] *Austrian Space Forum*

Corresponding Author: gernot.groemer@oewf.org

The Austrian Space Forum, in cooperation with SPIRE Inc and FINDUS Venture Inc., is developing **ADLER-1**, a 3U cubesat to be flown in late 2021 to measure small space debris particles at ca 500 km altitude. Two instruments are implemented: Firstly, **APID (Austrian Particle Impact Detector)**, a deployable piezoelectric detector array, able to measure particles in the range of down to ca 10 um. Given ESA's MASTER model and the instrument properties, we expect >100 impact events over the projected lifetime of at least 1 year. The detector will provide impact energy data.

Secondly, a continuous-wave radar shall measure both radar cross section and Doppler-derived velocity vectors for larger mm-sized particles. Both payloads are intended as in-orbit validation of the detection technique and shall contribute to complement the ESA MASTER-model with in-situ data sets.

Talks - Day 3 / 9

Collision Risk: The Insurer's View

Author: Chris Kunstadter[None]

Corresponding Author: chris.kunstadter@axaxl.com

Space insurance is a critical enabler of innovation and investment in space activity - it unlocks the economic potential and provides an economic safety net for the risks associated with space activity. Space insurance covers virtually all technical risk from launch onwards, through the life of a spacecraft. Space insurers recognize the significant increase in collision risk in Earth orbit, and seek tools to evaluate the space environment as well as to perform forensic analysis following a spacecraft anomaly. The ability to absolve collision as a cause of an anomaly - or, indeed, to confirm it - allows more appropriate corrective actions, reducing cost and risk for future missions.

Talks - Day 2 / 10

MASTER in support of environmental impact assessments

Authors: Francesca Letizia[1]; Stijn Lemmens[1]

[1] *European Space Agency*

Corresponding Author: francesca.letizia@esa.int

In recent years, several metrics have been proposed to quantify the impact of a mission on the space debris environment. These emerging approaches are meant to go beyond the analysis of compliance of missions with space debris mitigation guidelines, by considering additional aspects such the short-term impact of a mission on its neighbours and the evolution of the environment.

Our formulation for such analysis is a risk metric that measures the fragmentation risk associated to a spacecraft, i.e. the collision probability and the severity of the potential fragmentation. For the computation of the collision probability, the data from MASTER is used to obtain the flux of debris at the orbit location and derive the distribution of the flux as a function of the object size. In order to allow for almost real-time computation, collision probability maps are generated where the relevant data for the simulation is store to avoid direct calls to the MASTER software.

The presentation will give an overview of the computation pipeline and present some typical applications.

Talks - Day 2 / 11

Impact flux predictions with MASTER

Author: Maximilian Klaß[1]

Co-author: Gerhard Drolshagen [2]

[1] *University of Oldenburg*

[2] *ESA/ESTEC*

Corresponding Author: maximilian.klass@uni-oldenburg.de

Launched in 2008, the Columbus module of the International Space Station (ISS) has by now been exposed for more than 10 years to fluxes from micrometeoroids and space debris particles. Numerous impact craters are present on its outer surfaces. A group of researchers from various German entities has initiated an impact survey of outer surfaces of the Columbus module. Such a survey was supported by ESA and NASA and finally carried out in September 2018 using a video camera on the Canadian robot arm. While the survey data was analysed, an effort was made to compare the different flux predictions of the available debris/meteoroid models. This presentation focuses on the analysis with the MASTER debris model. The software that was used, including ESABASE2/debris and the MASTER standalone software will be briefly presented. Then, geometrical and non-geometrical results will be shown. The presentation will conclude by giving a short overview of the work with MASTER.

Talks - Day 3 / 12

Calibration and validation of MASTER model through space based optical observations

Author: Srinivas J. Setty[1]

Co-authors: Christoph Bamann [1]; Stefan Frey [1]; Luisa Buinhas [1]

[1] *Vyoma GmbH*

Corresponding Author: srinivas.setty@vyoma.space

Space environmental models are required for mission planning, orbit design, collision –avoidance-manoeuvre planning, and space sustainability ratings. Generally, the distribution of debris objects and micro-meteorites is modelled statistically and calibrated empirically, requiring re-calibration and validation at regular intervals.

The MASTER model provides flux estimates of orbiting objects down to the invisible range. The distribution of debris fragments can be estimated based on the observation of orbital events and using break-up models. The micro-meteorites environment is modelled as an empirical system. Observing these objects regularly and over a wide range of altitudes and latitudes has the potential to greatly improve the accuracy of statistical environmental models. Current observation techniques, however, are limited to

- counting the meteorites entering the atmosphere.
- counting impacts on spacecrafts where possible (including ISS)
- performing costly, and temporarily- and spatially-limited observation campaigns

In recent years, another source of calibration data has been gaining traction: images from space-based optical sensors. Small Earth-orbiting debris and meteorites have been detected and recorded by onboard camera instruments onboard of science spacecraft, such as those dedicated to the study of extrasolar planets. These objects leave traces of their existence in the long-exposure images in the form of streaks. Such images arose initially as a by-product of scientific missions.. however, this information can potentially be exploited to increase the fidelity of existing models and inherently improve their accuracy.

At Vyoma, we are planning to launch a small constellation of space-based optical sensors to observe and track Earth-orbiting space debris. Next to objects with sufficiently strong reflectivity and thus signature, we are expecting to observe many fragments with streaks that are too faint to determine its orbit or to correlate it with previous observations. This will produce a large pool of data, temporally and spatially distributed, to be exploited for statistical modelling.

We are studying the object sizes, properties and orbital ranges that can be covered with space-based optical sensors and how the acquired images can complement existing ground-based radars and passive optical systems for calibration of MASTER. Next to the results of this study, we propose preliminary techniques to convert optical streaks from in-situ sensors into object counts.

Talks - Day 3 / 13

Describing the sustainability of the Space Debris Environment

Author: Kerstin Soggeberg[1]

Co-author: Lorenz Boettcher [1]

[1] *Institute of Space Systems, TU Braunschweig*

Corresponding Author: k.soggeberg@tu-braunschweig.de

In the context of the increasingly important discussion about environmental protection on Earth, the environmental protection of space is also a developing field of research. During the last years, the discussion about a sustainable use of the limited resource of space has increased and is getting even more important when looking at the sophisticated plans of some stakeholders, e.g. SpaceX and the Starlink mega-constellation. For a description of the sustainability of the space debris environment it is essential to be able to quantify it. Some efforts for such quantification were undertaken in the past that are beyond the widely known key indicators, such as spatial density or the simple number of objects. The disadvantage of most of the already existing indices for quantification is often a relatively small number of indicators that are considered and that no weighting of the indicators is made. This is the starting point of the present work: we worked on an index to describe the space debris environment, that allows the consideration of various key indicators with weighting factors in order to provide a normalized metric. These weighting factors can reflect the relative importance of single indicators with respect to the global sustainability. The index is based on the one hand on a survey among diverse stakeholders from the space sector. The survey enabled us to include different opinions on sustainable space flight. On the other hand, we included not only typical indicators of the debris environment, but equally an inquiry in various non-space research areas, like economy, forestry, and oceanography. With a look into different research areas we were able to describe how complex correlations and in which manner, qualitative indicators were made quantifiable in these areas. With this background we defined different key indicators and their respective composition and weighting to form a generalized sustainability index. The possibility to quantify the space environment's health in a proper and generalized way is the first step for a definition of a sustainable space debris environment.

Talks - Day 1 / 14

The validation of the MASTER model

Author: Carsten Wiedemann[None]

Corresponding Author: c.wiedemann@tu-braunschweig.de

MASTER is based on a validated debris population. The process of generating the population is complex. It is a combination of statistical and deterministic methods. The debris release events are described using statistical methods. The orbital distribution is calculated semi-analytically. The distribution of the space debris varies significantly between different orbits. Selected examples are used to illustrate how the MASTER population can be validated with published measurement data.

Talks - Day 2 / 15

MASTER and Systema-Debris

Author: Meggie Vilaranda[1]

[1] *Airbus DS*

Corresponding Author: meggie.vilaranda@airbus.com

Due to their high velocity, micrometeoroids and small orbital debris (MMOD) represent a threat to the spacecraft or its components. Moreover, the amount of debris in space is continuously increasing. It is thus necessary to assess the probability of spacecraft damage or failure due to a MMOD impact during its mission lifetime. The aim of a risk assessment is to identify the SC components sensitive to MMOD, provide inputs to assess the SC reliability and, if necessary, support the implementation of shielding to improve spacecraft survivability. Systema-Debris is a software that perform this kind of risk assessment analysis. One of the inputs of Systema-Debris is the environment description of the STENVI files , output of MASTER.

The objective of the presentation is to present the computing process of the risk assessment tool Systema-Debris and in particular how it relies on MASTER's background population, how MASTER can participate in the improvement of Systema-Debris and raise interrogations about the STENVI format.

Talks - Day 1 / 16

Orbital Debris Engineering Model (ORDEM) 3.1 Development and Validation

Authors: Alyssa Manis[1]; Mark Matney[1]

[1] *NASA*

Corresponding Authors: alyssa.p.manis@nasa.gov, mark.matney-1@nasa.gov

The newest version of NASA's Orbital Debris Engineering Model, ORDEM 3.1, incorporates the latest and highest fidelity datasets available to build and validate representative orbital debris populations encompassing low Earth orbit (LEO) to geosynchronous orbit (GEO) altitudes for the years 2016-2050. Observational datasets used for building model populations include those from the U.S. Space Surveillance Network (SSN) catalog (sizes down to ~10 cm in LEO and ~1 m in GEO), the Haystack Ultrawideband Satellite Imaging Radar (HUSIR; sizes down to ~5 mm in LEO), the Michigan Orbital Debris Survey Telescope (MODEST; sizes down to ~30 cm in GEO), and returned surface data from the U.S. Space Transportation System orbiter vehicle (Space Shuttle) radiators (sizes between ~100 microns and ~1 mm) and windows (sizes between ~10 microns and ~100 microns). This presentation will discuss the new data and new data analyses used to build the ORDEM 3.1 model populations and sample results of validation against separate datasets from HUSIR, the Goldstone Solar System Radar, returned surfaces from the Hubble Space Telescope, and MODEST.

Talks - Day 2 / 17

MASTER in view of a ESABASE2/Debris developer and user

Author: Anatoli Miller[1]

[1] *etamax space GmbH*

Corresponding Author: a.miller@etamax.de

The exploration and utilisation of space is affecting the environment in the vicinity of the Earth. The remains of space missions reach from paint flakes detached due to ageing to "dead" satellites and upper stages. These remains are called space debris and have more and more increasing effects on space-faring activities. Consequently, the space debris environment needs to be considered during the mission planning and spacecraft development, which requires a model describing this environment. The Meteoroid and Space Debris Terrestrial Environment Reference (MASTER) model

is European Space Agency's (ESA) standard model to describe the debris environment in the vicinity of the Earth.
Based on the MASTER model different aspects of a space mission can be evaluated. One of the aspects is the evaluation of the effects of the space debris environment on the spacecraft due to impacts. ESABASE2/Debris is ESA's tool for this purpose. It allows to use different space debris environments to analyse the effects of the debris impacts on 3D-model of the spacecraft. The MASTER models are part of the pool of the available space debris environments.
This talk is intended to look at the experience with MASTER models as an ESABASE2/Debris user and developer and MASTER models "beta-tester", with special consideration of the STENVI interface.

Talks - Day 2 / 18

Use of MASTER and ARES for Operational Collision Avoidance Support Planning

Authors: Sven Flegel[1]; Francesca Letizia[2]; Klaus Merz[3]

[1] *IMS Space Consultancy GmbH*

[2] *European Space Agency*

[3] *ESA*

Corresponding Authors: sven.flegel@ext.esa.int, francesca.letizia@esa.int

MASTER and ARES are used in the preparation of operational collision avoidance support. Specifically, two tasks are addressed: a) Determination of the probability of collision threshold above which a manoeuvre is initiated. b) Defining of feasible avoidance manoeuvres, given realistic encounter scenarios. The use of these tools is exemplified based on the two HEO missions INTEGRAL (2002-048A) and XMM (1999-066A) that are being supported by ESOC's Space Debris Office.

Talks - Day 1 / 19

Micro-particle measurements as part of ESA Space Weather missions

Author: Melanie Heil[1]

[1] *ESA*

Corresponding Author: melanie.heil@esa.int

The measurement requirements of ESA's Distributed Space Weather Sensor System (D3S) include sub-mm particle measurements in Low Earth Orbit (LEO) as well as Geostationary Orbit. The currently ongoing small satellite study for D3S is looking at the opportunity to host a micro-particle instrument in the few kg range to address this requirement for LEO. An overview of the D3S measurement requirements as well as the SmallSat mission will be provided.

Talks - Day 2 / 20

The role of uncertainties for computing micrometeoroid and space-debris impact risk

Authors: Jens Rodmann[1]; Karl Dietrich Bunte[2]; Anatoli Miller[2]

[1] *etamax space*

[2] *etamax space GmbH*

Corresponding Author: j.rodmann@etamax.de

Hypervelocity impacts of man-made and/or natural microparticles pose a significant environmental hazard to any space systems. Therefore, a detailed assessment of the impact risk sustained in a particular environment (e.g. LEO, GEO, interplanetary) over the mission duration needs to performed during the design phase of the space system.

Due to the high complexity of the risk and damage analyses on a three-dimensional spacecraft geometrical model, considering shadowing effects as well as impacts of so-called secondary ejecta, and allowing the application of various environment models and particle/wall interaction models, complex software tools are needed to perform these kind of analysis. An example is ESABASE2/Debris, the standard software for microparticle impact risks assessments used by ESA, various European satellites manufacturers, as well as in academia.

During spacecraft design, such tools are used to verify via numerical analysis that the probability of failure of a component, subsystem or the complete space system is below a pre-defined acceptable level. Typically, for manned space system (space station modules, crewed capsules etc.) more stringent design requirements apply. In case the analysis shows an unacceptable impact risk, the shielding properties of the vulnerable elements need to be changed. Conversely, microparticle impact risks assessments can be used to make saving in mass (and production and/or launch cost) by optimising shielding properties.

Spacecraft designer and operators need robust estimates of the microparticle impact risks, including quantified errors and confidence intervals for computed values. Currently, microparticle impact risk assessment tools do not support uncertainty quantification nor end-to-end propagation of uncertainties.

In this talk, we will look at ESABASE2/Debris analysis workflow to identify relevant sources of modelling uncertainties, ranging from the underlying microparticle environment models (MASTER, ORDEM), to the impact simulation (e.g. raytracing), and damage prescriptions (e.g. ballistic limit equations). We will propose approaches towards a more robust, quantitative microparticle impact risk assessment software having full uncertainty quantification and end-to-end uncertainty propagation.

Talks - Day 1 / 21

DEDRA on-board MOVE-III: An in-situ detector to support the validation of MASTER

Author: Xanthi Oikonomidou[1]

Co-authors: Eleftherios Karagiannis [2]; Marius Schlaak [2]; Alexander Hacker [2]; Paul Pucknus [2]; Luis Pretsch [2]

[1] *European Space Agency*

[2] *Technical University of Munich*

Corresponding Author: xanthi.oikonomidou@esa.int

Since the beginning of the space age in 1957, numerous artificial objects have accumulated in orbits around the Earth. While a portion of the defunct objects are large enough to be tracked by surveillance networks, the vast majority is non-trackable debris. Within the past decades, several models have been developed, aiming at modelling the ever-changing space debris and meteoroid environment. The characterization of the environment is not an easy task, especially when the non-trackable population is considered. Whilst on-orbit remote sensors have the potential of detecting

non-catalogued objects, at present, the sub-millimetre realm can only be effectively studied with in-situ impact techniques.

Models such as ESA's MASTER depend on in-situ measurement data to validate their small object population estimates. Typically, the main validation source are impact features from spacecraft or components exposed to the space environment for a period of time and brought back to Earth. Returned surfaces can provide invaluable information but they depend on missions to return them, and are characterized by limited orbital coverage and time of exposure. A potential validation source for the MASTER model, which could help reduce the spatial and temporal knowledge gaps of the small object population, is data from in-situ detectors.

MOVE-III is a CubeSat project of the Department of Aerospace and Geodesy at the Technical University of Munich, that aims to provide in-situ measurements of sub-millimetre space debris and meteoroid impactors. The main payload of MOVE-III consists of an assembly of impact ionisation DEDRA (DEbris Density Retrieval and Analysis) sensors, carried on a 6U Platform. The design of the sensor is based on the legacy of the MDC (Munich Dust Counter) sensor and the lessons learnt from the three missions that carried the instrument on-board. The basic information provided by the sensor is the number of impacts encountered at a specific location and time. Additional processing determines the mass and speed of each single impactor, which may allow the classification of the impactor's origin. Directional information provided by the advanced DEDRA sensor design recovers the full velocity vector, allowing a first order approximation of the impactors orbit.

In the new era of satellite technology, CubeSats can provide a robust and, at the same time, low cost platform, which can be employed to collect in-situ space debris and meteoroid impact data using dedicated impact detectors. Well-established sensor technologies and data processing chains may open a new path to continuous in-situ data collection (e.g. CubeSat constellations or shared platforms) that can support the efforts of modelling the small space debris and meteoroid environment, and contribute in the validation of models like MASTER.

Talks - Day 1 / 22

Validating dust flux models with active and passive collectors

Author: Aishling Dignam[1]

Co-authors: Penny Wozniakiewicz [1]; Mark Burchell [1]

[1] *University of Kent*

Corresponding Author: aishlingdignam@gmail.com

Over the past six decades, the near Earth environment of space has changed dramatically, from one traversed only by naturally occurring meteoroids and micrometeoroids (**MM** s), to one that is populated by thousands of artificial satellites dedicated to communications, navigation and the collection of Earth observation and astronomical data. Although around 1,200 operational satellites currently orbit Earth, the planet is also currently surrounded by a very large number of other objects produced by human activities in space - orbital debris (**OD**) [https://www.esa.int/Our_Activities/Operations/Space_Debris/About_space_
To enable predictions of particle flux with time for the OD and MM populations, and hence the hazard they pose to spacecraft, environmental computer models such as NASA's Orbital Debris Engineering Model (ORDEM) and ESA's Meteoroid and Space Debris Terrestrial Environment Reference (MASTER) have been developed. Agreement between the fluxes predicted by these two models is not always good [Krisko et al., 2015] and it is therefore vital to validate and improve their predictive power with real data. Objects larger than ~few mm can be detected using ground and space-based radar and optical telescopes [e.g. Goldstein et al., 1998; Stokely et al., 2006]. For smaller objects, we must look to directly measure the flux, either in situ by means of active detectors or by returning spacecraft surfaces (either dedicated passive collectors or opportunistic samples e.g. solar cells, radiator panels etc.) for study in laboratories on Earth.

The choice between active and passive methods is dependent on the information required. Active sensors are designed to measure dust impacts in real-time, being able to measure numbers, velocities and trajectories (and potentially orbit) of particles. However, such detectors have rarely incorporated compositional analysis and therefore cannot distinguish between OD and MM origins. The degree of damage caused by these dust particles is heavily dependent on characteristics such as their relative velocity, impact angle, shape and composition (e.g. OD relative velocities are typically slower than for MM, but OD particles are likely to be less porous). It is also therefore important to be able to distinguish between the OD and MM populations, to fully understand the threat posed by these particles. Dedicated passive collectors are designed for return to Earth where surviving residues of the impactor can be studied by high sensitivity analytical instruments, permitting rapid identification of MMs versus OD, based on distinctive chemical signatures. For example, OD particles are commonly composed of metallic elements in major element combinations not typically found in natural MMs (e.g. Al, Fe, Ti, Ni, Cu, Cr, Mn in OD alloys). When supported by complementary laboratory analogues, details of the impactor's size and structure can also be inferred. However, unless a constant pointing of the surface was guaranteed throughout the mission, pre-impact orbits cannot be determined.

In our talk we will describe some of the active and passive collection methods, their pros and cons and present details of the dedicated passive collector we are currently working on.

References:
Krisko et al., 2015. ORDEM 3.0 and MASTER-2009 modeled debris population comparison. Acta Astronautica, 113:204-211.
Goldstein et al., 1998. Radar observations of space debris. Planetary and Space Science, 46:1007-1013.
Stokely et al., 2006. Debris flux comparisons from the Goldstone radar, Haystack radar, and Hax radar prior, during, and after the last solar maximum. In Proceedings of the 36th Scientific Assembly of COSPAR, Beijing; China.

Talks - Day 1 / 23

The impact of satellites and space debris on Hubble Space Telescope observations

Author: Sandor Kruk[1]

Co-authors: Bruno Merín [2]; Pablo Garcia Martin [3]; Ross Thomson [4]; Samet Karadag [4]; Javier Duran [5]

[1] *ESA/ESTEC*

[2] *ESA*

[3] *Universidad Autonoma Madrid*

[4] *Google*

[5] *ESAC*

Corresponding Author: sandor.kruk@esa.int

Being situated in low Earth orbit, the NASA/ESA Hubble Space Telescope is susceptible to higher orbit artificial satellites and space debris crossing its field of view. We use Google's AutoML Vision object detection algorithm based on deep learning and trained on volunteers' classifications from the Hubble Asteroid Hunter citizen science project (www.asteroidhunter.org) to identify asteroids and satellite trails in HST archival images taken in the past 20 years.

We measure, for the first time, the fraction of images impacted by artificial satellites for different instruments, filters and as a function of time. We show results from this project and discuss the prospects of using deep learning and citizen science to identify trail shapes in astronomical images. Many astronomers have recently raised concerns about the impact of future satellite constellations on ground-based observations. We argue that mega-constellations will also impact observations from low-Earth orbit, such as those with the Hubble Space Telescope.

Talks - Day 3 / 24

Debris Mitigation Facility - A new way to use MASTER

Authors: Jonas Radtke[1]; Christopher Kebschull[1]; Sven Müller[1]

[1] *OKAPI:Orbits GmbH*

Corresponding Author: jonas@okapiorbits.com

Debris Mitigation Facility (DMF) is a stream of activities procured by ESA, to provide a single set of software and procedures to perform space debris mitigation related analyses. The development of DMF is stated building on existing Space Debris Tools from ESA, such as MASTER and DRAMA, but re-invents their usability: Whereas up to now, each tool is self-standing which runs independently, DMF is being set-up as a mission-centric software, following the ideas and practices of model based engineering (MBSE). As such, DMF will be connected to CDP4/OCDT, ESA's approach to MBSE during concurrent design (CD) activities. Over time, the tools and software attached to DMF will provide functionalities that go far beyond what MASTER and DRAMA are currently offering. While DMF will keep all features that are available for mission analyses by MASTER and DRAMA, as its core it is intended to be used for space debris mitigation requirements validation, such as ESA requirements, ISO 242113, or the American Orbital Debris Mitigation Standard Practices (ODMSP). As such, it can be understood as a consumer of MASTER and the provided debris environment, with the requirements for the software mostly stemming from satellite manufacturers/operators to gain short-to-medium insight in the interaction between their mission with the space debris environment, while being able to fulfil the demands from applicable guidelines, regulations, and standards. The developments of DMF is accompanied by providing a platform to facilitate the multi-lateral exchange between stakeholders of this system.

The presentation will show the approach for the framework development for the DMF system, as well as introduce some of its use cases. It will point out the needs of environmental modelling, as seen from a consumer perspective. In the following, it will introduce the approach taken for the new user communication platform. The main intent of this contribution is to reach out to the community of MASTER developers and users, raise awareness of the development of the DMF framework, and initiate communication between involved stakeholders to develop the DMF framework in the direction that fulfils their actual needs.

Talks - Day 1 / 25

SOLID - A solar panel based impact detector

Author: Waldemar Bauer[1]

[1] *DLR*

Corresponding Author: waldemar.bauer@dlr.de

SOLar panel based Impact Detector (SOLID) is a DLR in-house developed method that can be used to provide in-situ measurement data regarding objects in space in the range >100 µm up to several cm. SOLID makes use of already existing solar panels of a satellite for impact detection and can be utilized on different spacecraft in different orbits. Until now, a prototype of SOLID solar panel was validated on ground by means of Hyper Velocity Impact (HVI) testing at the Fraunhofer Institute for High-Speed Dynamics. Furthermore, four experimental panels were manufactured, integrated on the nanosatellite TechnoSat and placed in orbit. The next step is the realization of SOLID sensor on the upcoming DLR satellite CompactSat.

Talks - Day 2 / 26

MMOD modelling in an industrial context: the use and application of MASTER

Author: Bayrem Zitouni[None]

Corresponding Author: bayrem.zitouni@ohb.de

With the multiplication of space missions and despite the severe European regulations, Man-made debris are still a major concern when it comes to satellite design. In order to be able to answer all projects demands, OHB put in place a quite complete process for applying the modelling in the context of MMOD analysis.
This process is based on MASTER on one hand and Systema/Debris on other hand. MASTER helps us setting the MMOD environment for several types of orbits (LEO, MEO, GEO, Exploration) and this environment is then used by Systema/Debris software as input for calculating the impact on the satellite surfaces.
In this presentation, OHB will explain this process and show in details how MASTER is connected to Systema (stenvi files) and what are the advantages and limits for such a method. This application in an industrial context will contain some kind of preliminary comparison between MASTER 2009 and MASTER 8. The outcome of this comparison can be used as a base of discussion of what possible improvements can be imagined for the modelling process.
Finally, OHB would present its objectives for the next years when it comes to MMOD modelling and what are the points of interest (Lagrange Point, BLE equations –if not out of scope-, Meteoroids models).

Talks - Day 3 / 36

Managing Space Debris with and for Society

Author: Michael Clormann[1]

[1] *Technical University of Munich*

Corresponding Author: michael.clormann@tum.de

Space debris appears on the verge of triggering broader political and public debates on sustainable conduct in outer space. Simultaneously, the space sector undergoes profound transformations towards the paradigm of NewSpace – further strengthening its socioeconomic impact.
Both processes are interdependent and raise the question of society's future role in spaceflight activities. Social studies of science and technology indicate that large-scale infrastructures such as satellite constellations often meet societal resistance once they establish significant socio-technical risks. Such resistance usually can be minimized by 1. better understanding risk perception mechanisms and 2. the early implementation of transparency and co-creative efforts.
This means going beyond traditional science communication efforts or politics of representative democracy: engaging stakeholders in development and risk management processes can provide previously untapped legitimacy for a future space sector.
The presentation outlines the potential for co-creative processes based on social science research conducted within the author's dissertation project.