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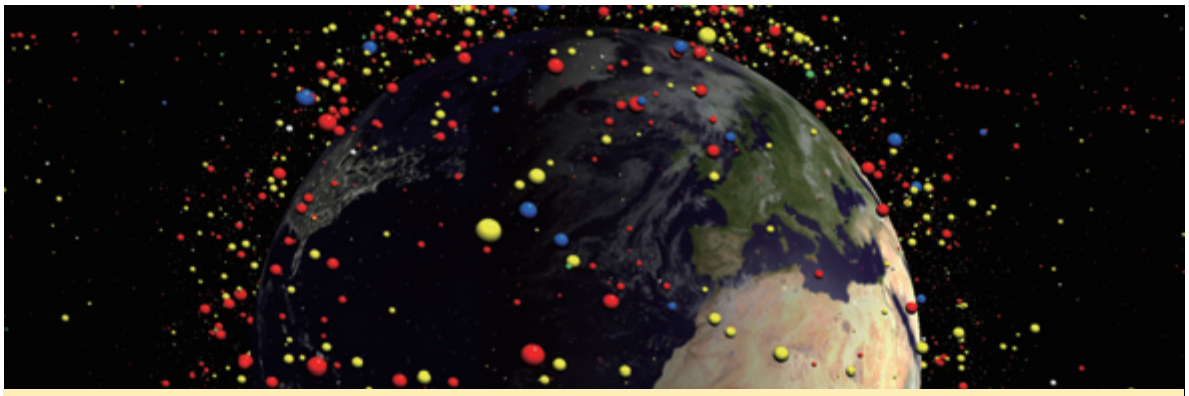

Modeling the Space Debris Environment - New Results

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Overview

Introduction

Space Debris
- Space debris sources
- Object distribution

New Simulations
- Centimeter population
- Decimeter population

Deliberate Fragmentations
- FengYun-1C
- USA-193
- Descent behavior

Summary

The Space Debris Team in Braunschweig

Carsten Wiedemann | Christopher Kebschull | Jonas Radtke | Sven Müller | Marcel Becker | Andre Horstmann | Enrico Stoll

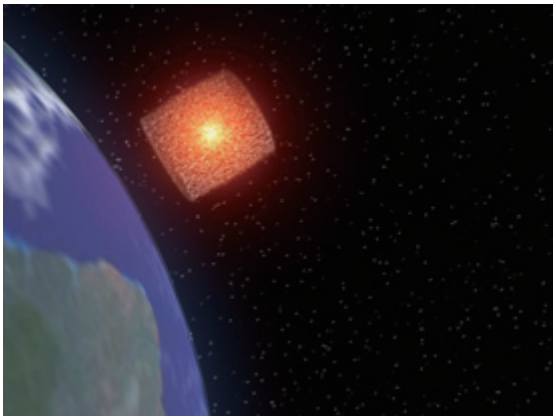
MASTER 2009 — PROOF 2009

Fragmentations

Is space debris a problem ?

Generation of space debris

- Most significant contribution: Explosion fragments
- 234 explosions of satellites and rocket bodies
- Common reason: unintentional self-ignition of residual fuel



High velocity impacts on satellite surfaces

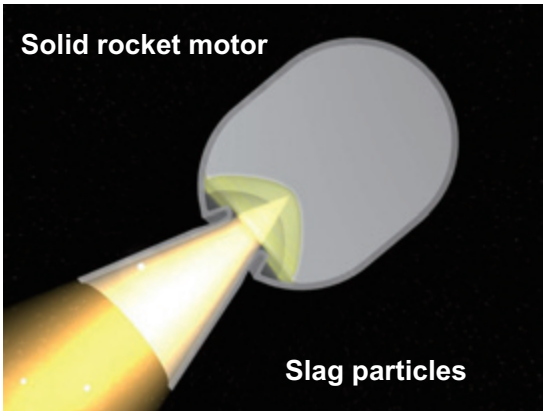
- High relative velocities of about 10 km/s
- Twelve times the energy of dynamite
- Centimeter object: energy of a hand grenade

Solid Rocket Motor Slag

New contributions to the space debris environment

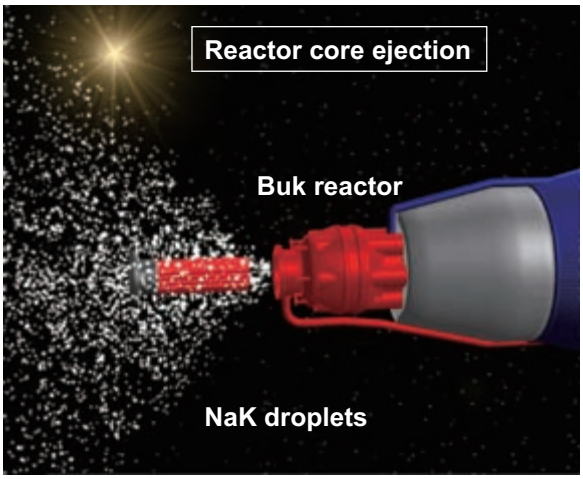
Solid Rocket Motor Slag

- 1,965 orbital transfer maneuvers
- Most maneuvers occurred at altitudes between 200 – 800 km and at 36,000 km
- Composition: mainly aluminum oxide
- Size of slag particles: up to 6 cm



Liquid Metal Droplets

RORSAT: Nuclear reactors in space



It is assumed that the release of reactor coolant is **an uncontrolled, unintentional by-product** of the core ejection process. A total of **16 core ejections events** have taken place.

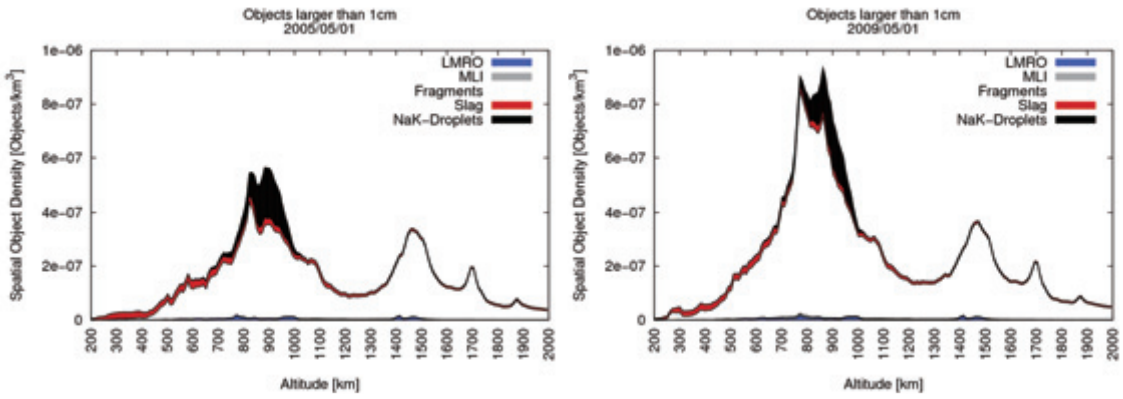
ESA's Space Debris Model MASTER

Meteoroid and Space Debris Terrestrial Environment Reference Model (MASTER)

Prime: Institute of Space Systems, Technische Universität Braunschweig

Spatial Density (> 1 cm)

Spatial density of debris larger than one centimeter according to MASTER-2009



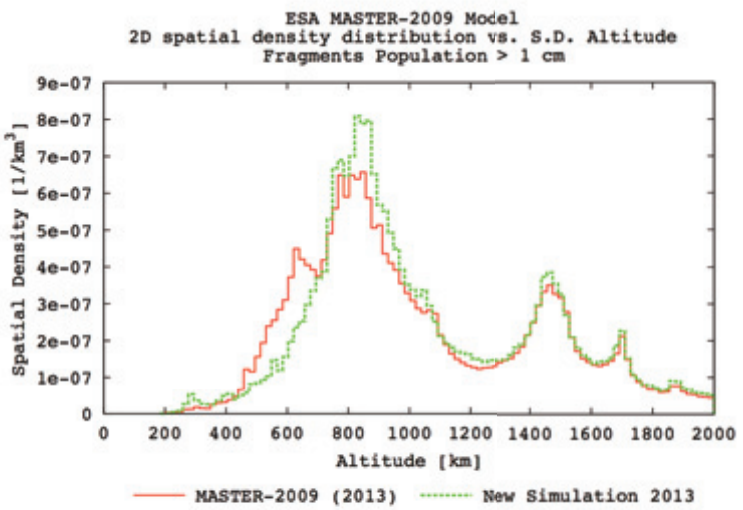
2005 2009

Fragments: New Simulations

The latest version of the model refers to the year 2009.
Since the year 2009, further fragmentations have occurred.
It is necessary to continuously update the population.
The individual additional events are simulated.

(The followings two slides refer exclusively to the fragments. Other contributions to space debris are not considered here.)

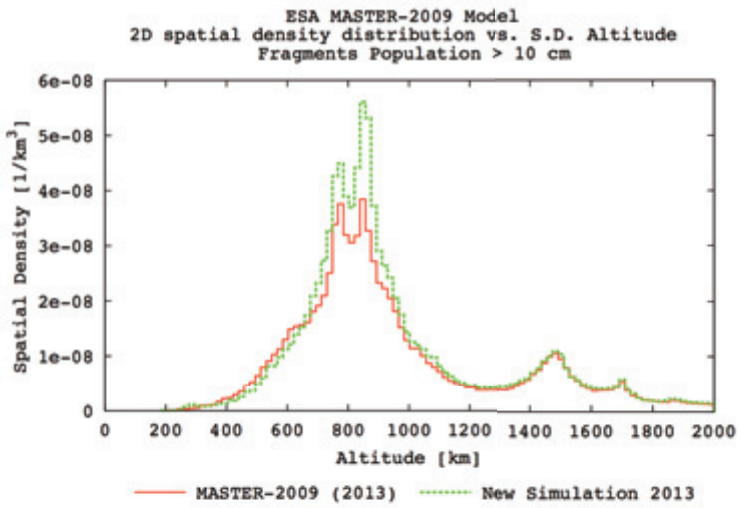
New Simulation: Spatial Density (> 1 cm)



Wiedemann, C., Flegel, S., Kebschull, C., Additional orbital fragmentation events, 65th International Astronautical Congress 2014 (IAC 2014), September 29 - October 3, 2014, Toronto, Canada, paper IAC-14.A6.P.57.

Spatial density of orbital fragments larger than one centimeter on LEO at January 2013, comparing the BAU scenario of MASTER-2009 with new simulations.

New Simulation: Spatial Density (> 10 cm)



Wiedemann, C., Flegel, S., Kebschull, C., Additional orbital fragmentation events, 65th International Astronautical Congress 2014 (IAC 2014), September 29 - October 3, 2014, Toronto, Canada, paper IAC-14.A6.P.57.

Spatial density of orbital fragments larger than ten centimeters on LEO at January 2013, comparing the BAU scenario of MASTER-2009 with new simulations.

Deliberate Fragmentations

In the history of spaceflight several satellites were destroyed intentionally on Earth orbits.

The released debris contribute significantly to the space debris environment.

In the recent past, there occurred two orbital fragmentation events, which attracted special attention. These were the destructions of

- the Chinese satellite FengYun-1C and
- the American satellite USA-193.

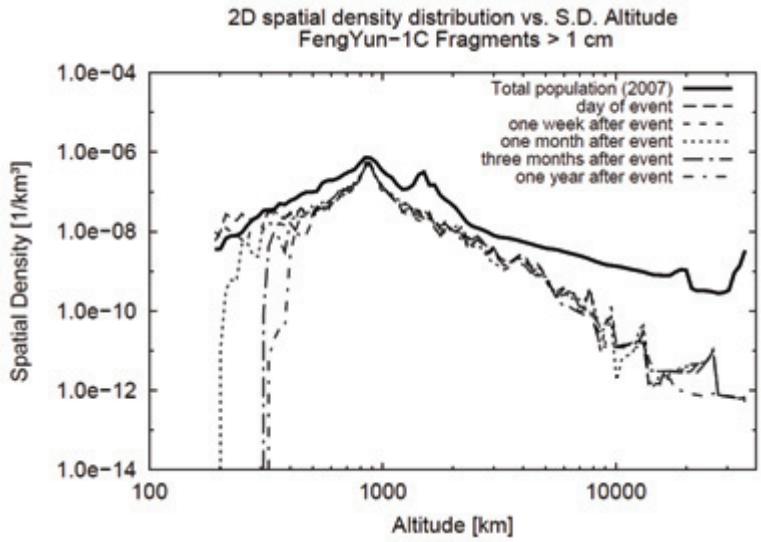
Both fragmentations can be described in a very similar manner. They differ considerably concerning the orbital lifetime of the generated debris.

(The following slides consider all contributions to the space debris environment.)

Fragmentation Events

	FengYun-1C	USA-193
USSPACECOM Catalog No.	25730	29651
International Designation	1999-025A	2006-057A
Start date	10. May 1999	14. December 2006
Launcher	LM-4B	Delta II – 7920-10
Launch Site	Taiyuan	Vandenberg SLC-2W
Mass	958 kg	1820 kg
Epoch (orbital data)	**11. January 2007**	**21.February 2008**
Eccentricity	0.0004	0.0021
Inclination	99.17°	58.5°
Perigee	**863.5 km**	**249.7 km**
Apogee	**869.3 km**	**277.5 km**
Right Ascension of the Ascending Node	1.77°	20°
Revolutions per Day	14.06096	16.02002
Orbital Period	102.1125 min	89.637 min

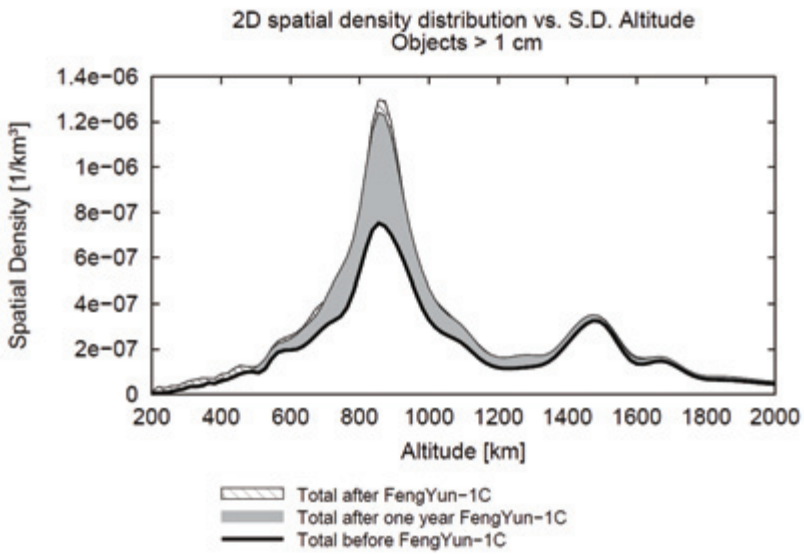
FengYun-1C: Centimeter Population (1)



Wiedemann, C., Horstmann, A., Kebschull, C., Flegel, S., Stoll, E., Die Auswirkung vorsätzlich herbeigeführter Fragmentationsereignisse auf die Weltraummüllumgebung, Deutscher Luft- und Raumfahrtkongress, Rostock, 22.-24. September 2015, paper DLRK 2015-370033.

The spatial density of objects larger than 1 cm in Earth orbits. Comparison of the background population with the debris cloud of the satellite FengYun-1C (simulation).

FengYun-1C: Centimeter Population (2)



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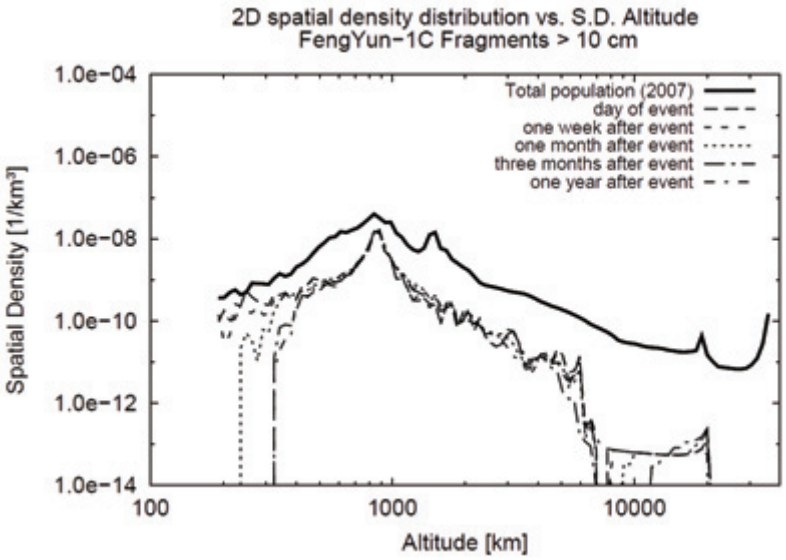
FengYun-1C: Decimeter Population (1)



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The spatial density of objects larger than 10 cm on Earth orbits. Comparison of the background population with the debris cloud of the satellite FengYun-1C (simulation).

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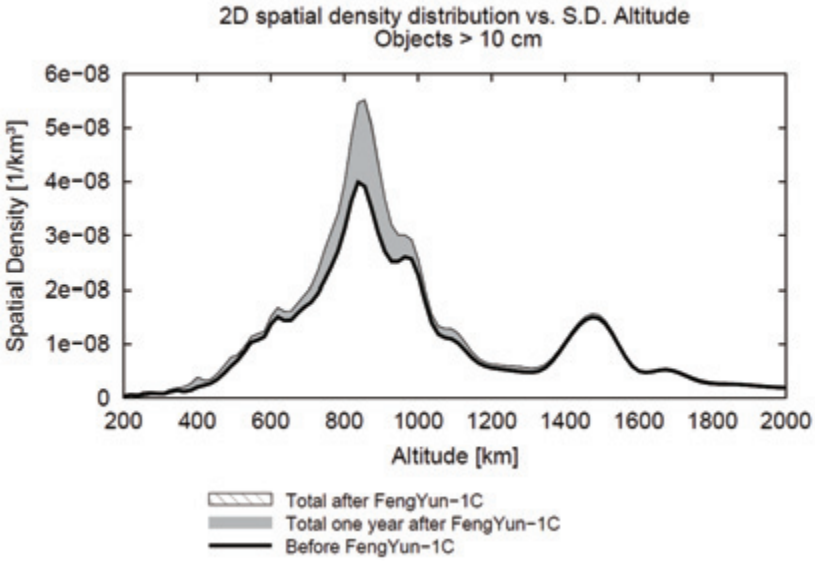
FengYun-1C: Decimeter Population (2)



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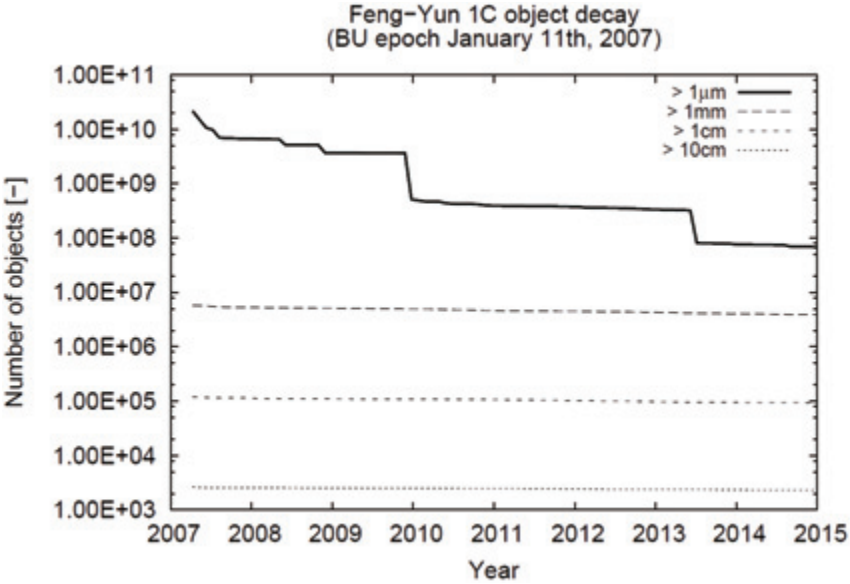
The spatial density of objects larger than 10 cm in Earth orbits. Comparison of the background population with the debris cloud of the satellite FengYun-1C (simulation).

FengYun-1C: Descent Behavior (1)



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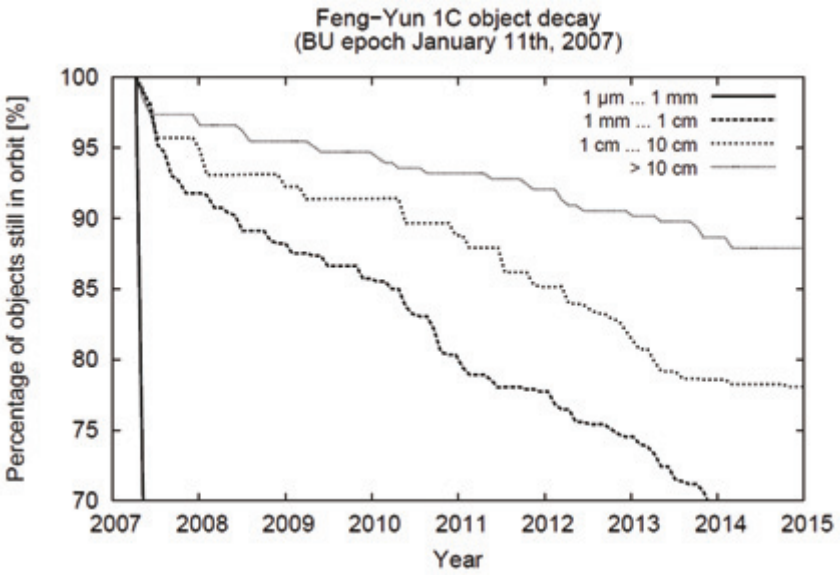
Descent behavior of the debris of the satellite FengYun-1C in different size classes (simulation).

FengYun-1C: Descent Behavior (2)



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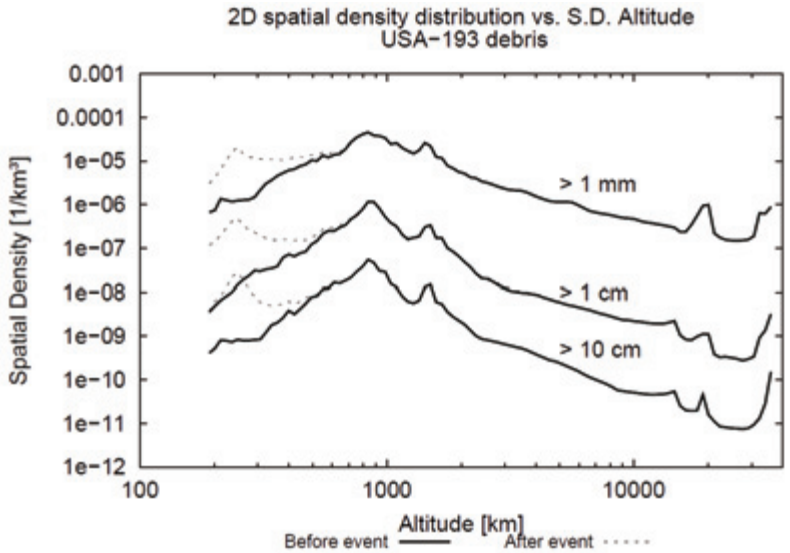
Relative descent behavior of the debris of the satellite FengYun-1C in different size classes (simulation).

USA-193



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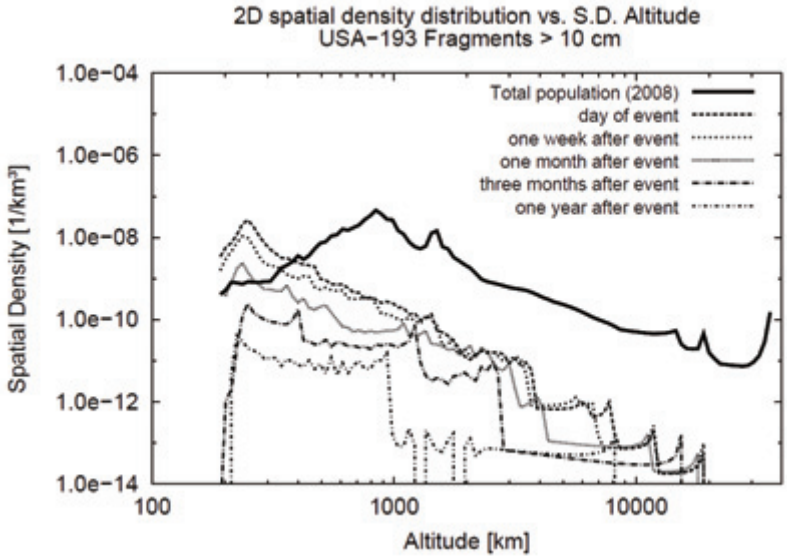
The spatial density of objects in different size classes on Earth orbits. Comparison of the background population with the debris cloud of the satellite USA-193 at the time of fragmentation (simulation).

USA-193: Decimeter Population (1)



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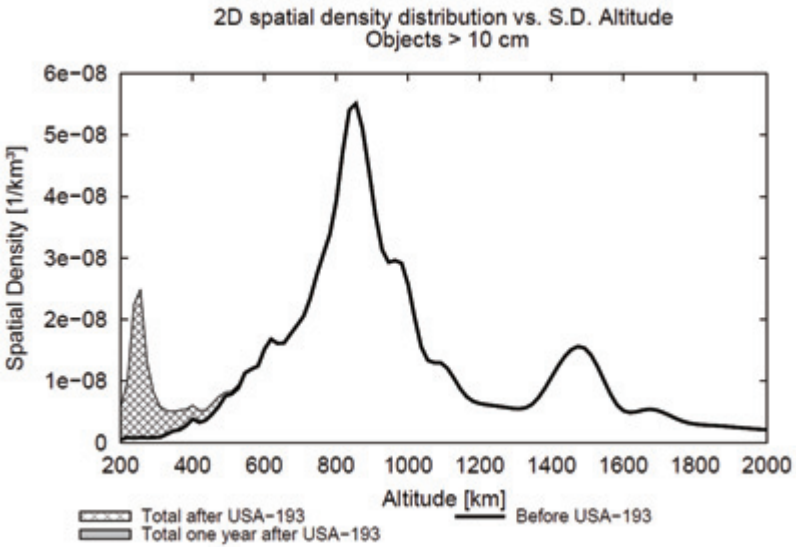
The spatial density of objects larger than 10 cm on Earth orbits. Comparison of the background population with the debris cloud of the satellite USA-193 (simulation).

USA-193: Decimeter Population (2)



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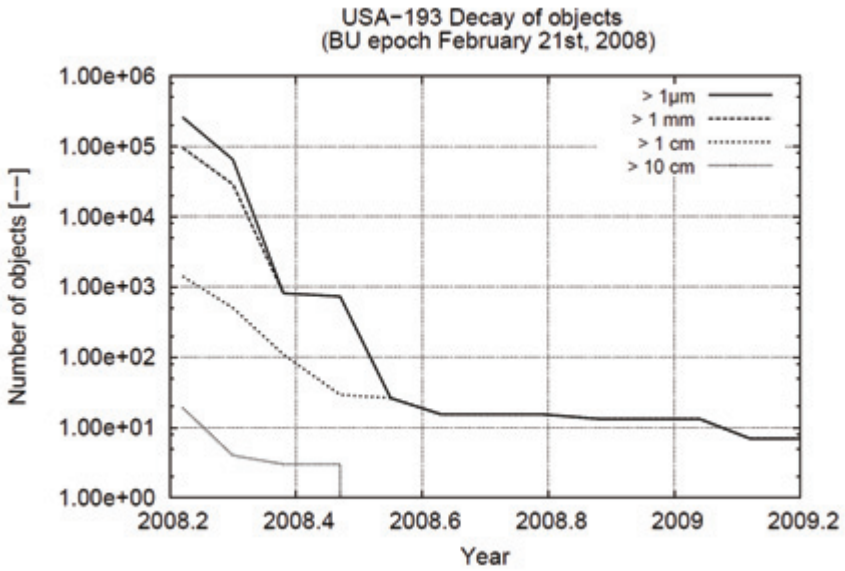

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Descent behavior of the debris of the satellite USA-193 in different size classes (simulation).

Summary

New Simulations

The number of released debris in the decimeter and centimeter range is higher compared to MASTER-2009.

FengYun-1C & USA-193

According to the analysis carried out here, it can be concluded that the FengYun-1C event has contributed significantly to the very critical 10 cm population in the 860 km altitude. The fragmentation of USA-193, cannot provide a long-term contribution to space debris environment.

The results published here are of a preliminary nature, since they have not yet been validated.