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Optical orbital debris spotter

Christoph R. Englert [a,*], J. Timothy Bays [b,1], Kenneth D. Marr [c], Charles M. Brown [a], Andrew C. Nicholas [a], Theodore T. Finne [a]

[a] Naval Research Laboratory, Space Science Division, Geospace Science and Technology Branch, 4555 Overlook Avenue, SW, Washington, DC 20375, USA
[b] Office of Naval Research-Reserve Component, 875N. Randolph Street, Arlington, VA 22203, USA
[c] NRC Associate in residence at Naval Research Laboratory, Space Science Division, Washington, DC 20375, USA

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ABSTRACT

The number of man-made debris objects orbiting the Earth, or orbital debris, is alarmingly increasing, resulting in the increased probability of degradation, damage, or destruction of operating spacecraft. In part, small objects (< 10 cm) in Low Earth Orbit (LEO) are of concern because they are abundant and difficult to track or even to detect on a routine basis. Due to the increasing debris population it is reasonable to assume that improved capabilities for on-orbit damage attribution, in addition to increased capabilities to detect and track small objects are needed. Here we present a sensor concept to detect small debris with sizes between approximately 1.0 and 0.01 cm in the vicinity of a host spacecraft for near real time damage attribution and characterization of dense debris fields and potentially to provide additional data to existing debris models.

1. Introduction

The effects of collisions occurring at orbital velocities range from minor to catastrophic. Increasing concentrations of orbital debris, for example in commonly used Low Earth orbit (LEO) altitudes between 400 and 2000 km make the possibility of in-orbit collisions an area of growing concern to space operations. Nearly 17,000 Earth orbiting objects greater than 10 cm in diameter have been cataloged by the Space Surveillance Network (SSN) and are tracked by various ground-based sensor systems [1]. The current density of objects in the Earth orbit (Figs. 1 and 2) continues to increase, especially in orbits above about 800 km, where atmospheric drag is not very effective in removing debris. The density is feared to eventually rise above a critical value, causing a run-away chain reaction, known as the Kessler syndrome [2,3]. In the Kessler syndrome, the creation of debris from collisions will occur faster than the removal of the debris by natural orbital drag, and all operating satellites in these particular orbital regions will quickly degrade or be destroyed within months or years, contributing further to the debris field. The Kessler syndrome represents an extreme condition, but can easily be envisaged, especially considering the trend toward increasing quantities of orbital debris in recent years.

Fig. 1 shows the rapid increase in the number of objects in the Earth orbit greater than 10 cm. In 2002, Crowther

Abbreviations: ASAT, Anti-satellite Test; CCD, charge-coupled device; FOV, field-of-view; ISS, International Space Station; LDEF, Long-Duration Exposure Facility; LEO, Low Earth Orbit; S/C, spacecraft; SSN, Space Surveillance Network

* Corresponding author. Tel.: +1 202 767 5528; fax: +1 202 404 7997.
E-mail addresses: christoph.englert@nrl.navy.mil (C.R. Englert), tim.bays@pnnl.gov (J.T. Bays).
[1] Present address: Pacific Northwest National Laboratory, 902 Battelle Boulevard, P.O. Box 999, MSIN K2-44, Richland, WA 99352, USA.

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0094-5765/

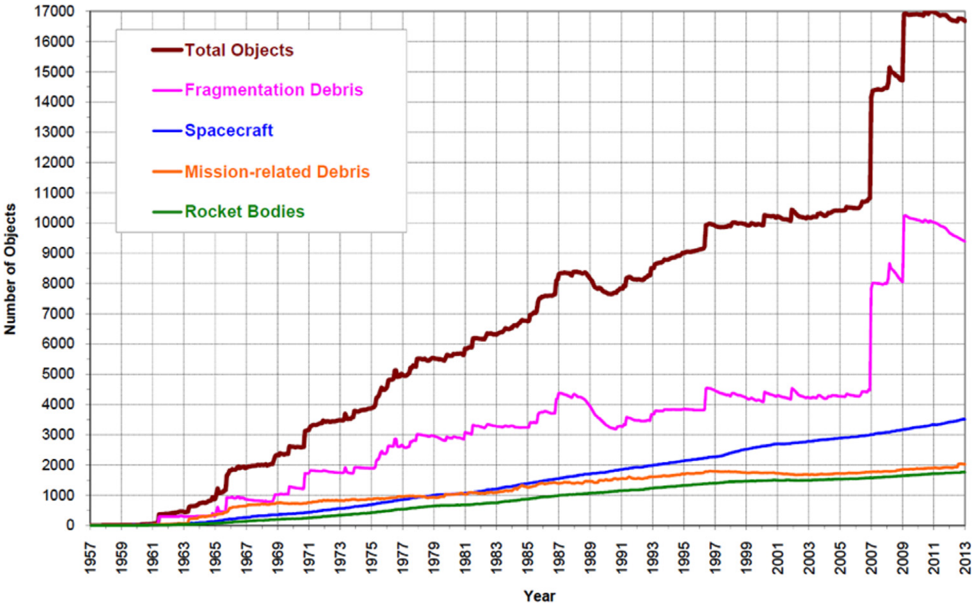

Fig. 1. Monthly number of objects in the Earth orbit cataloged by the US Space Surveillance Network (SSN), organized by object type. The two step increases in 2007 and 2009 result from fragments from the FY-1C ASAT test and Iridium 33/Cosmos 2251 collisions, respectively [1].

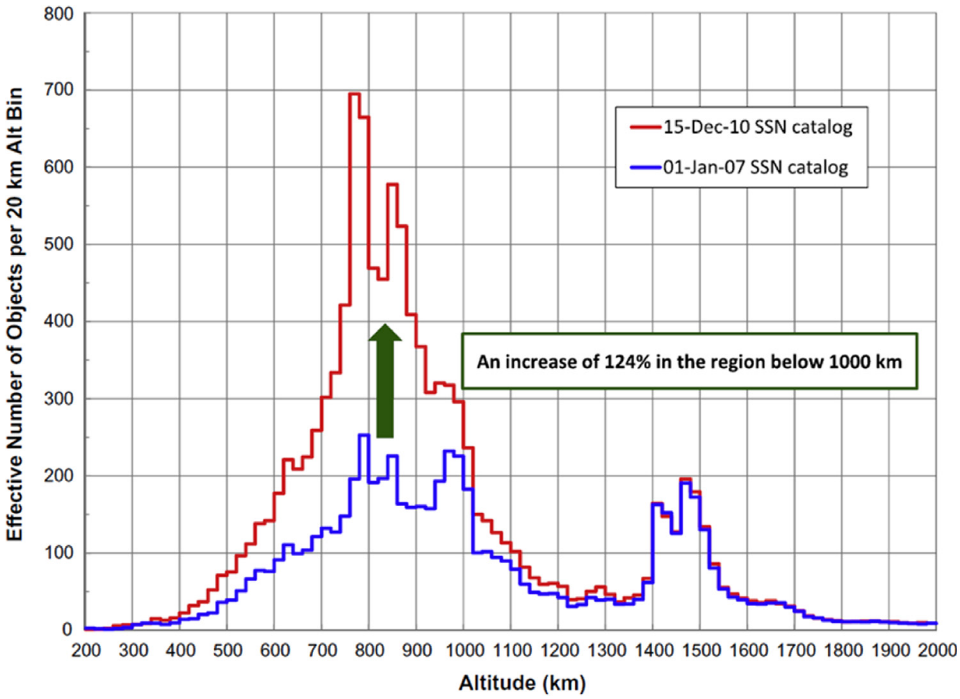

Fig. 2. Change in distributions of SSN cataloged objects in LEO following the FY-1C ASAT test and Iridium 33/Cosmos 2251 collisions (Figure from Liou [10]). More information on the distribution of orbital debris and projections for the future can be found in the literature (e.g. [10,11]).

categorized objects >10 cm as "cataloged", e.g. via the SSN, objects 1–10 cm as "lethal", and objects <1 cm as a "risk" and provided estimates for each category, with more than 100,000 objects in the "lethal" category [4]. By 2012 Levin et al. estimated there to be 500,000 potentially lethal objects in the centimeter range (1–10 cm), considerably more than the number estimated by Crowther [4,5]. Objects smaller than 1 cm in cross section become increasingly difficult to detect from ground-based sensors as their size decreases, and their numbers cannot be reliably estimated [4,5]. Since 2002, two notable events, the Chinese Anti-satellite Test (ASAT) in 2007 and the collision of the Cosmos–Iridium satellites in 2009, have added approximately 40% to the debris in LEO, significantly increasing the challenges of operating in LEO [6–9]. The effects of these collisions can be observed in the step