G6

IDEA OSG 1による微小デブリ環境サンプリング

Sampling of LEO debris environment in sub-millimeter size regime by IDEA OSG 1

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宇宙機の安全安心な航行の実現において, スペースデブリ環境の中でも特に地上からの監視が困難かつ宇宙機に被害を及ぼすリスクを持つ微小デブリ(0.1mm~数 mm サイズ)環境を常時監視する能力を持つことは大変重要である. 九州大学が始動した IDEA プロジェクト(in-situ debris environmental awareness)は, 微小デブリの衝突センサを搭載する超小型衛星による微小デブリ環境の監視を目指している. アストロスケール社は IDEA シリーズの 1 機目となる IDEA OSG 1 の開発を担っている. 本発表では取得データの分析方法を中心に IDEA OSG 1 のミッションアーキテクチャを紹介する.

Timely mapping and tracking capabilities for space debris in sub-millimeter size regime are essential to model the LEO environment and to improve spaceflight safety. IDEA project (in-situ debris environmental awareness), initiated at Kyushu University, aims at continuously sampling the submillimeter size debris environment by deploying micro satellites carrying impact sensors in the Earth orbits. IDEA OSG 1, the first of the IDEA series, has developed by Astroscale. This presentation introduces the mission architecture of IDEA OSG 1 focusing on mission data processing schemes.

Sampling of LEO debris environment in sub-millimeter size regime by IDEA OSG 1

Masahiko Uetsuhara, Mitsunobu Okada; ASTROSCALE

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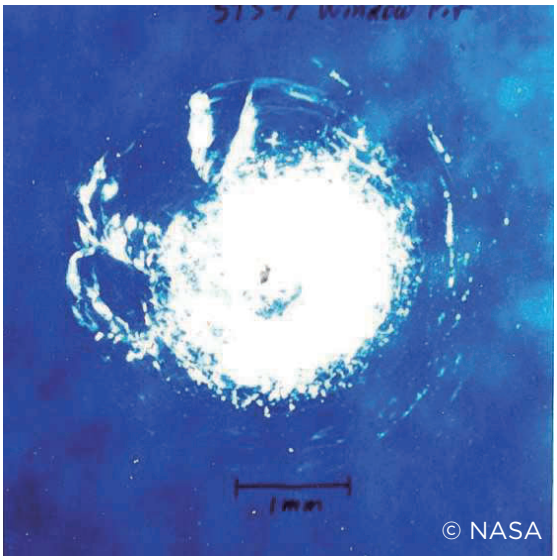
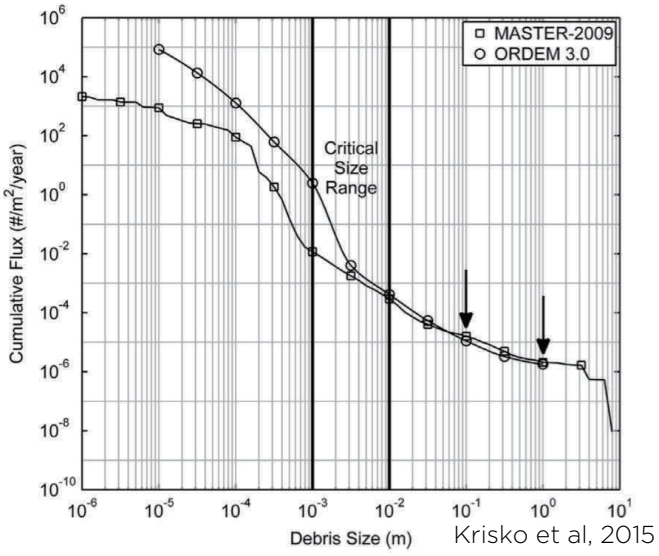


Small but damaging



Krisko et al, 2015

Extrapolation to critical size range

Motivations of Sampling Sub-millimeter Size Debris Environment

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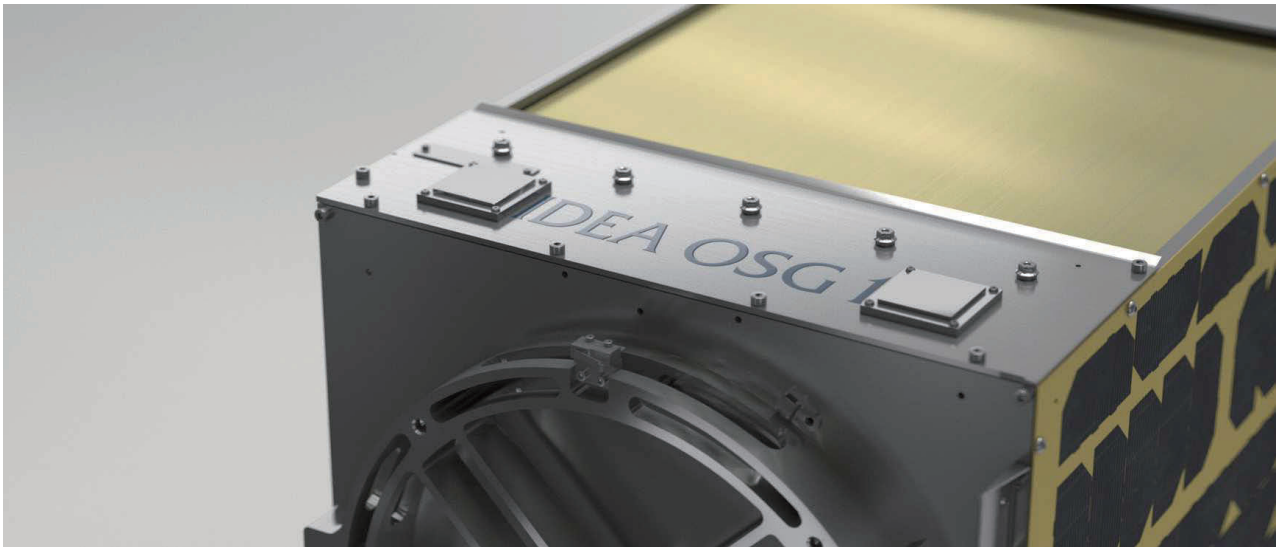

Microsatellite x Impact sensor
= Cost efficient way for maintain tracking small debris environment

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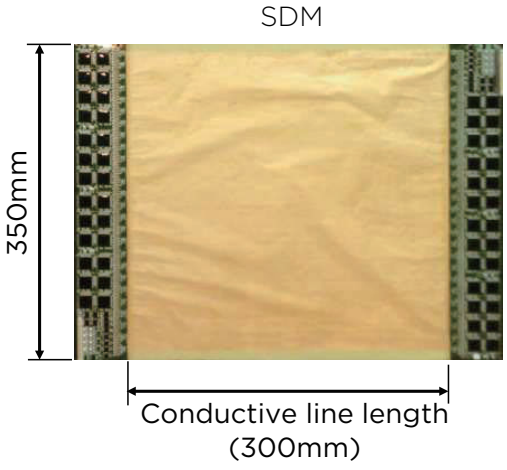

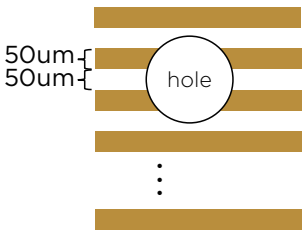

SDM raw data	
Conductive line address	Conductive line state 0: dead 1: active
1	1
2	0
3	0
4	1
3300	1

e.g. 200 um dia. debris penetrates the SDM film with severing the 2nd and 3rd conductive lines

Space Debris Monitor (SDM) and SDM raw data

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Size, Mass	380mm × 380mm × 600mm, 22 kg
Mission module	Space debris monitor (SDM-1,2)
Communications	Downlink/Uplink: S-band transceiver
Power supply	GaAs solar cells (30W) NiMH battery(10Ah) Power control unit
Attitude det. and control	Sun sensor, Magnetometer, MEMS gyro, Magnetorquer for 3-axis control
Command and data handling	Bus OBC (SH4), Mission OBC (FPGA), Watch dog (PIC)
Deorbit device	Retractable deorbit sail
Time and orbit det.	GPS sensor

IDEA OSG 1 Specifications

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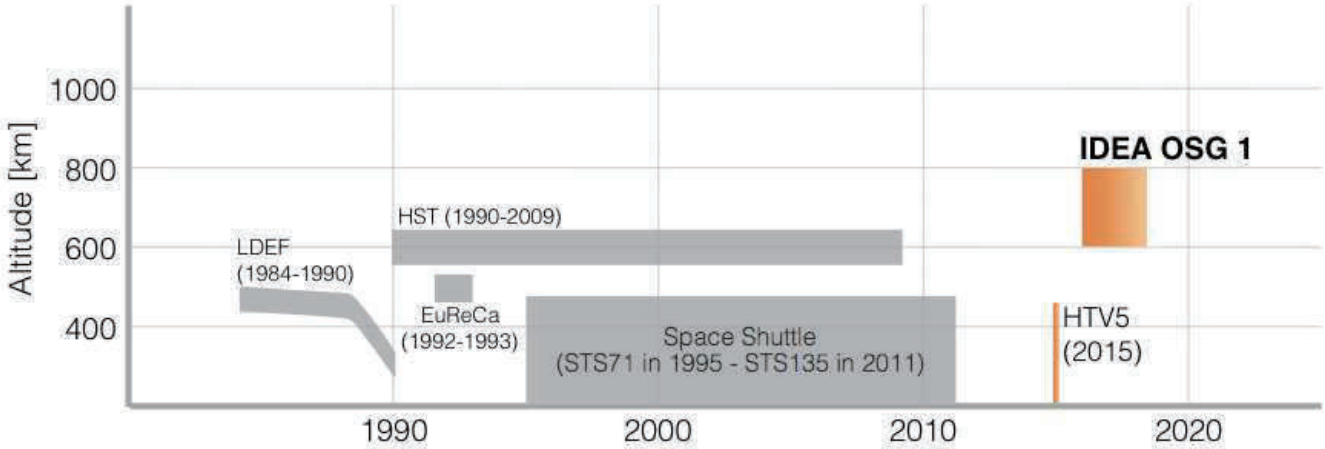

Environmental Sampling Regime of IDEA OSG 1

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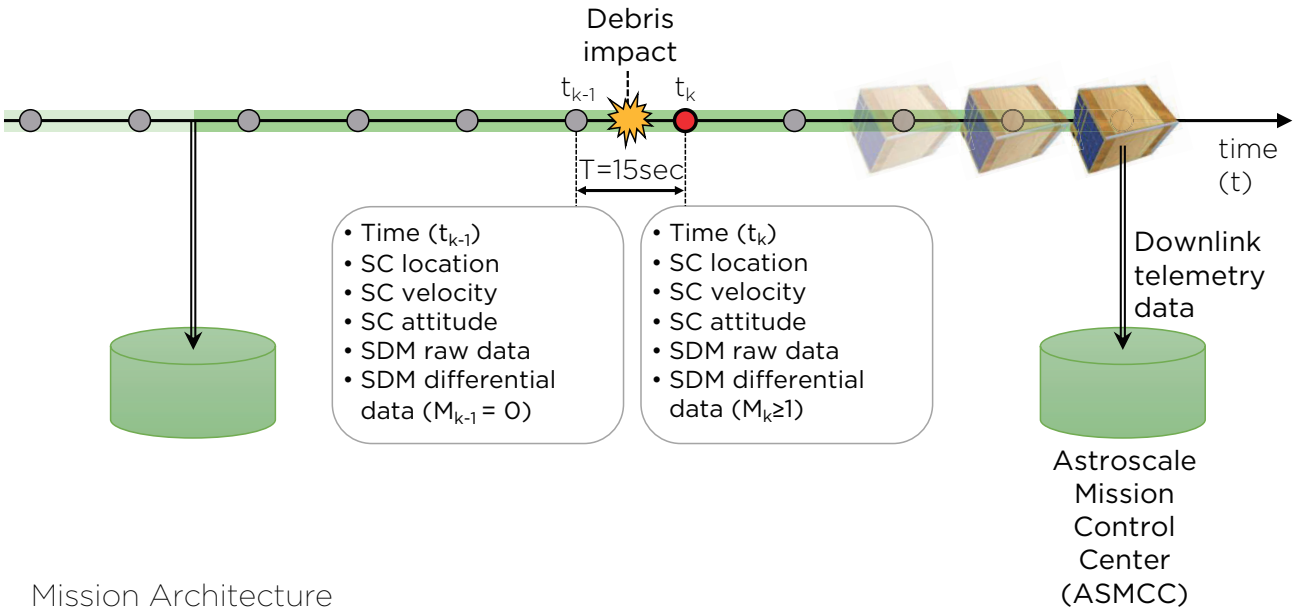

Mission Architecture

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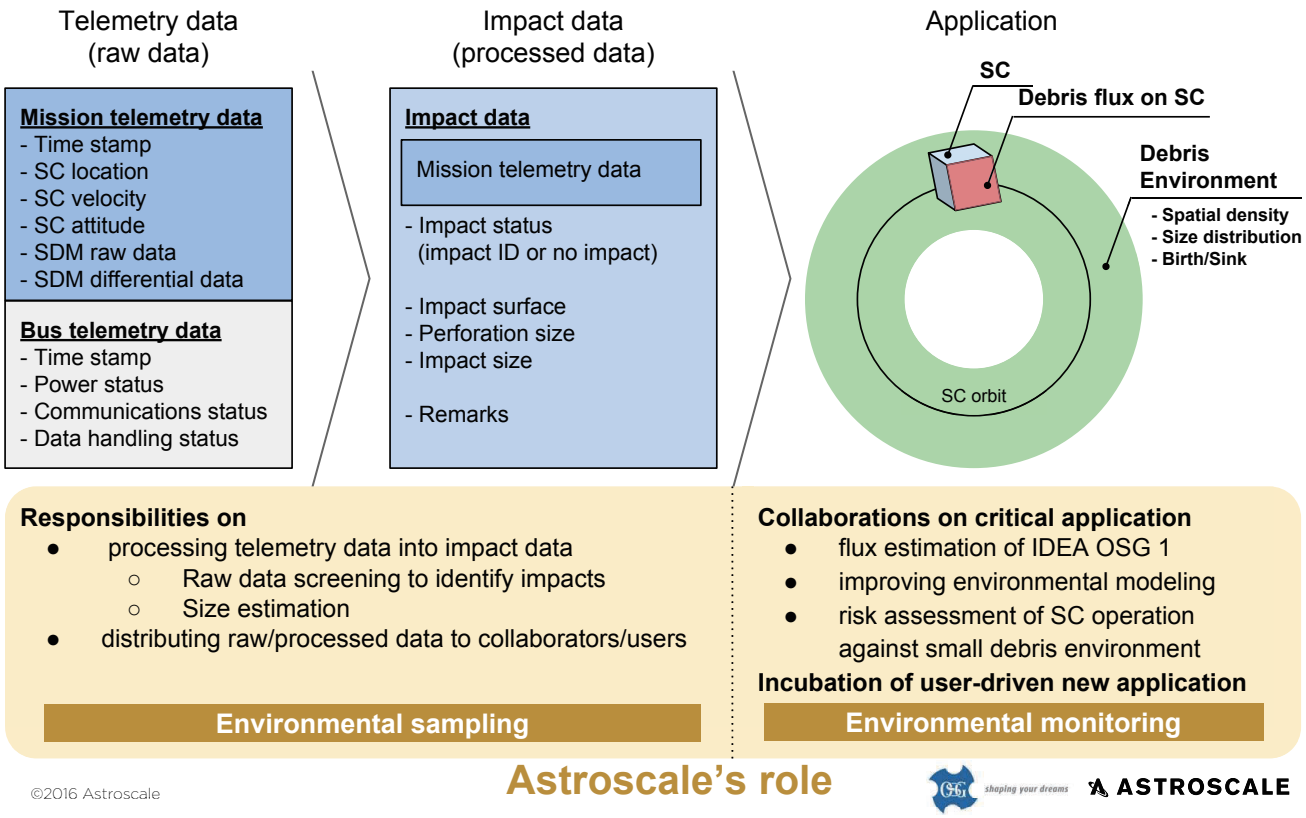

Astroscale's role

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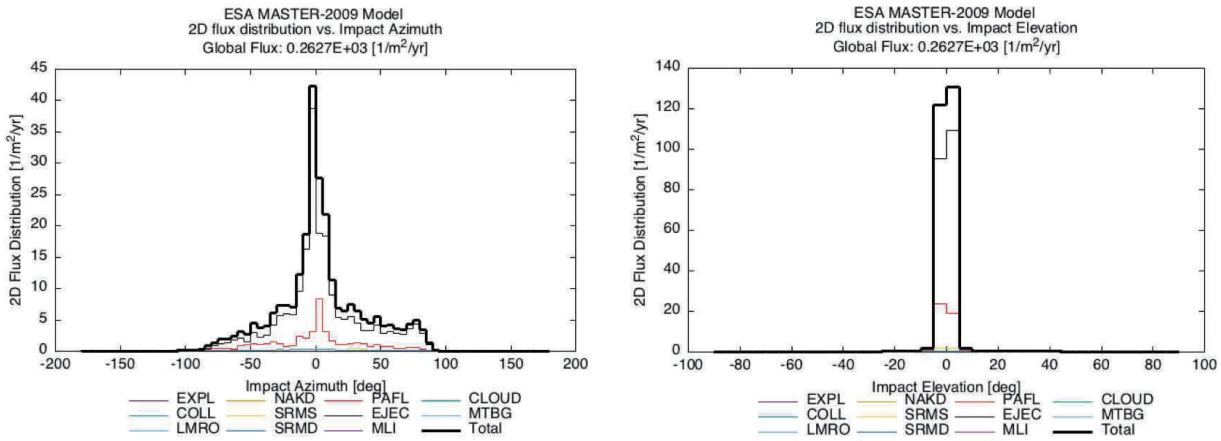
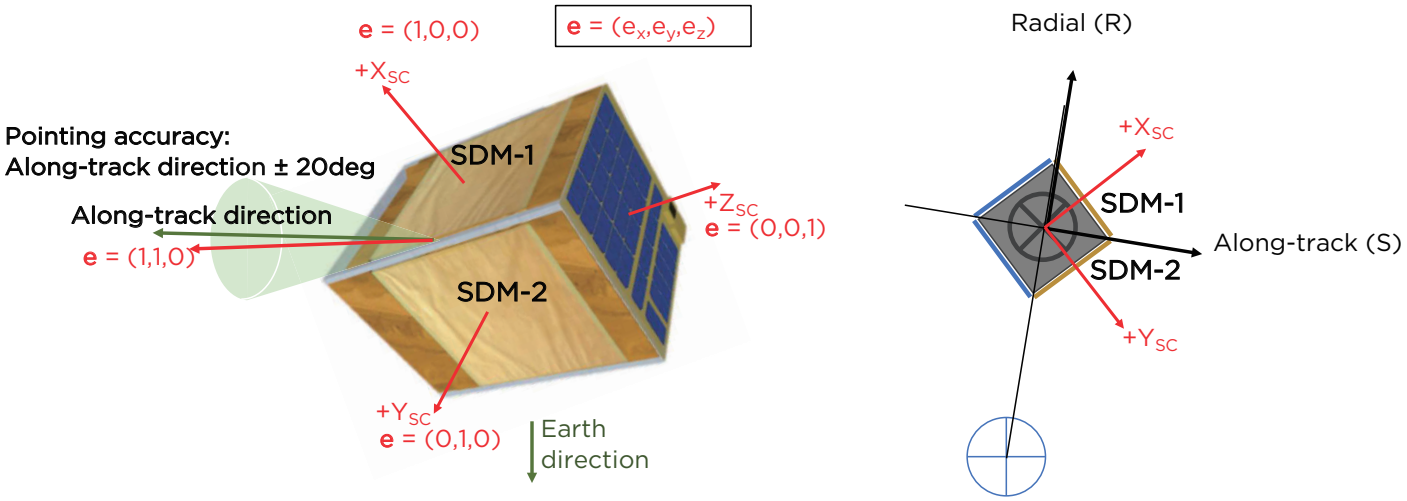
Data distribution direction	Item	The kickoff timing of data distribution (X: Launch)	Data distribution timeliness after the kickoff
IDEA OSG 1 to ASMCC (downlink)	Bus telemetry data (satellite bus status)	≥X+1 day	≤24 hours after sampling
	Mission telemetry data * except for SDM raw data	≥X+1 week	≤24 hours after sampling
ASMCC to data users	Bus telemetry data (satellite bus status)	≥X+ 1 month	**≤24 hours** after downlink
	Mission telemetry data * except for SDM raw data	≥X+ 1 month	**≤24 hours** after downlink
	Impact data (screened)	≥X+ 6 month	**≤48 hours** after impact
	SDM raw data	≥X+ 6 month	**≤48 hours** after impact

Data distribution timeline



Impact Angle Distribution (The prediction by MASTER2009)



IDEA OSG 1 Mission Attitude Definition

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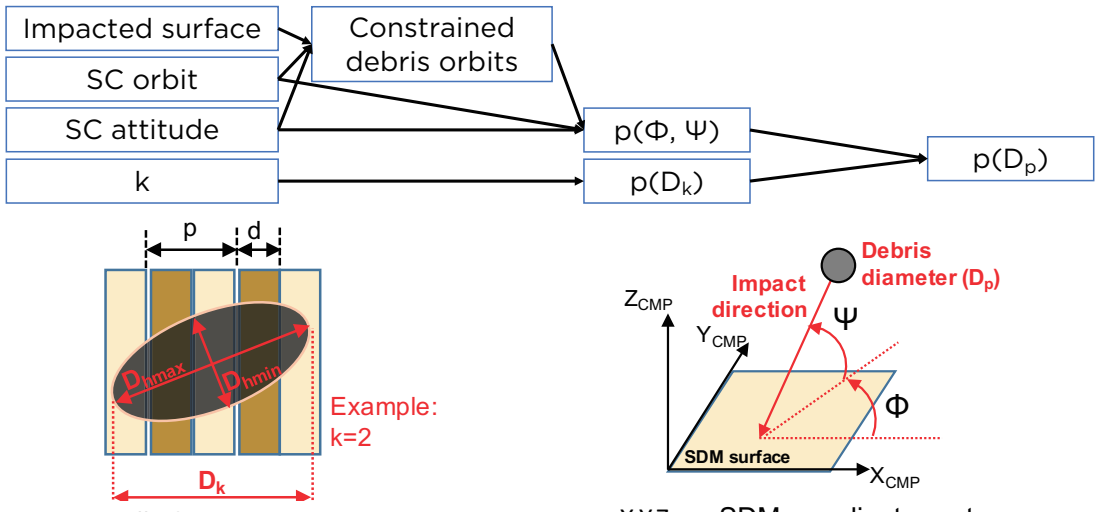

k; # of severed lines
d; conductive stripe width
D_k; 1-D perforation size
D_{hmax}, D_{hmin}; perforation shape factor

X,Y,Z_{CMP}; SDM coordinate system
Φ; impact azimuth angle on SDM surface
Ψ; impact elevation angle on SDM surface
D_p; Debris diameter

Size estimation flow

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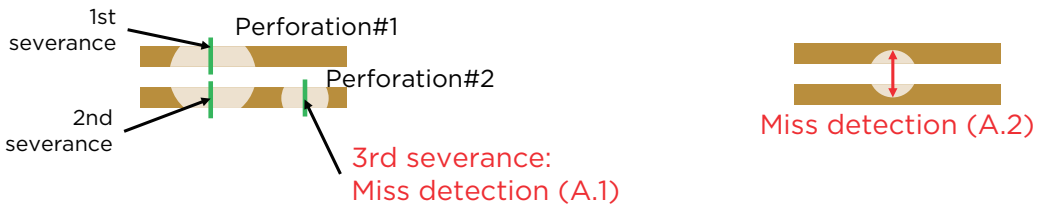
- Miss detection type (A.1)
  - Debris impact makes a perforation on conductive lines of dead state only
- Miss detection type (A.2)
  - Debris impact makes a perforation on a conductive line of active state but not fully serves an active line. (= too small to detect)

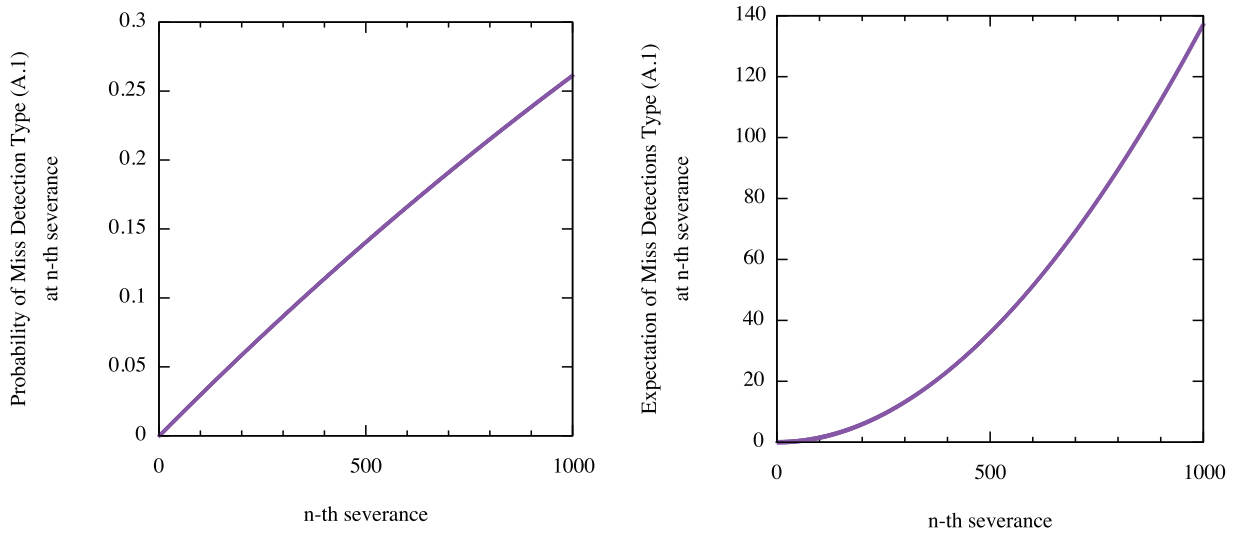


Miss detection classification

$$P(n,j) = \underbrace{\frac{j}{N}P(n-1,j)}_{\text{Probability of severing a dead line}} + \underbrace{\left(1-\frac{j-1}{N}\right)P(n-1,j-1)}_{\text{Probability of severing a active line}}$$

- $P(n,j)$; the probability of having j conductive lines of dead state at n-th severance.
- n; the accumulated number of severances on conductive lines due to perforations regardless of the active/dead states
- j; the number of conductive lines of dead state

Relation between n-1 th severance and n th severance



Evaluation of Miss Detections (Type A.1) for one SDM film (3300 conductive lines)

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- IDEA OSG 1 will sample sub-millimeter size debris environment at 15-second interval by sensing the SDM and distribute the sampled data to the ground segment timely
- Telemetry dataset is designed to suggest whether or not any new debris impacts occur in past 15 seconds
- The data distribution service will start in one month or later after the launch. The screened impact data and its source data (SDM raw data) will be released in half year or later after the launch.

Concluding Remarks

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