P13

cm サイズ宇宙デブリのレーザーアブレーションによる脱軌道ミッション

Deorbiting Mission of cm-Sized Space Debris by Laser Ablation

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In recent years, deorbiting by laser ablation has been attracting increasing attentions as an almost unique effective method to remediate cm-sized space debris. Ebisuzaki et al. 2014, proposed the deorbiting operation by the following three steps: In the first step, a super-wide field telescope detects the reflection signal of the solar light by a space debris and roughly determines its position and moving direction. In the second step, laser beams are emitted in the direction of the debris to determine the accurate position and velocity as well as its distance. In the final step, a high intensity laser beam is focused onto the debris surface to induce laser ablation on the surface. The reaction force of the ablation leads the debris to deorbiting in Earth's atmosphere.

We will present an idea of a mission dedicated for the deorbit of the cm-sized space debris in a polar Sun-synchronous orbit with an altitude of 600-900 km.

We also present the status of the demonstration missions onboard the Russian module of International Space Station (ISS). Mini-EUSO is a 25-cm UV telescope, which will be attached on the UV transparent window, can observe the dark side of the Earth. It can perform demonstration experiments for the debris from space detection from the space at the twilight time. Furthermore, the K-EUSO telescope, a Schmidt camera with a 4 m reflection mirror is planned to attached to the outside of the Russian module of ISS for the observation of ultra-high-energy cosmic rays above 1020 eV. It can also demonstrate the detection of cm-sized space debris from space in full scale sensitivity.

References

[1] Ebisuzaki et al., Demonstration designs for the remediation of space debris from the International Space Station, Acta Astronautica, 112 (2015), 102-113.

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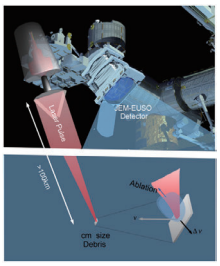
Concept of our the laser removal of 0.5-10 cm space debris



- **EUSO**
  - Detection
  - Position and velocity
    - » Crude determination
- **Space laser system**
  - Search beam
  - Position and velocity
    - » Fine determination
  - Shooting Operation

Three steps of debris removal

Target Debris
a=0.5-10 cm, d~50 km, v_{rel}~1-15 km

1. **Detection** (~0.1 seconds)
   - EUSO telescope ±30°
   - position(Δθ<0.07°)and velocity (1%)
2. **Tracking** (~1 seconds)
   - Cassegrain telescope (1.5m) (~1s)
   - Pencil beam illumination (Δφ~0.07°Δτ~1ns)
   - position(Δθ<10^{-6} rad, Δ*R*~1 km)
3. **Laser Shooting** (~10 seconds)
   - E_p~10 J、R_p~10^4 Hz

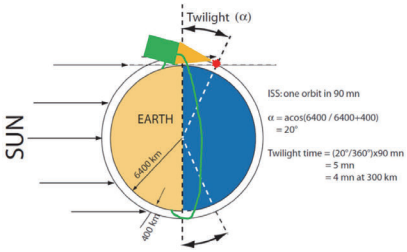
Three Step Approach with ISS cosmic-ray missions

1. 25cm class Telescope: **mini-EUSO** at International Space Station
   - Technical demonstration of debris detection
   - Launch Scheduled in **2019**
   - 25 cm UV telescope
   - Collaboration of ASI and ROSCOSMOS with JEM-EUSO collaboration (Italy, Russia, France, Japan: 16 countries)
2. 2.5m Class telescope (**KLYPVE/K-EUSO**)
   - Planning in collaboration with Russia, Italy, France and Japan
   - +High intensity laser? Demonstration of Tracking
3. Dedicated Free-Flyer
   - EUSO+Space laser
   - Altitude 600-900km
   - Sun-synchronous orbit

Dedicated Free Flyer mission

- Eccentric orbit with **altitude 900-600** km
- **Sun-synchronous**:
  inclination=98.3 degree
- **Always in twilight zone**
  Observe anti-sun direction
- 2.5 m **EUSO** + **Space laser** (100 kW)
- Range: <50km
- 10^5 operation per year
- Significant fraction of the orbital debris (0.5m-10 cm) ~five years

Dedicated Mission in the Sun-synchronous orbit

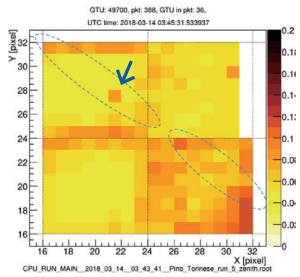


Step 1: Demonstration of DetectionMini-EUSO

ROSCOSMOS-ASI mission Will be launched in 2019

Possible satellite transit at zenith

2018/03/14 at 04:10:52 UTC from Pino Torinese Observatory



In the animation: 1 frame every 10 GTUs

In the FOV for 400 GTUs (182 GTUs in the first PMT, 173 GTUs in the second PMT, 45 GTUs not visible), for a total of 16.4s.

Equivalent distance travelled in the first PMT (~9.2 pxl) in 7.45s (182 GTU x 41ms/GTU)
(1 pixel FOV ~ 0.55°)

"New techniques for the detection of space debris"; Id Project: CSTO164394

Tests at Pino Torinese Observatory

- Chieri and Moncalieri city lights
- Stars, Jupiter
- Planes

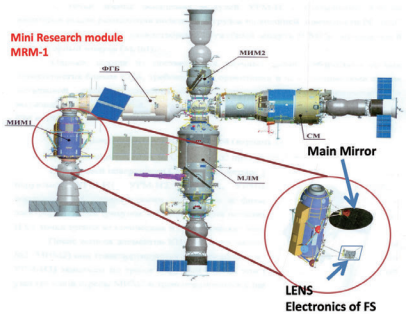
Obtained values from MASTER for the parameters obtained by ESAF simulation(1): reflectance 0.5

debris diameter[m]	altitude[km]	distance from Mini-EUSO[km]	average_nSD_root[km^3] for dec ±51.64[deg, refl 0.5]	nDetection_per_day
0.095-0.105	291	109	1.84E-09	1.79E-01
0.085-0.095	301	99	5.19E-13	4.17E-05
0.075-0.085	308	92	5.49E-13	3.81E-05
0.065-0.075	319	81	6.07E-13	3.27E-05
0.055-0.065	339	61	3.23E-11	9.84E-04
0.045-0.055	347	53	5.03E-10	1.16E-02
0.035-0.045	353	47	8.79E-10	1.59E-02
0.025-0.035	365	35	1.35E-08	1.36E-01
0.015-0.025	381	19	1.52E-08	4.51E-02
			TOTAL(nDetection/day)	3.88E-01

Total number of space debris detection if the reflectance is 0.5: **142 debris/yr**

"New techniques for the detection of space debris"; Id Project: CSTO164394

Location on ISS



Summary

- Reentry by Laser Ablation: 1-10 cm
- Laser ejection from Spacecraft
  - Detection **EUSO telescope**
    - » Super wide field (~60°), super high speed (~microseconds)

  Tracking system of 1.5 m and CAN laser (100 kW)
  - **Space (CAN) laser**: Multi-Step approach
  - **Mini-EUSO**: UV transparent window on ISS
    - » Launch is scheduled in 2019
  - **K-EUSO**+ laser on ISS
  - **Dedicated free flyer** polar orbit 1000 ⇔ 500 km