H1

メガコンステレーションが軌道環境へ与える影響評価

Influences of MEGA Constellations on the Orbital Environment

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人類の宇宙開発活動を持続可能にすべく, 各国宇宙機関はデブリ環境推移モデルを開発し, 様々なシナリオの変化を考慮したデブリ環境の将来予測を繰り返して, より適切な低減対策を探求してきた. 現在, デブリ環境に対して非常に大きなインパクトを持つと考えられているのがメガコンステレーションである. 宇宙ブロードバンドネットワークに向けて, LEOに数百, 数千機の衛星を配置する計画であるが, 一切の対策を講じずにこのようなコンステレーションを実現すれば, デブリ環境の悪化は甚大であろう. まずは, メガコンステレーションがどれほどの影響を及ぼしうるかを評価する必要がある. 日本では, JAXA と九州大学が推移モデル NEODEEM を共同開発してきた. 本研究では, 基本的に 1,000 機の小型衛星によるコンステレーションを想定し, まずはそのデブリ環境へのインパクトを評価しつつ, 環境悪化のメカニズムを示す. その後, 種々のシナリオによる環境変動を比較した.

For the sustainable human space development activities, space agencies have developed their own orbital debris environment evolutionary model, projected the debris environmental prediction considering various future scenarios, and studied better mitigation ways. Currently, some companies are developing space broadband network systems and planning to deploy hundreds or thousands of satellites into LEO, which might impose enormous impacts on the debris environment. The influences of such large constellations, called MEGA constellations, are necessary and urgent tasks to be evaluated. In Japan, JAXA and Kyushu University have jointly developed the evolutionary model “NEODEEM”. Present study assumes a large constellation with 1,000 small satellites and evaluates its impacts on the debris environment. The mechanisms of the environmental deteriorations are explained and then various scenarios are simulated and compared to each other.

Influences of MEGA Constellations on the Orbital Environment

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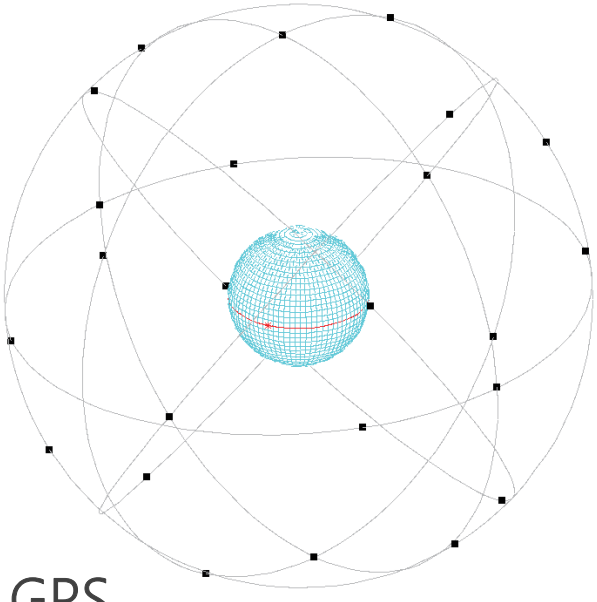
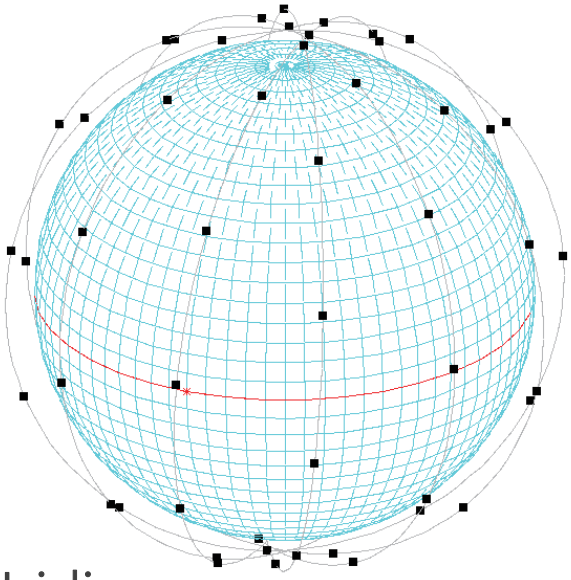
Satellite Constellations



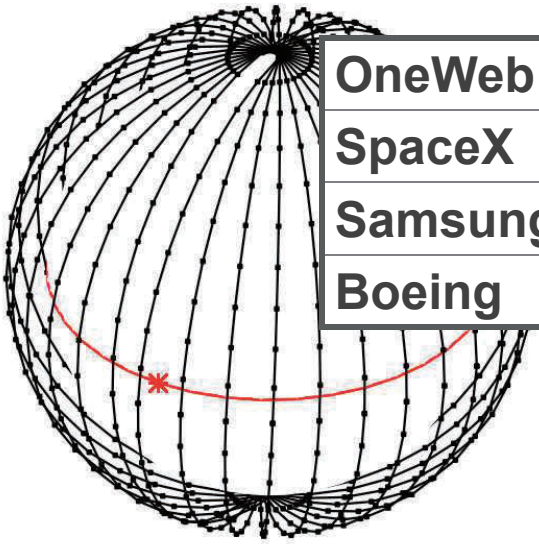
GPS



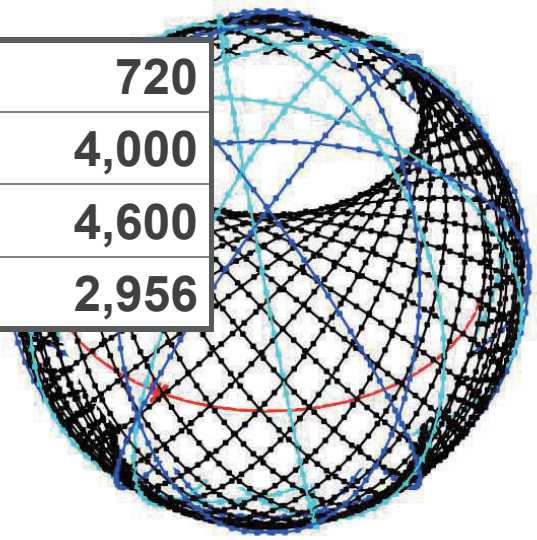
Iridium

MEGA Constellations

OneWeb	720
SpaceX	4,000
Samsung	4,600
Boeing	2,956



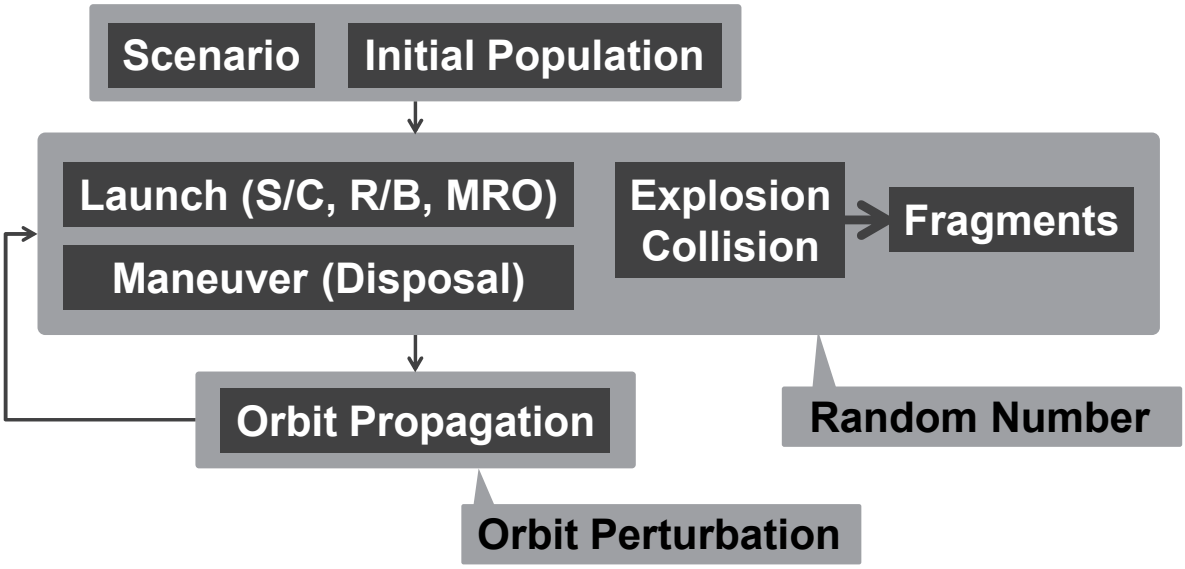
OneWeb



SpaceX

Evolutionary Model

Orbital Debris Environment Evolutionary Model



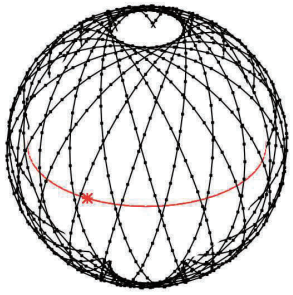
NEODEEM

Near-Earth Orbital Debris Environment Evolutionary Model

Computation Assumptions

MEGA constellation	
1,000 satellites	**1,200 km** altitude (circular orbits)
20 orbit planes	Walker delta pattern (i : $t/p/f$ = **75 deg** : 1000/20/1)

Constellation satellites	
5 years mission lifetime	150 kg mass
3.0 m^2 average cross sectional area	



1000 satellites

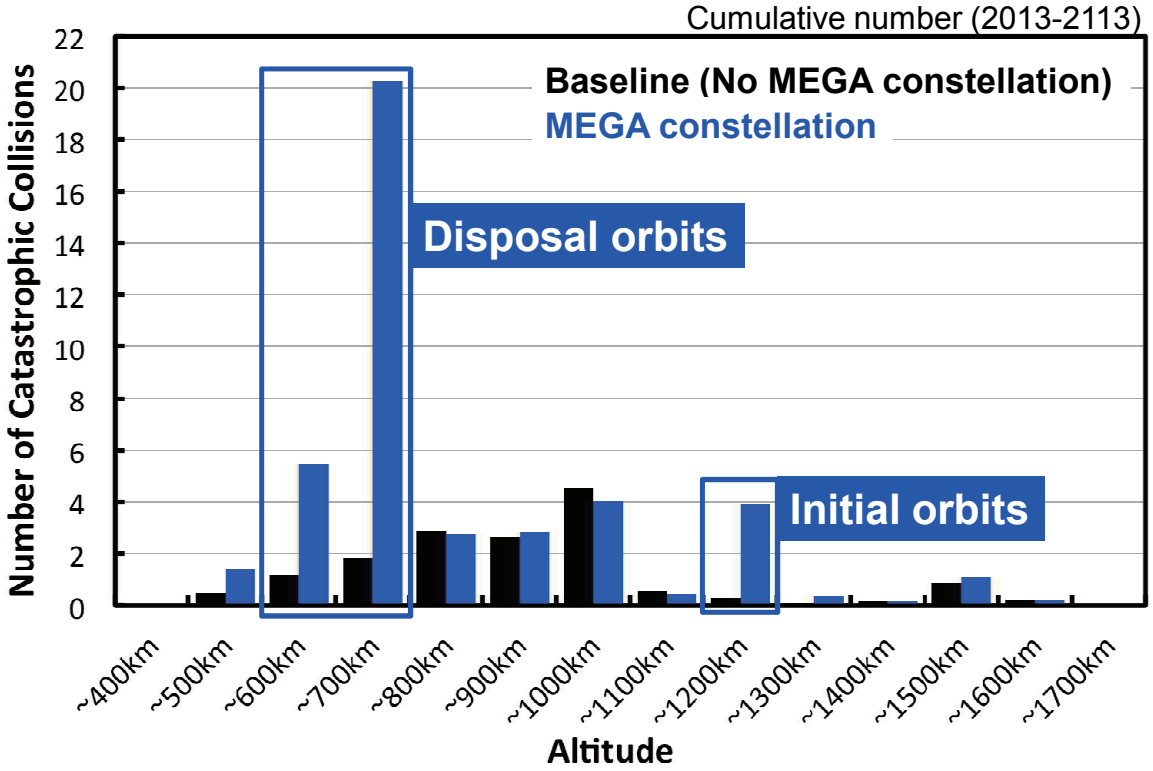
Launch scenarios	
Full service operation	**2020-2049 (30 years)**
Launch duration	2016-2049 (34 years)
Yearly launch	**200 satellites**
Total launch	6,800 satellites
EOL (End of Life) process	Decay into lower and circular orbits

Computation Scenarios

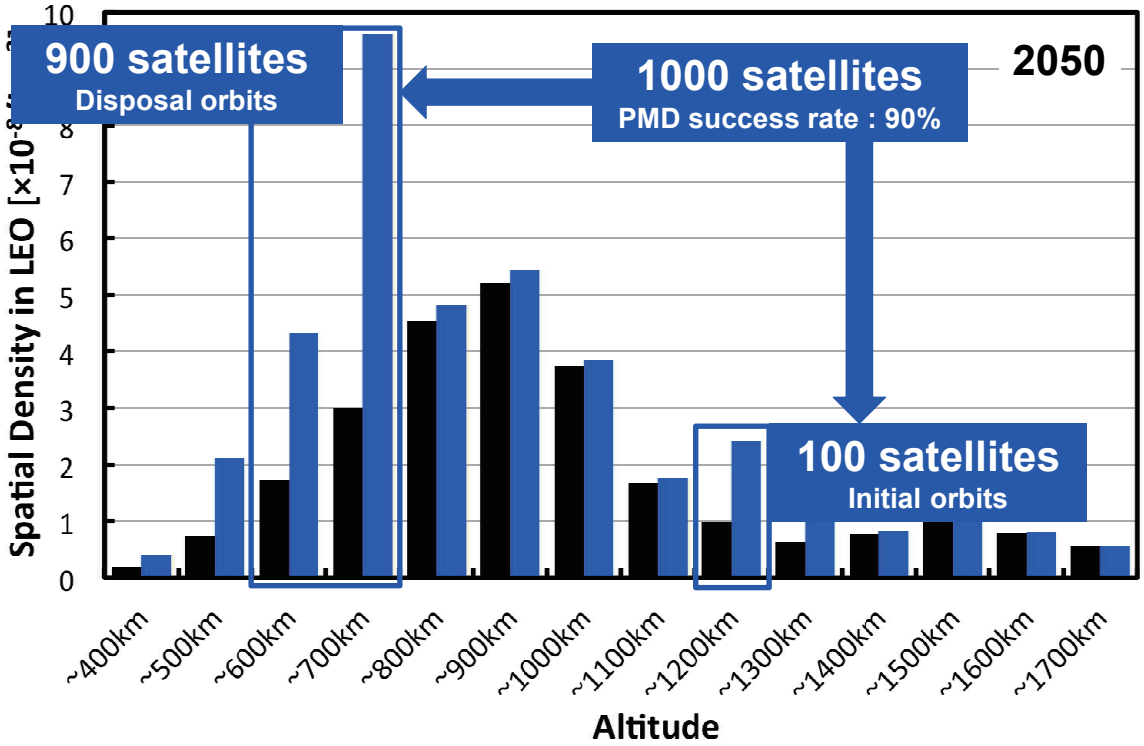
- **Baseline (No MEGA constellation) scenario**
  - **PMD** success rate : **90%** (for background objects and future launch objects)
  - Orbital lifetime after PMD : **25-year rule**
  - Initial population in LEO 16,000 (2013) (>10cm)
  - 100 Monte-Carlo computations (for all scenario)

- **MEGA constellation scenario**
  - **PMD** success rate : **90%** (for both background or future launch objects and MEGA constellation satellites)
  - Orbital lifetime after PMD : **25-year rule**
  - **CA** (Collision Avoidance) : No collision of MEGA constellation satellites while their mission lifetime (5 years)

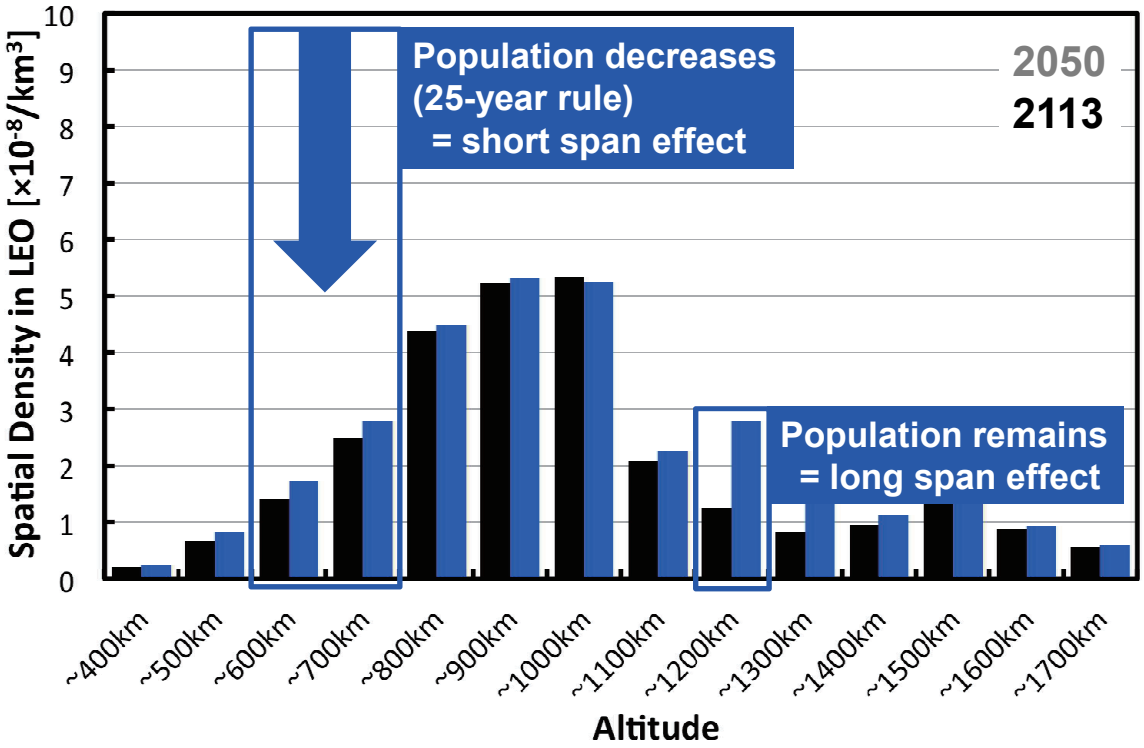
Results Baseline & MEGA constellation



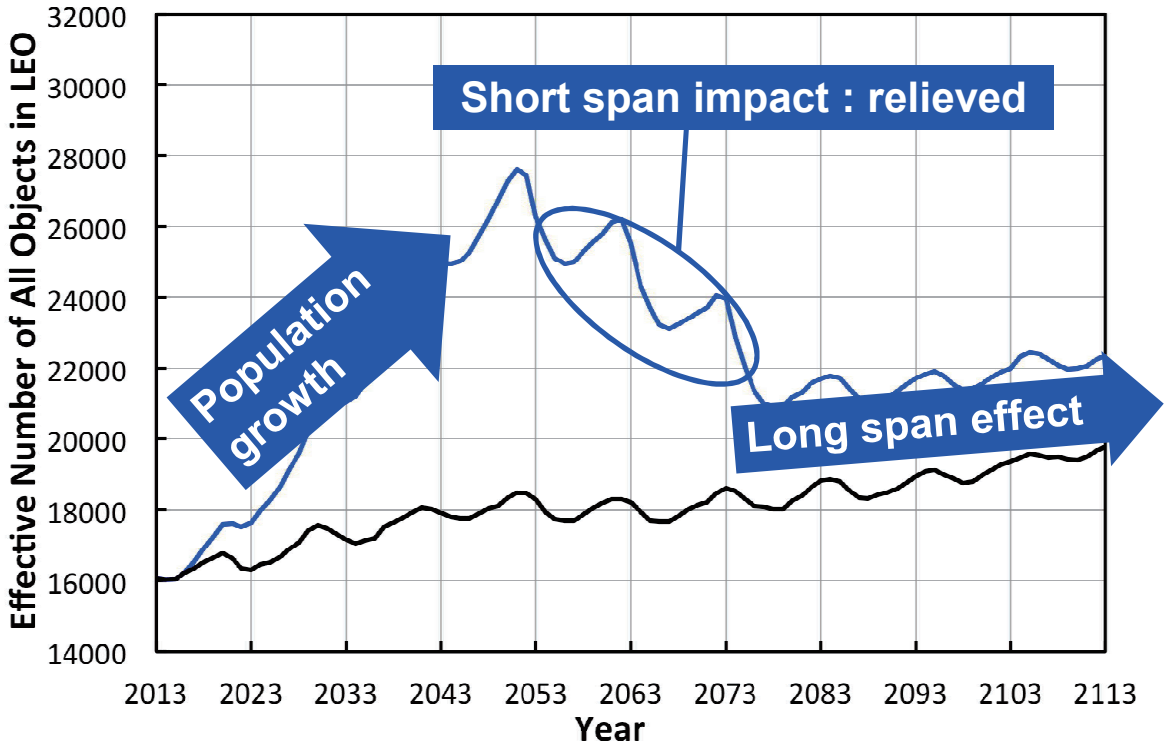
Results Baseline & MEGA constellation



Results Baseline & MEGA constellation

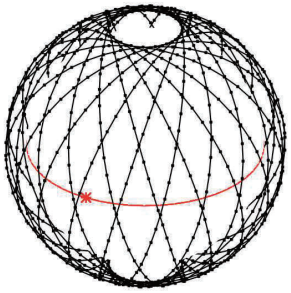


Results Baseline & MEGA constellation



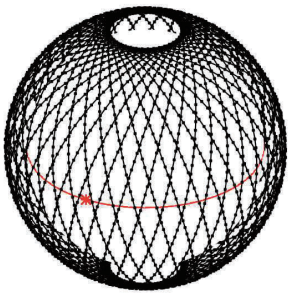
Computation Scenarios

1000 satellites PMD30%	
1000 satellites	**PMD** success rate : **30%** **(Only for MEGA constellation satellites)**
25-year rule	CA : adopted
To evaluate the impact of PMD success rate	



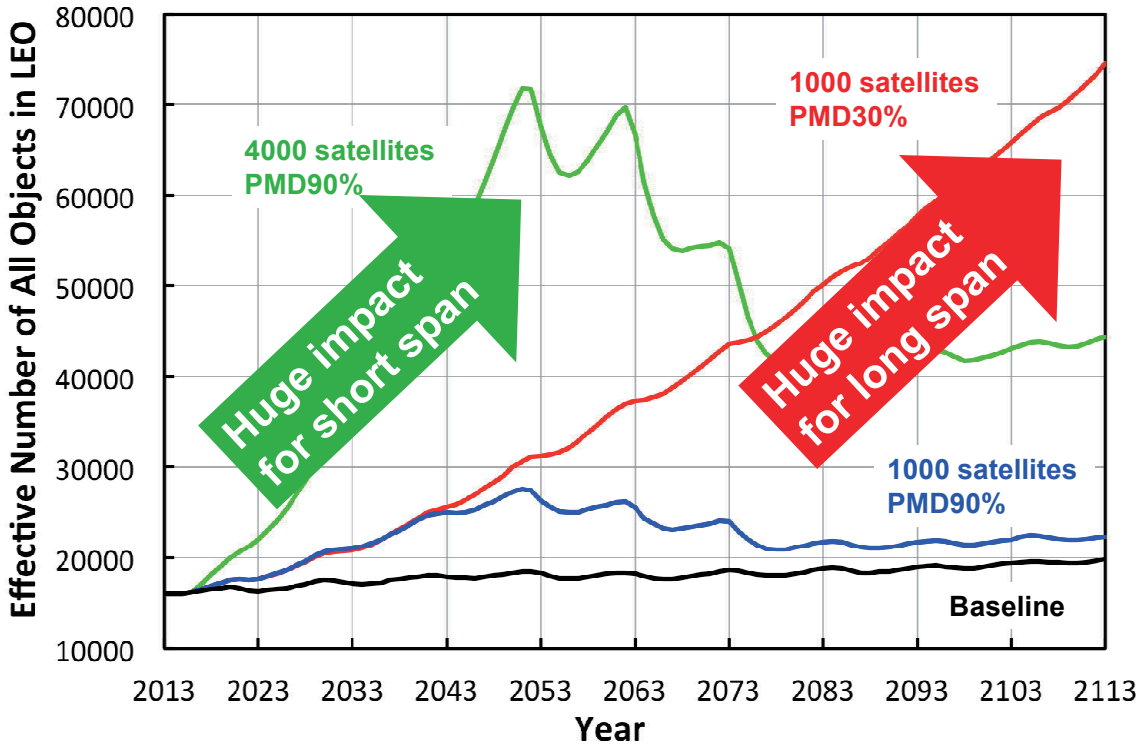
1000 satellites

4000 satellites PMD90%	
4000 satellites	**PMD** success rate : **90%**
25-year rule	CA : adopted
To evaluate the impact of the number of satellites	

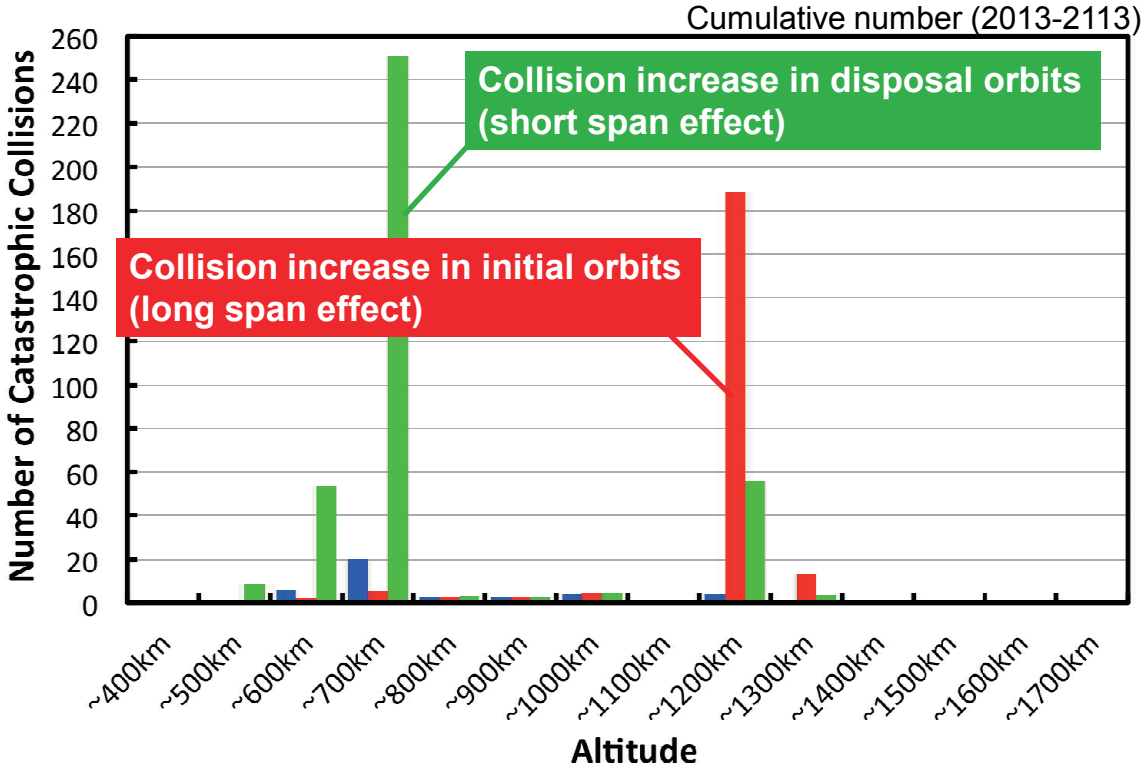


4000 satellites

Results PMD30% & 4000 satellites



Results PMD30% & 4000 satellites



Results PMD30% & 4000 satellites

Scenarios	Number of objects	
	Disposal to lower orbits (600-700 km)	Remain as intact debris on the initial orbits (1100-1200 km)
1000 satellites PMD90%	900	100
1000 satellites PMD30%	300	700
4000 satellites PMD90%	3600	400

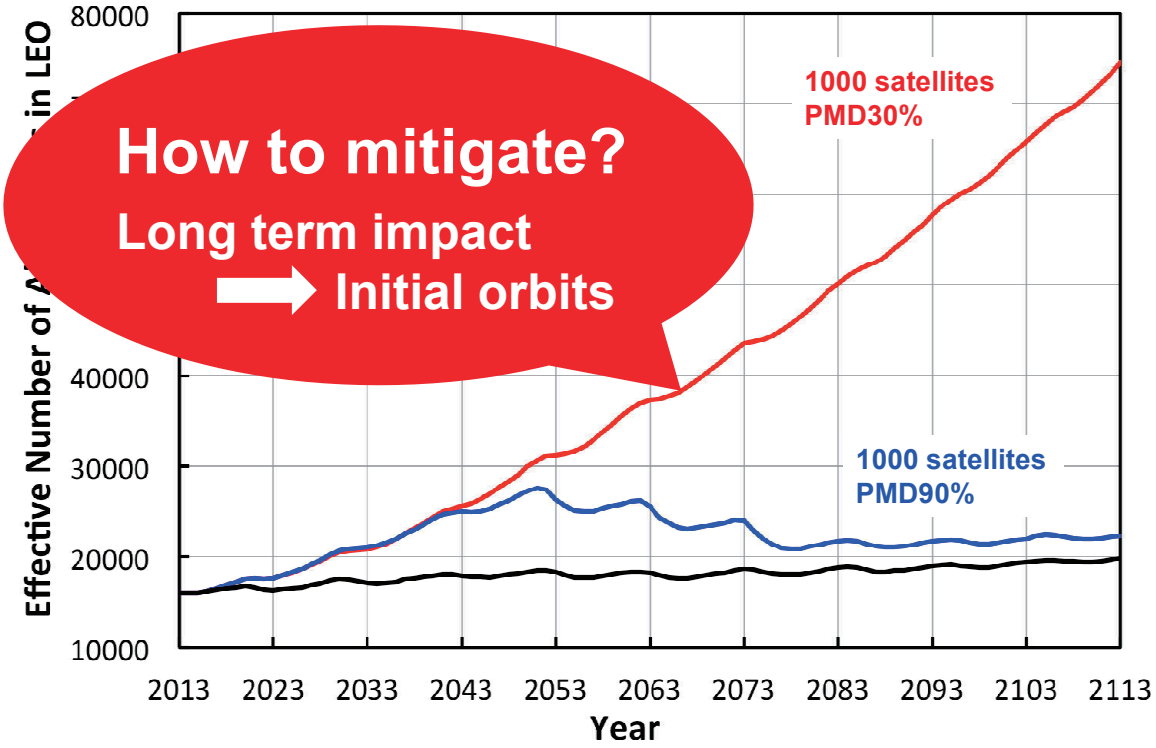
1000 satellites PMD30% < 1000 satellites PMD90% < 4000 satellites PMD90%

Short span effect

1000 satellites PMD90% < 4000 satellites PMD90% < 1000 satellites PMD30%

Long span effect

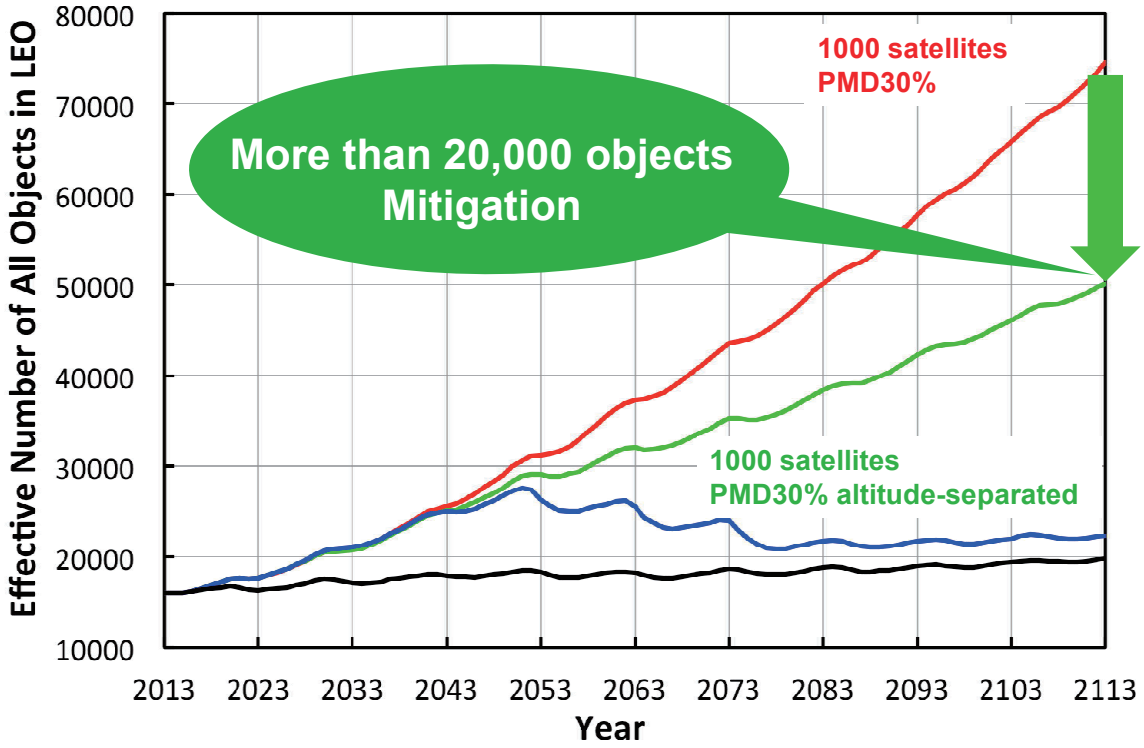
Computation Scenarios



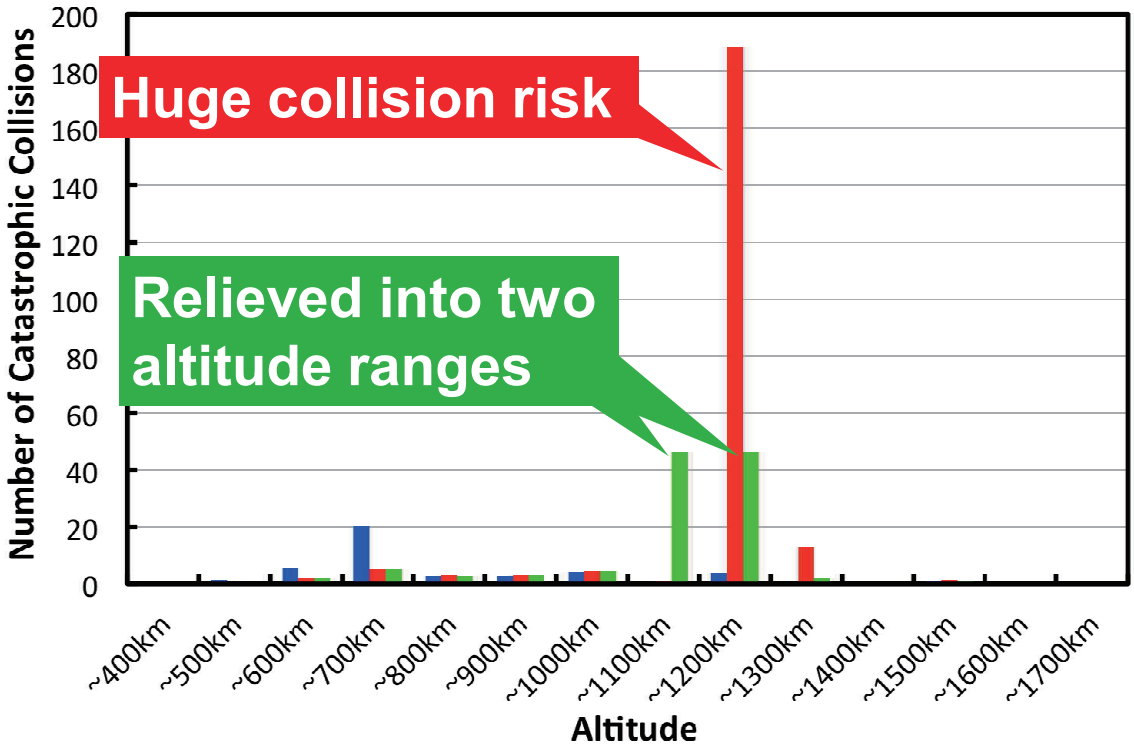
Computation Scenarios

1000 satellites PMD30%	
1000 satellites	**PMD** success rate : **30% (Only for MEGA constellation satellites)**
25-year rule	CA : adopted
1000 satellites into 1200 km orbits	
1000 satellites PMD30% altitude-separated	
1000 satellites	**PMD** success rate : **30% (Only for MEGA constellation satellites)**
25-year rule	CA : adopted
500 satellites into 1100 km orbits, 500 satellites into 1200 km orbits	
To evaluate the mitigation effect to long term impact	

Results PMD30% & PMD30% altitude-separated



Results PMD30% & PMD30% altitude-separated



Conclusions

- The **influences of MEGA constellations** can be **huge** in the scenarios with large number of launch or lower PMD success rate. Some **proper measures must be taken**.
- Two aspects of the influences.
  - **Short span impact** on the **disposal (lower) orbits**.
  - **Long span impact** on the **initial (higher) orbits**.
- The most **critical factor** to determine the impacts is **the number of objects inserted into each range of altitude** as intact debris.
- Possible **ways to limit the impacts** can be indicated through the environmental analysis.