B04

低軌道 ADR ミッションにおけるターゲット物体の姿勢運動解析

Analysis on Attitude Motion of ADR Target in LEO

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高速大容量通信の実現を目的とする数千機規模のコンステレーション衛星の計画をはじめとした、宇宙利用の急速な拡大に伴い，軌道環境のより一層の混雑が懸念されている．その解決策の一つとして，スカパーJSAT 株式会社は不用な衛星等を対象にレーザーアブレーションの技術を応用した非接触方式の ADR 衛星の設計および開発に着手している． 一般に ADR ミッションでは，ターゲット機体の回転量を事前に把握し、ミッション運用に反映する必要がある。ターゲット機体には様々な外乱トルクが加わるため，複雑な運動が予測される．本発表では，低軌道衛星を対象に，重心位置のずれを考慮した，姿勢および角速度解析の結果を示す．

The orbital congestion is becoming an urgent issue with increasing space activities, such as satellite constellations for high-speed and large-capacity communications. Therefore, SKY Perfect JSAT Corporation has started out designing and developing an ADR satellite. The satellite applies laser ablation technologies so that it does not require any physical contact with a target object. ADR mission generally requires grasping the rotational motion of the target object in advance and reflecting it in its mission operations. The target object’s motion is usually complicated due to various disturbance torques acting on it. This presentation shows the short-term and long-term variation of attitude and angular velocities of the target object in Low Earth Orbit, considering the shift of the center of gravity.

Analysis on Attitude Motion of ADR Target in LEO

低軌道ADRミッションにおけるターゲット物体の姿勢運動解析

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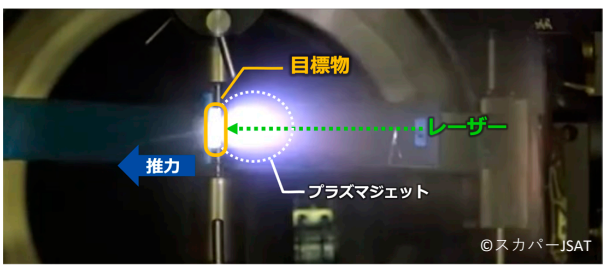
ADR satellite developed by SKY Perfect JSAT

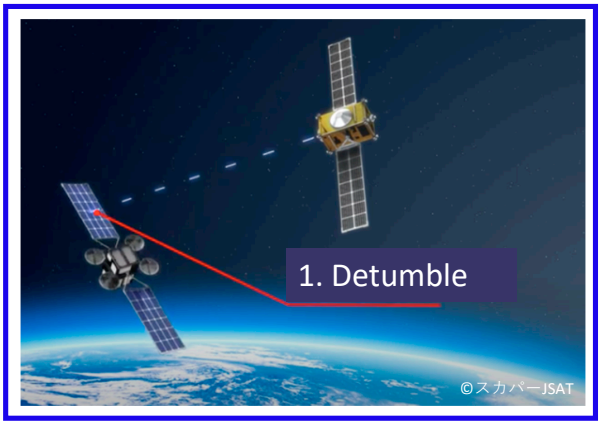
- The orbit congestion is becoming an urgent issue with increasing space activities.
- SKY Perfect JSAT Co. has started out designing and developing ADR satellite using laser ablation technologies.
- ADR system using laser is economical and does not require physical contacts.

ADR satellite designed and developed by SKY Perfect JSAT



Laser ablation technologies

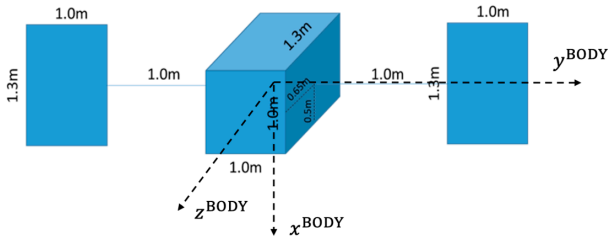
ADR mission using laser ablation technologies



Output of this research

- Quantitative analysis of attitude angles and angular velocities for debris in LEO to clarify mission requirements

Target object



The satellite model

■ Orbital elements

a	7578.14 km
e	0
i	87.9 deg.
Ω	0 deg.
ω	0 deg.

■ The satellite model parameters

Mass	150 kg (bass: 138 kg, panel: 6 kg)	assumption
Center of mass	(1) $[0.078, 0.030, 0.078]$ m	6% shift in all axes
	(2) $[0.078, 0.000, 0.000]$ m	6% shift in x axis
Moment of inertia	$[71.31, 24.00, 56.44]$ kgm^2	
Surface properties	$[0.1, 0.2, 0.7]$	

Conditions

■ Initial values

Attitude angles	$[0.0, 1.0, 1.0]$ deg.
Angular velocities	① $[0.0, 0.0, 0.0]$ deg./min. ② $[0.0, 60.2, 0.0]$ deg./min.

assumption

Angular momentum of a reaction wheel (0.42Nms) on the minor axis of inertia (Max initial angular velocities)

■ Perturbations

- Gravitational gradient
- Aerodynamic drag
- Solar Radiation Pressure

Need to be considered in Low Earth Orbit

■ Unconsidered conditions

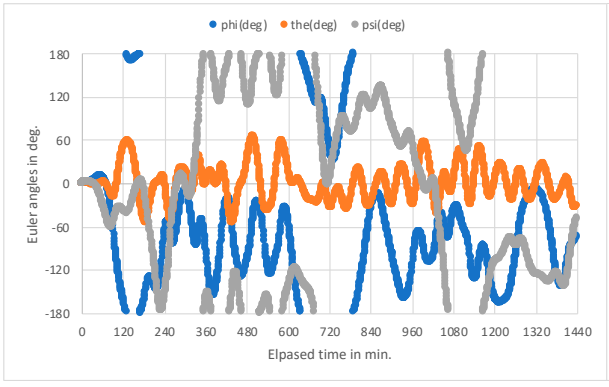
- Self-shadowing
- Product of inertia

Almost no effect on angular velocities in preliminary analysis

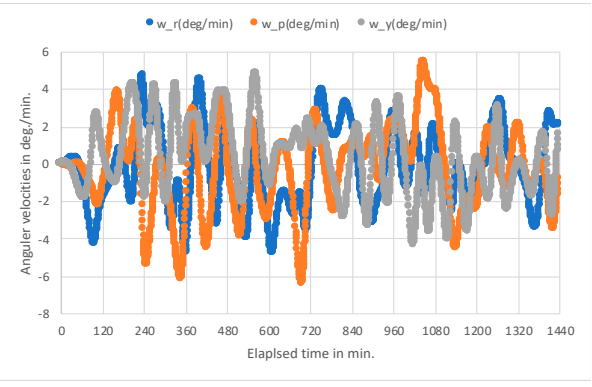
The moment of inertia in each axis increases by about 2%, which is a safe condition.

- No initial angular momentum

Center of mass	(1) $[0.078, 0.030, 0.078]$ m
Angular velocities	① $[0.0, 0.0, 0.0]$ deg./min.



Attitude angles in deg.



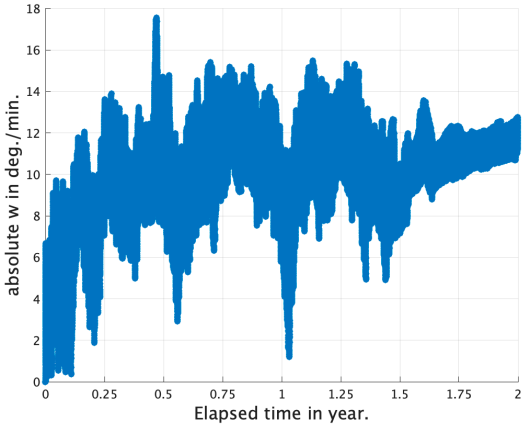
Angular velocities in deg./min.

2-years analysis

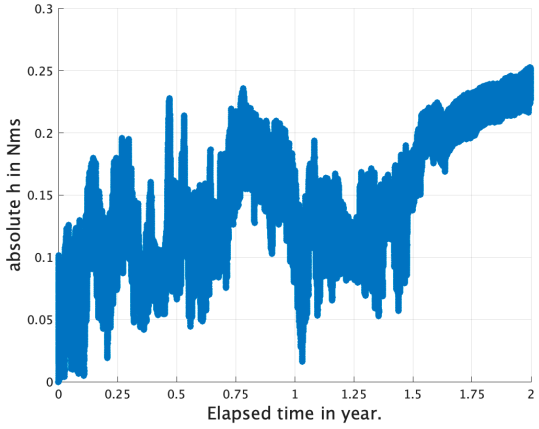
Assumption

- Center of mass deviated by 6% from center of geometry on all axes
- No initial angular momentum

Center of mass	(1) $[0.078, 0.030, 0.078]$ m
Angular velocities	① $[0.0, 0.0, 0.0]$ deg./min.



Norm of angular velocities in deg./min.



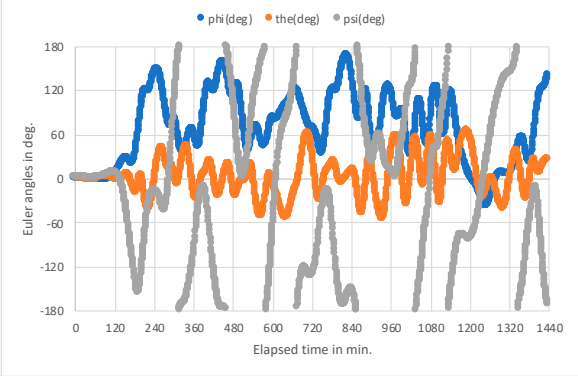
Norm of angular momentum in Nms

1-day analysis

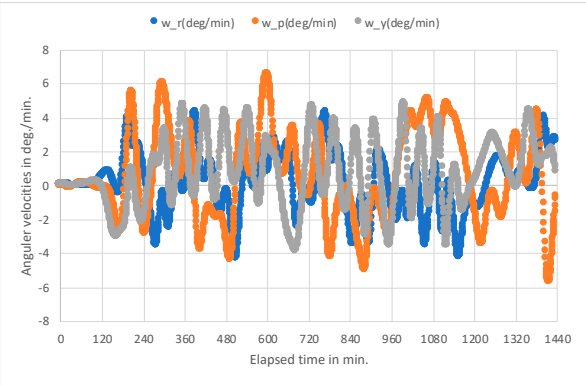
Assumption

- Center of mass deviated by 6% from center of geometry on x axis
- No initial angular momentum

Center of mass	(2) $[0.078, 0.000, 0.000]$ m
Angular velocities	① $[0.0, 0.0, 0.0]$ deg./min.



Attitude angles in deg.



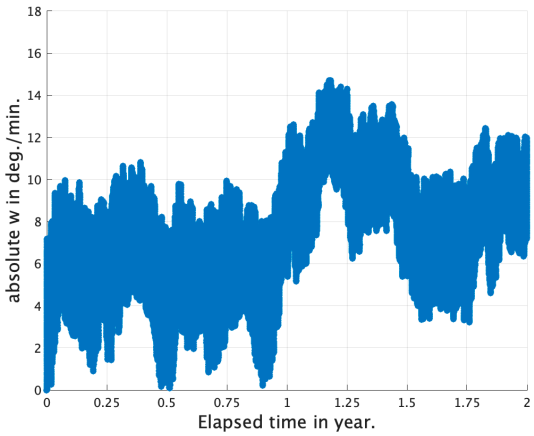
Angular velocities in deg./min.

2-years analysis

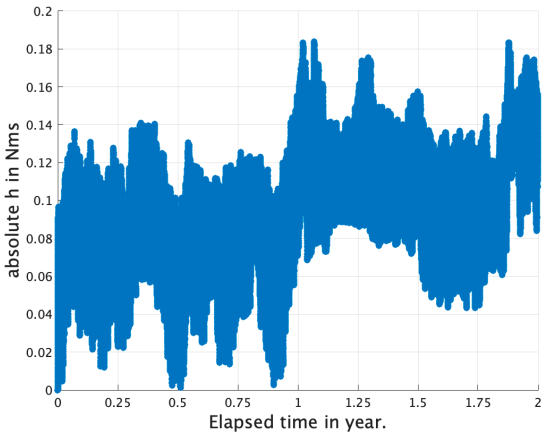
Assumption

- Center of mass deviated by 6% from center of geometry on x axis
- No initial angular momentum

Center of mass	(2) $[0.078, 0.000, 0.000]$ m
Angular velocities	① $[0.0, 0.0, 0.0]$ deg./min.



Norm of angular velocities in deg./min.



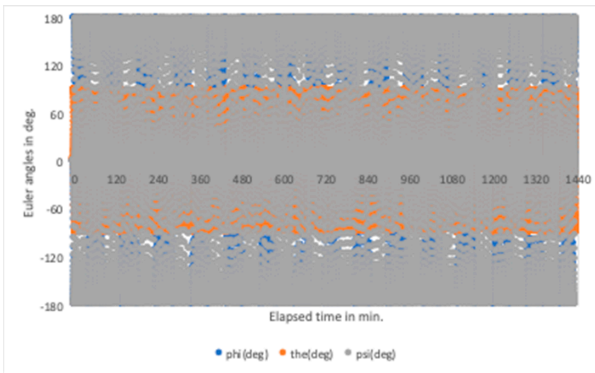
Norm of angular momentum in Nms

1-day analysis

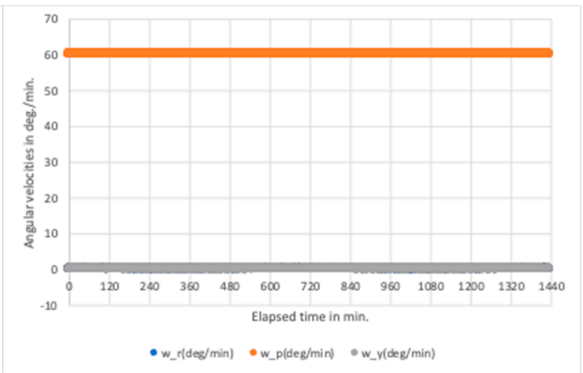
Assumption

- Center of mass deviated by 6% from center of geometry on all axes
- Angular momentum of a reaction wheel (0.42 Nms) on the minor axis of inertia (y-axis)

Center of mass	(1) $[0.078, 0.030, 0.078]$ m
Angular velocities	② $[0.0, 60.2, 0.0]$ deg./min.



Attitude angles in deg.



Angular velocities in deg./min.

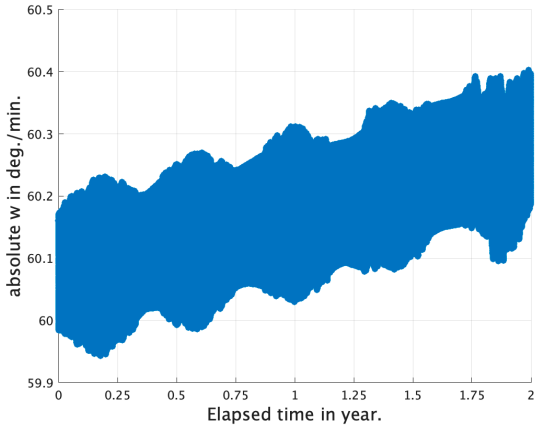
2-years analysis

Both the norm of angular velocities and angular momentum are almost same as the initial values

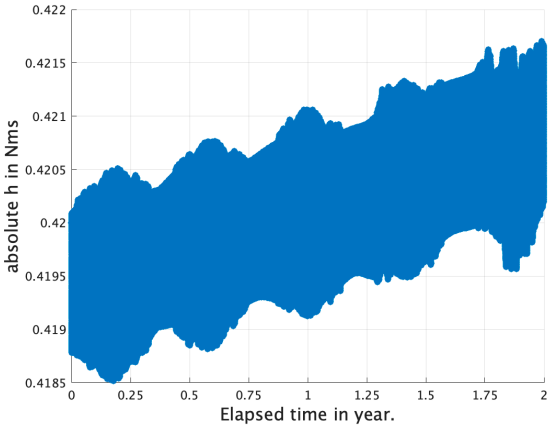
Assumption

- Center of mass deviated by 6% from center of geometry on all axes
- Angular momentum of a reaction wheel (0.42 Nms) on the minor axis of inertia (y-axis)

Center of mass	(1) $[0.078, 0.030, 0.078]$ m
Angular velocities	② $[0.0, 60.2, 0.0]$ deg./min.



Norm of angular velocities in deg./min.



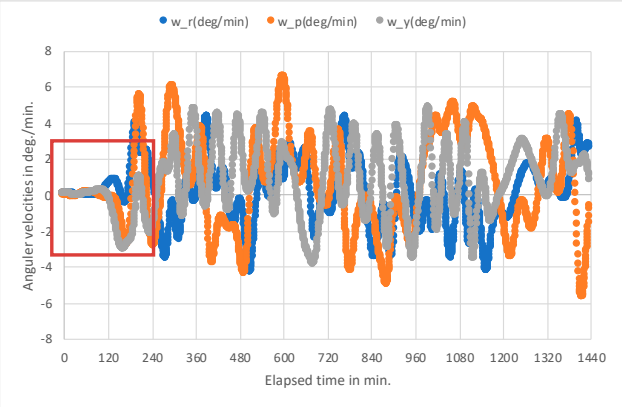
Norm of angular momentum in Nms

Summary

Center of mass	Residual angular momentum	Angular velocities	Angular momentum
6% shift in all axes	Zero	< ±6 deg./min.	Max 0.25 Nms
6% shift in x axes	Zero	< ±6 deg./min.	Max 0.18 Nms
6% shift in all axes	0.42 Nms	Single spin the rate of 60 deg./min.	0.42 Nms

Discussion

- The satellite starts rotating again after a certain period.
- The operation without increasing rotation of the satellite is necessary during the deorbit process.



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Conclusion

- This research demonstrates the short-term and long-term variation of Euler angles and angular velocities of the target object in LEO.
- We obtained quantitative analysis of attitude for debris in LEO to clarify mission requirements.

Future work

- Redefinitions of the shift in center of mass and initial momentum are needed after detailed target determination.