B09

日豪 2 地点からの低軌道物体光学観測実証

Optical Observation Demonstration of LEO Objects from Japan and Australia

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近年，低軌道物体の数が増加している。宇宙空間の安定利用のためには，低軌道物体の位置・軌道把握が不可欠である。 低軌道物体の位置・軌道を精度よく把握するには，複数地点での観測データを用いた軌道決定が有効である。さらに，同一パスの観測データを用いて軌道決定することで，より早く，精度の高い軌道把握が実現できる。このことにより，レーダを用いたスペース・フェンスと同様の宇宙状況監視を光学観測により実現できる。 本研究では，複数地点観測による低軌道物体検出，追尾の実証を実施した。地球上の遠隔にある 2 地点で同一パスの観測データを光学的に取得し軌道決定精度を確認した。観測地点としては，太陽同期軌道の軌道傾斜角に沿った，豪州にある JAXA サイディング・スプリング観測所と日本の IHI 相生観測所の 2 地点を利用した。本講演では，実証の第 1 ステップとして既知物体の観測および軌道決定精度評価の結果を報告する。

In recent years, the number of low-earth orbit (LEO) objects has been increasing. For stable use of outer space, it is essential to grasp the position of LEO objects. In order to accurately grasp the position and orbit of those LEO orbit objects, it is effective to determine the orbit by using observation data from multiple observatories. Furthermore, it is possible to realize a faster and more accurate orbit determination by using the same path observation data. Thus, it is possible to realize space situational awareness similar to a space fence using radar by optical observation. In this study, we will demonstrate optical observation of LEO objects from multiple observatories. Addition, we realize improvement of orbit determination accuracy by using data of the same path that observed from multiple observatories. Two observatories, JAXA Siding Spring Observatory and IHI Aioi Observatory, were used for this study. Those observatories are placed along the angle of sun-synchronous orbit. In this paper, we will report the observation results of known objects and the results of their orbit determination accuracy evaluation.

9th Space Debri Workshop

Optical observation demonstration of LEO objects from Japan and Australia

IHI

25th Feb. 2021

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Contents

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1. Background
2. Objective
3. Observatory
4. Data Processing
5. Observation
6. Evaluation
7. Analysis
8. Conclusion

1. Background

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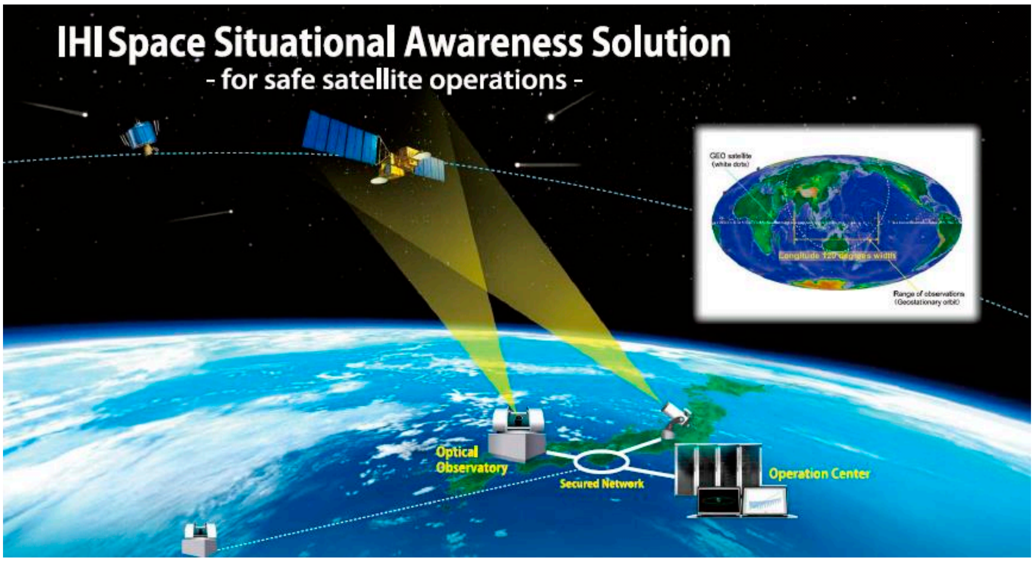
Space situational awareness (SSA), to understanding orbit of object in space, is essential for space utilization. Especially in low earth orbit (LEO), the demand for understanding orbit of satellite and debris is increasing.

IHI have been developing optical observation technology for SSA.



2. Objective

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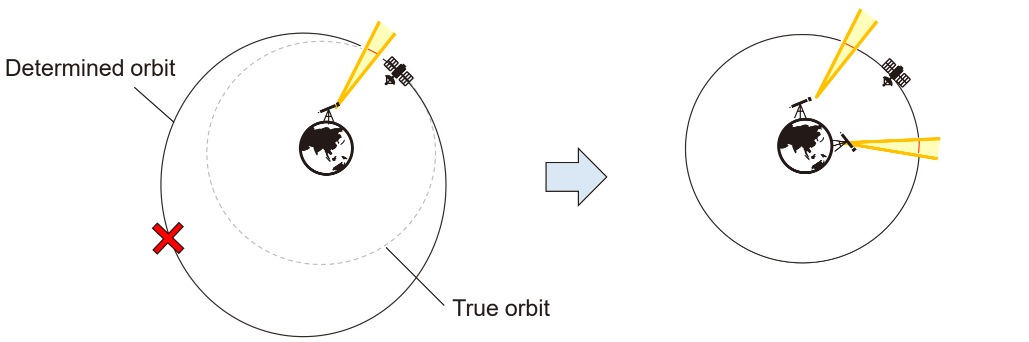
To improve optical observation accuracy, it is effective to determine the orbit by using observation data from multiple observatories.

Furthermore, it is possible to realize a faster and more accurate orbit determination by using the same path observation data.

In this presentation, we report the orbit determination result which is based on same path data from two observatories
(JAXA Siding Spring Observatory in Australia and IHI Aioi Observatory in Japan).



One observatory → Low accuracy

multiple observatories → High accuracy

3. Observatory

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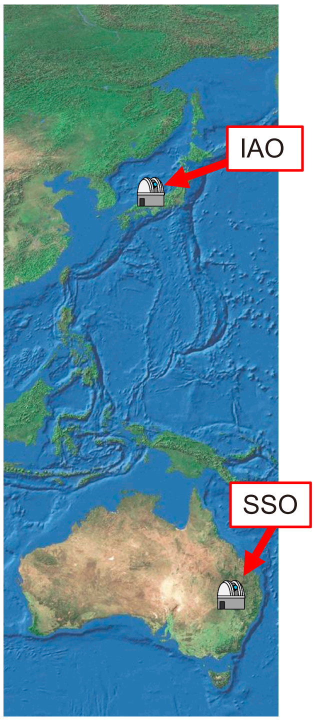
(1) IHI Aioi Optical Observatory (IAO)
- Location
  Latitude: 34.7901 [deg]
  Longitude: 134.457 [deg]
  Altitude: 33.0 [m]
- Specification
  40 cm telescope,
  CCD camera
  Field of view: 1.0 x 1.0 [deg]



(2) JAXA Siding Spring Observatory (SSO)
- Location
  Latitude: -31.2735 [deg]
  Longitude: 149.064 [deg]
  Altitude: 1153.02 [m]
- Specification
  Four 18 cm telescopes,
  CMOS camera
  Field of view: 4.3 x 2.4 [deg]

4. Data Processing

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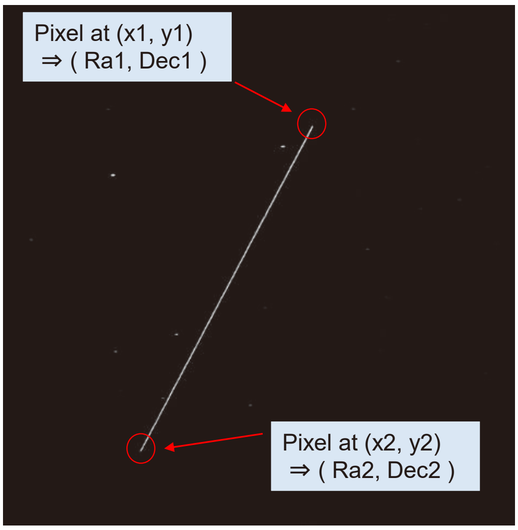
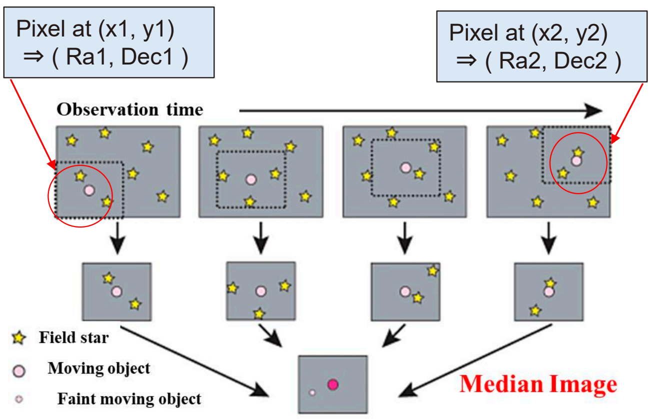
●IAO
Convert the end points of bright line in image to the position of the object on the celestial sphere.

●SSO
Extract the position on the celestial sphere from the object on the first and last image of the observation.

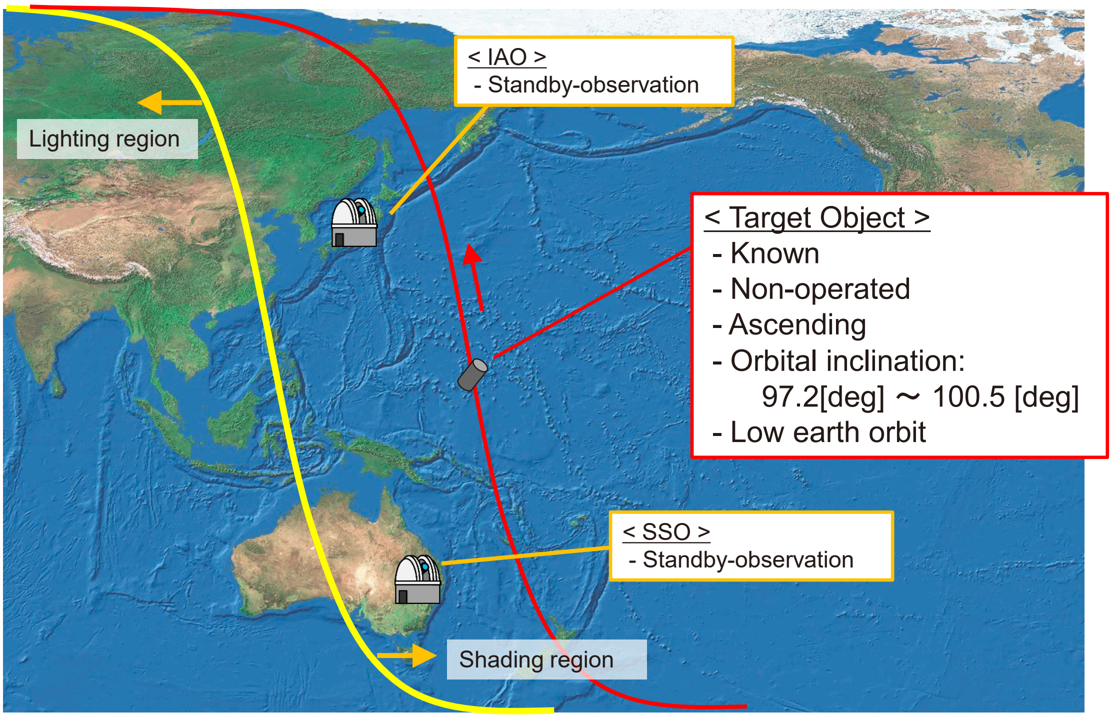


(Observed image with 1.0 [sec] exposure)



5. Observation

IHI



5. Observation

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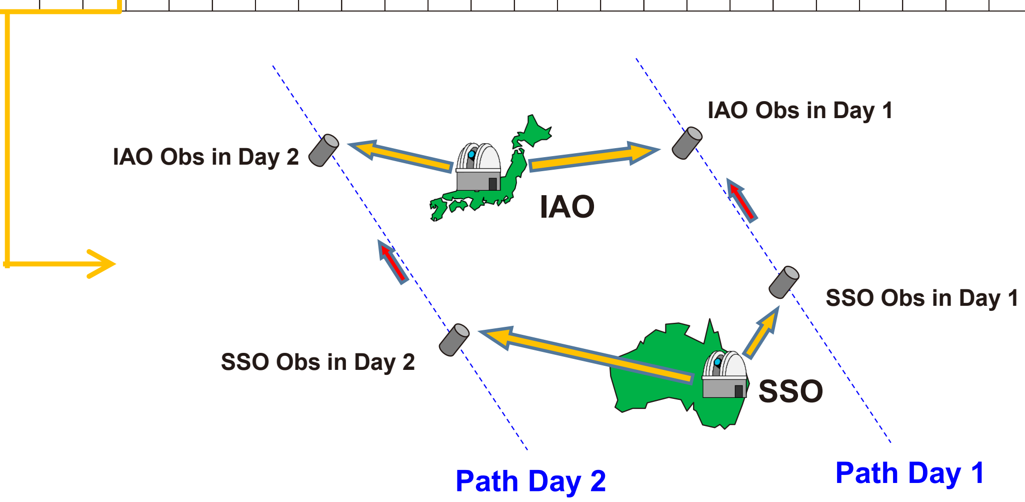
< Case_1 > Observation from 2 observatories for 2 days
- Object : CZ-2C R/B
- NORAD ID : 28480

● : observed

	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		Day 8		Day 9		Day 10		Day 11		Day 12		Day 13	
	SSO	IAO	SSO	IAO	SSO	IAO	SSO	IAO	SSO	IAO	SSO	IAO	SSO	IAO	SSO	IAO	SSO	IAO	SSO	IAO	SSO	IAO	SSO	IAO	SSO	IAO
Case_1	●	●	●	●	●						●	●	●	●			●			●						●



5. Observation

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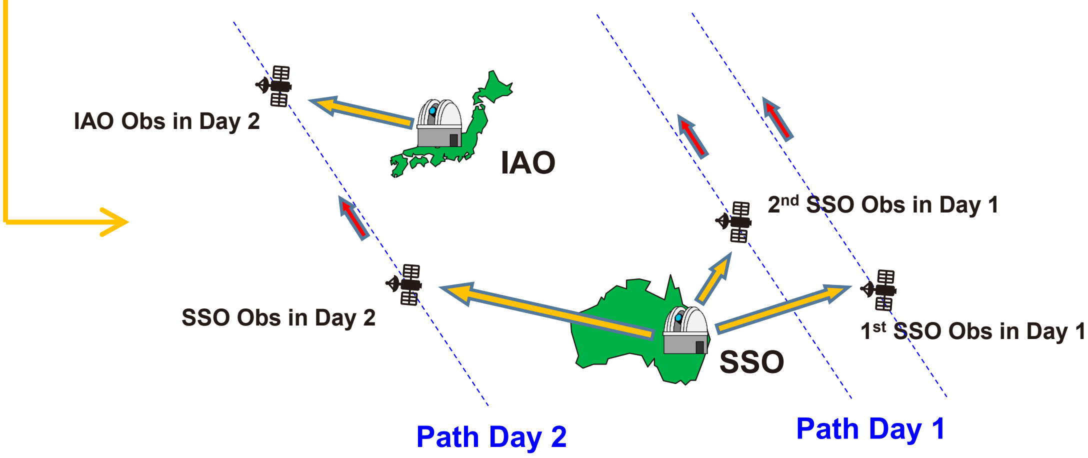
< Case_2 > 2 Paths Observation in 1 day and 1 path observation
- Object : SERT 2
- NORAD ID : 04327

● : observed

	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		Day 8		Day 9		Day 10		Day 11		Day 12	
	SSO	IAO	SSO	IAO	SSO	IAO	SSO	IAO	SSO	IAO	SSO	IAO	SSO	IAO	SSO	IAO	SSO	IAO	SSO	IAO	SSO	IAO	SSO	IAO
Case_2	●● (2paths)		●	●			●			●								●				●	●	●



6. Evaluation

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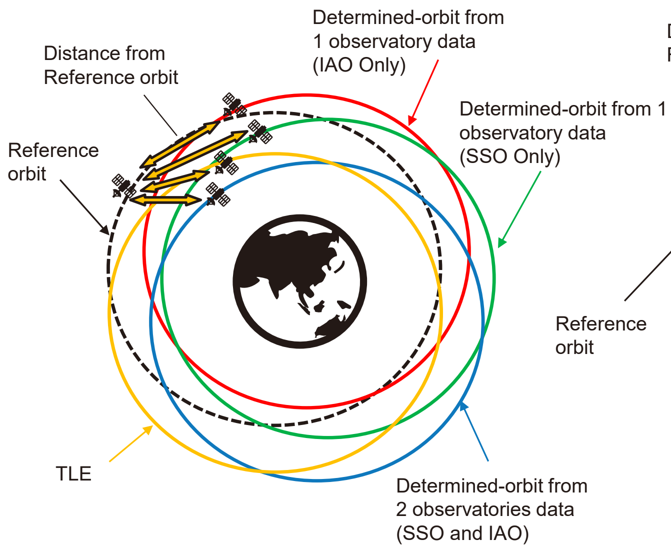
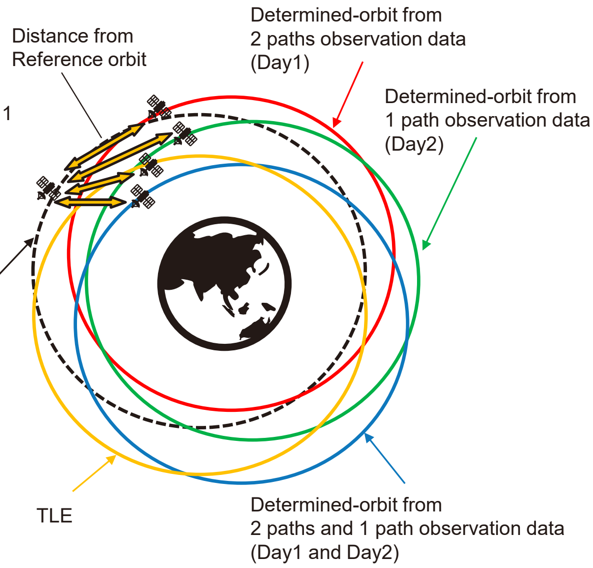
(1) Effect of the number of observatory



(2) Effect of 2 paths observation in 1 day



NOTE:
(1) In all cases, we evaluated change over time of the difference from “Reference orbit“ and determined-orbit or TLE.
(2) “Reference orbit” which is calculated from all observation data, is regarded as the “most probable orbit“.6

6. Evaluation

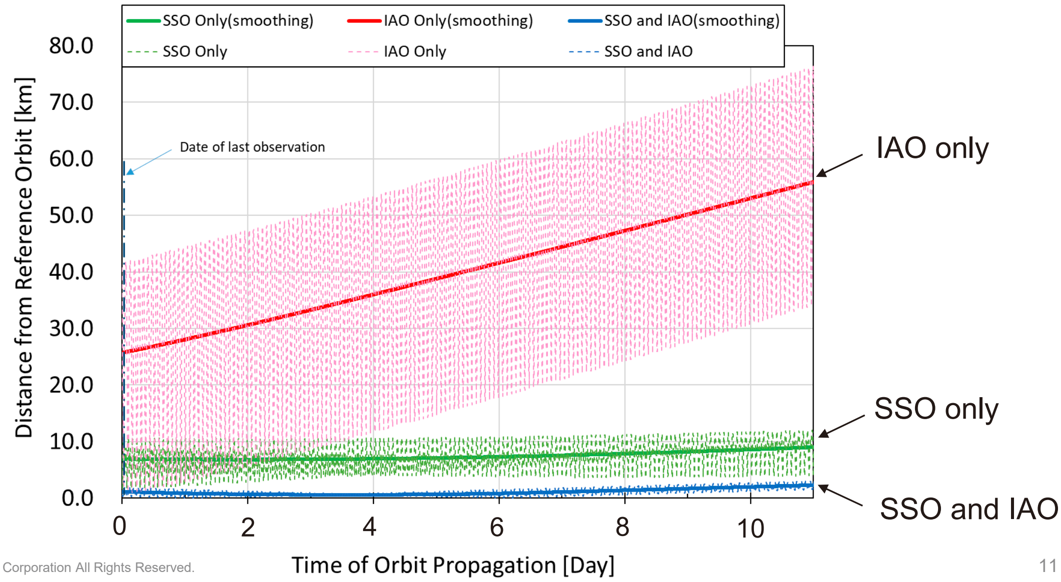
IHI

(1) Effect of the number of observatory

<Comparison orbit>

<Case_1> CZ-2C NORAD ID: 28480	Data of Orbit Determination				Total time of observation [sec]
	Day 1		Day 2		
	SSO	IAO	SSO	IAO	
SSO Only	●		●		8.6
IAO Only		●		●	5.6
SSO and IAO	●	●	●	●	14.2

Orbit determination was improved by using 2 observatories data



11

6. Evaluation

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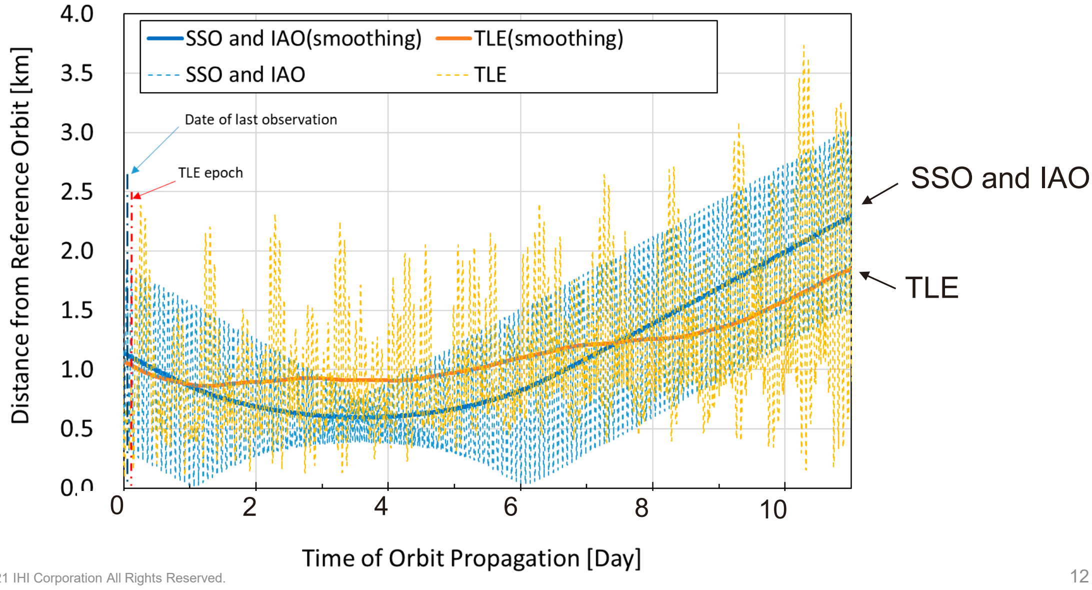
(1) Effect of the number of observatory

<Comparison orbit>

<Case_1> CZ-2C NORAD ID: 28480	Data of Orbit Determination				Total time of observation [sec]
	Day 1		Day 2		
	SSO	IAO	SSO	IAO	
SSO and IAO	●	●	●	●	14.2
TLE	N/A				N/A

With 2 observatories data, orbit determination accuracy will be equal or better than TLE.



12

6. Evaluation

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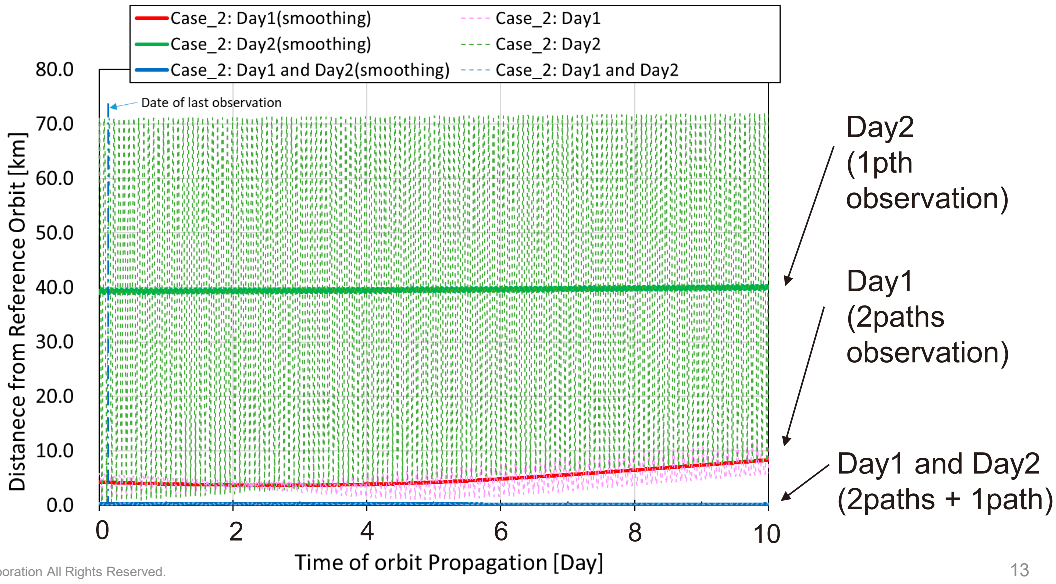
(2) Effect of 2 paths observation in 1 day

<Comparison orbit>

<Case_2> CZ-2C NORAD ID: 04327	Data of Orbit Determination				Total time of observation [sec]
	Day 1		Day 2		
	SSO	IAO	SSO	IAO	
Day1	●●				12.6
Day2			●	●	7.0
Day1 and Day2	●●		●	●	19.6

With 2 paths observation, orbit determination accuracy will be better than orbit from 2 observatories data.



 13

6. Evaluation

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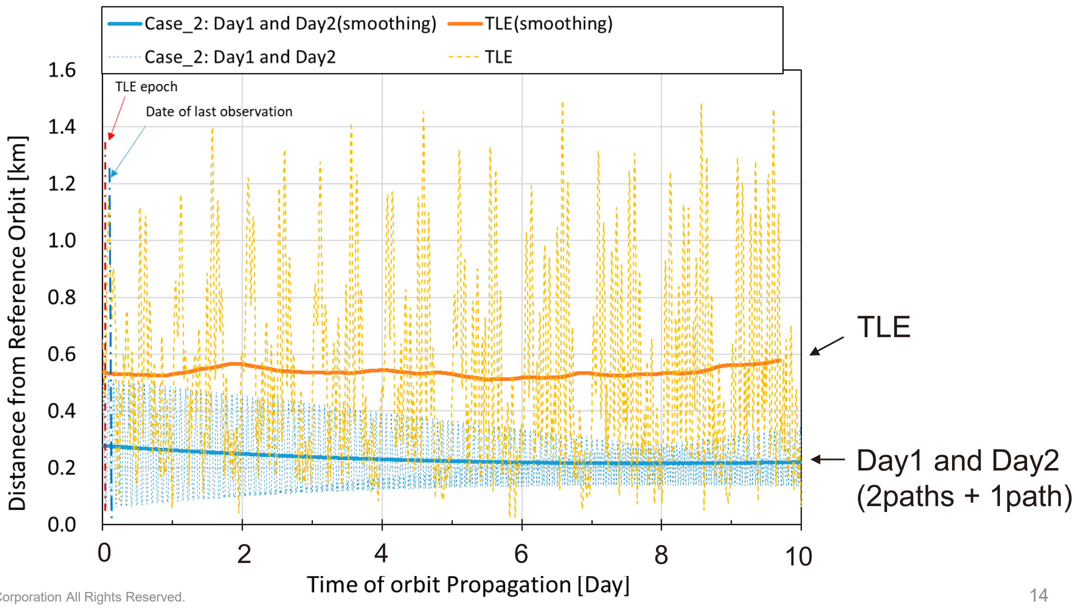
(2) Effect of 2 paths observation in 1 day

<Comparison orbit>

<Case_2> CZ-2C NORAD ID: 04327	Data of Orbit Determination				Total time of observation [sec]
	Day 1		Day 2		
	SSO	IAO	SSO	IAO	
Day1 and Day2	●●		●	●	19.6
TLE	N/A				N/A

Even though, total observation time is short (less than 20 [sec]), orbit determination accuracy will be equal or better than TLE.



 14

7. Analysis

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< Objective >
Investigated the deference between reference orbit and determined-orbit in the view of the orbital elements.

< Method >
Replace one of the orbit 6 elements of the reference orbit with that of the determined-orbit.

<Result>
Semi Major Axis (SMA) is the most predominant element for orbit accuracy.

NORAD ID:28480

No.	Name	Epoch	SemiMajor Axis	Eccentricity	True Arg of Latitude	Inclination	RAAN	ArgofPerigee	Max Disitance from Reference orbit in 10 days
[-]	[-]	[-]	[km]	[-]	[deg]	[deg]	[deg]	[deg]	[km]
1	Reference Orbit	15 Oct 2020 13:46:31.466 UTCG	7174.543	0.01379	109.648	98.072	315.156	231.718	-
2	Obs Orbit	15 Oct 2020 13:46:31.466 UTCG	**7174.546**	**0.01380**	**109.648**	**98.072**	**315.157**	**231.822**	3.109
3	SemiMajorAxis	15 Oct 2020 13:46:31.466 UTCG	**7174.546**	0.01379	109.648	98.072	315.156	231.718	3.492
4	Eccentricity	15 Oct 2020 13:46:31.466 UTCG	7174.543	**0.01380**	109.648	98.072	315.156	231.718	0.268
5	TruArgofLatitude	15 Oct 2020 13:46:31.466 UTCG	7174.543	0.01379	**109.648**	98.072	315.156	231.718	0.169
6	Inclination	15 Oct 2020 13:46:31.466 UTCG	7174.543	0.01379	109.648	**98.072**	315.156	231.718	0.031
7	RAAN	15 Oct 2020 13:46:31.466 UTCG	7174.543	0.01379	109.648	98.072	**315.157**	231.718	0.047
8	ArgofPerigee	15 Oct 2020 13:46:31.466 UTCG	7174.543	0.01379	109.648	98.072	315.156	**231.822**	0.983

7. Analysis

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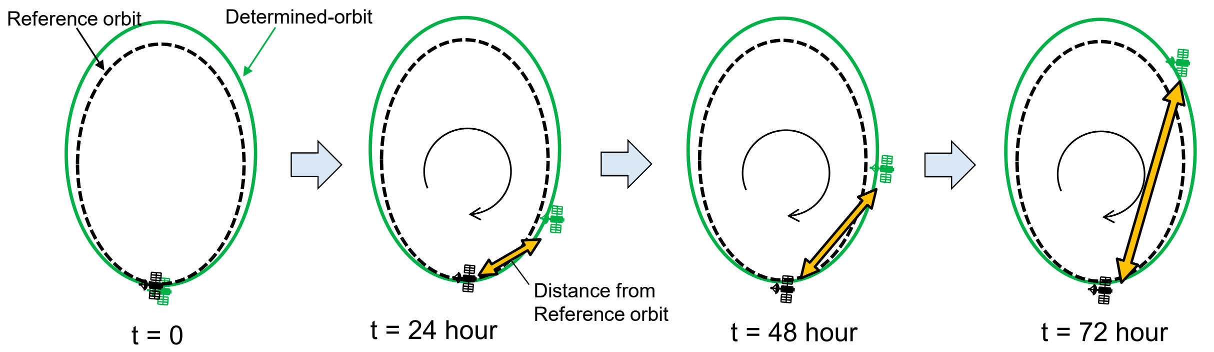
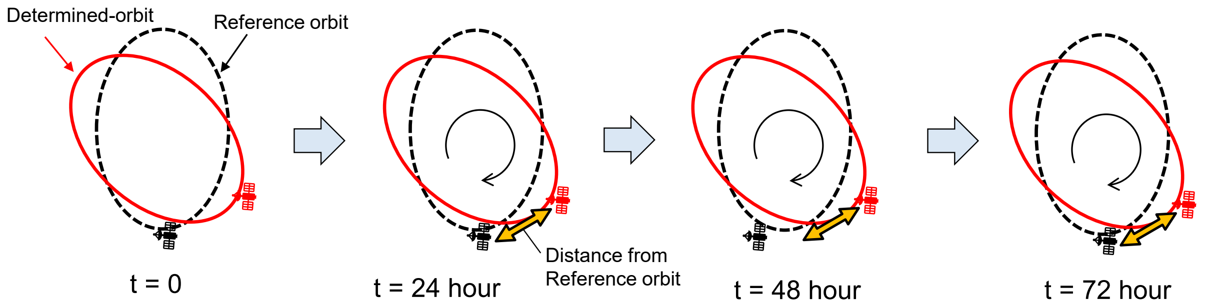
Even though, Difference of SMA is small value, distance from reference orbit will increase after few period.



If only difference is the angle of the orbit, the distance from reference orbit will not increase.



8. Conclusion

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< Conclusion >

(1) Orbit determination accuracy was improved by using 2 observatories data.

(2) Even though, total observation time is short (less than 20 [sec]), orbit determination accuracy with 2 paths observation will be equal or better than TLE.

(3) Semi Major Axis (SMA) is the most predominant element for orbit accuracy.

< Future Work >

(1) Acquire highly accurate orbit determination technology that can be used for SSA/STM services

(2) Orbit determination of unknown object.

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Realize your dreams