E6

静止軌道周辺の破砕事象の観測とモデル化

Measurement and modeling of breakup events in the geostationary region

○上津原正彦，花田俊也（九大），柳沢俊史（JAXA），北澤幸人（IHI）
○Masahiko Uetsuhara, Toshiya Hanada (Kyushu University),
Toshifumi Yanagisawa (JAXA), Yukihito Kitazawa (IHI)

昨今活発に議論されているデブリの発生防止策・低減策の立案には，軌道上のデブリ環境を推定・予測した数値計算結果が積極的に用いられている．時々刻々と変化するデブリ環境に対して推定・予測結果の不確定性を抑えるためには観測・モデル化技術の向上が必要不可欠である．本研究の目的は，静止軌道周辺で発生した破砕事象の観測とモデル化である．運用中の人工衛星が約400機存在する重要な領域である静止軌道周辺では，未知デブリ(起源未同定のデブリ)がこれまでに数多く発見されている．未知デブリの起源は破砕を起こした宇宙機である可能性が高い．本発表では，観測における破砕事象の識別や未知デブリの起源同定方法，そして観測結果に基づく個々の破砕事象のモデル化方法について紹介する．

In this presentation we introduce measurement and modeling techniques applicable for spacecraft breakup events in the geostationary region. A large number of uncatalogued objects have been found in the geostationary region. Spacecraft breakup event is a possible cause of the population of uncatalogued objects. The techniques to be introduced may include observation planning for breakup fragments, origin identification of uncatalogued objects, and breakup event modeling based on the origin identification result. This research will contribute to space debris mitigation/remediation measures, whose effectiveness largely depends on our understandings of current space situation and its future prediction.

KYUSHU UNIVERSITY JAXA IHI

静止軌道周辺の破砕事象の観測とモデル化

Measurement and Modeling of Breakup Events in the Geostationary Region

UETSUHARA Masahiko[1], HANADA Toshiya[1], YANAGISAWA Toshifumi[2], KITAZAWA Yukihito[3]

[1] Kyushu University, Fukuoka, Japan
[2] Japan Aerospace Exploration Agency, Tokyo, Japan
[3] IHI Corporation, Tokyo, Japan

Objective

This research aims to establish a comprehensive method to understand and define the current orbital debris (OD) environment contributed by spacecraft breakup events

Breakup event is a major contributor to the catalogued in-orbit Earth satellite population

Ref.) HISTORY OF ON-ORBIT SATELLITE FRAGMENTATIONS 14th Edition, NASA/TM–2008–214779 , 2008.

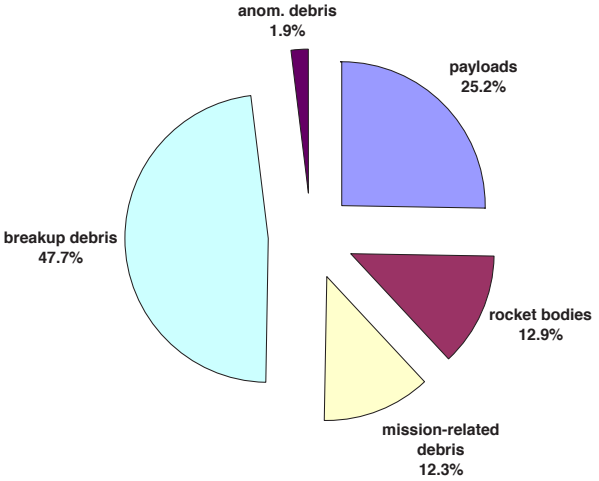
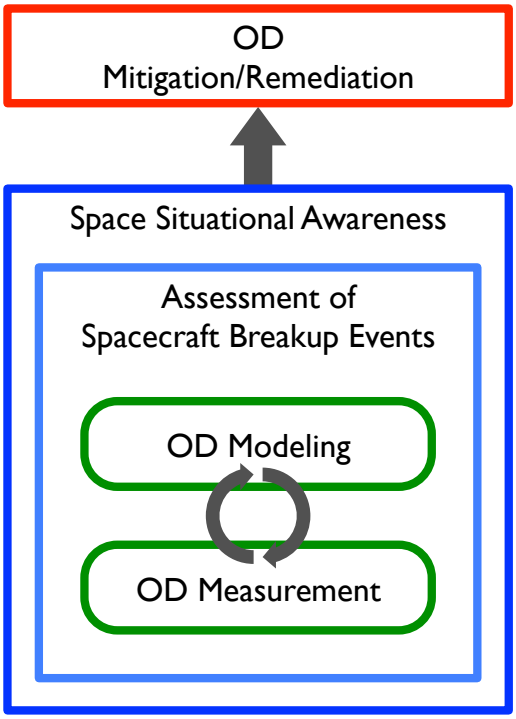


Figure 1.0-2. Relative segments of the cataloged *in-orbit* Earth satellite population.

Approach and Contribution



- Objective
  - To estimate the characteristics of breakup events
  - To confirm the presence of unconfirmed breakup events
- Approach
  - To model the observable states of breakup events
  - To verify and revise the modeling results via optical measurements
- Contribution
  - To understand the current space situation and predict its future
  - To plan effective orbital debris mitigation/remediation measures

R&D Roadmap

- Verification in GEO (2010-2013)
  - Development of the effective strategy applicable for breakup events in GEO
  - Confirmation of possible breakup events
  - Characterization of breakup events
- Application to LEO (2013-)
  - Establish the effective strategy applicable for breakup events in LEO

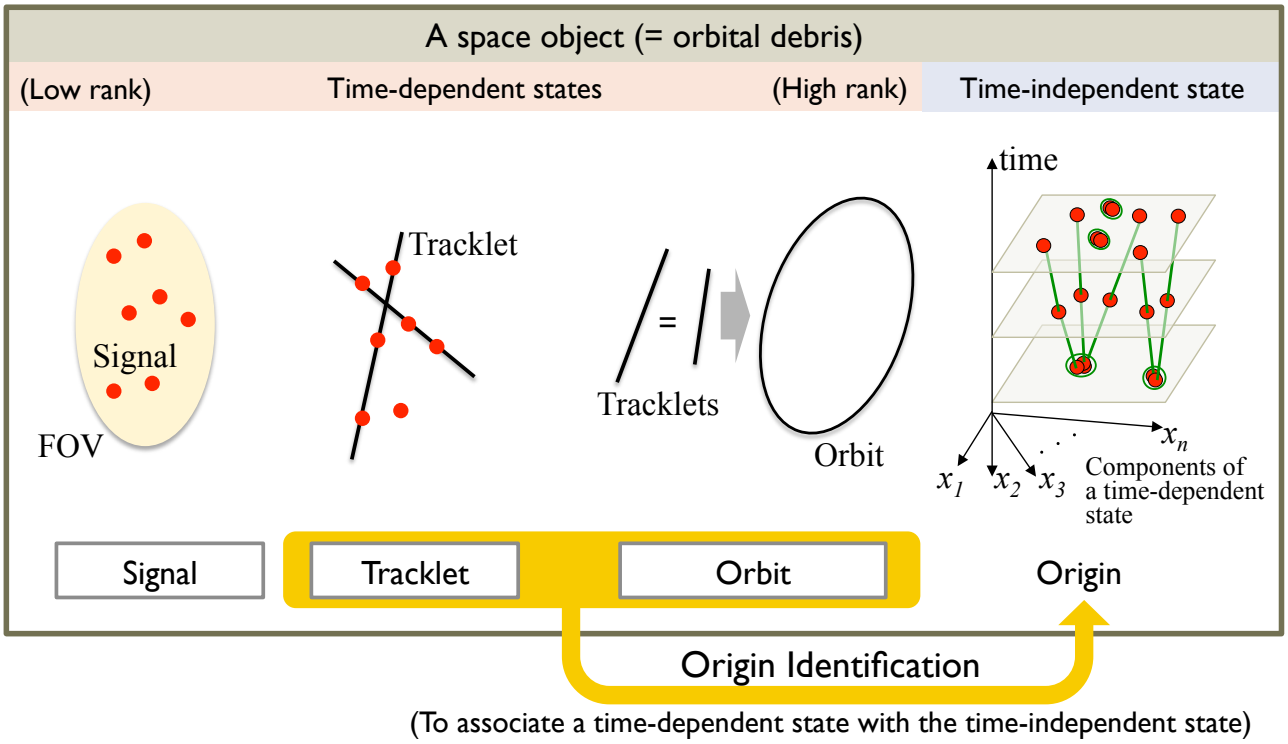
Breakup Events in GEO

Six rocket bodies (only Trastage!), four satellites, and two artificial events.
Two confirmed events (1968-081E and 1977-092A), and ten unconfirmed events.

ID	Cataloged name	Event epoch (YYDDD.dddd)
1966-053J	TITAN 3C TRANSTAGE R/B	87276.6882
1967-066G	TITAN 3C TRANSTAGE R/B	94045.4161
1968-081E	TITAN 3C TRANSTAGE R/B	92053.3745
1973-040B	TITAN 3C TRANSTAGE R/B	81067.2007
1975-117A	SATCOM 1	99257.6799
1975-118C	TITAN 3C TRANSTAGE R/B	87072.6430
1977-092A	EKRAN 2	78174.0000
1979-053C	TITAN 3C TRANSTAGE R/B	82309.0000
1979-087A	EKRAN 4	82157.7550
1988-018B	TELECOM 1C	02263.0000
(AE-02)	-	98180.0000
(AE-03)	-	92280.0000

(Oswald, 2008)

States of Orbital Debris



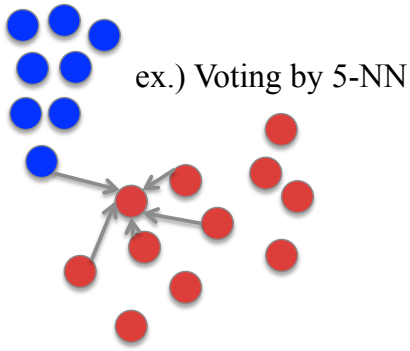
(To associate a time-dependent state with the time-independent state)

Origin Identification (1)

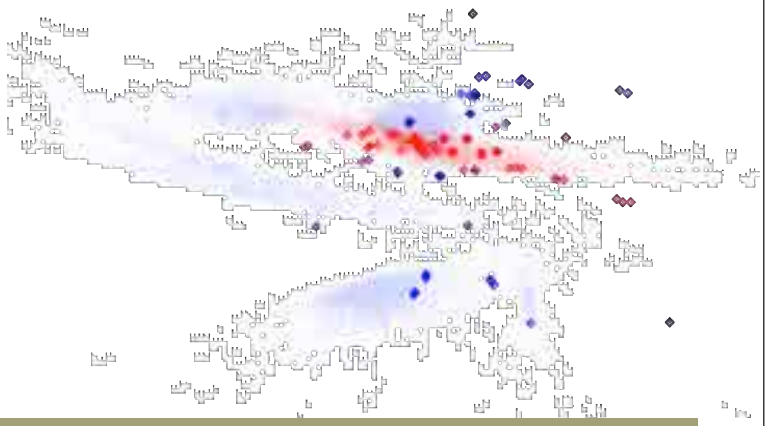
Tracklet

- Probabilistic assessment
  - To associate the tracklets with the predictions of breakup fragments in the angular velocity plane by using a k-NN (k nearest neighbor) algorithm

k-NN algorithm



Sample Result

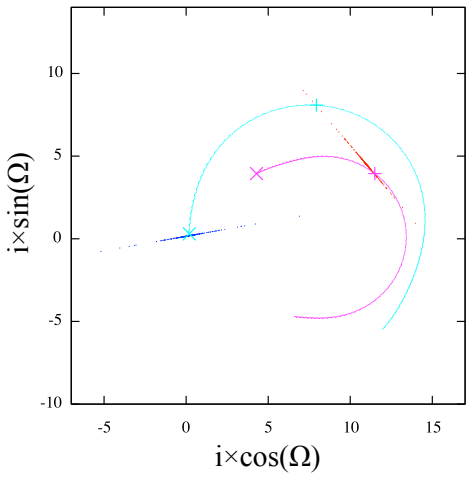


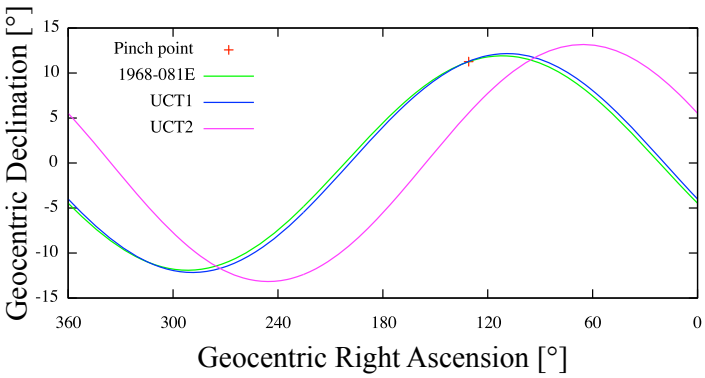
Origin Identification (2)

Orbit

- Deterministic assessment
  - Origins of breakup fragments can be identified in the parameter spaces related with orbital plane

Sample results from test cases (1968-081E, 1977-092A)

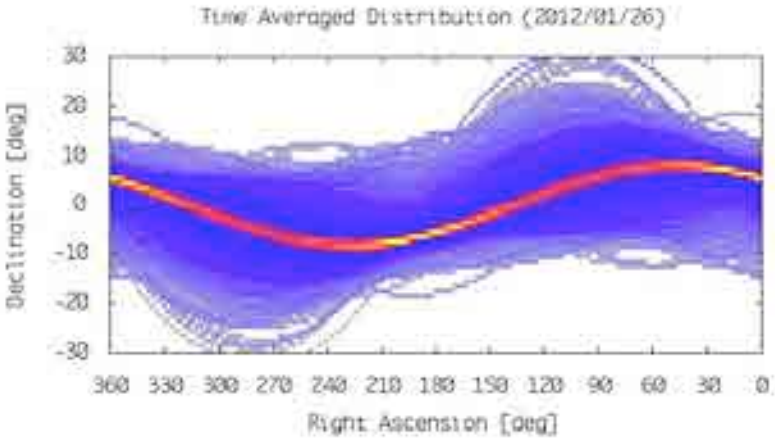




Event Identification

- To identify an orbital anomaly as a breakup event
- Problems to be solved
  1. How to plan survey observations of the possible breakup fragments
  2. How to identify the origin of observations with the possible breakup event, i.e., how to confirm the presence of the possible breakup event

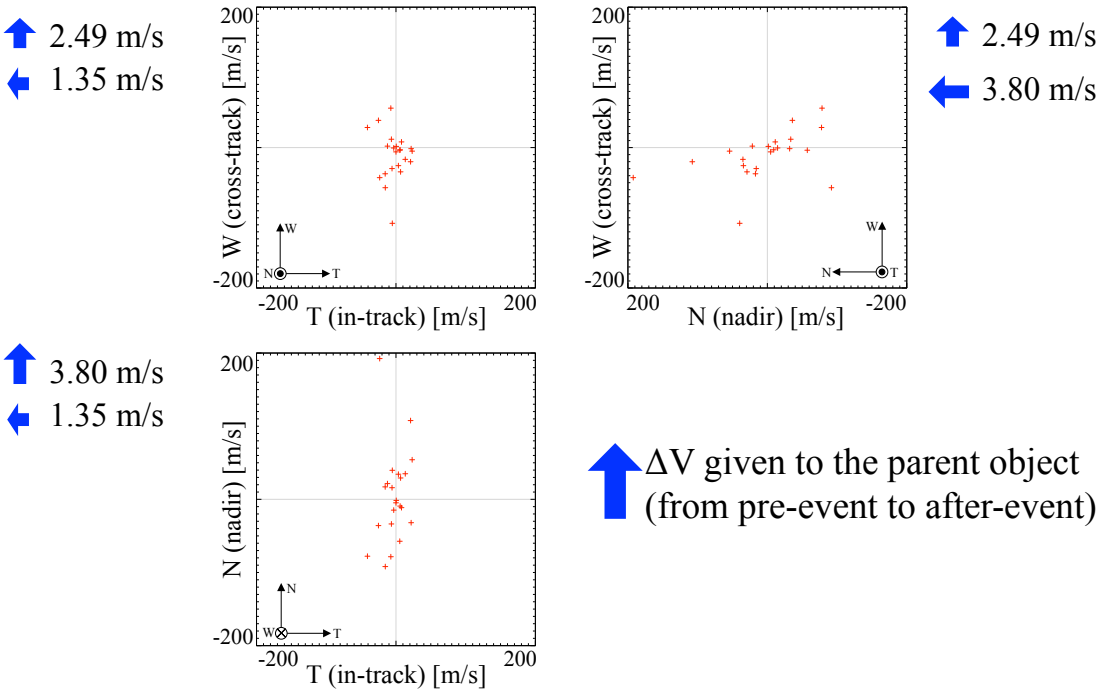
The evolution of possible fragments of 1967-066G



Suitable observation points can be determined even if there are uncertainties in the event epoch

Breakup Event Modeling (1)

- ΔV given to the 1968-081E fragments

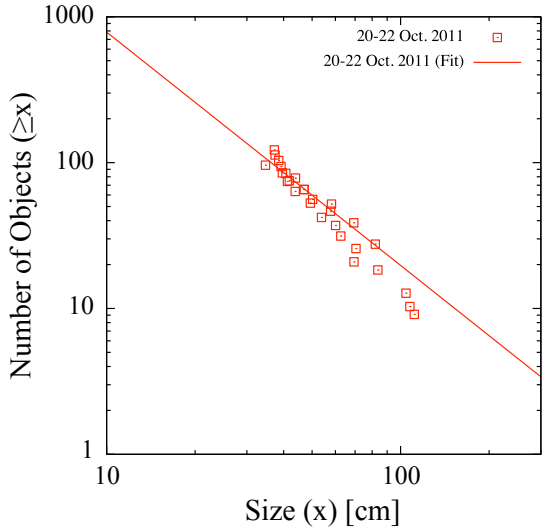


Breakup Event Modeling (2)

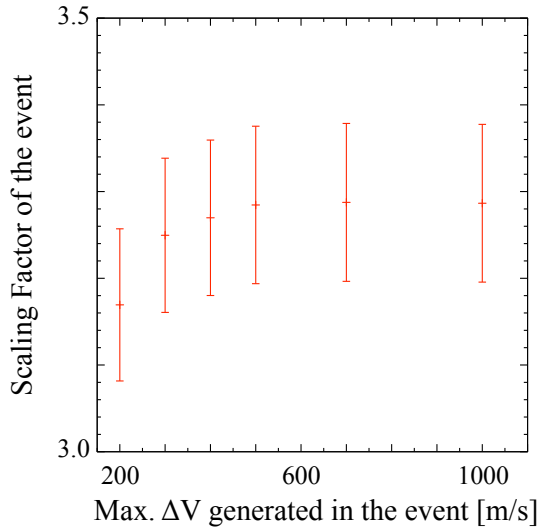
- Scaling factor (the term defined in the NASA's breakup model)

Results of the test case (1968-081E)

A size distribution estimated from the correlated observations



The scaling factor estimated for several hypotheses about max. ΔV of the event



Conclusions

- To effectively combine the OD modeling and the OD measurement, we should select the right states to be handled
- Not only the deterministic assessments, but also the probabilistic assessments are necessary and helpful for characterizing breakup events

Acknowledgements

A part of this research is supported from Grant-in-Aid for JSPS Fellows Grant Number 243000.

IHI Corporation wishes to acknowledge US Air Force Office of Scientific Research (AFOSR) Asian Office of Aerospace Research and Development (AOARD) to support a part of this research under the grant No. FA2386-10-1-4136 (AOARD 104136).

BACKUP MATERIAL

The Effective Strategy applicable for Spacecraft Breakup Events