A03

JAXA 商業デブリ除去実証 (CRD2:Commercial Removal of Debris Demonstration)の最新状況

Latest updates on JAXA Commercial Removal of Debris Demonstration (CRD2)

○山元 透（JAXA）
○YAMAMOTO Toru (JAXA)

JAXA は「デブリ除去を新規宇宙事業として拓き、民間事業者が新たな市場を獲得する」ことを目的として「商業デブリ除去実証 Commercial Removal of Debris Demonstration (CRD2)」を開始した。このプログラムの目標は二つある。軌道上大型デブリ除去技術の実証と、民間企業がデブリ除去をビジネスとして実施する道筋をつけることである。フェーズ I と II の 2 段階で構成されている。フェーズ I では軌道上に存在する日本のロケット上段に接近し近傍制御と映像撮影を行う。フェーズ II ではフェーズ I 実証範囲に加えてターゲットの当初軌道からの除去を行う。フェーズ I のパートナー企業には株式会社アストロスケールが選定され、プロジェクトが 2020 年 3 月に開始された。現在は基本設計が進行している。本講演では、CRD2 の概要と、フェーズ I プロジェクトの最新状況についてご紹介する。

JAXA has launched the Commercial Removal of Debris Demonstration (CRD2) program with the purpose of establishing debris removal as a new business and developing a market by private sector. The program has two goals: to demonstrate active debris removal (ADR) technology and to pave the way for the private sector to implement ADR as a business. The program consists of two phases, Phase I and Phase II. In Phase I, the demonstration spacecraft will approach the Japanese rocket upper stage in orbit to perform proximity operations and take detailed images. In Phase II, the target will be removed from the initial orbit in addition to the Phase I mission sequences. Astroscale Corporation has been selected as the partner company for the Phase I, and the project has been launched in March 2020. The preliminary design activities are currently underway. This presentation will provide the overview of CRD2 program and the latest updates on the Phase I project.

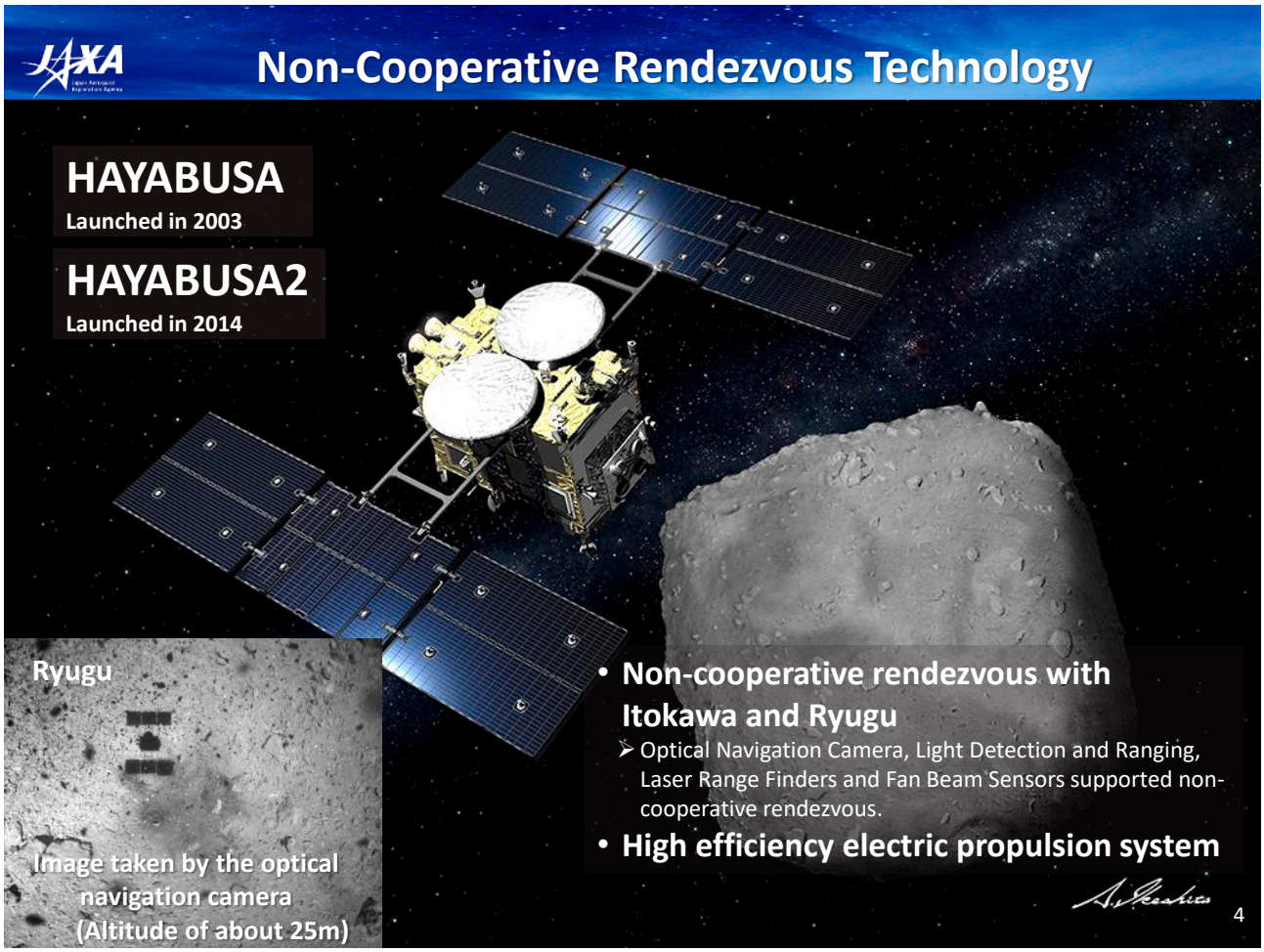
JAXA 商業デブリ除去実証（CRD2：Commercial Removal of Debris Demonstration）の最新状況

9th Space Debris Workshop

Japan Aerospace Exploration Agency
Toru Yamamoto
Feb. 24, 2021

JAXA's Activities on Ensuring Stable Use of Outer Space

- As space use activities grow, threats and risks posed by space debris increase. Securing stable use of outer space is one of the most important issues.
- Basic Plan on Space Policy of Japan includes ensuring national security and enhancement of national security ability as objectives.
- JAXA's activities include:
  - Space Situational Awareness (SSA)
  - Contribution to international standardization activities on space utilization
  - **R&D to mitigate threats and risks of space debris ⇨ CRD2**



Technologies for Active Debris Removal

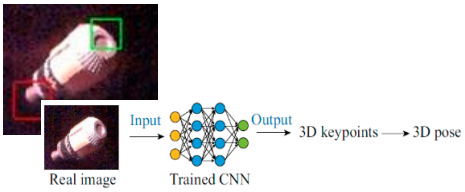
■ Past results

ETS-VII (1997)
Rendezvous and docking technology demonstration

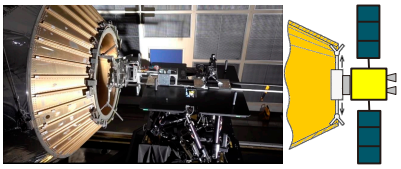
HTV
ISS approach using cooperative rendezvous

HAYABUSA/ HAYABUSA2
Small lightweight propulsion system

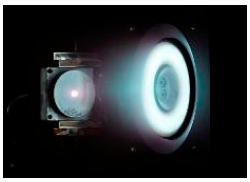
■ Ongoing elemental technology R&D



Rendezvous
Onboard real-time image navigation using deep learning-based pose estimation



Capture
Dedicated capturing mechanism for non-cooperative object



Removal
Low power, high total-impulse electric propulsion

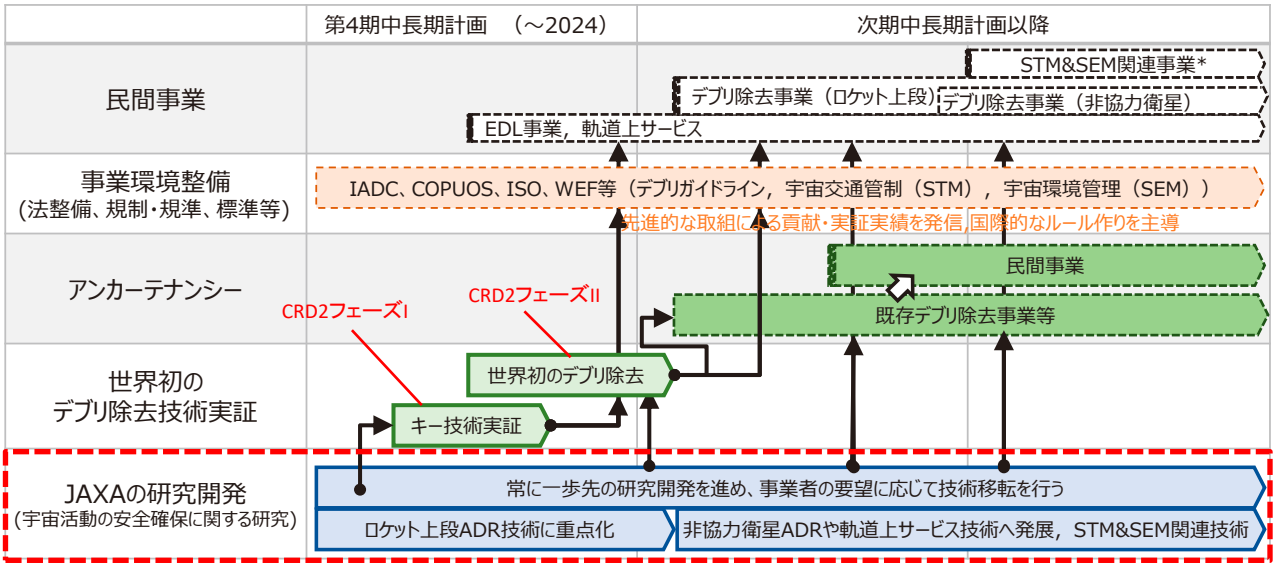
5

Commercial Removal of Debris Demonstration (CRD2)

意義・目的

- スペース・デブリ対策の事業化を目指す民間事業者等と連携し、新たな市場の創出と我が国の国際競争力確保に貢献する取組を行う
- 大型のロケットデブリを対象とした世界初の低コストデブリ除去サービスの技術実証を目指す

目指す姿：**「デブリ除去を起点に新規宇宙事業を拓き、民間事業者が新たな市場を獲得する」**



*)衝突回避サポート（観測（監視），予測，回避），EOLサポート，軌道変更など

Commercial Removal of Debris Demonstration (CRD2)

Aiming at the world's first Active Debris Removal in partnership with private enterprises

Demonstration of the removal of large space debris left in orbit in two phases

Phase-I

Planned for launch in FY2022

Key technologies demonstration

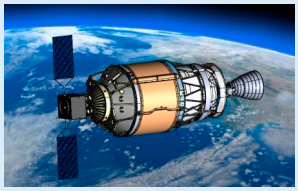
- **Non-cooperative rendezvous, proximity operation, inspection**

Phase-I demonstration satellite

Phase-II

FY2025~

ADR demonstration



Re-entry

- Non-cooperative rendezvous, proximity operation, inspection
- **Removal and re-entry of 2nd stage of launch vehicle**

Phase-I partner, Astroscale Japan Inc.

Partnership with private sectors

A new partnership initiative with private sectors.

- As new partnerships with our industries, JAXA will focus on taking an "oversight role" with all the R&D assets, having partners strongly lead the system design to fulfill both our technical requirements and their business strategies.
- This new partnership will give our industries opportunities to advance their business to an upper stage.

Phase-I partner, Astroscale Japan Inc.

CRD2における新たな取り組み（事業者が主体性を発揮するためのマネジメントの特徴）

事業者が事業戦略に基づき主体的に宇宙機開発・技術実証を行うための JAXAによる総合的マネジメントおよび技術的支援

JAXAは衛星ではなく、サービスと研究開発成果を調達する

- JAXAは「目標デブリに接近し、映像を取得する」サービスへの要求を提示
- 民間事業者がサービス要求に応える衛星開発仕様決定、製造、運用を実施
- 信頼性・品質基準を、事業者から提案できる

マイルストン・ペイメント方式で支払いを行う

- 当初契約時にサービス要求を確定し全額を契約
- 契約時に複数のマイルストン（その開発段階の達成基準）を設定、マイルストン審査結果による支払い

民間事業者と資金を出し合うパートナーシップ事業

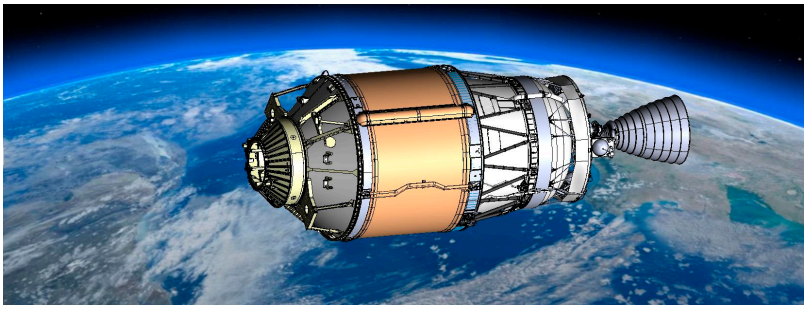
- JAXAは民間事業者に対して技術アドバイスの提供と試験設備の供与を行う
- JAXAはサービスと研究開発成果を得る
- 民間事業者は事業化へ向けた技術開発成果、事業開発成果を得る
- 競争参加資格を拡大

9

CRD2 Phase-I / Target

- Target candidates
  - **Real** upper stages left in Low Earth Orbit
  - **Domestic** upper stages
  - Altitude = **approx. 600km** for safe demonstration

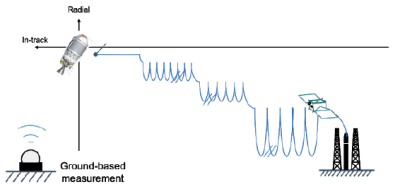
Catalog ID No.	Flight No.	Main payload
28932	H2A F8	ALOS
33500	H2A F15	GOSAT
38341	H2A F21	GCOM-W1
39771	H2A F24	ALOS-2
43067	H2A F37	GCOM-C1
43682	H2A F40	GOSAT-2



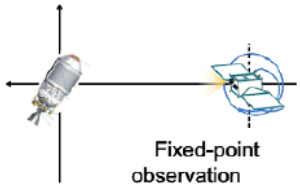
10

CRD2 Phase-I / Service Specification

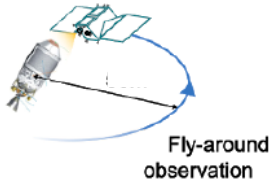
- Service specification（サービス仕様）is defined in the document "**GKD-2019013 CRD2 (phase-I) service specification**"
- Required services:



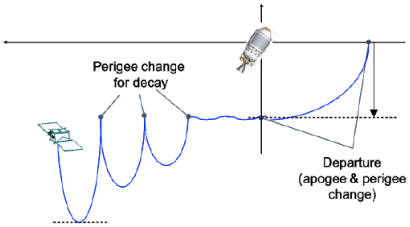
(1) Rendezvous performance report service



(2) Fixed-point observation service



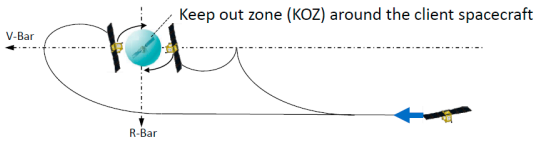
(3) Fly-around observation service



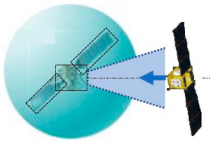
(4) Mission termination service

CRD2 Phase-I / Safety Requirement

- In order to limit, manage or avoid the risk or collision upon rendezvous, proximity and servicing operation, the safety standard "**JERG-2-026 Safety Standard for ON-ORBIT Servicing Missions**" is defined and required for CRD2.



Sample trajectory in the far field



Sample approach path into KOZ

Basics in trajectory design

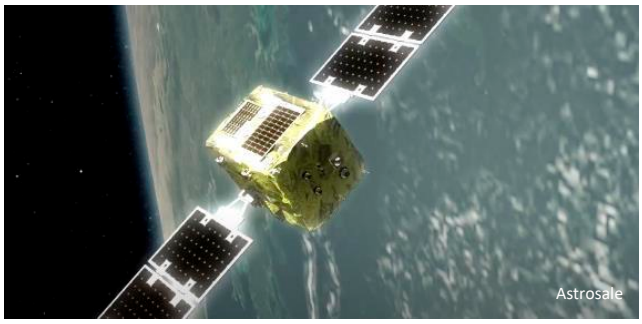
In the far field, the servicing spacecraft takes safe trajectory which does not interfere with Keep Out Zone (KOZ) even in the passive state. In the closed approach, the servicing spacecraft comes into the designated approach path without crossing over the path boarder.

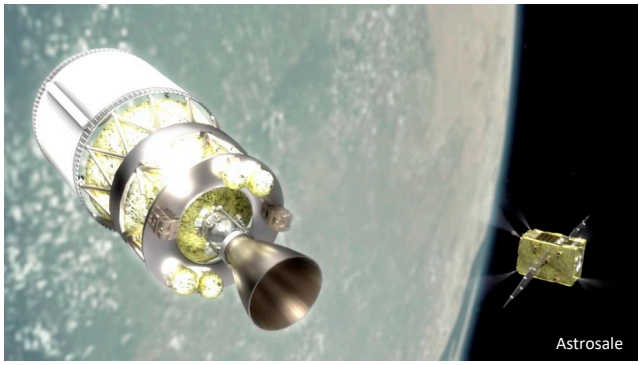
General requirements

- The total system shall be one fault tolerant (1FT) to the critical event such as breakup. Hence no single failure shall not lead to collision, or loss of mandatory function for proper disposal.
- Analysis, evaluation and safety reviews are based on the system safety engineering practices. A spacecraft developer performs hazard analysis based on its design and operation.

CRD2 Phase-I / Chaser Spacecraft

- **ADRAS-J**: Spacecraft for CRD2 Phase-I **manufactured and operated by Astroscale Japan Inc.**
- Wet mass: approx. 180kg
- **Full-range rendezvous and proximity operation capability** targeting a non-cooperative H2A rocket upper stage left in orbit





13

CRD2 Phase-I / Mission

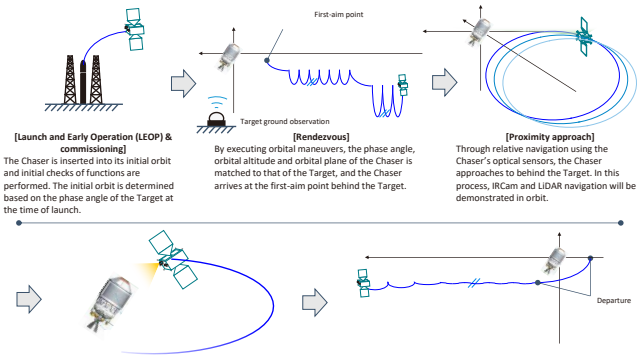
商業デブリ除去技術実証フェーズIプロジェクト

JAXAサービス仕様

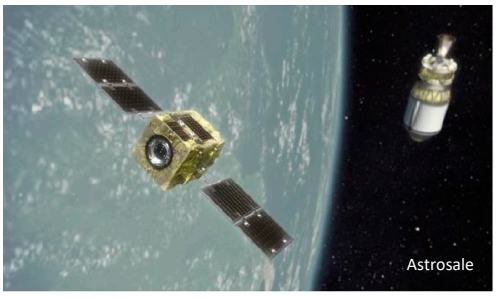
1. デブリ接近計画に対する実績の確認サービス
2. 定点観測サービス
3. 周回観測サービス
4. 終了処理サービス

事業者が実施する技術実証

1. フェーズIIの事前診断
2. ターゲットPAF直上までの極近傍接近
3. エクストラミッション



Astrosale



14

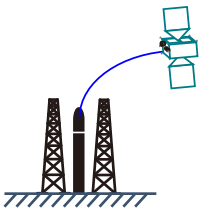
CRD2 Phase-I / Milestones

- Four milestones are defined
- For each milestone achieved, a pre-determined amount is paid
- The final milestone payment (Milestone 4) is more than 25% of the total payment
- Launch: FY2022

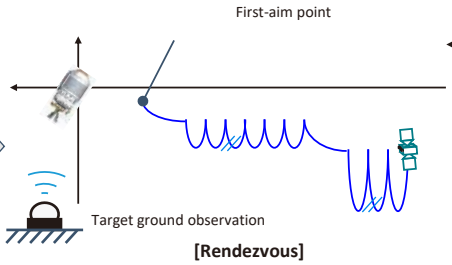
Preliminary Design	Critical Design	Manufacture, IAT	Operation
Milestone review 1 (PDR included)	Milestone review 2 (CDR included)	Milestone review 3 (PQR, Launch Readiness Review included)	Milestone review 4 (Service results)

15

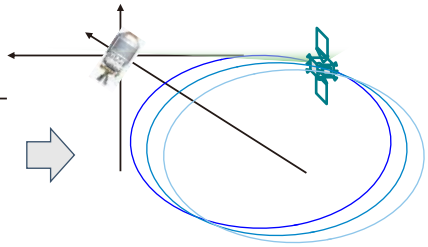
CRD2 Phase-I / Concept of Operation



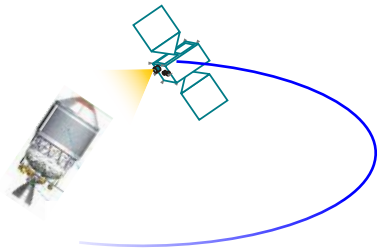
[Launch and Early Operation (LEOP) & commissioning]
The Chaser is inserted into its initial orbit and initial checks of functions are performed. The initial orbit is determined based on the phase angle of the Target at the time of launch.



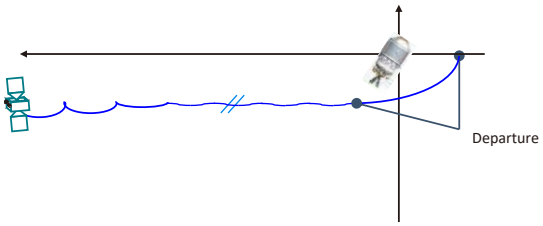
[Rendezvous]
By executing orbital maneuvers, the phase angle, orbital altitude and orbital plane of the Chaser is matched to that of the Target, and the Chaser arrives at the first-aim point behind the Target.



[Proximity approach]
Through relative navigation using the Chaser's optical sensors, the Chaser approaches to behind the Target. In this process, IRCam and LiDAR navigation will be demonstrated in orbit.



[Proximity operation]
Fixed-point observation and go-around observation of the Target, and testing of final approach to the PAF section of the rocket upper stage is conducted. In addition, if there are surplus resources, extra mission will be carried out.



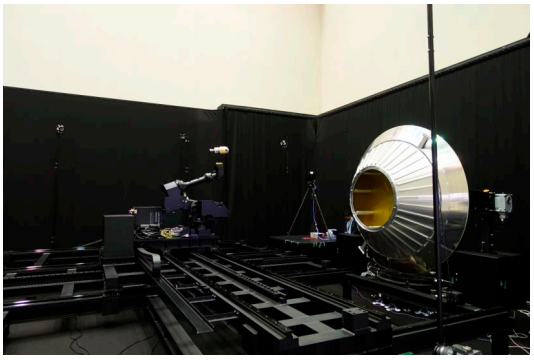
[Departure]
Through orbital maneuvers, the Chaser will break away from Target proximity, move to an orbit below the Target, and end the mission.

This chart provided by Astrosale

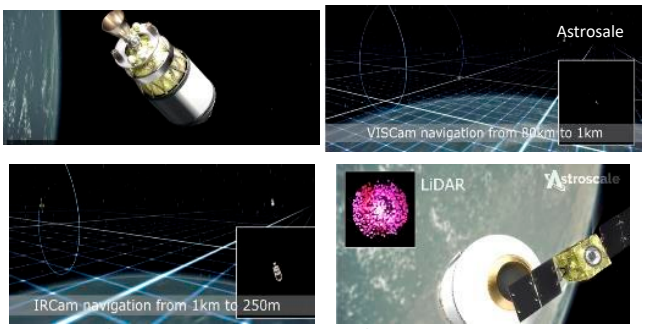
16

CRD2 Phase-I / Milestone-1 status

- Preliminary design has been conducted
  - Concept of Operation design
  - System/Subsystem requirement definition
  - System design
  - Subsystem design
  - Test and verification of COTS rendezvous sensor BBMs
  - Safety design
  - Manufacture, integration, assembly and test planning
- Milestone 1 review is currently underway



COTS rendezvous sensor BBM test at the JAXA SATDyn facility

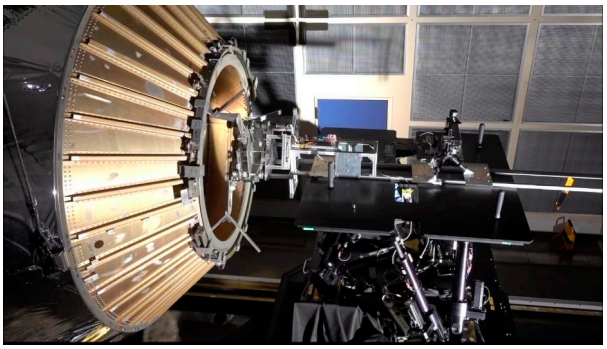


Preliminary design of navigation system for non-cooperative target with multiple types of COTS sensors

17

Way forward

- As a result of Phase-I, establishment of technologies for full-range rendezvous and stable proximity operations with space debris is expected
- In parallel, JAXA is conducting R&Ds on the key technologies required for Phase-II
- The activities of CRD2 will continue for sustainable space activities and creation of new on-orbit services



18