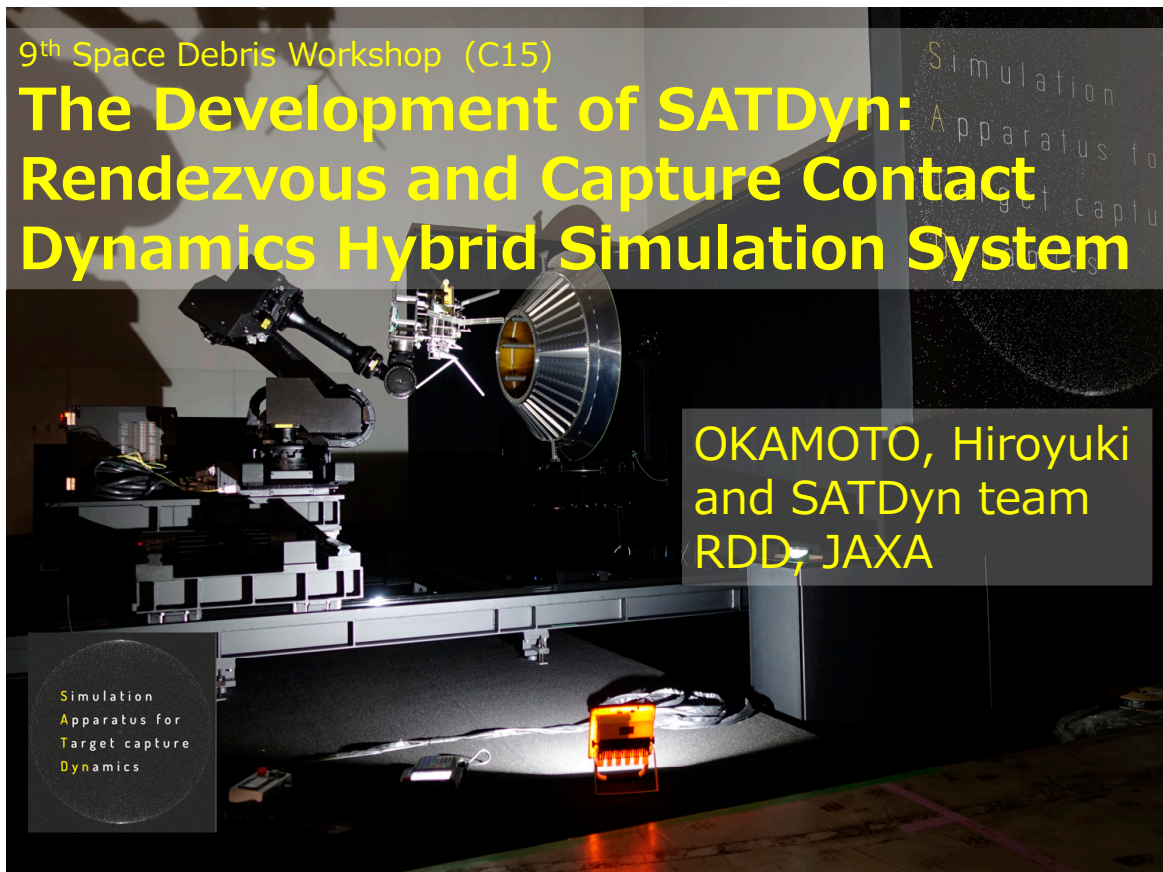## C15

動ターゲット捕獲検証プラットフォーム（SATDyn）の開発
The Development of SATDyn:Rendezvous and Capture Contact Dynamics Hybrid Simulation System

○岡本　博之, SATDyn チーム（JAXA）
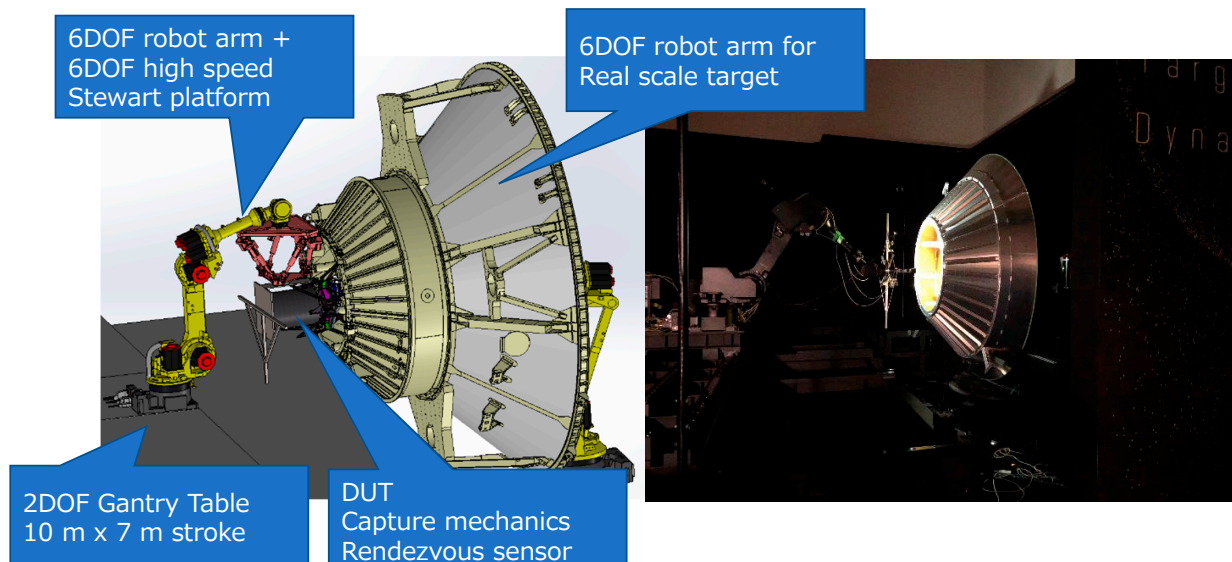○OKAMOTO Hiroyuki, SATDyn Team (JAXA)

JAXA では実物大のランデブならびに捕獲ダイナミクスの検証を行うハイブリッドシミュレータである動ターゲット捕獲検証プラットフォーム（通称：SATDyn）を開発している。SATDyn はチェイサ部とターゲット部で構成されている。チェイサ部は 10m x 7m のガントリステージとその上に搭載されている 6 自由度ロボットアームで構成されており、チェイサ衛星の重心の運動が模擬される。ロボットアームと捕獲機構の間に力トルクセンサが搭載され、計測された力トルクを用いてチェイサの力学計算を行いチェイサ CG 位置ならびに姿勢を再現する。高速の衝突現象シミュレーション用に高速プラットフォームをロボットアームと捕獲機構の間に具備する予定である。ターゲット駆動装置は 3 自由度の姿勢運動装置でターゲットの姿勢運動を再現する。実物大の1194PAF 模型がターゲットとして準備されている。チェイサならびにターゲットの位置姿勢計測用のモーションキャプチャシステムが具備されている。また、SATDyn エリアはできる限り暗幕で覆われ、迷光をできる限り除去している。模擬太陽光も準備されており、可視光センサによる航法のシミュレーションにも供される。SATDyn は JAXA 研開共用設備として共用予定である。

JAXA is developing the real-scale hardware dynamics simulator for the tumbling target rendezvous and capturing, called SATDyn (ab. Simulation Apparatus for Tumbling target capturing DYNamics). SATDyn consists of the chaser dynamics part and the target dynamics part. The chaser dynamics part equips 10m x 7m stroke gantry stage with 6-DOF robotic arm, by those the chaser CG dynamics will be simulated. The force torque sensor is equipped between the SATDyn robotic arm and the real target capturing device. The output of FT sensor is used as the input for the dynamics calculation, and the calculated CG position and attitude is expressed by the robotic arm. The fast actuating 6-DOF platform is planed to be equipped between the robotic arm and FT sensor for simulating the high speed contact dynamics. The target dynamics part equips the 3-DOF attitude simulation device by which the target dynamics will be simulated. The real-scale 1194PAF is prepared as the target. SATDyn has the motion capture system for measuring the position and attitude of the chaser and the target. The black curtain is surrounded SATDyn area to reduce the unexpected light condition. Solar simulator is also prepared for the visual based navigation simulation.
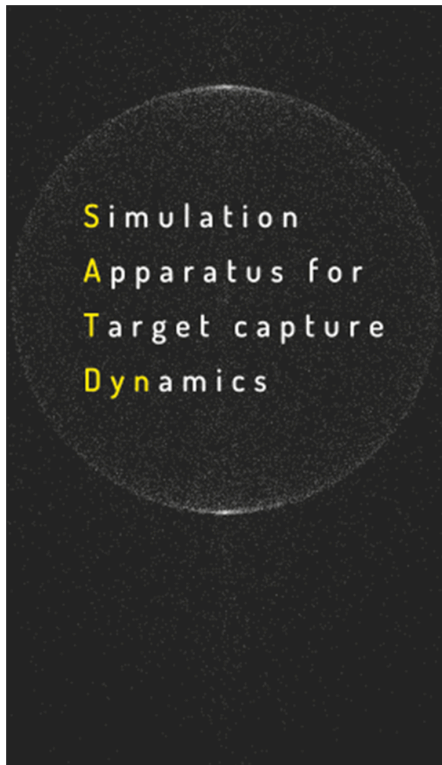
9th Space Debris Workshop (C15)

The Development of SATDyn: Rendezvous and Capture Contact Dynamics Hybrid Simulation System

OKAMOTO, Hiroyuki
and SATDyn team
RDD, JAXA

Simulation
Apparatus for
Target capture
Dynamics

SATDyn

Simulation Apparatus for Target capture Dynamics (SATDyn)

- ➤ Numerical and Physical hybrid simulation system including contact dynamics
- ➤ ADR proximity operation simulation with real hardware (navigation sensor systems, capturing mechanics)
- ➤ 10m x 7m stroke 2DOF Gantry table with 3x6DOF Robotic arms for the chaser's relative motion simulation with external force torque measurements
- ➤ Solar simulator (Xe lump) and Full area motion capture system

6DOF robot arm +
6DOF high speed
Stewart platform

6DOF robot arm for
Real scale target

2DOF Gantry Table
10 m x 7 m stroke

DUT
Capture mechanics
Rendezvous sensor

Agenda

Simulation Apparatus for Target capture Dynamics

- Background and Objective

- Design

- Current Status

- Summary

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Background

ADR Sequence Sample

Launch

Rendezvous

Proximity operation

Capture

Post Capture Service

Deorbit

Reentry
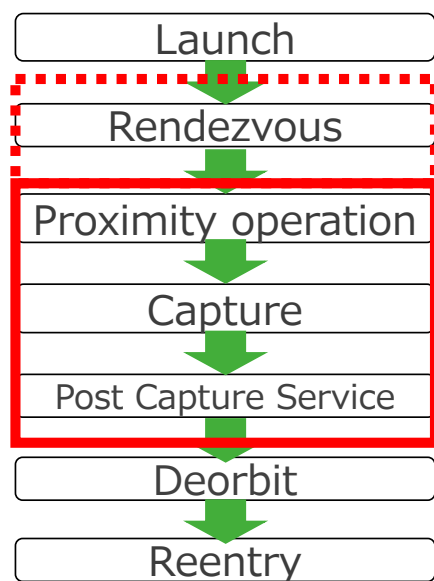
Ground Test Facility Required for verification of those technologies

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Background

- JAXA has the Rendezvous and Docking Operation Test System (RDOTS) .
  - The RDOTS was established as a system to demonstrate the rendezvous technology of the H-II Transfer Vehicle (HTV), a spacecraft used to transport supplies to the International Space Station (ISS).

- Capturing dynamics is not in the scope of RDOTS
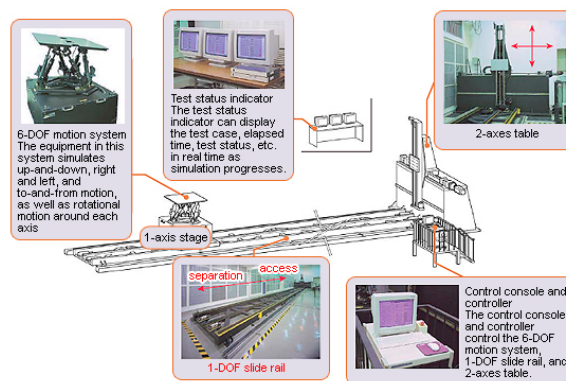
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Objective

- Integrated on-ground ADR verification system is needed
  - Rendezvous and capturing the tumbling large target is a candidate of ADR method

- Due to the 1G environment on ground, numerical and physical hybrid simulation techniques are being studied.
  - Motion dynamics is numerically calculated
  - Forces and torques are physically measured using real hardware
  - Dynamic open loop test with preplanned orbit
  - Dynamic closed loop test with force/torque feedback simulation

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Objective

Hybrid Simulator
- Issue: Instability due to the system delay
- Countermeasures: Low delay robot
  - Assumed Chaser-Target system natural frequency is less than 5 Hz at capturing
    - Nominal 4Hz
  - 2 Robots are equipped for the chaser dynamics simulation
  - 1 for large maneuver with less response
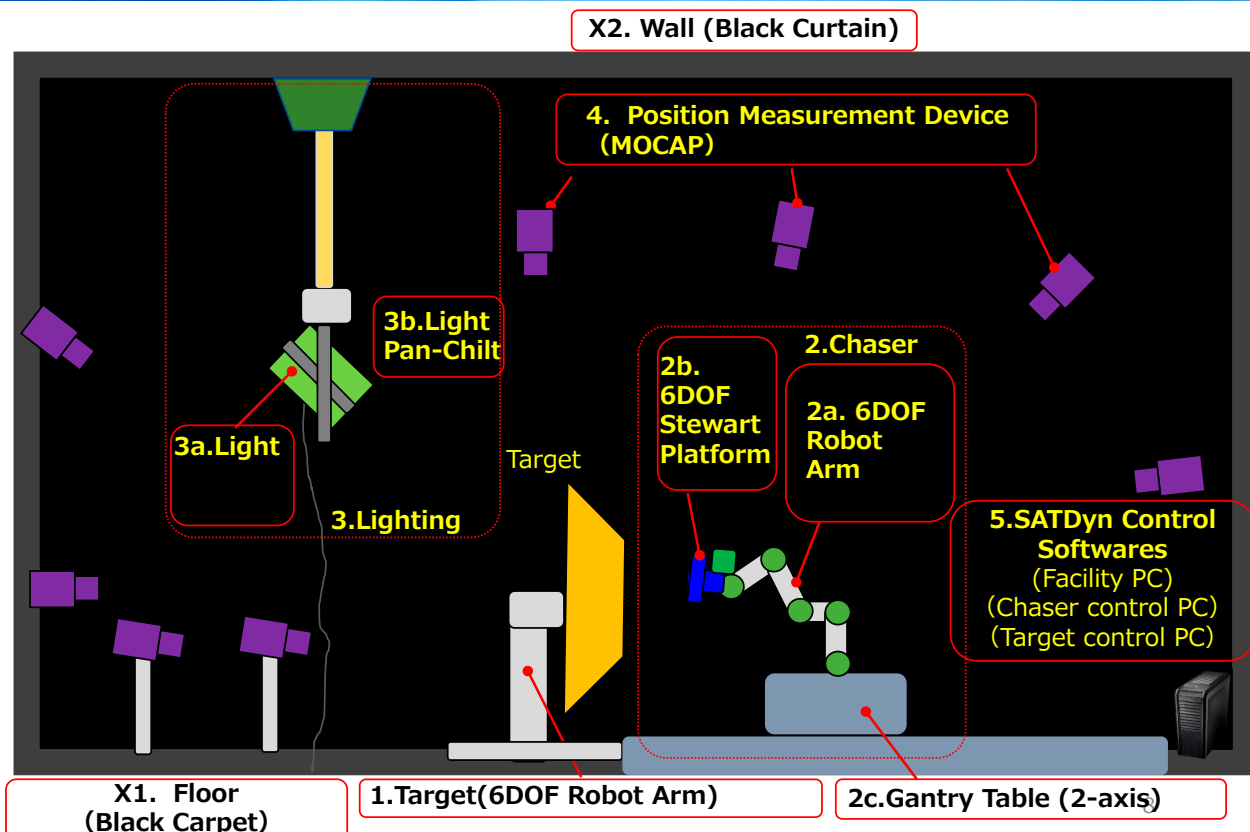 - 1 for small maneuver with high response

Optical Environment Simulator
- Required for the visual based navigation
- Issue: Solar simulation (illumination area, direction), Darkroom (darkness, stray light)
- Countermeasures : Dark curtain
  - The model fidelity is more important

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SATDyn Schematics

Development Plan

- Assumed Use Cases
- CRD2Phase-I tests
  - Navigation sensor (sub-scale model test)
- CRD2Phase-II tests
  - Capture device dynamics test（Full scale model test）
  - Force torque feed-back simulation test
- Others
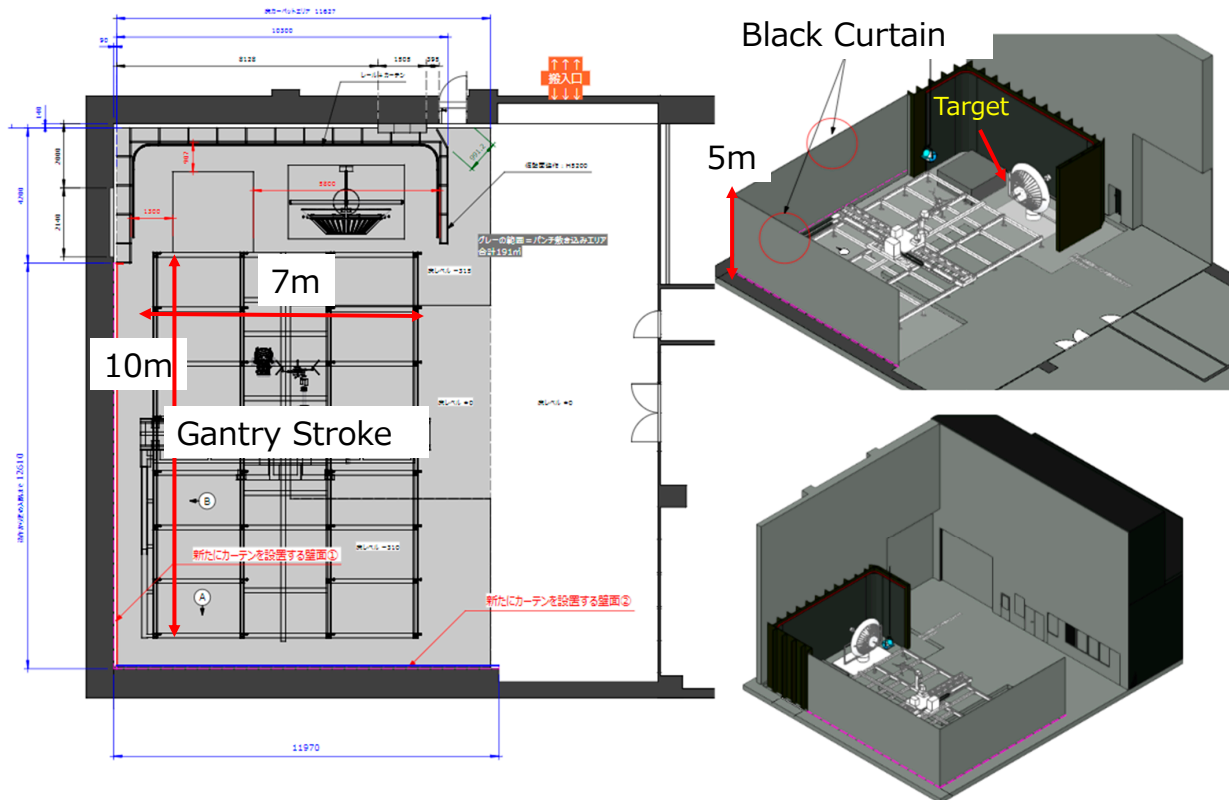 - Satellite debris capture, Docking, etc.

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SATDyn design

Specifications:

- 2D gantry rails for fly around operation simulation
  - 3 m/s over velocity capability
- 6DOF chaser dynamics simulation
  - 40 kg DUT capability
  - 130 kg DUT without contact dynamics simulation
  - AC 100V supply for DUT
  - Wired LAN interface
- 6DOF target dynamics simulation
  - 200 kg Target/DUT capability
- Around 0.5 solar irradiation (50,000 lux) with black curtains
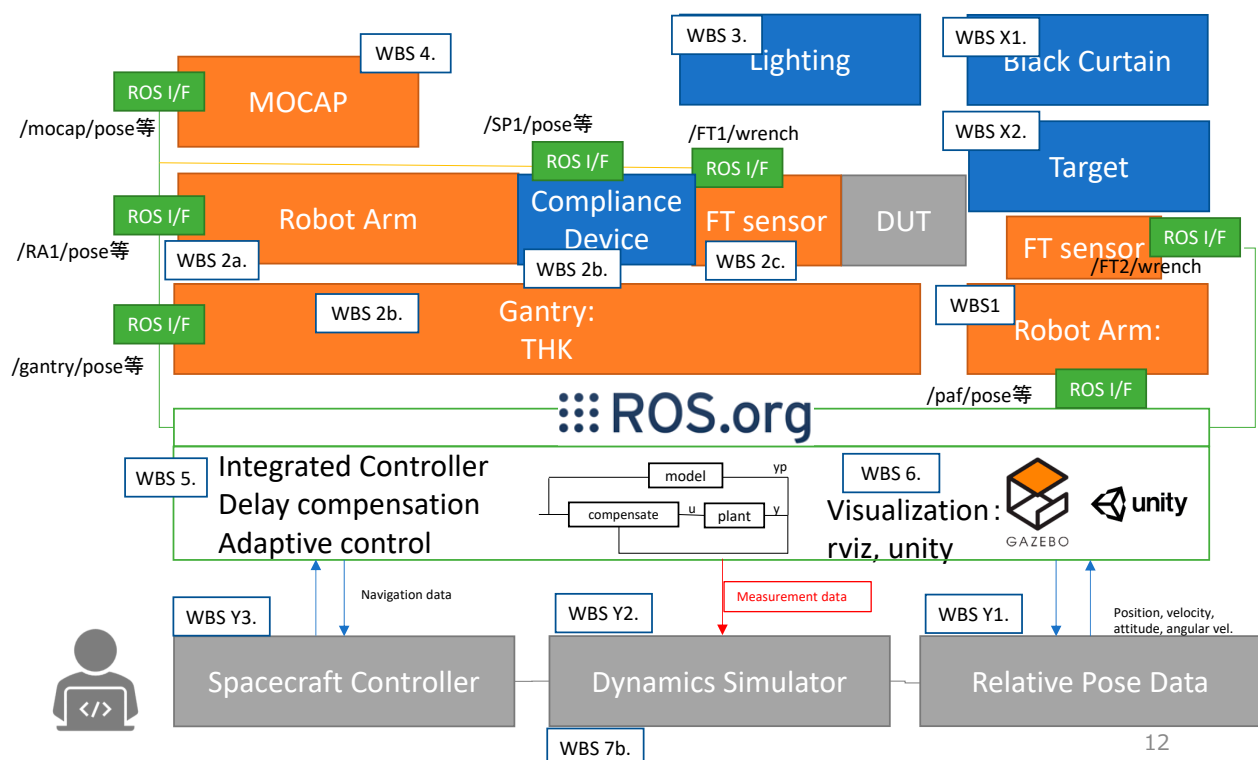- Full area motion capture

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SATDyn Construction

Black Curtain

Target

5m

7m

10m

Gantry Stroke

SATDyn Software Architecture

WBS 4.
ROS I/F   MOCAP
/mocap/pose等

WBS 3.   Lighting

WBS X1.   Black Curtain

/SP1/pose等

/FT1/wrench

ROS I/F
/RA1/pose等   Robot Arm
WBS 2a.

ROS I/F
Compliance
Device
WBS 2b.

ROS I/F
FT sensor
WBS 2c.

DUT

WBS X2.   Target

FT sensor   ROS I/F
/FT2/wrench

ROS I/F
/gantry/pose等   WBS 2b.   Gantry:
THK

WBS1   Robot Arm:

/paf/pose等   ROS I/F

ROS.org

WBS 5.   Integrated Controller
Delay compensation
Adaptive control

model   yp
compensate   u   plant   v

WBS 6.   Visualization:
rviz, unity
GAZEBO   unity

Navigation data

Measurement data

Position, velocity,
attitude, angular vel.

WBS Y3.   Spacecraft Controller

WBS Y2.   Dynamics Simulator

WBS Y1.   Relative Pose Data

WBS 7b.

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Current Status

- 2D Gantry, 6DOF chaser arm and 3DOF target gimbal are ready.
  - Fast acting 6DOF platform will be installed this March.
  - 6DOF robotic arm for the Target will be installed this March.
- Mocap, FT sensors, Xe lump and Black curtains are ready.
- SATDyn is still in development but can be used.
  - JAXA sensor test has been conducted.
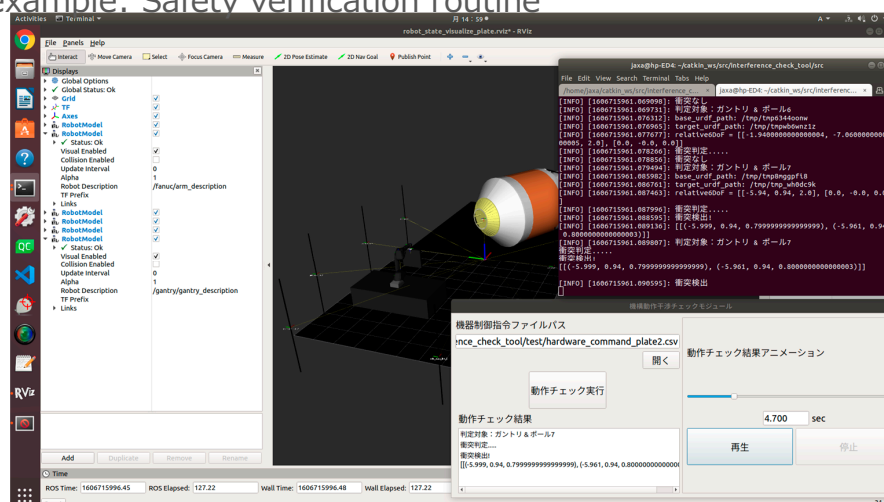 - CRD2 phase I sensor test has been conducted.

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User Interface

- System utilizes Robotic Operation System (ROS)
- Preparing CSV file interfaces for DOLT
- Another dedicated interface is TCP/IP which is similar to the Optical simulator in Chofu
- UDP interfaces may be installed for DOCT
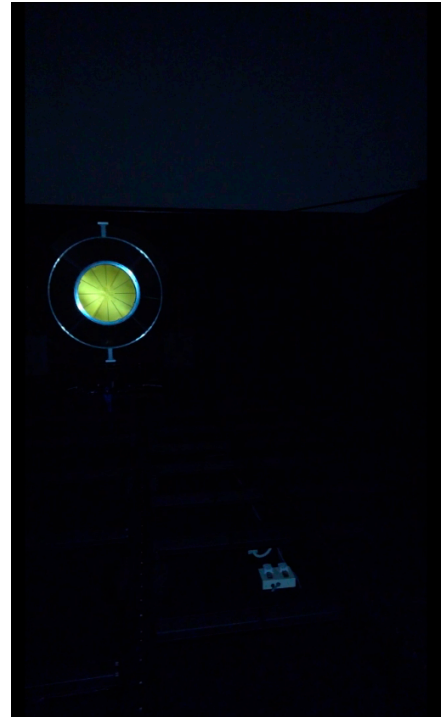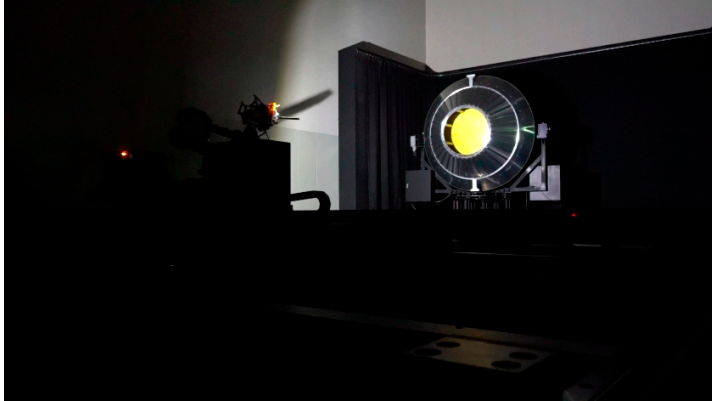
GUI example: Safety verification routine

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Demo

- Demonstration movies
- From ground
- From chaser

Demo

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Demo

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Summary

- Hybrid simulator "SATDyn" is in development now
- HKK, capturing mechanics, will be subjected into the verification with SATDyn in this year
- The facility is open as a shared facility of JAXA
  - **User feedback is important for the SATDyn development**