Intra-Vehicular

Free-Flying Robots:

A Review

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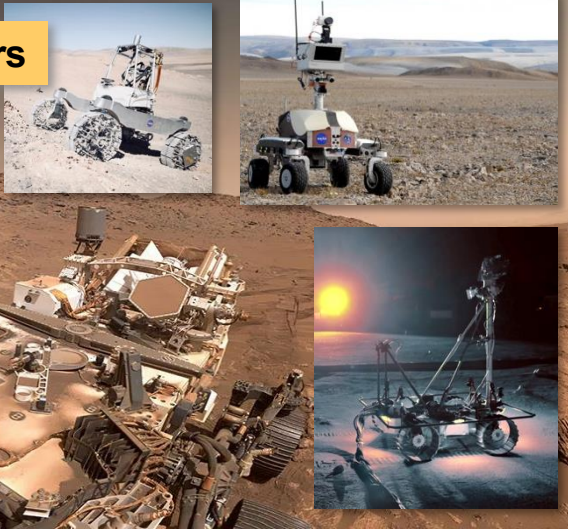
NASA Ames Research Center

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Types of Space Robots

Planetary Rovers

Reconfigurable Robots
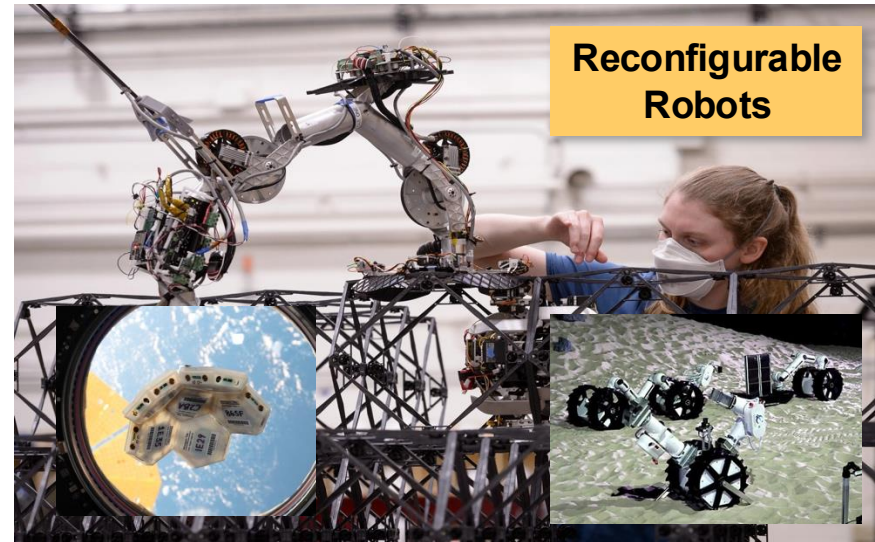
Humanoids

Arms and Manipulators

Image Credits: NASA

Intelligent Robotics Group
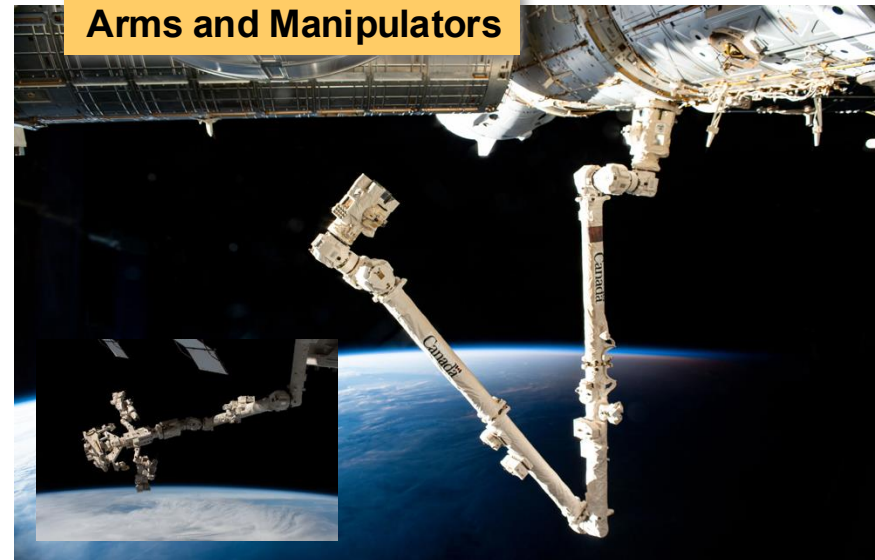
Image Credit: ESA

Free-Flying Robots

Intra-Vehicular

Extra-Vehicular

Inside ISS

In Space

Image Credits: Space News

Image Credits: NASA

Free-Flyer Overview

Review Goal

- Capabilities during development
- Intended concept of operations,
- Contribution to the state-of-the-art for intra-vehicular free-flying robots
- Outline the current free-flying capabilities to map gaps from lessons-learned

| IV Free-Flyer	Affiliation	Year Flown to ISS	State-Of-The-Art
SPHERES	MIT/NASA	2006	First, satellite formation
Int-Ball	JAXA	2017	Vision capabilities
Int-Ball2	JAXA	2023	Increased autonomy
CIMON	Airbus/DLR	2018	Artificial Intelligence
CIMON-2	Airbus/DLR	2019	Autonomous navigation
Astrobee	NASA	2019	Hardware payloads
Xiao Hang	CMSA	2025	TBD

Summary Table of all IV free-flyers

SPHERES

SPHERES Overview

- Synchronized Position, Hold, Engage, Reorient, Experimental Satellites (SPHERES)
- Developed by MIT Space Systems Lab (SSL)
- Funded by DARPA, NASA, Aurora Flight Sciences
- Flown to ISS in 2006 (meant to in 2003)
- Test novel satellite constellation formation
    - *Flight*
    - *Docking*
    - *Rendezvous*
- ConOps: Low-cost long term ISS testbed for microgravity GNC algorithms
- SPHERES guest science program (GSP)
- MIT Zero Robotics (ZR) Competition
- Relied on CO_2 tanks to "free-fly"

Image Credits: MIT/NASA
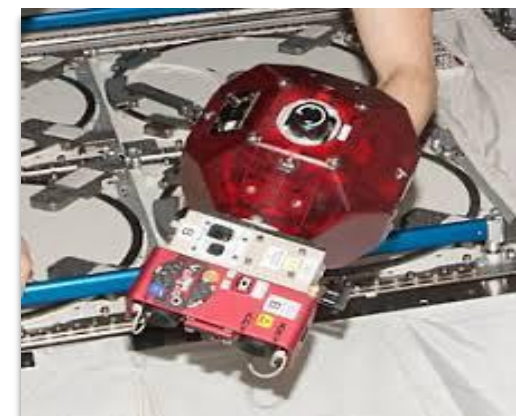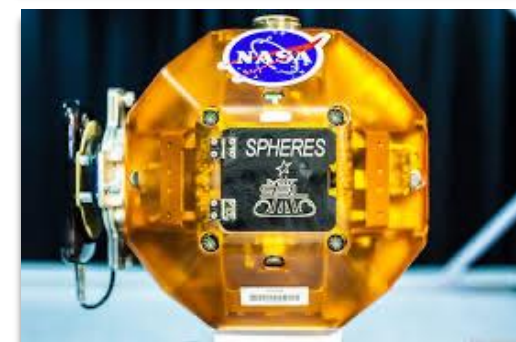
Int-Ball/Int-Ball2

Int-Ball Series Overview

- Internal Ball Camera (Int-Ball)
- Developed and funded by JAXA
- Int-Ball flown to ISS in 2017
- Int-Ball2 flown in 2023
  - Increased autonomy for navigation
  - Increased perception
- Complementary metal-oxide-semiconductor (CMOS) digital camera module onboard
- High performance embedded CPU onboard
- ConOps: Reduce crew-time in routine photography and videography in the Japanese Exploration Module (JEM)
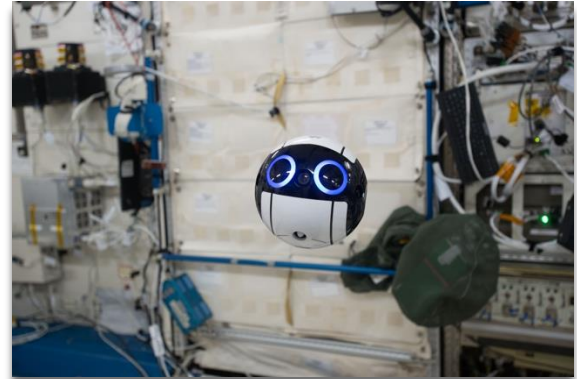- Fans to fly

Image Credits: JAXA

Image Credits: Space News

CIMON/CIMON-2

CIMON Series Overview

- Crew Interactive MObile companioN (CIMON)
- Developed and funded by Airbus and DLR
- CIMON flown to ISS in 2018
- CIMON-2 flown in 2019
  - Increased autonomous navigation
  - Increased battery life
- Voice-enabled free-flyer with AI
  - Face recognition
  - Natural Language Processing (NLP)
- Human robot interaction
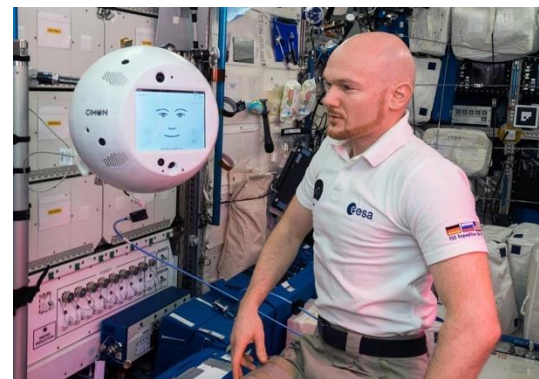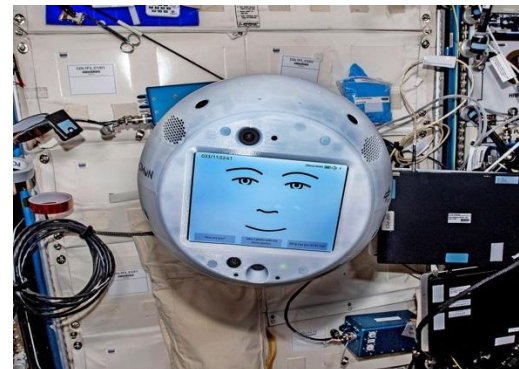- ConOps: Conversational interaction with crew
- Fans to fly

Image Credits: DLR/Airbus
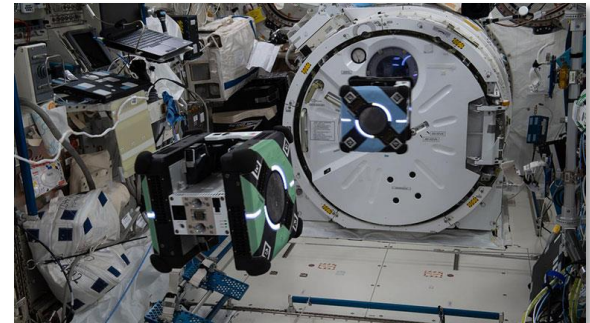
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CIMON/CIMON-2 activities on the ISS

Astrobee

Astrobee Overview

- Succeeded the SPHERES
- Developed and funded by NASA (GCD)
- Flown to ISS in 2019
- Hardware interface to have payload
- ConOps: Assisting crew and reducing crew time through manipulation, perception, and guest science
- Astrobee GSP
  - Manipulation (gecko, CLING-ERS, etc.)
  - Perception (ISAAC)
  - Computing (MRS)
- MIT Zero Robotics (ZR) Competition continued
- Centripetal acceleration fans to fly

Astrobee activities on the ISS

Xiao Hang

Xiao Hang Overview

- Developed and funded by CMSD
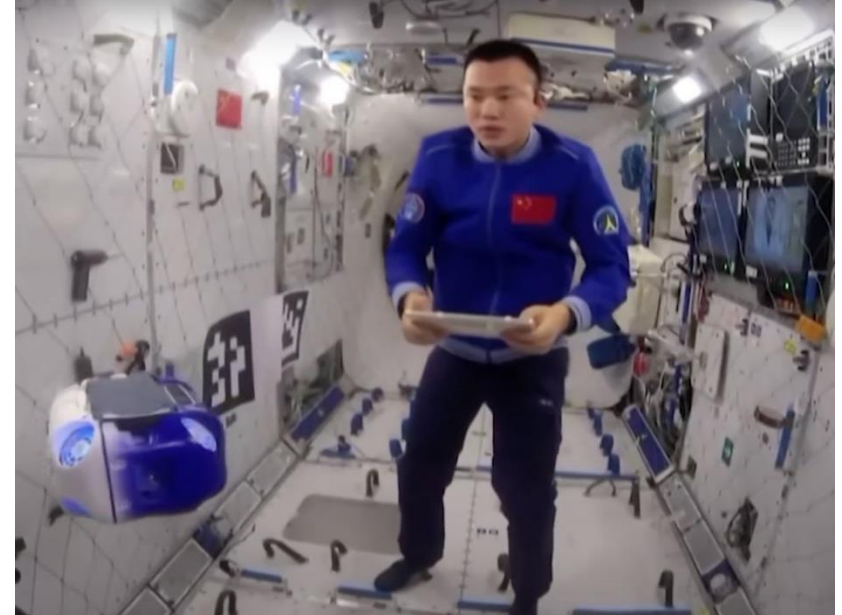- Flown to ISS in 2025 (January)
- Not much known
- Teleoperated

Image Credits: Space News

Thank you! ☺

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