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CSA Activities in On-orbit Robotic Servicing (ORS)

**NASA GSFC Int. Workshop
on On-Orbit Satellite Servicing
March 24-26, 2010**

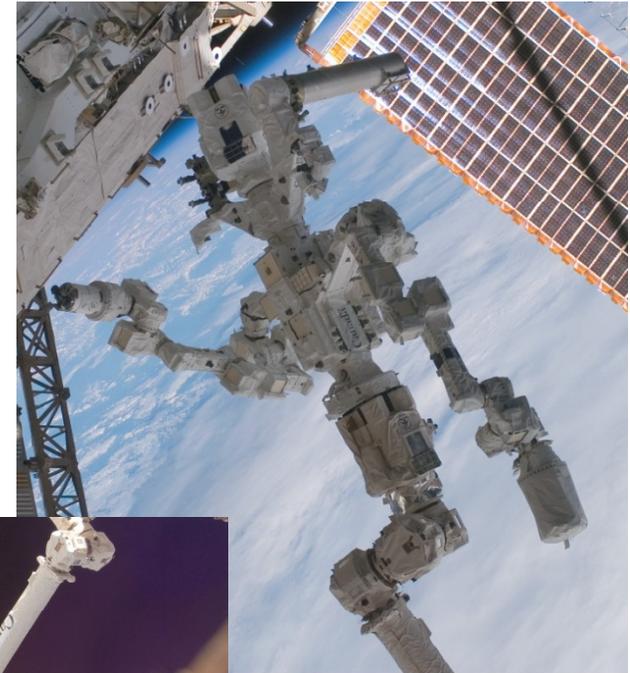
CSA welcomes this opportunity to better understand future needs, potential missions, and potential collaborations.



Canadian Space Agency
Agence spatiale
canadienne

Canada

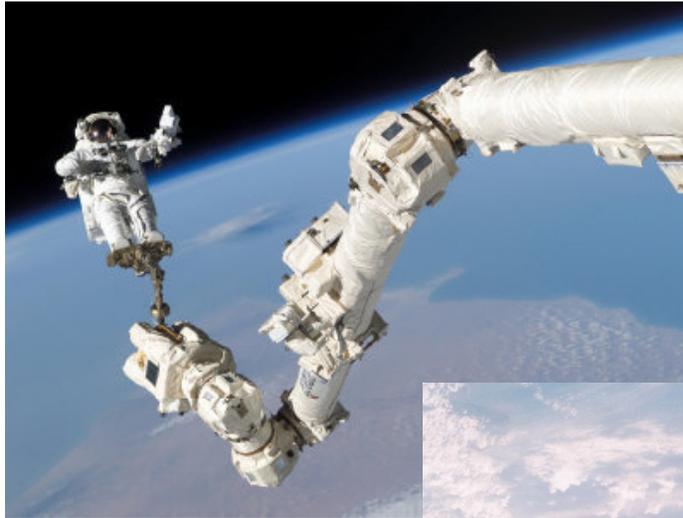
On-orbit Heritage – Operational Systems



CSA has delivered 3 state-of-the-art robotic systems for operational use in LEO: the Shuttle Canadarm, the ISS Canadarm2 and the ISS Dextre.



Mobile Servicing System - Capabilities



Completed in 2008 the MSS now has the following capabilities:

- Assembly
- Inspection
- Payload handling
- Capture and Berthing
- Cooperative Servicing:
 - EVA Support
- Robotic Servicing:
 - Change-out of On-orbit Replaceable Units (ORUs)

The MSS is also self-serviceable on-orbit, with 6 types of robotically friendly ORUs.



ORS Heritage – Ops Tools & Methods



CSA expertise includes: Mission Planning, Simulation, Training, Task Verification, Operations, and Ground Control.



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Manipulator Performance Evolution



	Canadarm (SRMS)	Canadarm2 (SSRMS)	Dextre (SPDM)
arm length	15.2 m	16.9 m	3.35 m
arm DOF	6	7	7 (each)
body DOF	n/a	n/a	1
height	n/a	n/a	3.67 m
width	n/a	n/a	2.67 m
payload	29,000 kg	116,000 kg	600 kg
accuracy	± 5.0 cm n/a	± 4.5 cm ± 30 N	± 6 mm ± 2.2 N
incremental motion accuracy	n/a	n/a	± 2 mm

Canadarm2 and Dextre both have a sense of touch and are capable of automatic accommodation of forces and moments during contact tasks.



Scorecard w.r.t 1980s dream

In addition to **ISS and MSS maintenance tasks**, **Dextre and MSS** were also envisioned to be used for:

-  providing lighting and CCTV monitoring,
-  providing power to a payload or ORU,
-  attaching and removing interfaces,
-  inspection,
-  servicing of attached scientific payloads,
-  mating/demating connections,
-  removing and installing thermal covers, and
-  cleaning surfaces

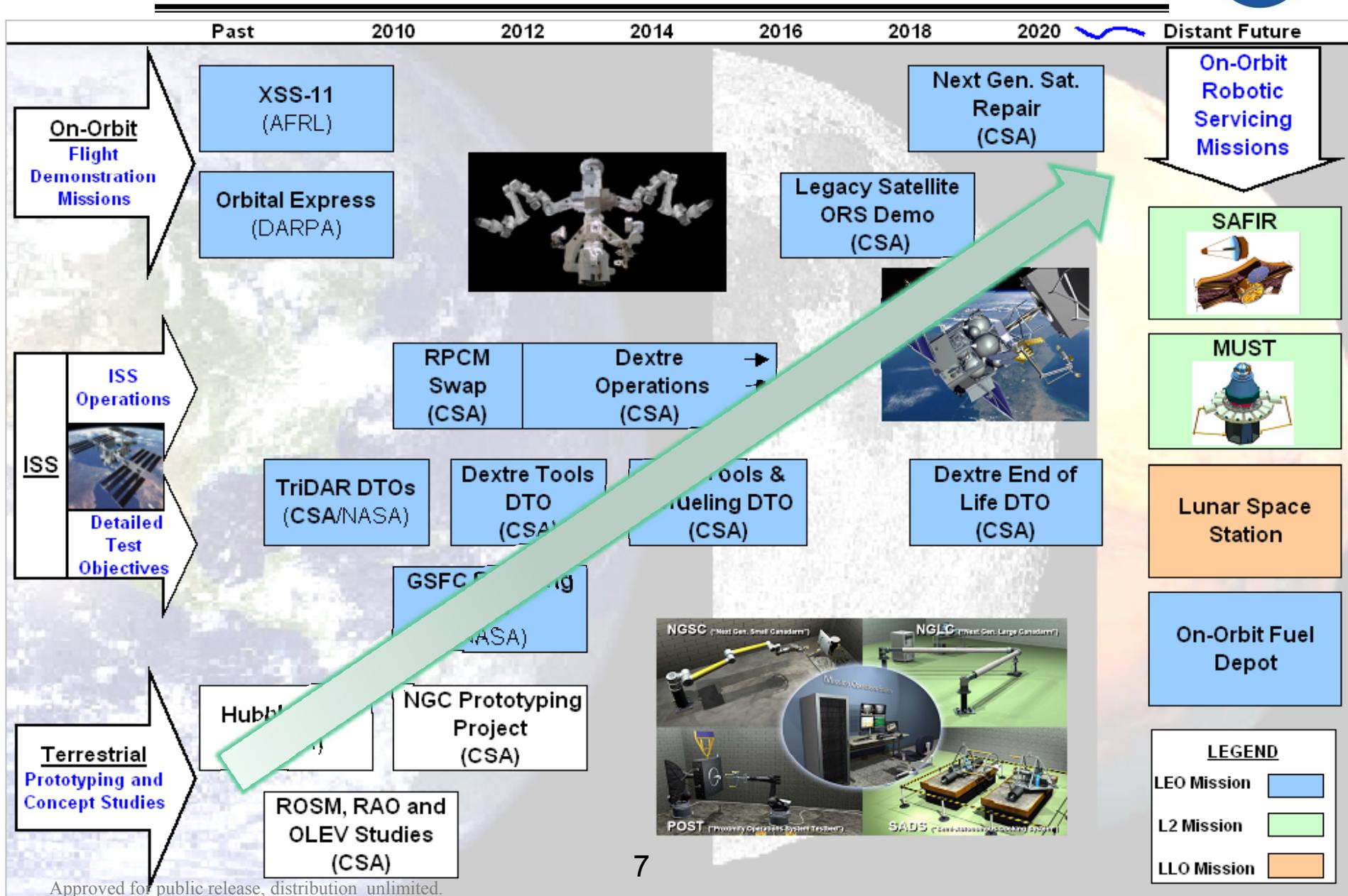
-  ground control
-  free flyer capture

Yes
Partially – currently no ISS need
Not yet – tool required
Not possible
New developments!

Canada's Roving Space Robot
The Mobile Servicing System for Space Station

Government of Canada / Gouvernement du Canada

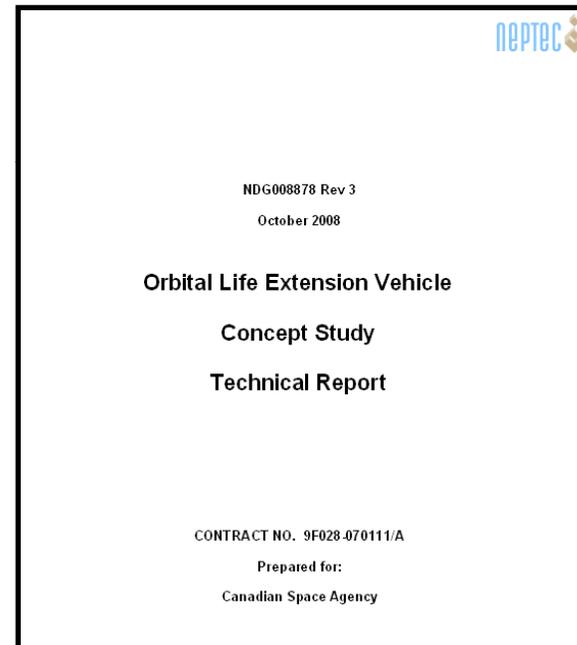
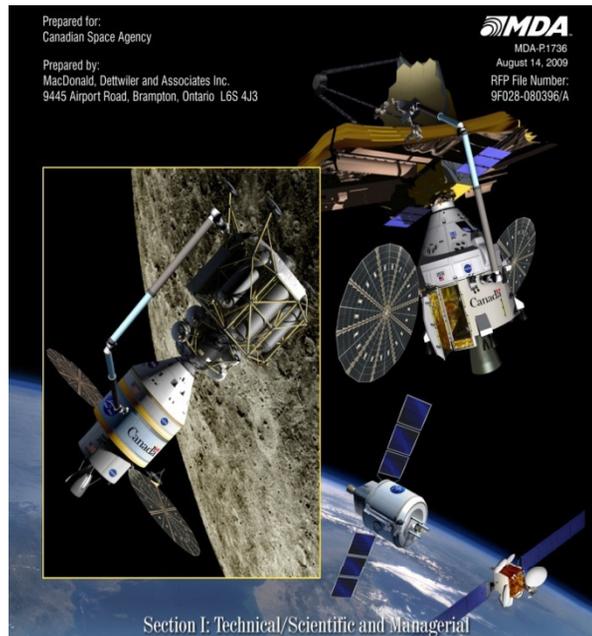
CSA ORS Summary Roadmap



Preparing for future On-Orbit Servicing



- Robotics and Automation for Orion (RAO) Concept Study
- Robotic On-Orbit Servicing Module (ROSM) Phase 0 Study
- Orbital Life Extension Vehicle Concept Study



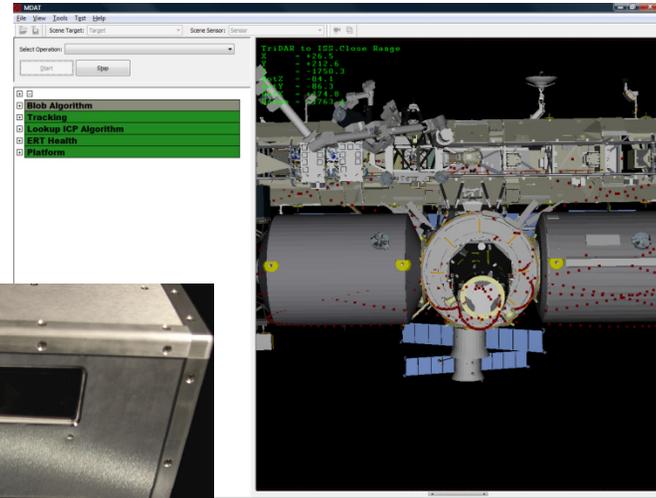
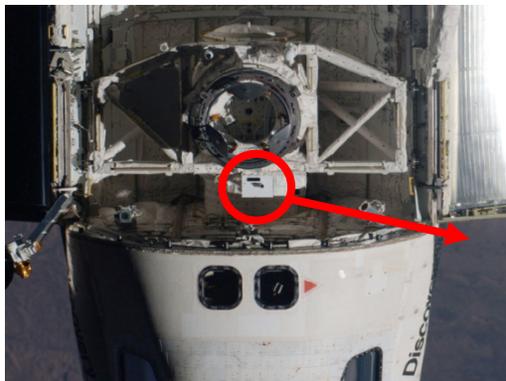
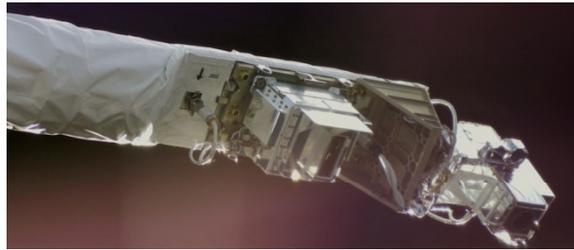
On-Orbit Robotic Servicing is an enabling technology that can benefit from further TRL advancements and cost reductions.



TriDAR DTO



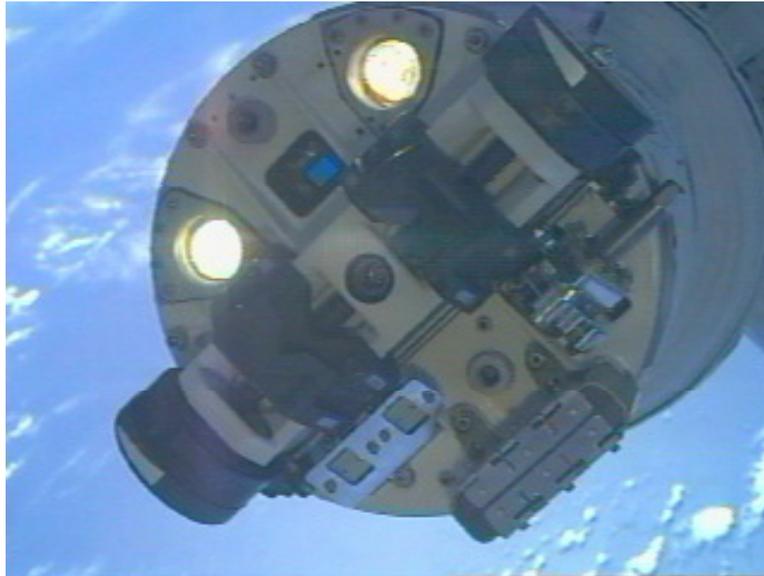
Building on the success of Neptec's Space Vision System (SVS) for Shuttle and Laser Camera System (LCS) for the inspection boom, TriDAR was successfully demonstrated during STS-128 and will be demonstrated again during STS-131 and potentially STS-133.



TriDAR can be used to guide rendez-vous and docking operations which are essential to future OOS missions



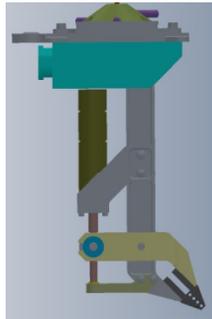
Dextre – Human scale ORS capability demonstration on-orbit



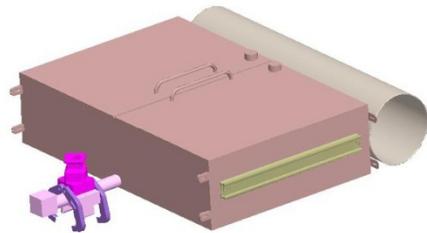
As Dextre executes its operational mission, each new task performed will yield a gain in knowledge w.r.t. On-orbit Robotic Servicing.



Potential Dextre Tool DTOs



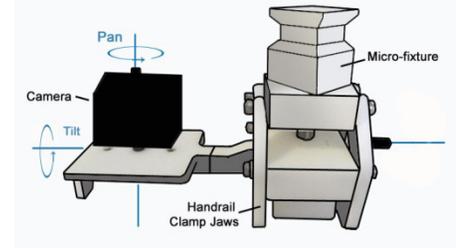
**Blanket
Cutter/Pincer Tool**



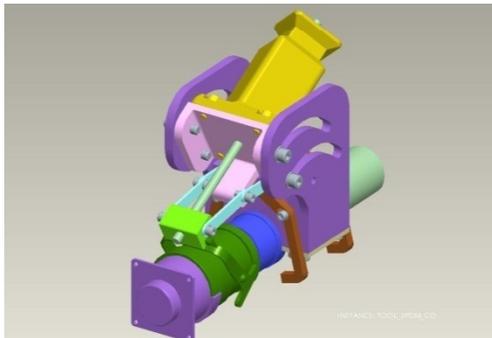
**Multipurpose On-
Orbit Stowage for
EVA (MOOSE)**



**Handrail
Clamp**



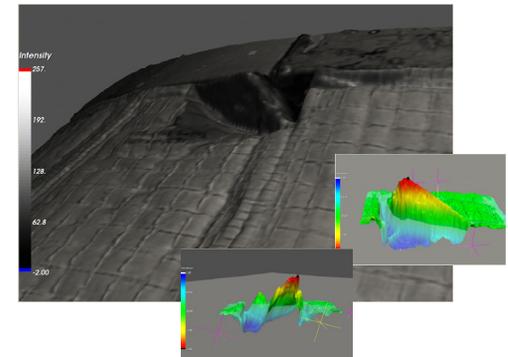
**Wireless
Camera**



**Generic EVA
Connector
Handling Tool**



**SPDM Under-Actuated
Versatile End Effector (SUVEE)**



**Laser
Camera**

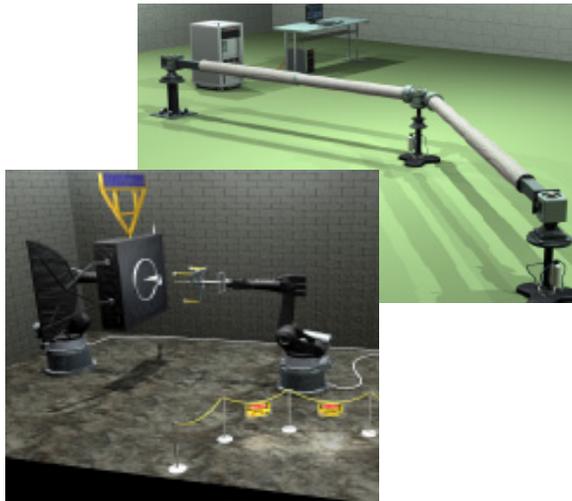


Next Generation Canadarm



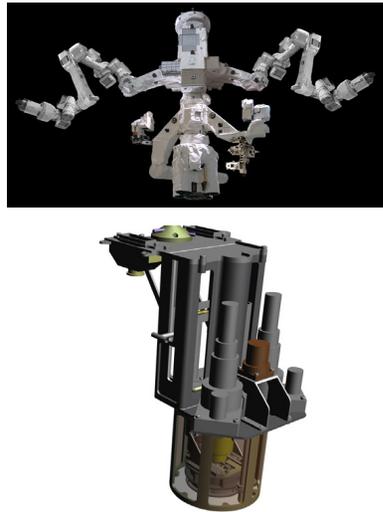
NGC Prototyping Project

2009 - 2012



NGC Tools DTOs using Dextre

2013



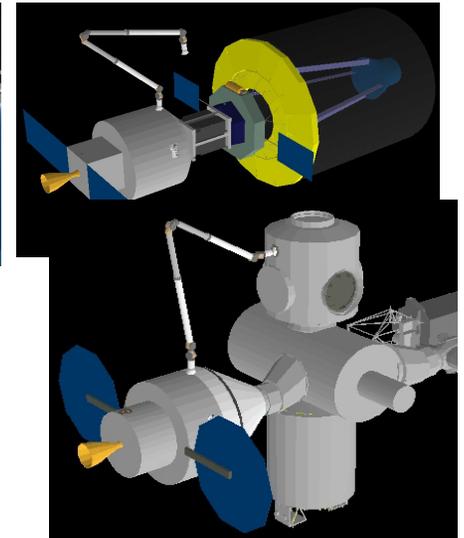
NGC On-Orbit Tech Demo

2018



NGC Operational OOS Missions

2020 →



Specific Tools and Technologies



Refueling Tools

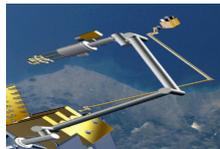


Next Generation Large Canadarm

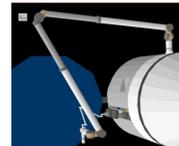
Next Gen. EVR To Client Standards



Next Generation Small Canadarm



Docking Tools



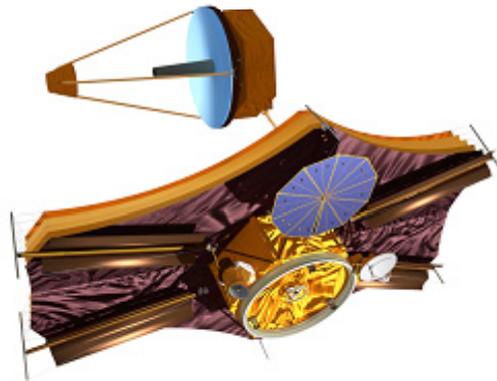
Next Gen. ORU To Client Standards

Next Gen. Ground Segment

Servicing of Future Scientific Satellites



2015
(JWST)



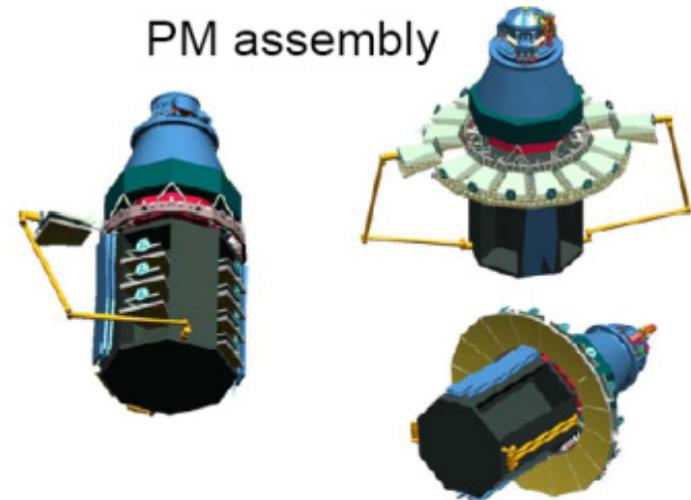
2020
SAFIR

2025
MUST

2030
AT-LAST

2035
TPF

PM assembly



Where Does Canada Fit In?



Laser Camera Systems

Next Gen. Canadarm

Serviceable Sub-Systems



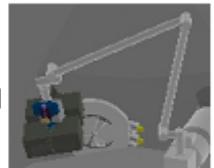
Refueling Tools



Docking Tools



Next Gen. ORU Tools

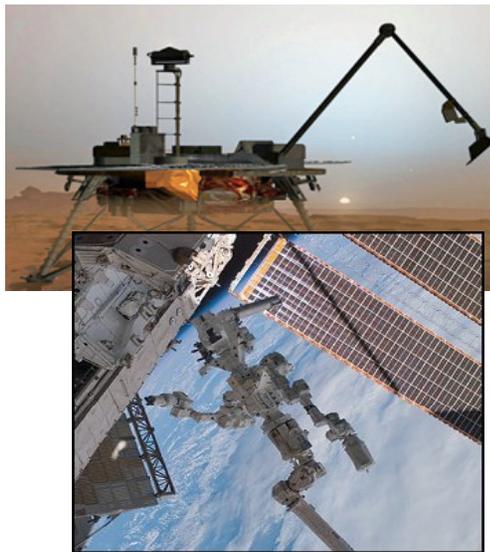


OOS and Exploration Spin-offs



ISS - Dextre, SSRMS

Phoenix Lander



Marco Polo

2018

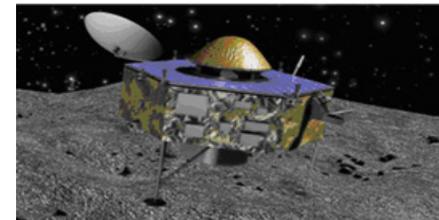


ExoMars

Mars Sample Return

Lunar Space Station

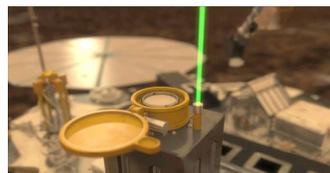
2025



Where Does Canada Fit In?



Dexterous Manipulators



Coring Tools



Vision/ Sensing Systems



Large Manipulators



Next Generation Canadarm
R&D Project
VIDEO (Draft)



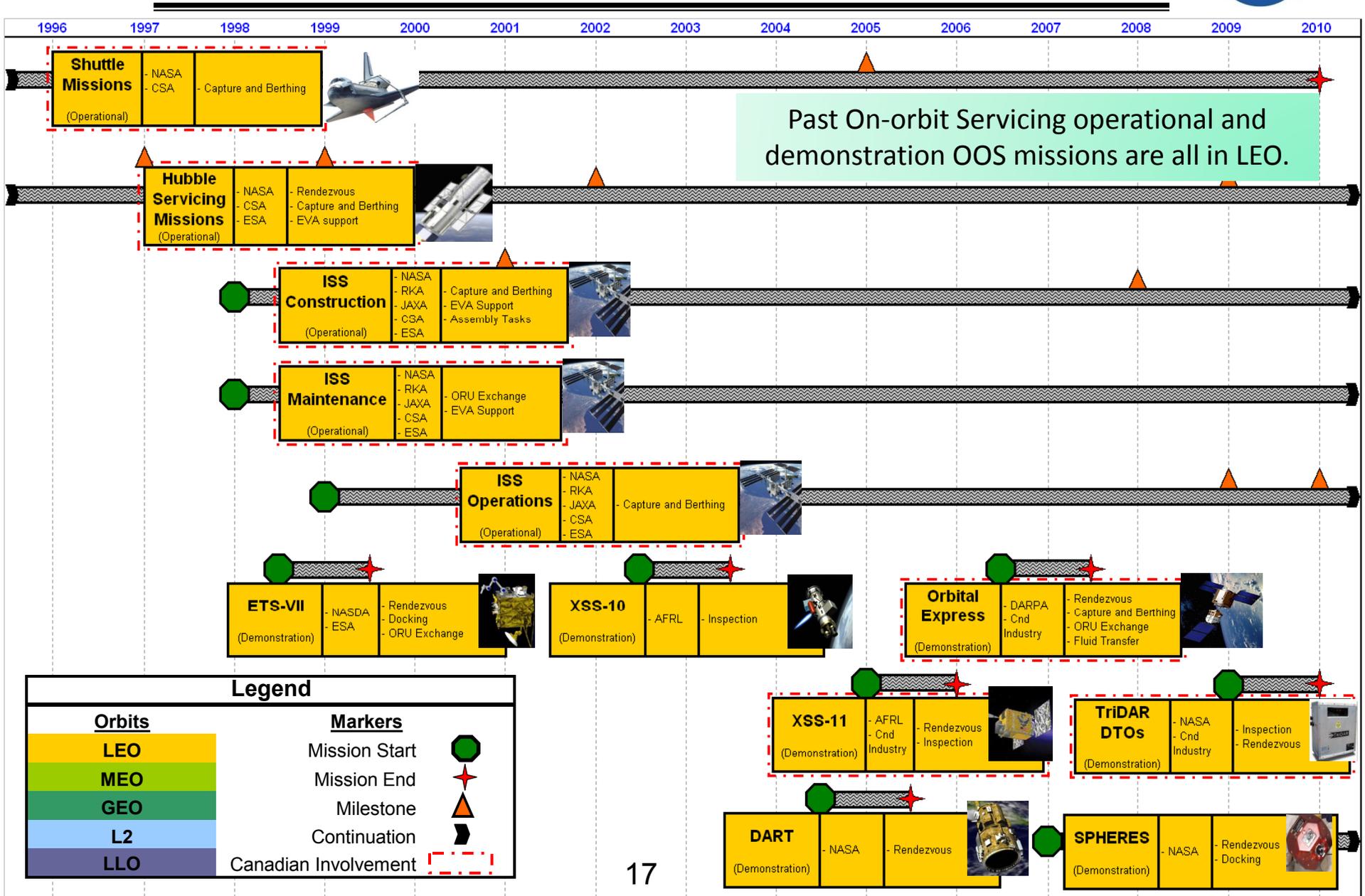
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BACK-UP SLIDES



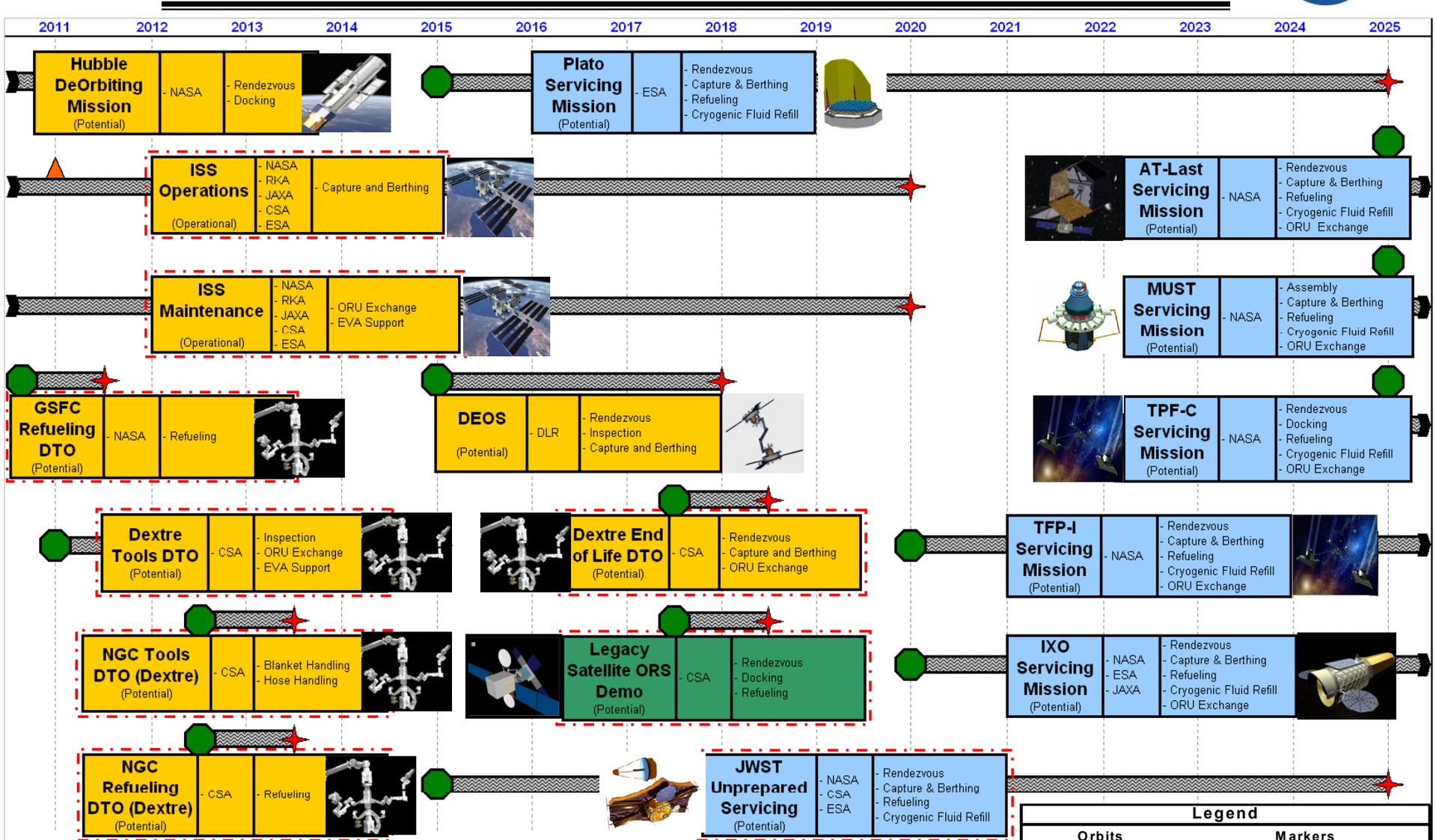
Past OOS Flight Missions



Legend	
Orbits	Markers
LEO	Mission Start
MEO	Mission End
GEO	Milestone
L2	Continuation
LLO	Canadian Involvement



Near-Future Flight Missions

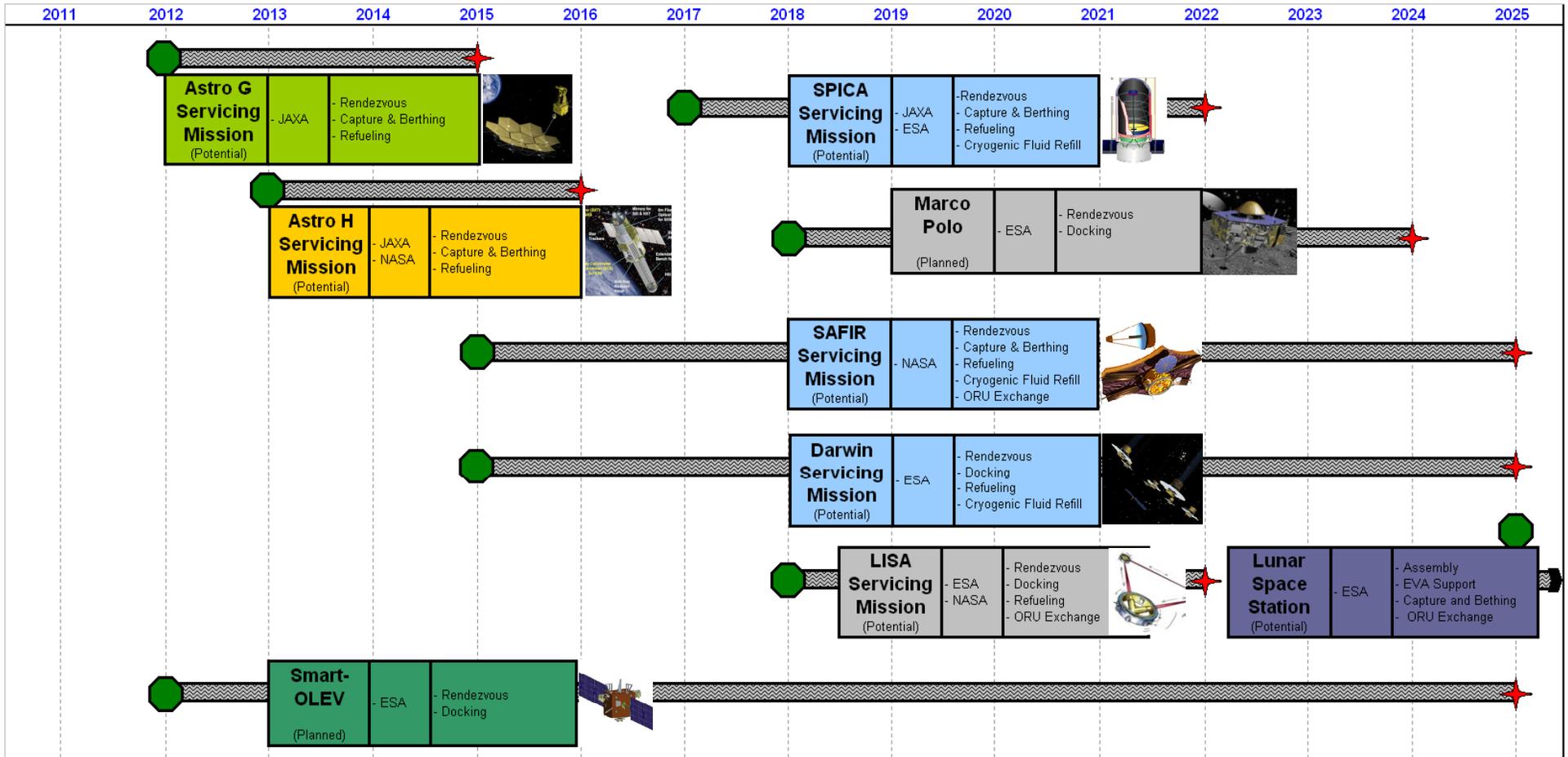


In the future, after ISS demos, we see a need for OOS at GEO and Lagrange point missions.

Legend	
Orbits	Markers
LEO	Mission Start
MEO	Mission End
GEO	Milestone
L2	Continuation
LLO	Canadian Involvement



Near-Future Flight Missions cont.

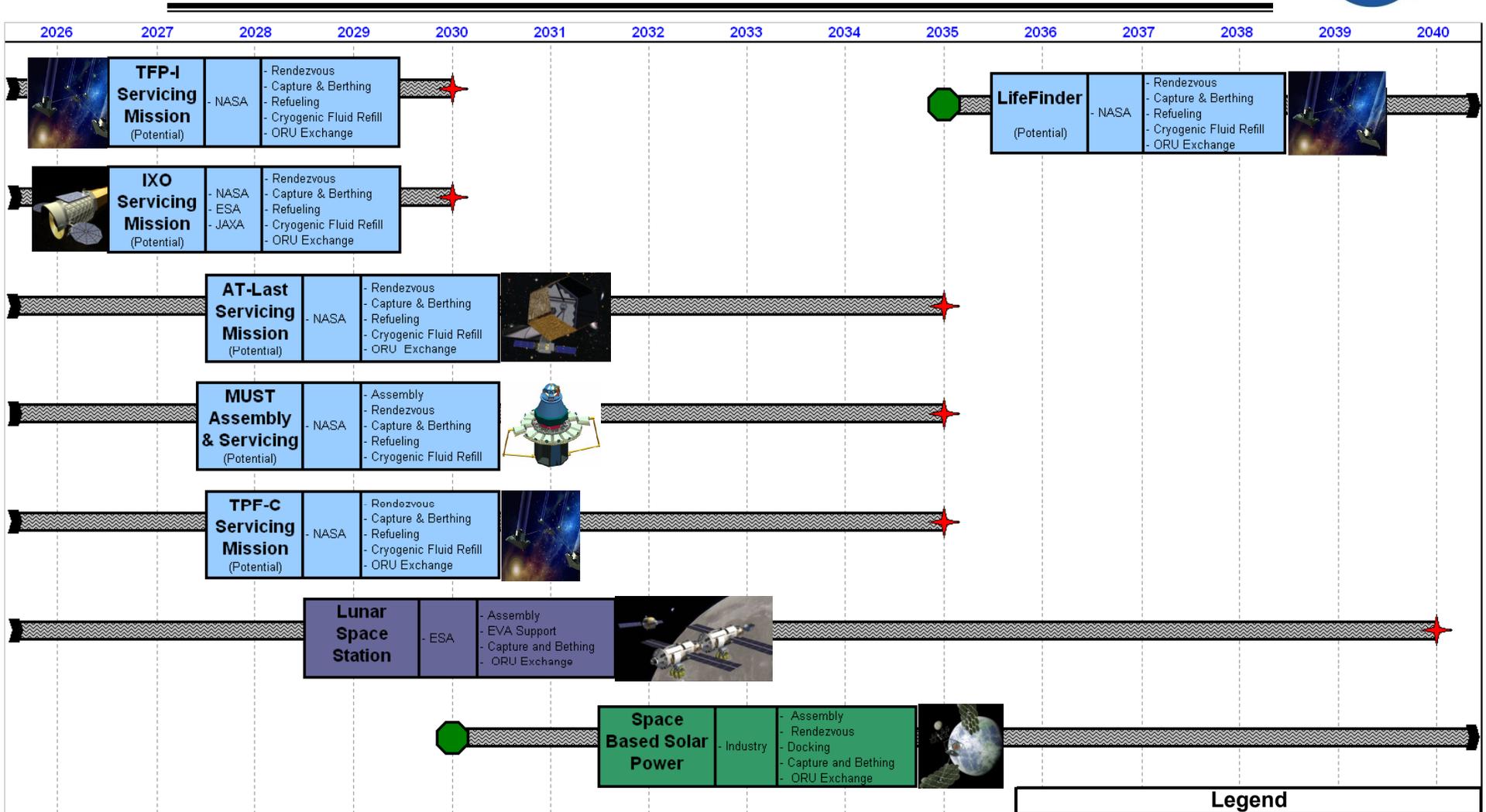


... with an eventual need for OOS in lunar orbit exploration missions,

Legend	
Orbits	Markers
LEO	Mission Start
MEO	Mission End
GEO	Milestone
L2	Continuation
LLO	Canadian Involvement



Distant-Future Flight Missions



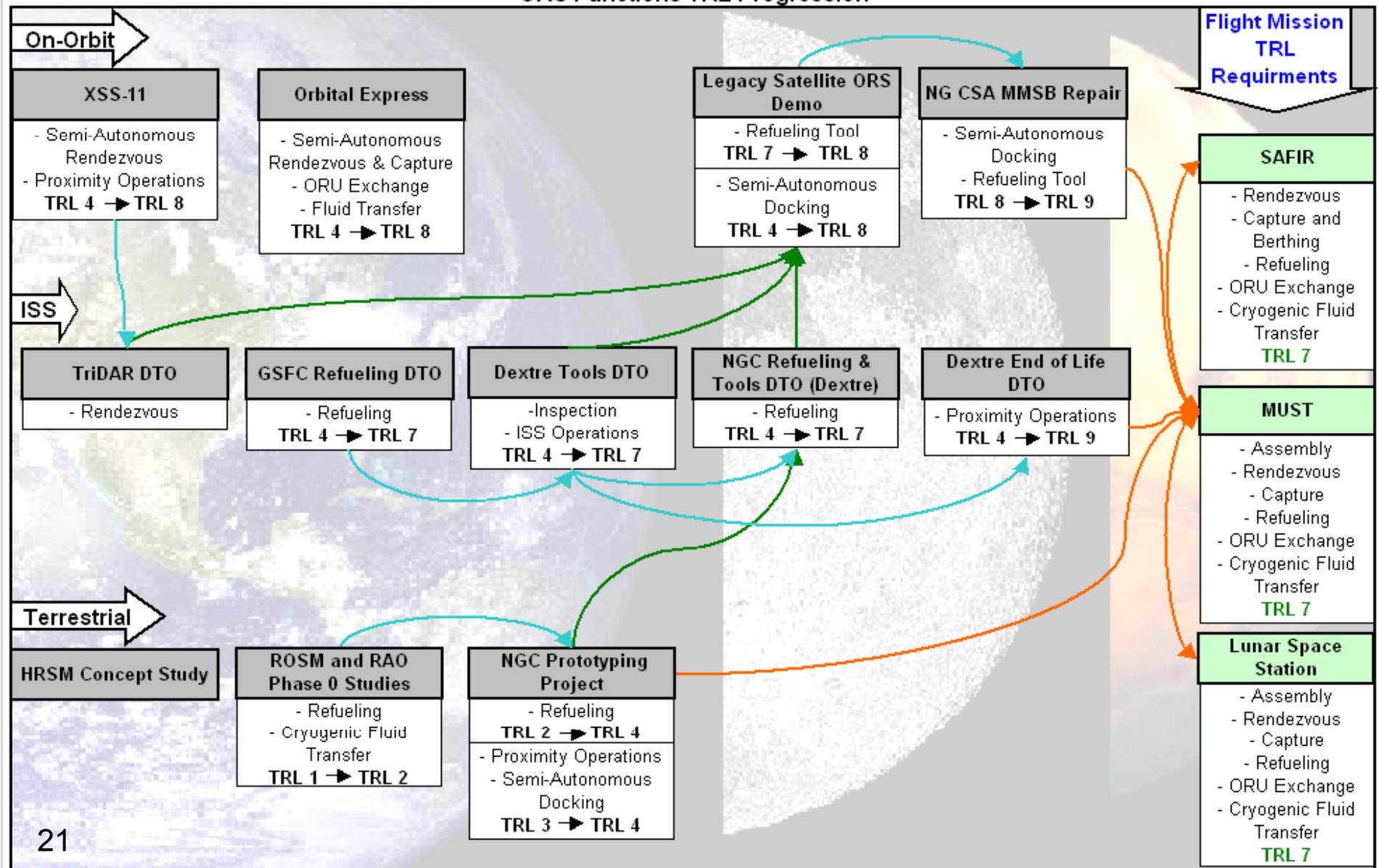
... and a family of potential next generation Observatory class satellite mission clients.

Legend	
Orbits	Markers
LEO	Mission Start
MEO	Mission End
GEO	Milestone
L2	Continuation
LLO	Canadian Involvement



CSA ORS Summary Roadmap

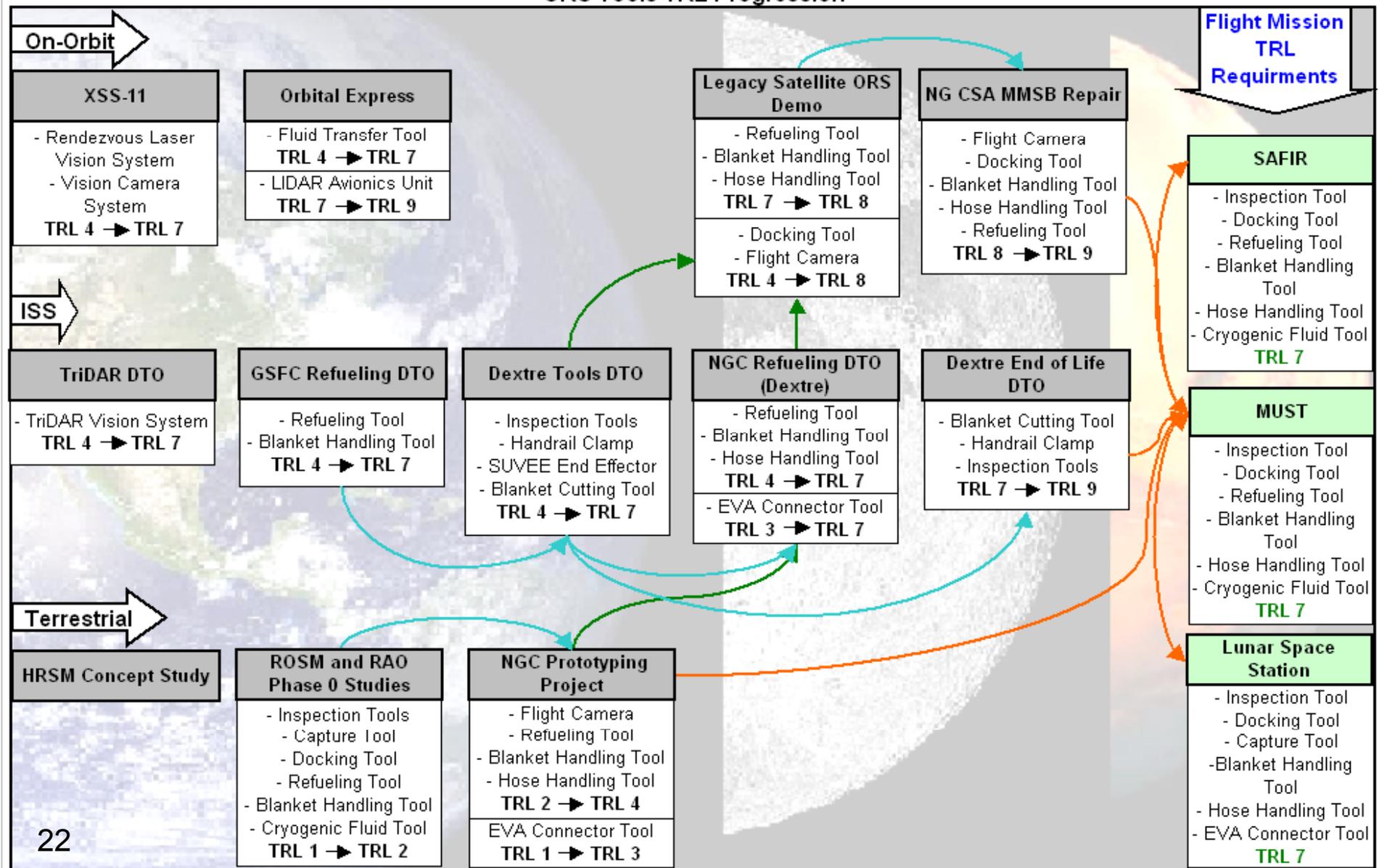
ORS Functions TRL Progression





CSA ORS Summary Roadmap

ORS Tools TRL Progression



Future Outlook



- The Canadian Space Agency looks forward to using our expertise in robotics and OOS to contribute to International Exploration Servicing Missions



- Based on Canadian expertise in various technologies for OOS and exploration, Canada will be in a position to make infrastructure contributions to international missions
- Canadian contributions may include robotic manipulators, vision systems, surface mobility systems, planetary landing systems and in-situ resource extraction

