VERIFICATION AND VALIDATION OF RENDEZVOUS AND CLOSE PROXIMITY OPERATION SAFETY

ESA AO/1-11351/22/NL/AS

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ESA Clean Space Industry Days 2023

STUDY OVERVIEW

/// Verification and validation of rendezvous and CLOSE proximity operation safety

- The goal is to define V&V methodology to verify and validate safety guidelines for CPO, following this approach
  - Input: ESA CPO safety guidelines 2.0
  - 1st step: to review the input and critical analysis of other available guidelines/regulation to identify possible gaps (CONFERS, ISO 24330, French Space Act (LOS), EOF, JAXA Safety Standard for OOS Missions, REX & literature)
  - 2nd step: to identify methods and tools and gaps in the V&V process for each guideline/requirement and discipline
  - 3rd step: is to apply to two use case (non-cooperative LEO, cooperative GEO).

- Consortium:
  - TAS
  - DEIMOS
  - GMV

/// Focus for today: high level safety requirements and their impact on the mission design

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KEY SAFETY REQUIREMENTS

///What does Mission Safety correspond to?

- For uncrewed missions, safety in Close proximity Operations (CPO) translates into avoiding the generation of debris, due to:
  1. Unintentional breakup of the servicer or the client.
  2. Intentional generation of micro-debris during the servicing operations (e.g., caused by the use of some capture method such as harpoons, intentional perforation of S/C surfaces such as MLI to enable refuelling operations, etc …).
  3. Collision of the servicer or the client with third parties.
  4. Unintentional degradation of the client (or the servicer) performance during servicing operations, preventing the client (or the servicer) from continuing its nominal mission after the IOS and precluding the possibility of carrying out End-Of-Life disposal.
  5. Collision of the stack with third parties.
  6. Collision of the servicer with the client.

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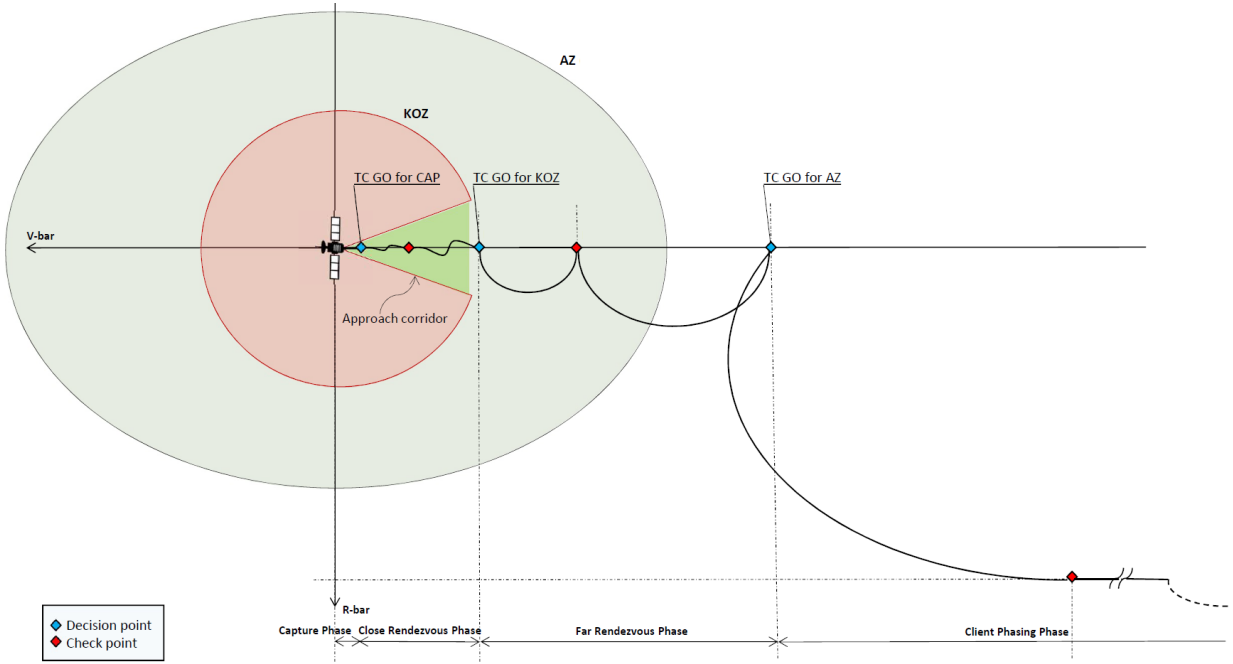
KEY SAFETY REQUIREMENTS

/// Zones and Phases

- Two zones are identified, that can be entered only after positive assessment of a set of conditions (GO/NO-GO)



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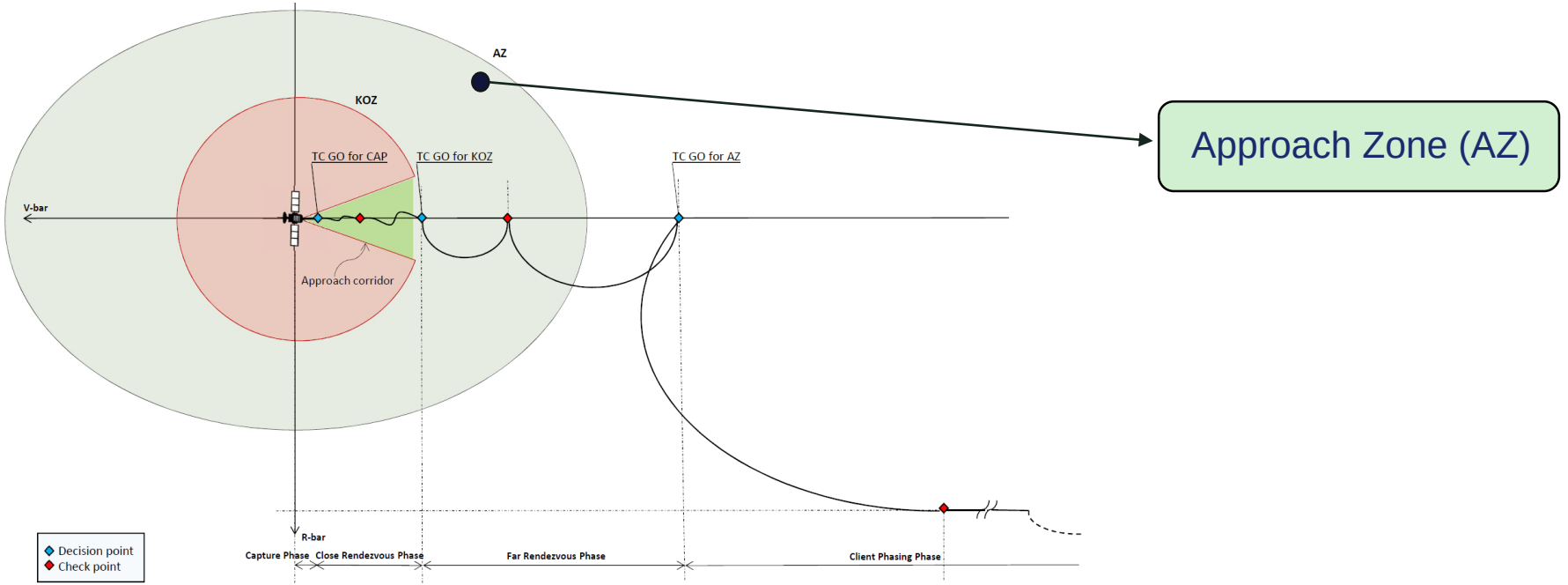

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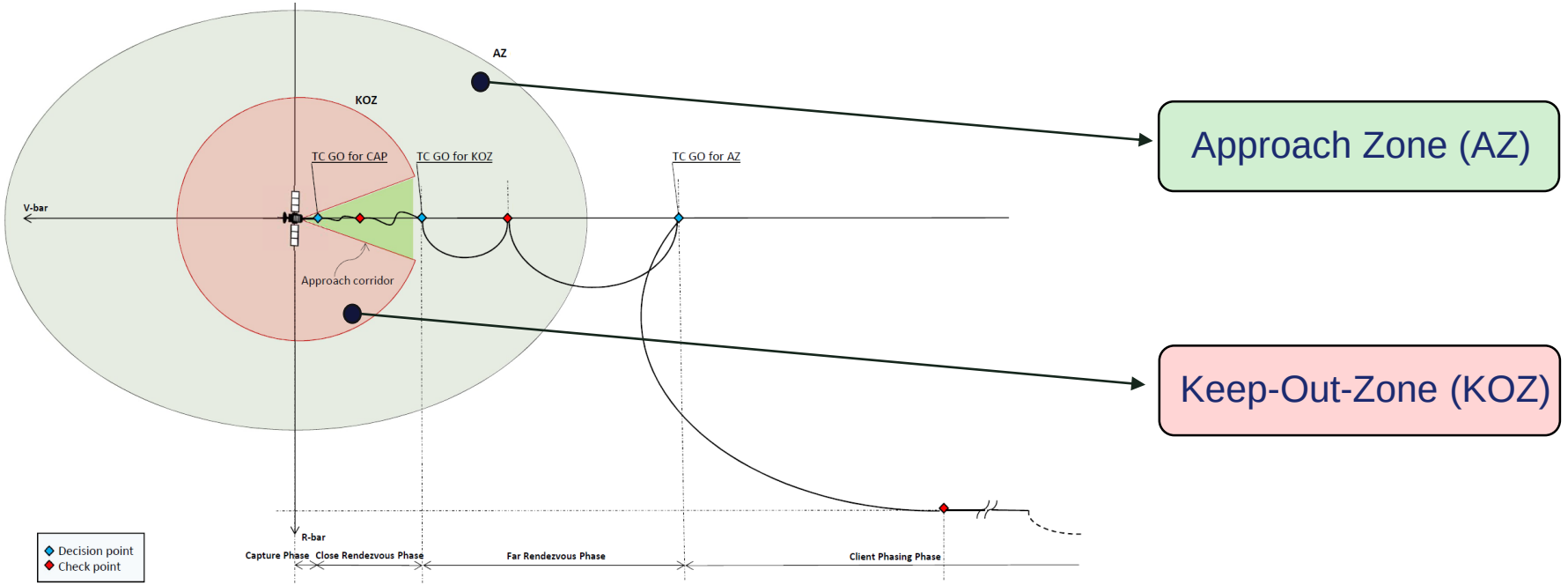

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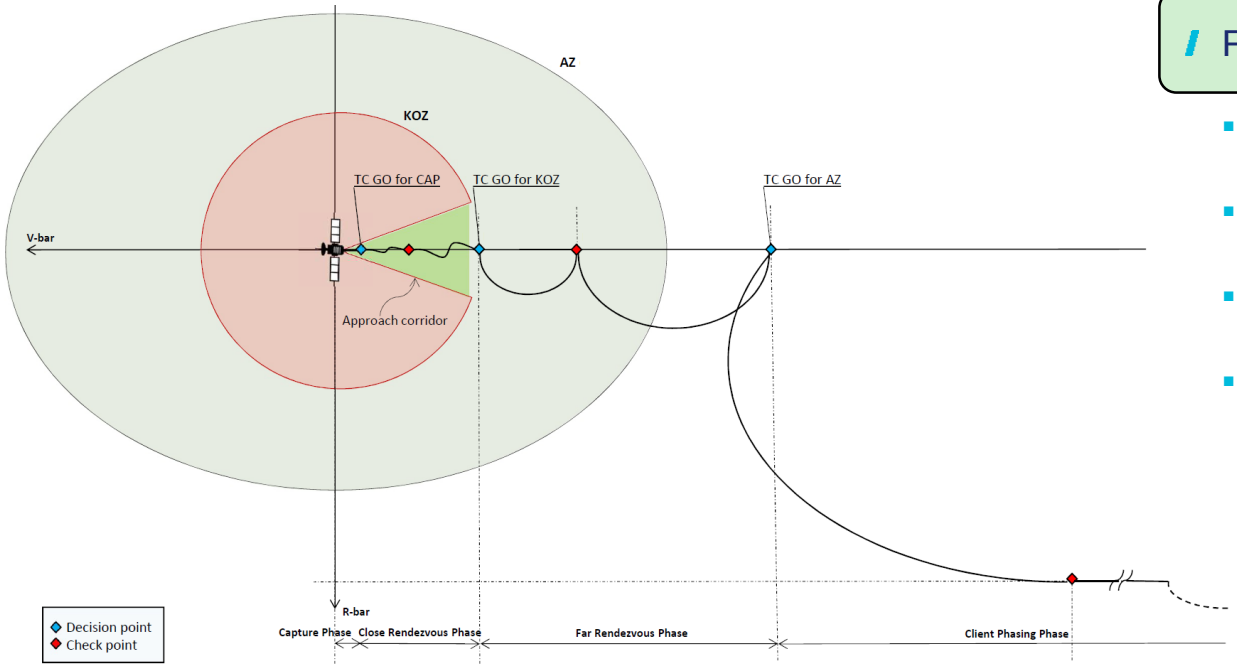

Far Rendezvous Phase:

- Initiated by the GO for Approach Zone
- Any trajectory allowed
- 3-DOF relative estimation
- Autonomous or Ground triggered:
  - Abort (mission safety)
  - Cancel (mission success)

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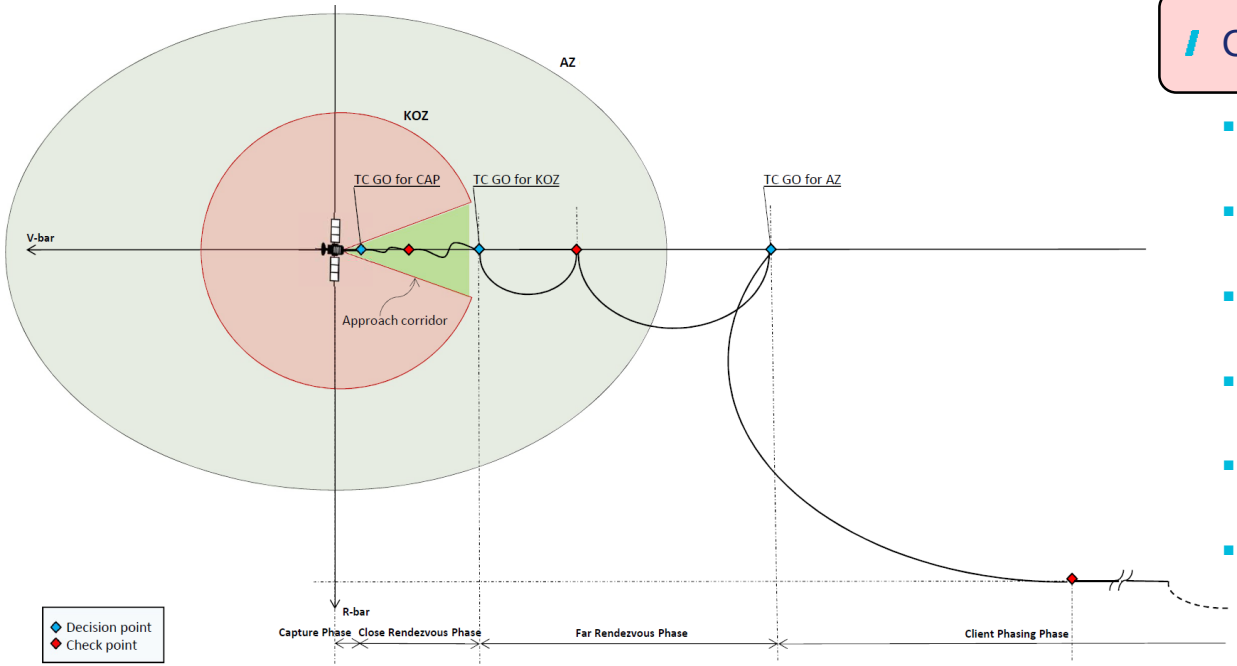

Close Rendezvous Phase:

- Initiated by the GO for Keep-Out-Zone
- Servicer within the Approach Corridor
- Closed loop 6-DOF relative control
- No crossing of clearance envelopes
- Abort Corridor
- Autonomous Abort execution

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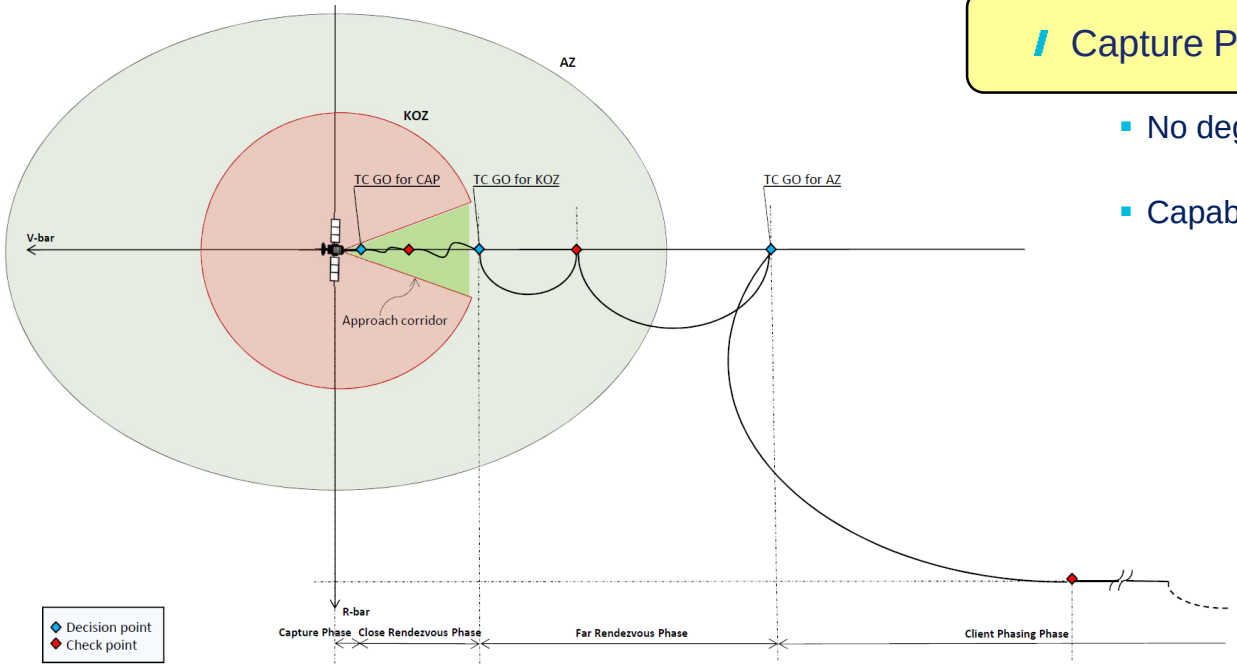

/ Capture Phase, Stack Configuration Phase:

- No degradation of client integrity/performance
- Capability to control the orbit and attitude of the Stack

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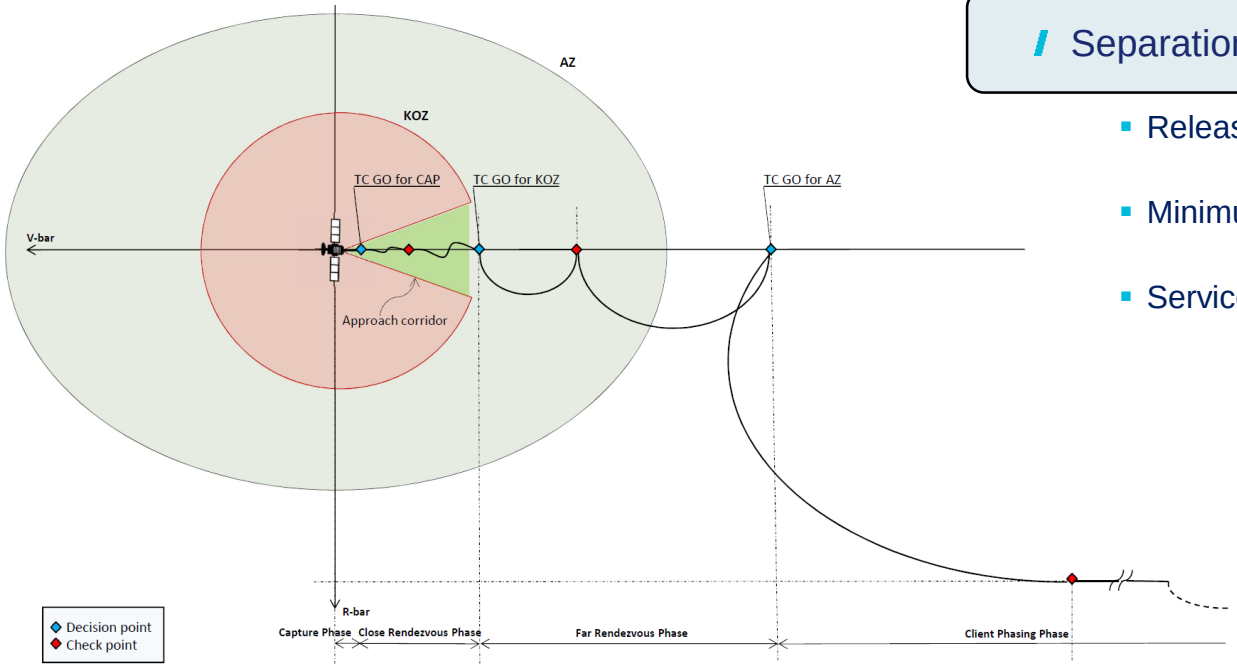

/ Separation phase, Departure phase:

- Release conditions compatible with control capabilities
- Minimum separation at release before first burn
- Servicer to respect the departure corridor

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IMPACT ON DESIGN

/// GO/NO-GO decisions between Phases

- Choice of decision points
- Identification of GO/NO-GO conditions
- Identification of critical items/parameters/thresholds (RAMS analysis, FDIR design, and monitoring of S/C units)

/// Abort, CAM, and Passively Safe Trajectories

- Sizing of the Abort Corridor to ensure Mission Safety
- Identification of conditions (on top of Abort Corridor violation) for autonomous CAM/Abort triggering:
  - Navigation emergencies
  - Control emergencies
  - Guidance emergency
  - …
- Abort capability to be ensured after a single point failure
- Servicer to be placed on a passively safe trajectory after an Abort
- Point-of-no-return

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IMPACT ON DESIGN

/// Capture Phase

- Minimization of plume impingement (e.g., thruster accommodation, final burn at given distance, …)
- No performance or integrity degradation of the client
- Relative velocities and rates and/or position and attitude to be within the acceptable range for the S/Cs and capture system
- Cooperative client to remain “passive”

/// Stack Configuration Phase

- To ensure controllability of the stack:
  - robustness towards MCI uncertainties, especially in case of debris
  - Inspection might be needed to update 3D model and MCI parameters
  - THRs size, accommodation and orientation to take into account Stack Configuration
- No accidental breakup during servicing operations

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IMPACT ON DESIGN

/// Separation Phase

- Conditions at release compatible with the client platform and mission
- Release mechanism/strategy to provide minimum impulse/separation
  - To prevent collision for a time frame compatible with the execution of a CAM
  - To avoid plume impingement

/// Departure Phase

- Servicer to follow the departure corridor

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WAY FORWARD

/// Study status:

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/// Next issue of “ESA CPO safety guidelines” to be released by end of the year

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END OF THE PRESENTATION

THANK YOU FOR YOUR ATTENTION !

ANY QUESTION?

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