7th ESA Workshop on Avionics, Data, Control and Software Systems - ADCSS 2013

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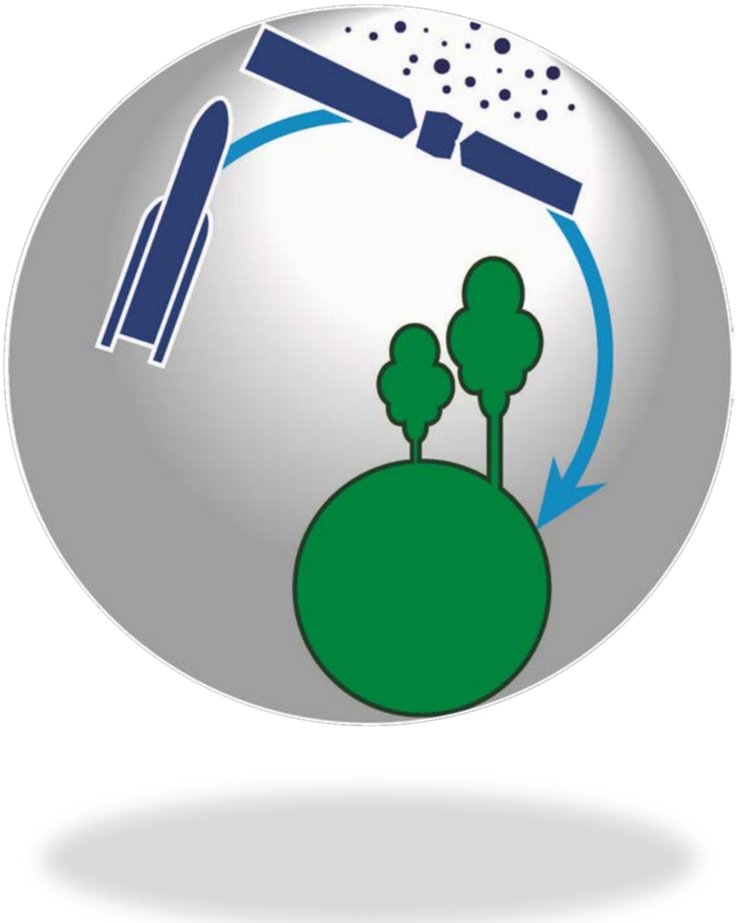


User cases:
Active Debris Removal

Luisa Innocenti

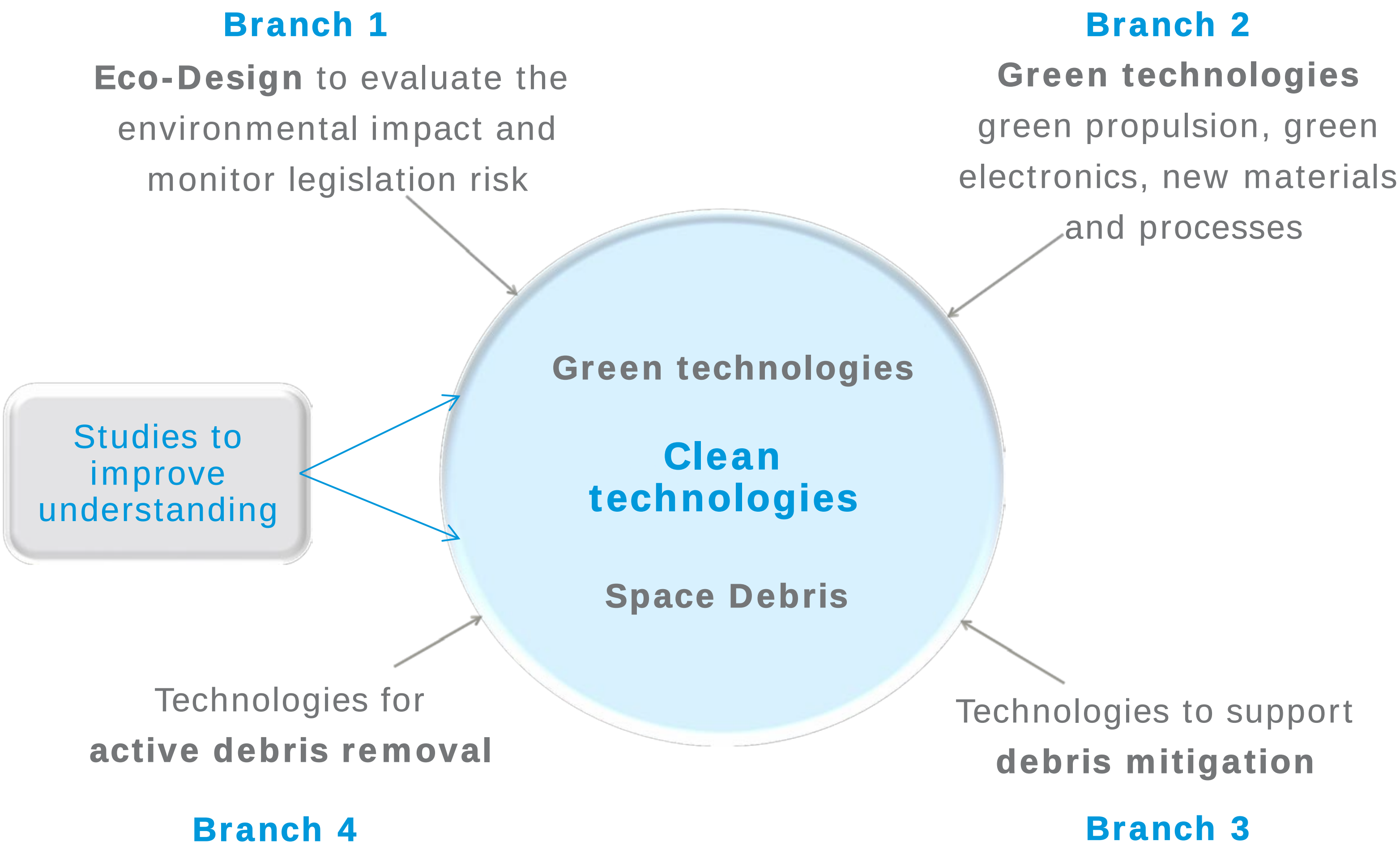
24/10/2013

Session: **Processing needs for advanced GNC Systems**

Track: High Performance Computing for GNC (24 October AM)

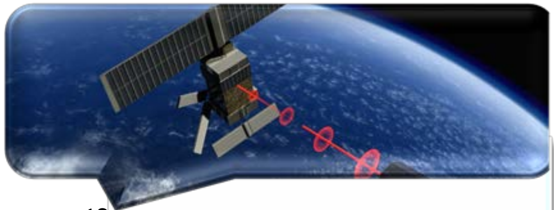
ESA/ESTEC - Room: Newton

Clean Space


Branch 1
Eco-Design to evaluate the environmental impact and monitor legislation risk
Branch 2
Green technologies
green propulsion, green electronics, new materials and processes
Studies to improve understanding
Green technologies
Clean technologies
Space Debris
Technologies for
active debris removal
Branch 4
Technologies to support
debris mitigation
Branch 3

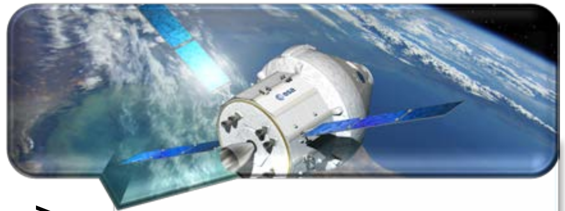
Branch 4 Space Debris Remediation

Why?



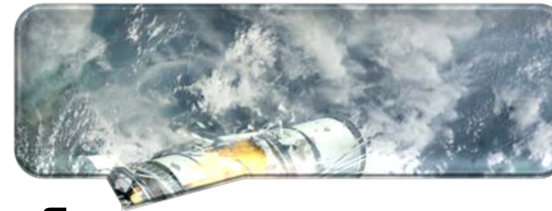
Compliance with mitigation requirements

- Raising number of debris
- World-wide actions by active debris removal (~5 objects per year)
- Increasing collision avoidance maneuvers



On ground safety

- Uncontrolled re-entry of debris causes a risk for on-ground safety



Innovation

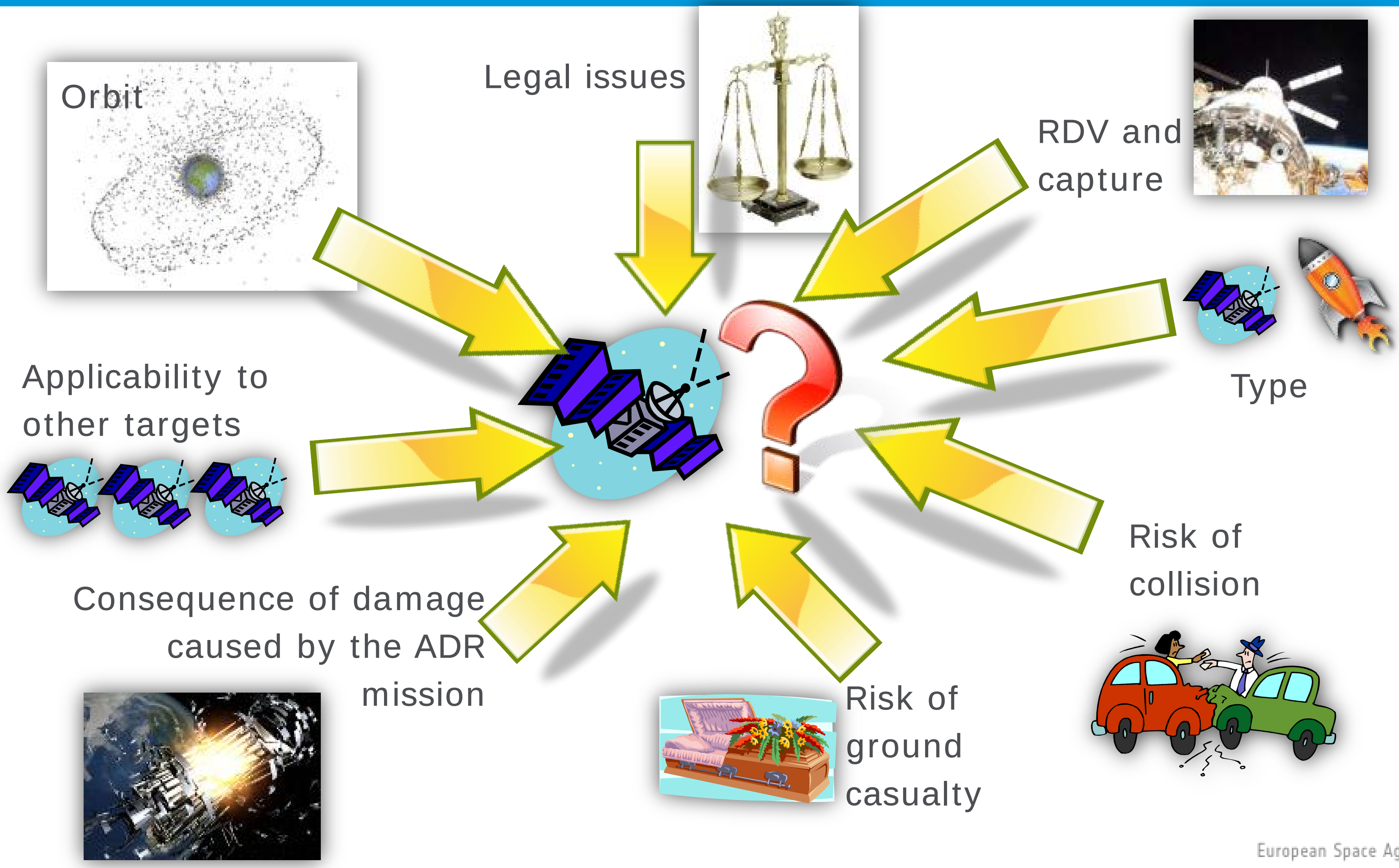
- Innovative technologies (e.g. capture, sensors) are necessary
- Possibility of new market for ADR

Risk of an ESA satellite encountering a catastrophic collision in the next 50 years between ~7.5% and ~11%

Branch 4 Space Debris Remediation
Objectives

- Develop technologies for space debris rendezvous, capture and re-entry
- Adopting a system approach, technology developments are planned to be focused on a mission for the controlled de-orbit of heavy objects
- Place European industry at a forefront position on anticipated future markets

Target Selection: metrics

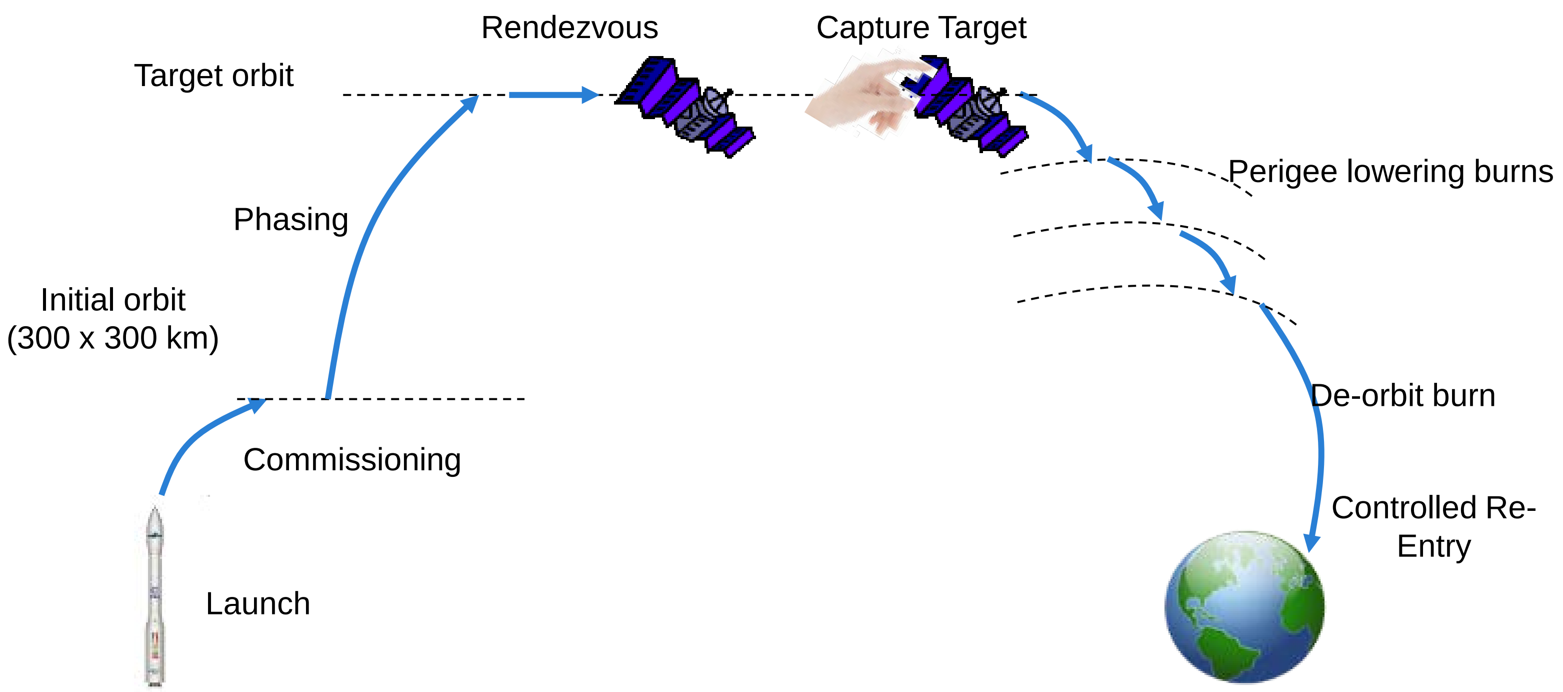


Recent and Ongoing ESA Activities

e.Deorbit

- Preliminary system design for most promising options, identify the required technology roadmap, and investigate their applicability to other missions

- Assessment of feasibility, programmatic, risk and cost aspects of a mission for the controlled de-orbiting and re-entry of a large, massive, un-cooperative target in SSO



Recent and Ongoing ESA Activities

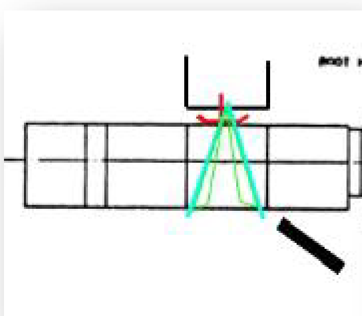
e.Deorbit – system options

Orbit
- Re-orbit to >2000 km
- De-orbit to <600 km
- Controlled re-entry

Propulsion
- Chemical (CP)
- Electrical (EP)

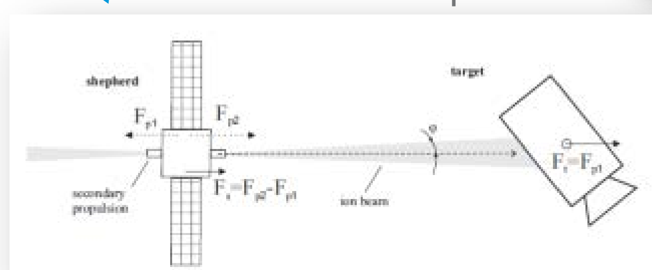
Capture techniques
- Others (harpoon, clamp, etc.)
- Net
- Clamping mechanisms
- Robotic arm
- Ion-beam shepherd

Clamping mechanisms

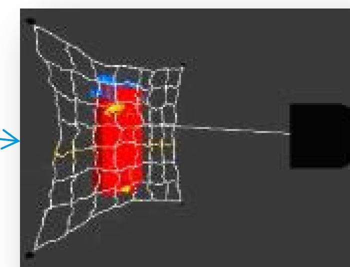


Robotic arm

Ion-beam shepherd



Net



Branch 4 Space Debris Remediation

How?

Mature ADR technologies:

- Adapt and upgrade existing sensor suit to perform rendezvous with un-cooperative target
- Evaluate capture mechanisms and promote technology maturation
- Control of stack after capture, selection of push or pulling approaches
- Verification & Validation framework

System approach targeting an ESA S/C controlled re-entry:

- Phase A and B1 mission design
- Service oriented approach to ADR

Study alternative approaches for other targets:

- Stabilisation of tumbling targets
- Ion Beam Shepherd

Active Debris Removal missions

- Any active debris removal mission can be sub-divided into mission arcs:
  - ascent and loitering,
  - far rendezvous with the debris,
  - the close approach,
  - the mating and capture,
  - and the final de-orbit
- Those mission arcs will make use of complex autonomous Guidance, Navigation and Control (GNC) systems on the chaser to allow the closed loop control operations to grab the uncooperative target and de-orbit the entire compound target-chaser

Autonomy & FDIR needs for ADR

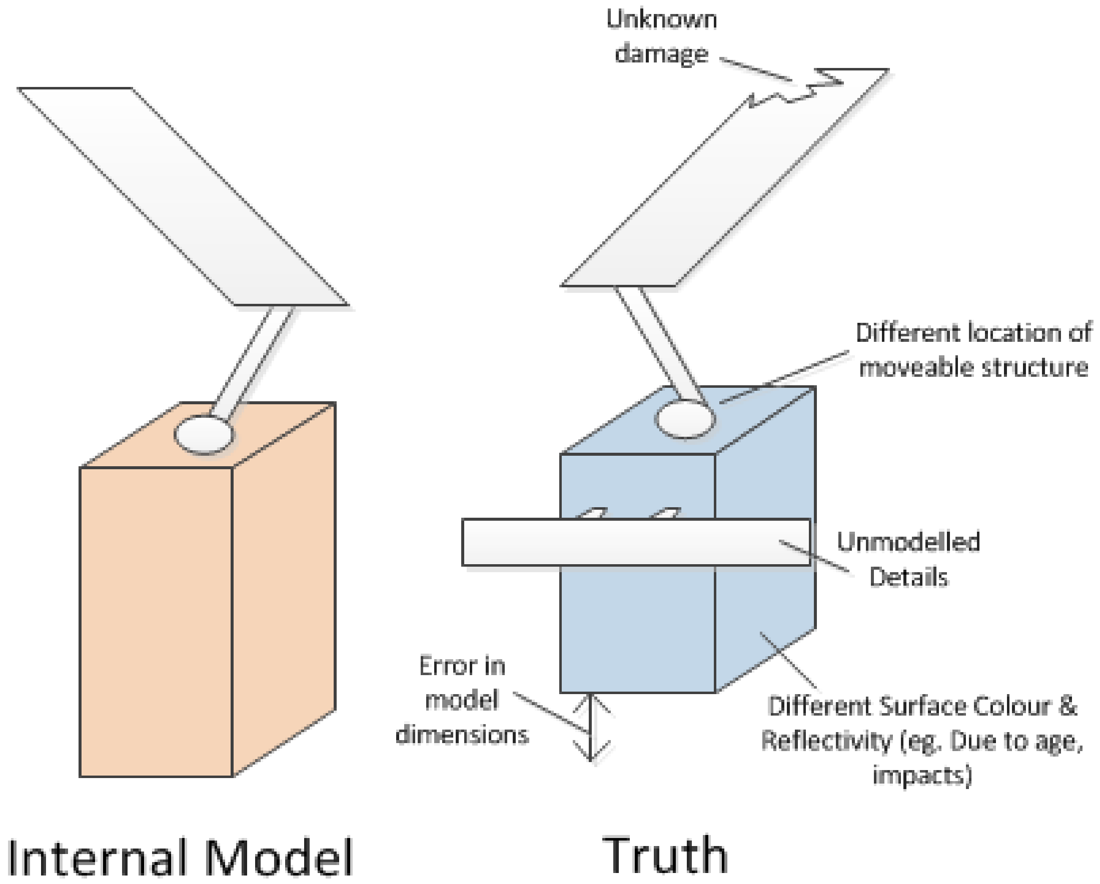
- Rapidly changing dynamics, potential Collision Risk
  - Manoeuvring within metres of a rotating target
  - Pulling the target with a tether
- Difficult / impossible to perform fully from Ground
  - Requires on-board Autonomy
  - => requires sufficient processing capabilities
- ADR requires a challenging FDIR
  - Rapid assessment of potential failure:
    - Sensor failure?
    - Incorrectly-identified ambiguity?
    - Target deformation (eg. micro-impact, internal explosion)?
  - Calculate how to escape…
    - … with a tether
    - … and not hit the rotating target's solar panel
  - Complex decision tree to be rapidly evaluated

Image Processing (IP) needs for ARD (1/3)

- For an ADR :
  - fast changes of illumination conditions (due to target rotation and revolution around Earth)
  - need to track complex shapes with highly reflective materials and textures of the target debris
- IP techniques need to solve for ambiguities linked to symmetry (e.g. symmetric solar arrays)
- Image processing techniques are required:
  - 3D shape reconstruction from 2D images
  - 3D shape reconstruction from 3D point cloud
  - Model-based pose (relative position and orientation) estimation
  - High sensor data through-put
  - Requires real-time processing, input to GNC closed-loop control

IP needs for ARD (2/3)

- IP algorithms must account for "Deformable" Target
  - Damaged Target
  - Movable sections (eg. Solar panels)
  - Incorrect / old model of Target
- Still need pose estimates in real-time



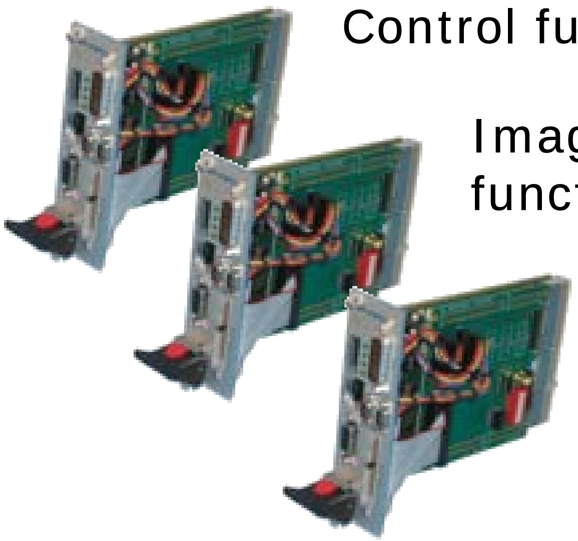
IP needs for ARD (3/3): Ambiguity Resolution example

- Ambiguity resolution is a complex problem.
  - Human brain can be deceived, let alone CPU + IP algorithms
- See simple example:
  - Which direction is the (non-symmetric) dancer rotating?
  - Answer: Could be either direction – insufficient information!
- IP needs to:
  - Identify possibility of ambiguity
  - Track all possibilities until sufficient information is available to decide
  - Requires multiple parallel filters

Current solution for high performance GNC

- A single core computer is duplicated, triplicated, quadruplicated, ...
- Each computer is devoted to a particular function
- Some times, RAM is shared between computers

Are multi-core architectures able to cope with the CPU demand requested?



Control function

Image processing function

FDIR function

What is needed?

- A simple, cost-effective yet high-performance computing solution
- ADR Avionics requirements are not fully mature, but it is clear they will be very challenging
  - Possibly most demanding mission ever flown, in terms of Avionics?
- A potential ADR avionics could be composed of:
  - A high performance computer
    - multi-core?
  - A high data-rate, high speed system bus
  - A real-time operating system
    - able to handle multi-core computers?
  - A test bed environment that allows verification and validation of the complete avionics solution

Thanks for attending