GNC CHALLENGES FOR HEAVY ACTIVE DEBRIS REMOVAL USING BLOW EFFECT TO PROCESS OR DE-TUMBLE DEBRIS

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ABSTRACT

In the next 150 years, the “Kessler cascade” effect explains that the population of objects in space will increase due to collisions between already existing large objects with other objects. Large objects are identified as major contributors to debris creation because of their fragmentation through collisions and explosions. It has been predicted that the active removal of 5 to 10 large objects per year from Low Earth Orbit would reverse this cascade effect. The research and development of technologies related to active debris removal is therefore essential for heavy debris.

Astrium has investigated different spacecraft solutions for heavy active debris removal. Through these studies, the main driver identified for GNC design is the choice of the nature of the capture mean. The latter can be:

- a rigid link in case of capture with clamps or robotic arm,
- a flexible link, in case of capture with net or tether,
- or no link at all in case of contactless solution such as blowing effect described in this paper.

Indeed, the chosen capture mean will drive the following items:

- the design of the vehicle,
- the duration of the mission,
- the complexity of the vehicle,
- the approach strategy,
- the mean used for de-tumbling phase (reduction of the angular rate of the targeted debris),
- and the way the debris is processed (modification of orbital parameters of the targeted debris to allow either de-orbiting or re-orbiting to graveyard orbit design).

Solutions for spacecraft design including capture with a link between target and the spacecraft, either rigid or flexible, can lead to strong constraints

- on the mission:
  - accuracy at close distance,
  - strategy of attitude,
  - communication needs,
  - distance of capture,
- and on the design of the vehicle:
  - redundancy necessary due to risk of collision with target,
  - propulsive architecture sized to cope with high angular rate of the debris,
  - consumption to manage de-orbiting with flexible link.

Therefore, in the search for optimal solutions for heavy active debris removal, alternative capture technologies without contact have been studied. In particular, the use of proximity blow effect of thrusters of the existing propulsive architecture of a spacecraft can be used during detumbling, to reduce angular rate or during processing, to reduce velocity of the target.

This paper presents the Flight Control analysis of the use of the alternative blowing method on both processing and de-tumbling phases for heavy debris. To widen the applicability of the method, both chemical and electrical propulsion have been studied for both phases. This paper details the constraints (such as attitude and relative position station keeping strategy) implied on the maneuver by the choice of blowing method. The drivers for Guidance, Navigation and Control design in terms of accuracy of the maneuver and efficiency will be given. A sizing method for all consumption contributors has been applied to have first rough estimation of consumption during the maneuver. Finally an application to a study case of a given spacecraft design will be presented. This application will show how the choice of blowing technique impacts the design of the spacecraft in terms of propulsive architecture and constraints on mission. It will give an order of magnitude for applicability of blowing method.