Project Proposal - ADR Spacecraft

Frédéric Berdoz, 260867318

I. Introduction

Space debris are becoming a real threat to spacial exploration. Indeed, lower earth orbits (LEO) are slowly becoming saturated with loose object. In the last 50 years, different countries around the world have sent their satellites in space without planning their abandonment. Sending additional satellites or human missions is thus becoming riskier.

ESA, the European Space Agency, is now dedicating some of its ressources tracking these objects and planning their extraction or destruction. Their program is called *Clean Space Initiative* [**?**], and it involves ADR, standing for Active Debris Removal. It consists of sending spacecrafts in space that can either send the large and dangerous objects into higher orbits, known as graveyards, or slowing them down in order to initiate their reentry into the atmosphere, which would destroy them. In parallel, they are pressing governments to address this problem in their respective space law.

ESA's first planned ADR mission is called *eDeorbit* and it has given rise to nummerous technical challenges, in particular in the field of robotics and advanced systems of guidance. They are currently exploring two options to catch the abandoned satellites.

1) A spacecraft with a robotic arm that can grip the object.
2) A spacecraft that can throw a net over the object.

In this project, I will attempt to model a simplified version of the second design.

II. Proposal

My design consists of a cylindrical spacecraft with one main propeller (P1), two auxiliary propellers (P2 & P3), and two reaction wheels (W1 & W2), as shown in Figure **??**. The goal of this project will be to model the kinematics and dynamics of this spacecraft and, if time allows, introduce some control design in order to place the spacecraft and the optimal position for the net launch.

Let $\mathcal{F}_E$ be the reference frame attached to the Earth (ground) and let $\underrightarrow{V}$ be the velocity of the debris w.r.t. $\mathcal{F}_E$. Let A_d be the axis spanned by $\underrightarrow{V}$ and passing through the center of gravity of the debris, G_d. The objective is to place the spacecraft's center of gravity, G_s, on A_d, at a constant distance from G_d and on the opposite direction of $\underrightarrow{V}$. In other words, we want to make the spacecraft follow the debris.

Then, W1 and W2 can be used to align A_s with A_d such that the net launcher is facing the debris. Once in position, the net can be launched and the two auxiliary propellers can be activated to slow down the debris just enough to initiate its reentry in the atmosphere.

In theory, two reaction wheels and one propeller are sufficient to guide the spacecraft in every possible direction. However, I'm a bit concerned with the complexity of the control and adding a third wheel perpendicular to the two others would certainly simplify it.

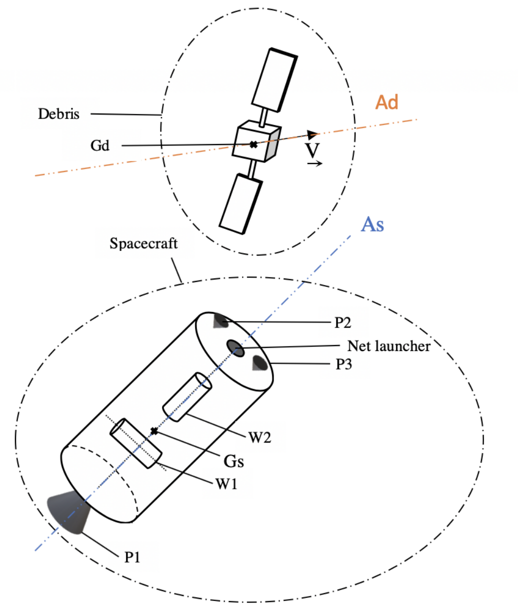

Fig. 1. Spacecraft and debris configuration.

In order to simplify the model, the following assumptions will be made (they are not final and might be subject to changes):

- The total mass of the space craft and its inertia properties remain constant throughout the mission, i.e. the mass of the propellant used during the activation of P1, P2 and P3 is negligible.
- The curvature of the space is negligible compared to characteristic size of the problem, i.e. instead of considering a LEO, both objects are treated like they were in deep space. In this case, $\underrightarrow{V}$ remains constant.

III. Conclusion

Although simplified, this problem should still include some interesting dynamics and some challenging control. This proposal will probably be subject to some changes in order to match Prof. Forbes' requirements.

References

[1] (2016, April) The European Space Agency website. [Online]. Available: www.esa.int/Our_Activities/Space_Engineering_Technology/Clean_Space