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NEOSHIELD-2: DESIGN AND END-TO-END VALIDATION OF AN AUTONOMOUS CLOSED-LOOP GNC SYSTEM FOR ASTEROID KINETIC IMPACTOR MISSIONS

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ABSTRACT

The possibility of a Near Earth Object (NEO) collision with our Earth is an often underestimated threat, as was reminded by the 2013 Chelyabinsk event. While the probability of such a disaster is low, it is statistically bound to happen again and could have catastrophic consequences over densely populated areas. It is also the only type of natural disaster which can be reliably predicted with a warning time sufficient for efficient mitigation through an adequate space mission.

This justifies worldwide endeavours for the development of mitigation technologies, in particular the funding by the European Union, in the frame of its Horizon 2020 research and innovation programme, of the NEOShield-2 project: within a large consortium of scientists and industrials studying among other aspects NEO characterization methods and properties through Earth-based observation or future space missions concepts, Airbus Defence and Space France has been tasked with the development and maturation of the Guidance, Navigation and Control (GNC) key technologies enabling the kinetic impactor mitigation mission concept. This concept is broadly acknowledged as the best alternative to nuclear deflection for NEO of moderately high to low masses with medium to long warning times, and relies on the modification of the hazardous NEO's velocity (therefore orbit) through the linear momentum transfer imparted by a collision with a high relative speed (order of 10 km/s) and high mass (order of the ton) spacecraft.

With such fast dynamics, it can be easily understood that hitting an object down to a 50m diameter is quite challenging, and requires a GNC both very accurate and completely autonomous for the last hours of the mission, never before implemented on a space mission. Within the framework of the first NEOShield study from 2012 to 2014, Airbus Defence and Space SAS has designed such a system, relying on high-performance vision-based navigation and advanced image processing as well as robust guidance and control laws, enabling the impact of even a poorly lit and very small asteroid. From the Technology Readiness Level (TRL) of 3 reached at the end

of this preliminary design, the NEOShield-2 activities aim at bringing this technology to TRL5-6 via intensive functional validation, real time tests on actual space grade processor, and tests with an optically stimulated camera, in the loop.

This article will briefly present the NEOShield-2 project, recall the kinetic impactor concept and detail the ensuing GNC design with specific focus on its image processing core-function. The work carried out for the system validation at functional, real time, and hardware in the loop level will then be illustrated through two mission application scenarios: a demonstration mission hitting a poorly lit 2001 QC34 under adverse conditions, assuming the asteroid has been characterized by a reconnaissance spacecraft in advance, and another theoretical case hitting Itokawa, already very well-known thanks to the Hayabusa mission, under much better conditions.