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A NOVEL CONCEPT FOR TARGET OF OPPORTUNITY OPERATIONS FOR FUTURE MISSIONS

Abstract

Target of Opportunities (ToOs) are unpredictable and unexpected or partially expected events of extraordinary scientific interest, such as gravitational wave events, supernovae, black holes, X-ray binaries, ultraluminous X-ray sources, transients and gamma ray bursts (GRB). Among them, GRBs afterglows decay very fast, thus requiring the observations to start promptly. For future missions such as ESA's X-ray observatory ATHENA, a fast response from receipt of ToO request to start of the observation, called reaction time, is not only foreseen but an important mission requirement. Specifically, ATHENA shall be able to perform narrow field observations of a GRB-ToO within 4 hours for at least 67The typical sequence of operations to handle an external ToO request involves several steps: from evaluating its feasibility, priority and impact, to generating the target requests, creating a new mission plan and uplinking the new timeline. The spacecraft will then slew towards the target sky position and the payload will be configured accordingly before finally starting the observation. Using current architecture as a reference, ESA's XMM-Newton has an average reaction time of about 7 hours, far from ATHENA's mission requirement. In this paper, we propose a novel concept to swiftly handle ToO requests to satisfy such stringent requirements on the reaction time for future missions. Firstly, we analyze the current ground segment and spacecraft designs and identify bottlenecks and limitations. Then, we present an architecture that builds on two novel concepts: 1) the use of artificial intelligence (AI) to optimize the re-planning of the observations that follow the ToO, and 2) a cloud network of ground stations to uplink the updated information. For 1), we specifically use machine learning (ML) to produce a sequence of observations - chosen to maximize the scientific return while minimizing the onboard resources - from accurately modelling the spacecraft attitude dynamics and its interaction with the space environment. For 2), an on-demand, fast booking service is envisioned. High level automation for tedious and repetitive tasks and autonomous systems to streamline the process will be discussed in detail. Finally, by exploiting a functional flow block diagram to describe the end-to-end operations sequence, we show how the proposed concept outperforms the present design and meets future missions' ToO reaction time requirements.