RETURN ON EXPERIENCE ON PHASING STRAGETY DESIGN IN THE ATV PROGRAM

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ABSTRACT

The European Space Agency's (ESA) program, the Automated Transfer Vehicle (ATV), has finished its duty of supplying the International Space Station (ISS) with dry and liquid cargo achieving a 100% success. The last vehicle of its kind, the so-called ATV-5 "Georges Lemaitre", was launched in June 2015, ending a 5 vehicle saga that started in March, 2008, with the ATV-1 "Jules Verne". For the time being, the ATV has become the heaviest spacecraft ever injected in orbit by the European launcher Ariane-5 and the ISS visiting spacecraft carrying the highest quantity of dry cargo, liquid cargo and maneuver capacity to raise the Station orbit.

This huge and unique European program involved many well-known actors of the space industry in Europe and all around the globe: Airbus Defense and Space (Airbus DS) as the Flight Segment primer contractor, Arianespace, Rocket Space Corporation-Energia (RSC-E), the Russian Space Agency (RSA) and NASA, between many others. Within this organization, the Ground Segment development and the Flight Operations were contracted to the Centre National d'Etudes Spatiales (CNES), which constructed the ATV Control Center (ATV-CC) in Toulouse, from which the ATV flight operations were conducted.

Since the preparation of the first ATV flight, a Generic Mission Profile was conceived, searching for the greatest Flight Domain coverage in terms of phasing angle, mission duration and targeted ISS altitudes. Despite the fact that this Generic Mission Strategy had to be updated and enhanced from one mission to another, the general characteristics and tools served all along the 5 ATV missions, and finally showed very high rates of re-use.

This generic mission profile, strategy and principles were covered in the Generic Mission Analysis (GSMA) document. One of the most important results of the GSMA baseline strategy was its high flexibility in terms of launch and docking scheduling which, on one hand, allowed Arianespace to offer slots of launch taking into account ISS or ATV planning constraint with a lower priority with respect to launcher programmatic aspects, and on the other hand, to schedule ATV docking to the ISS without any need of ISS on-board specific cooperative maneuvers, as it does for other visiting vehicles such as Progress or Soyuz.

The main characteristics of the generic phasing strategy were the following: 1) orbital maneuvers until ISS vicinity computed on-ground, 2) coverage of every phasing angle with respect to the ISS (between 0° and 360°), 3) every ISS altitude for docking was targeted in the range of altitudes allowed for the entire ISS orbital life, 4) the possibility to perform a parking phase as long as a maximum of 56 days and 5) demonstration by Monte Carlo analysis of the safety and robustness of all the strategies. But also

other meaningful capacities of the maneuver strategies must be underlined: 6) multiple drift altitude solutions to avoid other visiting vehicles trajectories if needed, 7) a certain degree of freedom in the choice of the targeted point at the vicinity of the ISS, allowing the execution of Optical demonstrative experiences on new rendezvous technologies, 8) some extraordinary GNC system performances at vehicle level which allowed the ground teams to perform safely critical maneuver plans at the proximity of the ISS in relative motion and 9) many complementary studies on contingency strategies demonstrating the high flexibility of the phasing scenarios.

Concerning the undocking and de-orbitation phase, an equivalent adaptability was achieved by the ATV vehicle in order to support several ATV reentry observation campaigns, easing the reentry operations scheduling and the ISS traffic planning with partners. Multiple alternative scenarios had been developed from which we would hold as an example one: the re-phasing of the ATV after undocking to use the Station as an observation platform during the ATV's hypersonic re-entry.

To summarize, the present paper will focus on the phasing strategy design for the ATV and will offer the audience a complete, synthetic and direct perspective on the different phasing problems and solutions that were encountered in –under several aspects of consideration- the largest and more complex European Spacecraft Program ever existed.