Geophysical Research Abstracts
Vol. 15, EGU2013-1919, 2013
EGU General Assembly 2013

Influence of the Mercury gravity field on the orbit insertion strategy of BepiColombo

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Ziel des Versuchs

BepiColombo is Europe's first mission to Mercury expected to launch on an Ariane 5 rocket in 2015. The European Space Agency (ESA), in cooperation with the Japan Aerospace Exploration Agency (JAXA), is responsible for the mission design and navigation. The mission has a high scientific interest as there are still many unsolved questions about Mercury, such as origin and evolution of the planet, its physical form, as well as its interior structure. Also instruments to measure the chemical composition, the exosphere and magnetosphere of Mercury will be on board of BepiColombo. The interplanetary journey based on ion propulsion and 7 gravity assists is followed by the challenging gravitational capture at Mercury.

This paper describes the manoeuvre sequences of the Mercury Orbit Insertion (MOI). The manoeuvres were optimized such that the two scientific elements - the Mercury Magnetospheric Orbiter (MMO) and the Mercury Planetary Orbiter (MPO) - can be released to their target orbits with minimum fuel consumption. The MOI consists of fifteen burns: After five burns the MMO will be released to its operational orbit of 600 km x 11624 km; after the fifteenth burn MPO shall arrive at its target orbit of 560 km x 1530 km. The optimum burn sequence was obtained by implementing the optimization package SNOPT into an orbit propagation software that considers orbital perturbations due to the non-sphericity of Mercury and the gravitational pull of the Sun.

Since the gravity field of Mercury is still not very well known - even after Messenger being in orbit around Mercury for almost two years - the final MPO orbit is still under discussion. Depending on the final choice of the MPO orbit, different orbit insertion sequences have to be optimised and the most probable ones are presented here. This also includes different argument of periherm values for MPO and MMO. Furthermore, the effect of the solar aspect angle constraints ("no direct Sun on MMO and on the thrusters"), of the total number of burns (14 or 16 instead of 15) and of the time until the thrusters reach 100 % thrust on the insertion ΔV are studied. Also the impact on the mission caused by the superior solar conjunction (when communications are interrupted because Mercury and the spacecraft are too close to the Sun) were analysed. Finally some failure cases were simulated, especially failures of one of the first five burns which could cause the delay of MMO separation.

In conclusion, the best manoeuvre sequences in terms of ΔV were found for all of the above mentioned cases. Back up plans for failed burns were worked out as well. The Mercury Orbit Insertion is crucial for the success of the BepiColombo mission, which hopefully will provide invaluable clues to the many unanswered questions about Mercury.