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Perihelion Power Constraint and Wheel-Off-Loading Impact on BepiColombo's Relativity Experiment

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In this paper the consequences of the Perihelion Power Constraint (PPC) are presented along with the impact of the Momentum Wheel-Off-loading (WOL) events on the estimation precision of the post-Newtonian parameters (PNP). This analysis will provide an estimate of the outcome of the relativity experiment in the framework of the joint mission between ESA and JAXA, named BepiColombo. The Mercury Planetary Orbiter (MPO), one of the two scientific elements of the composite spacecraft, aims to verify Einstein's theory of General Relativity plus alternative theories of gravitation to an unprecedented degree of accuracy [1].
The PPC describes the switch-off of the Ka-transponder when Mercury is $\pm 35^{\circ}$ around perihelion [2]. This causes a decrease in the quality of radiometric measurements. The implemented PPC distinguishes between different geometries such as inferior and superior constellations. Moreover, it differentiates between the case in which Mercury is close to superior solar conjunction (SSC) while being around perihelion and the one of only being in SSC. Our treatment has the essential effect that the standard deviation of range and doppler measurements is increased in the perihelion region by up to $1.83 \cdot 10^{-5}$ km/s (doppler noise). There is no clear trend to be seen in the resulting PNP uncertainties. For instance, the value of the estimation bias of the PNP γ of $8.232 \cdot 10^{-6}$ is almost by factor two larger than in the case when the PPC is not activated ($4.243 \cdot 10^{-6}$). But applying the PPC to the back-up trajectory this trend is not confirmed, since the reverse is true for the γ uncertainty $\sigma_{(\gamma_{PPC})} < \sigma_{(\gamma_{ref})}$. However, the order of magnitude is comparable to the results obtained by Schettino [3], that is $1.04 \cdot 10^{-6}$.
The influence of the WOL frequency of about 12 hours compared to about 24 hours is investigated. Wheel off-loadings are implemented in the software by increasing the diagonal values of the covariance matrix that correspond to the spacecraft velocity components at each event. In our approximation there is no preferred direction of the parasitic ΔV. Instead, each direction receives a ΔV of $\frac{3}{\sqrt{3}}$ cm/s per half a day and ΔV of $\frac{6}{\sqrt{3}}$ cm/s per day [4]. There is a strong impact of the WOL to be seen on the achievable accuracy of the PNP. The chosen approach is suitable for spacecraft orbit prediction errors, but in real operations the WOL ΔV is estimated. This means in reality the knowledge improves in the course of time.
This work has been performed with the software tool GRETCHEN by Deimos Space that is based on the Square Root Information Filter (SRIF). A series of covariance analyses was performed in order to obtain the results.
A profound understanding of gravitation is of special importance to humankind's exploration of space. One fundamental step is the experimental verification of theories. This analysis gives an overview of the sensitivity of the relativity experiment to the PPC and WOL.

References

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