

Status of the ELT data center

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Abstract. The Atomic Clock Ensemble in Space (ACES) will be launched in spring 2018. ACES is an ESA mission in fundamental physics which will establish a very precise time scale in space. The European Laser Timing (ELT) experiment is an additional time transfer experiment conducted from satellite laser ranging (SLR) stations to the very precise clocks on ACES. We will present the structure of the data center, show the required observation data and where to obtain them. The analysis of the experiment is shown together with the protocol the participating stations get as quick-look data. The simulation tool will be demonstrated together with a best tracking strategy. We will show which new difficulties come along with range gate opening on board and how we can deal with it.

Introduction

The European Laser Timing (ELT) experiment will carry out time transfer measurements to the International Space Station (ISS), where, within the ACES (Atomic Clock Ensemble in Space) mission, a clock module of unprecedented accuracy and stability [Cacciapuoti and Salomon 2010] will be mounted. ELT [Schreiber et al. 2009], like its precursor experiments T2L2 [Saimain et al. 2014] and LLT [Fumin et al. 2006], is a combined optical two-way and one-way ranging technique. In figure 1 the principle of time transfer is shown. In contrast to T2L2 the detector onboard ACES will be operated in single-photon mode and with predefined detector range gates, which moves some complexity from the space segment to the satellite laser ranging (SLR) ground segment operation. Apart from laser eye safety requirements to protect the astronauts on the ISS, the station operators have to control the laser power to obtain the single photon level at the detector and the laser firing epoch has to be tuned in order to hit the detector on ACES close to gate opening. The gating is done periodically every 10 ms, respectively 1 ms, with respect to the ACES time scale. On the other hand the orbit predictions of an extended structure, like the ISS flying in a very low Earth orbit, will be a challenge, too. The requirements of the orbit accuracy make it necessary to generate predictions approximately every orbit.

The following steps have to be performed by station operators for a successful tracking and time transfer to the ISS: First of all the go-nogo-flag has to be evaluated indicating whether laser fire to the ISS is allowed. After down loading the actual predictions every pass, tracking can be started. Laser firing has to be controlled on a shot-by-shot basis according to the actual range to the ISS, local offsets and system delays of the SLR station. Furthermore the time offset of the ground station clock and the ACES timescale relative to UTC have to be included in the epoch corrections. The actual range can be estimated by correcting the predictions to noticed or measured time-bias of the ISS. This suggests a lively use of the real-time data exchange. The offsets and delays of the SLR stations have to be measured in advance. A calibration campaign

will be performed at least once prior to the launch of the mission. The offsets of the ACES timescale to UTC will be calculated by the ELT data center [Schlicht et al. 2012] and will be included in the prediction file as a linear fit to the predicted clock.

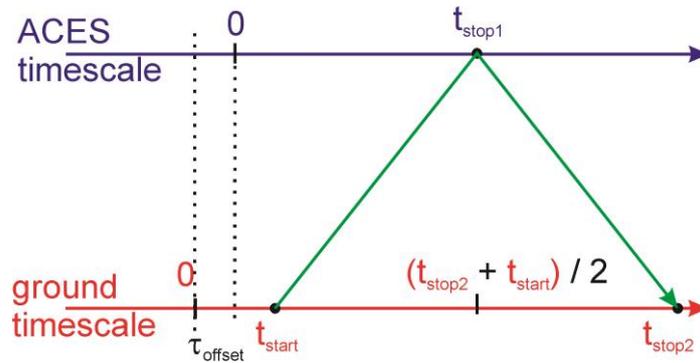


Figure 1: Principle of time transfer. A time transfer measurement needs a data triplet: start time at the station, stop at ACES and stop on ground.

ELT data center

The duty of the data center is to support the stations where ever possible and to provide a frictionless data flow. The data center is cooperating therefore very closely with the Eurolas Data Center (EDC) of the International Laser Ranging Service (ILRS). EDC has assumed the responsibility to collect all necessary data from ESA and the participating stations. The stations obtain the go-nogo-flag and orbital predictions via ftp on their usual account and can use this way to up-load their tracking data, too. The notification of a successful time transfer together with an analysis of staying in single photon mode, will be send by e-mail. The stations get the protocol of the full data processing. The data flow is shown in figure 2.

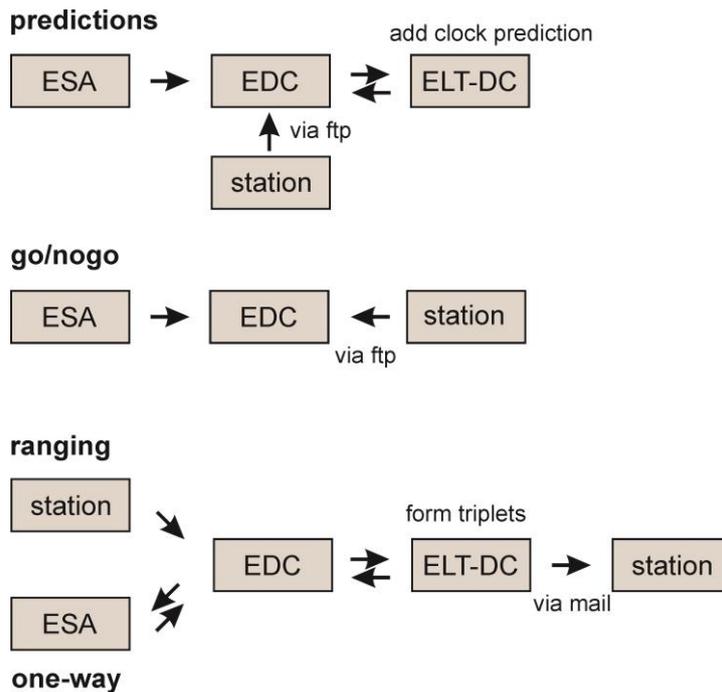


Figure 2: Data flow between ESA, EDC, ELT data center and the stations.

ELT data center will predict the drift of the ACES timescale relative to UTC by applying corrections for the effects of relativity, make a linear fit to the clock prediction and integrate the clock behavior into the orbit prediction file, delivered by ESA. The data analysis is performed in three steps: In step 1 a second order tracking offset is adjusted on the SLR two-way measurements. This allows a reconstruction of the appropriate stop time on ground if no signal is detected due to single-photon mode on ground. The second step is the filtering procedure of the one-way data according to the fire times on ground. Due to the single-photon mode detection on the ACES module the majority of the one-way data consists of noise. In the last step the time transfer triplets are built and reconstructed triplets are marked. This analysis is done with the predicted orbit as a quick-look for the stations and with the final orbit for the final time transfer product. In order to test the data analysis program a simulation tool was designed in Matlab. It includes the simulation of the detector noise in space and on ground, the single-photon detection scheme, the relativistic propagation of light, the geometry with orbit and attitude and the simulation of noise contributors like clock noise, detector jitter and laser pulse width. Figure 3 to 5 show the three analysis steps of a simulated pass analyzed with the data processing software. As can be seen some further work has still to be applied to make the plots more apparent. These three plots will be included in the protocol each station will receive for each measured pass, together with a graph showing their history of time transfer to ACES, which allows a conclusion on the stability of the time transfer on the station.

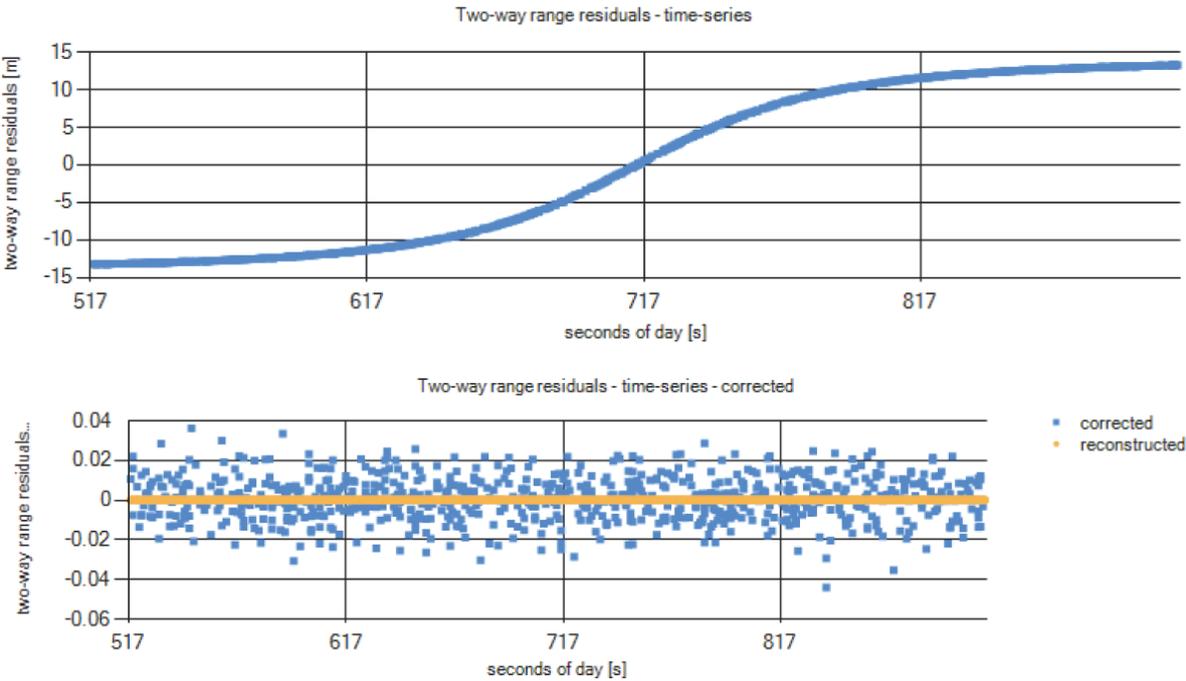


Figure 3: A third order tracking adjustment on the SLR measurements allows a reconstruction of all two-way data in the time transfer triplets.

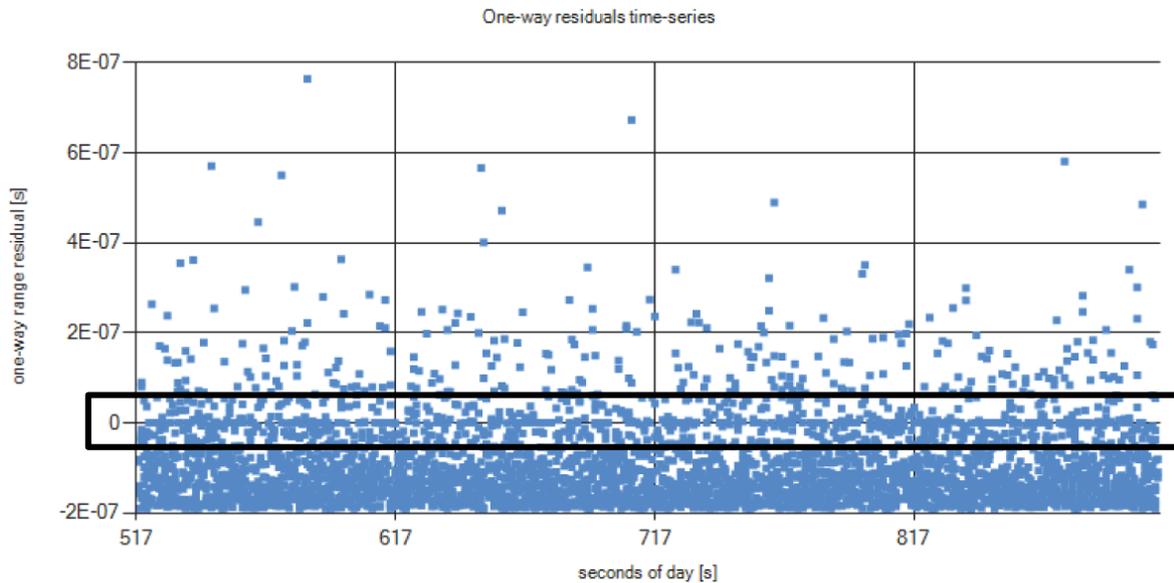


Figure 4: The one-way data has to be filtered. The single-photon mode detection principle is characterized by a low return-rate and high noise rate.

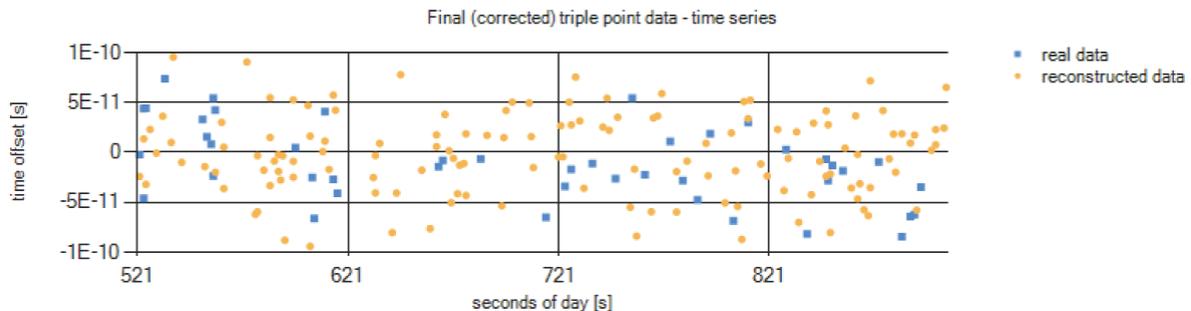


Figure 5: The triplets of the time transfer between ground and space. In blue the real measured triplets and in yellow the reconstructed triplets from the orbit fit in step 1.

Conclusion

A simulation tool was developed which allows a test of the analysis software as well as a characterization of future mission set-ups. Parameters which may vary are laser pulse width and firing rate, clock noise, return rate, station location, orbit parameters of the satellite and detector parameters. As the albedo illumination of the detector is also integrated, daytime and night time passes can be simulated. A simulation of the multi-photon peak on the detector is missing. This is the next step to make the simulation more realistic. The data analysis is consistent with the simulation but has up to now some limitations in the graphical representation. This will be improved soon.

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