# Combination of VLBI, GPS and SLR Software Development at FFI

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**Abstract**

FFI's contribution to the IVS as a Technology Development Center will focus primarily on the development and validation of the GEOSAT software for a combined analysis at the observation level of data from VLBI, GPS and SLR. This report shortly summarises the latest improvments of the GEOSAT software. FFI is currently an Analysis Center for IVS and ILRS, a Technology Development Center for IVS, and a Combination Research Center for IERS.

## 1. The GEOSAT software

The advantages of the combination of independent and complementary space geodetic data at the observation level is discussed in Andersen ([1]). The models of GEOSAT are listed in Andersen ([2]). Recent changes are described in the following.

It is a fact that the position of the effective phase center of the transmitter antenna of the GPS satellites is not very well known. This leads to a scale inconsistency with VLBI and SLR of 2-14 ppb depending on the model used for the phase center variation of the receiver antenna. It is therefore a standard procedure in analysis with GEOSAT to estimate the z-coordinate of the mean position of the transmitter phase center. With GPS data alone it is only possible to determine the phase center position relative to the position of the phase center of a reference satellite. Since the GPS data in our case are combined with VLBI and SLR data absolute positions of the phase center of all satellites can be determined. Since the estimate of the GPS transmitter antenna phase center depends on the models used for the correction of the receiver antenna phase center variations, absolute models for the latter have lately been incorporated in the GEOSAT software.

Another possible candidate for scale inconsistencies between the different techniques is the tropospheric mapping function. The VLBI and GPS data are currently analyzed with the use of the NMF mapping function. The tropospheric signal delay for SLR was previously calculated using the Marini-Murray model. The current analyses use the new Mendes tropospheric model.

Other recent improvements in GEOSAT include:

* A new planetary ephemeris, JPL DE405
* The use of Tchebychef interpolation of planetary ephemerides
* Multi-day estimation of any stochastic parameter
* A hybrid model for station motion consisting of stochastic position/eccentricity vector and constant velocitiy components
* Estimation of VLBI antenna axis offset and gravity coefficients C21 and S21 to make satellite-determined PM estimates consistent with VLBI-determined PM estimates
* VLBI clock with minimum synchronization error relative to UTC is automatically selected as VLBI reference clock to secure continuity of consecutive estimates of UT1
* All EOP partials have been checked by numerical derivation and found to be correct

* A new VLBI observation equation has been implemented following in the smallest detail the procedure recommended in the IERS 2000 Standard

In GEOSAT data from the different techniques are combined in batches of one day which is called an arc. The state vectors and complete variance-covariance matrices from the analyses of a number of independent arcs of space geodetic data can be combined using the CSRIFS (Combined Square Root Information Filter and Smoother) program. Four parameter levels are available and any parameter can, at each level, either be represented as a constant or a stochastic parameter (white noise, colored noise, or random walk). The batch length (i.e. the time interval between the addition of noise to the SRIF array) can be made time- and parameter dependent. More details can be found in Andersen ([1]).

Two new programs in the GEOSAT system are under development. The CSRIFS-IERS program will transform the output from internal reference frames in GEOSAT to the external reference frames of the IERS. Also the final combined covariance matrix of CSRIFS will be rotated. The SINEX program will write the global solution in the SINEX format.

The GEOSAT software will be converted to PC/LINUX in 2002.

## 2. Technical Staff

Table 1 lists the FFI staff involved in IVS activities.

Table 1. Staff working at the FFI AC and TDC

| Name | Background | Dedication | Agency |
|---|---|---|---|
| Per Helge Andersen | geodesy | 40% | FFI |

## References

[1] Andersen, P. H. Multi-level arc combination with stochastic parameters. Journal of Geodesy (2000) 74: 531-551.

[2] Andersen, P. H. High-precision station positioning and satellite orbit determination. PhD Thesis, NDRE/Publication 95/01094.