TRF Combination at NRCan: Status Report

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This is a contribution to the International Terrestrial Reference Frame (ITRF) activities by NRCan as an ITRS Combination Center for the International Earth Rotation Service (IERS). The current objective is to develop and apply the capability to combine solutions containing station coordinates and velocity determined with the DORIS, GPS, SLR and VLBI techniques, available using the Software INdependent EXchange (SINEX) format. Two other centers are currently involved in similar activities (IGS & DGFI) with the objective being to have redundancy in the TRF solution. Since the late 1980's IGN has been the sole responsible for determining the ITRF realizations. The recent work at NRCan related to the ITRF combination activities was almost exclusively dedicated to the combination/analysis software upgrades and data analysis. In principle all the contributing solutions are combined simultaneously to generate the final solution. At NRCan, the data combination is currently done using a two-step procedure. In the first step, the solutions within each technique (intra-technique) are combined separately. In the second step, all the intra-technique solutions obtained in the first step are combined to generate the final solution. This approach has been chosen because it is less demanding on the available resources. With the two-step approach, it is also easier to detect and isolate some problems. This approach introduces some approximations. As is most often the case in this type of analysis, iterations are required.

In the intra-technique combination, the following activities are performed: 1) standardize the solutions to a consistent "flavor" of SINEX; 2) remove constraints & rescale covariance; 3) Remove outliers (previous iteration); 4) align all solutions to a reference using 14 or less transformation parameters as appropriate; 5) combine; 6) analyze results. Techniques with only one solution available (e.g.: LLR) can obviously bypass this step. For techniques with only 2 solutions, the isolation of outliers is problematic. At this time, the problematic stations are noted and rejected from both solutions. For a few solutions, the removal of the constraints caused a significant degradation of the relative station coordinates/velocities. Several attempts were made to keep all the techniques solutions, but to avoid unduly slowing down the process at this time; some solutions have been excluded from the analysis. There may be some numerical problems/inconsistencies in the apriori/estimated matrices of those solutions and further investigation is required. Some intra-technique combinations are almost ready, e.g.: 3D-RMS of the position residuals is about 6 mm for the GPS combination.

During the second step, combinations were also made with the results from the first step and the local ties. At this time, only the stations that have ties are included in the combination. The other stations will be added subsequently in an extended adjustment or by using back substitution. The ties at each site are allowed to translate (TX, TY, TZ) in the adjustment. The combined solution currently includes the DORIS, GPS, SLR and VLBI. The 3-D RMS of the residuals varies from 8 mm to 29 mm in position, and from 2 to 9 mm/y in velocity. The origin (SLR), scale and rate (VLBI & SLR), orientation and rates (ITRF97 & NNR) will also need further attention as the adjustment progresses. Table 1 summarizes the 3-D RMS statistics for each technique after the latest intra-/inter-technique combinations. In the intra-technique columns, the RMS residuals are between each relevant solution

and the combined intra-technique solution. Similarly, the inter-techniques RMS are between the technique combination and the inter-technique combination. Positions RMS are determined from the position residuals at the minimal position variance. In the table, the GPS-D technique refers to the GPS densification solutions. Since in this case, there is little or often no overlap between the solutions, they were compared to the IGS combined solutions to extract meaningful statistics; those solutions haven't yet been included in the inter-technique combination. There were also two (GRIM5, CSR) multi-techniques solutions. Those haven't been included yet.

Table 1 3-D RMS position and velocity statistics for the intra-technique and inter-technique combinations

	Intra-technique		**Inter-technique**	
Techniques	**Position 3-D RMS (mm)**	**Velocity 3-D RMS (mm/y)**	**Position 3-D RMS (mm)**	**Velocity 3-D RMS (mm/y)**
DORIS	35	11	33	10
GPS-D	8	6	–	–
GPS	13	6	4	2
Multi	–	–	–	–
SLR	26	10	24	5
VLBI	16	2	6	3

A few more iterations of the combination process are needed to produce the final solution. Analyses of the quality of the determination of the origin and scale consistency also need to be done. Comparisons with the official ITRF 2000 will also be performed.