

Proposals for the IERS Combination Pilot Project

IERS Central Bureau
central_bureau@iers.org
April 21, 2004

Call for Participation Form

for the

IERS Combination Pilot Project

Deadline for proposals: **February 22, 2004**

Please send the completed form, duly signed, by mail or fax to:

IERS Central Bureau
Bundesamt fuer Kartographie und Geodaesie
Richard-Strauss-Allee 11
60598 Frankfurt am Main
Germany
fax: ++49-69-6333-425
email: central_bureau@iers.org

and a copy to:

Markus Rothacher
IERS Analysis Coordinator
Forschungseinrichtung Satellitengeodaesie
Technische Universitaet Muenchen
Arcisstr. 21
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Germany
fax: ++49-89-289-23178
email: Markus.Rothacher@bv.tum.de

Participating Organization/Institution/Service:

Name (primary scientist or person of contact): **Zuheir Altamimi**

Organization/institute/service: **Institut Géographique National**

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Staff members that will contribute to the CPP:

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Patrick Sillard

Daniel Gambis
Christian Bizouard
G rard Francou
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Jean Souchay
Anne-Marie Gontier
Christophe Barache

G rard Petit
Felicitas Arias
Jim Ray

Contribution to (see Call for Participation):

Part 1: Generation of "Weekly" Intra-Technique SINEX Files (Step 1):	no
Part 2: Generation of Combined Weekly Inter-Technique Solutions (Step 2):	yes
Part 3: Validation of Combined Weekly Inter-Technique Solutions (Step 3):	yes
Part 4: Generation of Special Combined Inter-Technique Products:	no

Part 1: Generation of „Weekly“ Intra-Technique SINEX Files (Step 1):

Technique (VLBI, GPS, SLR, LLR, DORIS; Combination on the observation level: list of techniques included in the combination):

Period covered by each single solution (session or week):

Parameter types included and their time resolution:

Constraints used:

Short description of solution:

Expertise and capabilities to perform the proposed task:

Additional comments (e.g. link to more information etc.):

Part 2: Generation of Combined Weekly Inter-Technique Solutions (Step 2):

List of techniques to be included in the combination (VLBI, GPS, SLR, LLR, DORIS): **all**

Parameter types to be combined: **Station positions and velocities, polar motion offsets and rates, UT1 and LOD, celestial pole offsets and rates**

Additional Parameters set up for the combined solution: **Helmert transformation parameters, local ties, possible additional bias parameters**

Datum definition strategy: **rigorous combination (using full variance-covariance information provided) of weekly/daily solutions of individual solutions together with local ties under minimum-constraint conditions to accurately define the combined frame; datum specifications can be applied either using a minimal alignment to ITRF2000 or to redefine a new datum in a similar manner as for ITRF2000**

Weighting method applied: **variance components estimation**

Short description of combination procedure:

- **remove constraints applied to individual solutions**
- **apply same minimum constraint to all individual solutions**
- **combine together with local ties under minimum constraints condition**
- **detect and properly handle outliers**
- **properly weight the individual solutions and iterate as necessary**

Expertise and capabilities to perform the proposed task: **the experience gained in ITRF combination over more than 15 years is an important factor for the success of the proposed task within the IERS Combination Pilot Project.**

Additional comments (e.g. link to more information etc.): **In order to combine satellite-based LOD and nutation rates with VLBI results derived using a true inertial frame, it is necessary to develop new combination methods to account for the time-varying biases from the satellite techniques.**

Part 3: Validation of Combined Weekly Inter-Technique Solutions (Step 3):

Parameter types to be validated (site coordinates, polar motion, UT1/LOD, nutation, quasar coordinates): **site coordinates, polar motion, UT1/LOD, celestial pole offsets, quasars coordinates.**

Short description of validation approach: **we propose to**

- **intercompare the intra-technique and inter-technique solutions resulting from step 2;**
- **verify the reliability and quality of local ties;**
- **compare inter-technique solution for station coordinates to external solutions such as the current ITRF2000 and IGS00 frames;**
- **compare inter-technique EOP solution to IGS and IERS series;**
- **also compare EOP series with geophysical excitation series based on atmospheric and oceanic model results;**
- **compare extra-galactic radio source positions to external solutions such as the ICRF;**
- **examine combination results for weaknesses, model deficiencies, and inconsistencies in the IERS Conventions**

Expertise and capabilities to perform the proposed task: **using the CATREF software package we have the capability to fully perform the proposed task. We are doing the validation of EOP solutions in our operational solutions. The validation of celestial reference frames was made yearly in the past.**

Additional comments (e.g. link to more information etc.):

We propose to archive and analyse the combined EOP inter-technique solutions .On a regular basis we will perform the validation of these series by comparisons of the individual combined solutions with the IERS C04 and other solutions (e.g., IGS and IVS combined) and also with geophysical excitation functions. An electronic report will be available within 4 weeks after the submission deadline for the weekly inter-technique combinations

Part 4: Generation of Special Combined Inter-Technique Products:

Techniques included in the combination (GPS, VLBI, SLR, LLR, DORIS):

Parameter type(s) to be combined:

Special product to be delivered:

Short description of combination approach:

Expertise and capabilities to perform the proposed task:

Additional comments (e.g. link to more information etc.):

Place and date:

Paris February 13, 2004

Name and position of responsible person:

Zuheir Altamimi

Signature of the responsible person:

Proposal for the IERS Combination Pilot Project

Participating Organization/Institution/Service:

Name (primary scientist or person of contact): Martine Feissel-Vernier

Organization/institute/service: IDS Analysis coordinator
Observatoire de Paris and
Institut Géographique National

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Cooperating organizations / institutes: Collecte Localisation Satellites (CLS)
Staff members that will contribute to the CPP:
IGN: Martine Feissel-Vernier
Karine Le Bail
CLS: Jean-Jacques Valette

Contribution to (see Call for Participation):

Part 1: Generation of "Weekly" Intra-Technique SINEX Files (Step 1): yes
Part 2 - Part 4: no

Part 1: Generation of „Weekly“ Intra-Technique SINEX Files (Step 1):

Technique: DORIS

Period covered by each single solution (session or week): week

Parameter types included and their time resolution: weekly station coordinates
daily x-pole and y-pole

Constraints used: ITRF2000 (minimum constraint)

Short description of solution: Combination of series of unconstrained solutions (Sinex)
from two or more IDS Analysis Centers.

Expertise and capabilities to perform the proposed task: First steps towards combinations for
the IDS 2002 Analysis Campaign (see http://lareg.ensg.ign.fr/IDS/events/2002_camp_report.pdf),
using the ICRS-PC CATREF software.

Additional comments (e.g. link to more information etc.): We plan to present first combined results
at the meeting planned in October 2004. Some individual IDS analysis centers are expected to
directly participate in the CPP.

Place and date: Marne la Vallée
20 February 2004

Name and position of responsible person: Martine Feissel-Vernier
IDS Analysis Coordinator

Signature of the responsible person:

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Technische Universitaet Muenchen
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80333 Muenchen
Germany
fax: ++49-89-289-23178
email: Markus.Rothacher@bv.tum.de

Participating Organization/Institution/Service:

Name (primary scientist or person of contact):
Detlef Angermann

Organization/institute/service:
Deutsches Geodätisches Forschungsinstitut (DGFI)

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Cooperating organizations / institutes:

Staff members that will contribute to the CPP:
Detlef Angermann
Michael Gerstl
Rainer Kelm
Manuela Krügel
Barbara Meisel
Volker Tesmer

Contribution to (see Call for Participation):

Part 1: Generation of "Weekly" Intra-Technique SINEX Files (Step 1):	no
Part 2: Generation of Combined Weekly Inter-Technique Solutions (Step 2):	yes
Part 3: Validation of Combined Weekly Inter-Technique Solutions (Step 3):	no
Part 4: Generation of Special Combined Inter-Technique Products:	no

Part 2: Generation of Combined Weekly Inter-Technique Solutions (Step 2):

List of techniques to be included in the combination (VLBI, GPS, SLR, LLR, DORIS):
VLBI, GPS, SLR, DORIS, (LLR?)

Parameter types to be combined:

Site coordinates, polar motion, UT1/LOD, nutation, quasar coordinates.

Additional Parameters set up for the combined solution:

Depending on the input data (intra-technique solutions and/or normal equations) it may be necessary to set up Helmert-transformation parameters for a particular solution that should not contribute to the datum of the combined solution.

Datum definition strategy:

At present, we use SLR to realise the origin, and VLBI and SLR for the scale. In future also GPS and DORIS may contribute to determine these datum parameters. The orientation is defined by no net rotation conditions w.r.t. to an external reference frame (e.g. ITRF2000) by using globally distributed "core" stations. The station networks of the different techniques are combined into a unique TRF frame via local tie information at co-location sites.

Weighting method applied:

Since the intra-technique solutions (normal equations) of the different techniques may have different variance levels, we estimate scale factors within the inter-technique combination. This will be done by variance component estimation.

Short description of combination procedure:

The weekly inter-technique combination will be done with the DGFI software DOGS-CS. The methodology is based on combining (unconstrained) normal equations of the different space geodetic techniques. Major processing steps are:

- Validation and analysis of input data (weekly intra-technique solutions and/or normal equations);
- Reformatting of SINEX into DOGS-CS format;
- Reconstruction of unconstrained normal equations;
- Combination and solution of normal equations with DOGS-CS.

Expertise and capabilities to perform the proposed task:

The long-term research programme of DGFI is based on the general theme "Fundamentals of Geodetic Reference Systems". DGFI has a many-years expertise in analysing space geodetic data of different techniques (mainly SLR, VLBI and GPS). It participates in the technique centres (services), i.e. IGS, ILRS, IVS, and is involved in the combination of different space geodetic observations. Within the IERS, DGFI acts as an ITRS Combination Centre and as a Combination Research Centre. In the framework of the IERS SINEX Combination Campaign DGFI has combined weekly solutions of different space techniques. The responsible scientist for the proposed task, Dr. Detlef Angermann, is a member in the IERS Working Group on Combination.

Additional comments (e.g. link to more information etc.):

For more information refer to publications on combination issues, e.g.:

Angermann, D., H. Drewes, M. Gerstl, R. Kelm, M. Krügel, B. Meisel: ITRF Combination - Status and recommendations for the future, submitted to IAG Proceedings, IUGG 2003 (in print).

Angermann, D., B. Meisel, M. Krügel, H. Müller, V. Tesmer: Time evolution of the terrestrial reference frame, submitted to IAG Proceedings, IUGG 2003 (in print).

Angermann, D., D. Thaller, M. Rothacher: Position paper: IERS SINEX Combination Campaign. Proceedings of the IERS Workshop on Combination Research and Global Geophysical Fluids, IERS Technical Note 30, pp. 94-101, 2003.

Drewes, H. and D. Angermann: Remarks on some problems in the combination of station coordinate and velocity solutions. Proceedings of the IERS Workshop on Combination Research and Global Geophysical Fluids, IERS Technical Note 30, pp. 30-32, 2003.

Gerstl, M.: Numerical aspects on combination at the observation equation and normal equation level. Proceedings of the IERS Workshop on Combination Research and Global Geophysical Fluids, IERS Technical Note 30, pp. 89-93, 2003.

Kelm, R.: Rank defect analysis and variance component estimation for inter-technique combination. Proceedings of the IERS Workshop on Combination Research and Global Geophysical Fluids, IERS Technical Note 30, pp. 112-114, 2003.

Krügel, M. and D. Angermann: Analysis of local ties from multi-year solutions of different techniques. IERS workshop on site co-location, Matera, 2003, IERS Technical Note (in print).

Krügel, M., B. Meisel: DGFI results of the IERS SINEX Combination Campaign. In: Geotechnologien Science Report No. 3, 96-100, Koordinierungsbüro Geotechnologien, Potsdam, 2003.

Meisel, B., M. Krügel, D. Angermann, M. Gerstl, R. Kelm: Intra- and inter-technique combination for the ITRF. Geotechnologien Science Report No. 3, 108-111, Koordinierungsbüro Geotechnologien, Potsdam, 2003.

Place and date:

München, 20.02.2004

Name and position of responsible person:

Dr. Detlef Angermann,
Coordinator of DGFI section on geometric reference systems

Signature of the responsible person:

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Participating Organization/Institution/Service:

Name (primary scientist or person of contact):
R. Noomen (ILRS Analysis Coordinator)

Organization/institute/service:
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Cooperating organizations / institutes:

Agenzia Spaziale Italia (ASI, Italy)
Deutsches Geodätisches Forschungs Institut (DGFI, Germany)
GeoForschungs Zentrum (GFZ, Germany)
University of Newcastle (NCL, United Kingdom)

Natural Environment Research Council Space Geodesy Facility (NSGF, United Kingdom)

Note: the exact list of contributors may change slightly, depending on the developments of the ILRS "pos+eop" pilot project in the coming months and decisions made therein. Contributions from

other ILRS analysis groups (BKG, CSR, Geosciences Australia, JCET and others) are also expected.

Staff members that will contribute to the CPP:

ASI: dr. V. Luceri, dr. C. Sciarretta

DGFI: dr. R. Kelm, dr. H. Müller

GFZ: dr. R. König

NCL: dr. K. Nurutdinov

NSGF: dr. G. Appleby

Contribution to (see Call for Participation):

Part 1: Generation of “Weekly” Intra-Technique SINEX Files (Step 1): yes

Part 2: Generation of Combined Weekly Inter-Technique Solutions (Step 2): no

Part 3: Validation of Combined Weekly Inter-Technique Solutions (Step 3): no

Part 4: Generation of Special Combined Inter-Technique Products: no

Part 1: Generation of „Weekly“ Intra-Technique SINEX Files (Step 1):

Technique (VLBI, GPS, SLR, LLR, DORIS; Combination on the observation level: list of techniques included in the combination): SLR

Period covered by each single solution (session or week): week

Parameter types included and their time resolution: station coordinates at mid-point of 7-day interval, Earth Orientation Parameters (xpole, ypole and LOD) at 1-day intervals, referred to 12.00 hrs of each daily interval.

Constraints used: none

Short description of solution:

The contribution will cover 2 steps: (i) the generation of network and EOP solutions computed by individual analysis centers, and (ii) the intra-technique combination of these solutions.

The first step is based on the processing of weekly batches of SLR data taken on a number of satellites simultaneously. Preferably, this is done on the basis of observations on LAGEOS-1, LAGEOS-2, Etalon-1 and Etalon-2; a number of analysis groups restricts themselves to the LAGEOS pair only. The observations are taken by the global network of stations and collected by two data centers (CDDIS and EDC). These observations are typically available within a few hours after the actual data-taking. The ILRS analysis centers that take part in this activity retrieve the data after about a day, and do their processing on the second day after the data-taking. This involves the computation of a mixture of satellite-specific parameters (position and velocity at beginning of arc, force-scaling parameters etcetera) and parameters that are common for all 4 satellites (station coordinates, EOPs). A priori information for the latter is taken from IERS' ITRF2000 (station coordinates) and IERS' Bulletin A (EOPs). The parameter estimation results (for the common parameters only) are written in a SINEX 2.0 format file and submitted to the data centers CDDIS and EDC within two days after the end of the arc.

In the second step of the analysis, these individual solutions are picked up by the combination centers, passed through a number of quality and integrity checks and combined into a single solution. It is this single, weekly solution that will be submitted to IERS within three days after the epoch of the last SLR observations.

Expertise and capabilities to perform the proposed task:

The ILRS Analysis Working Group (AWG) has been in the process of development of an official ILRS product for a number of years. At this moment, a product very similar to the one requested in the Call for Participation (station coordinates, xpole, ypole and LOD estimated, based on SLR data on 4 satellites, with an arc length of 7 days) is in an official testing phase, which began in June 2003. Currently, 4 different analysis groups submit their individual solutions automatically a few

days after the date of the latest SLR observation, and 3 combination centers produce, also in a quasi-operational fashion, the combination products. The ILRS is expected to select one of these combination centers as the center responsible for the official ILRS combination product, whereas the other(s) will serve as back-up (this arrangement may change after a few years). This final selection is expected to take place during an ILRS AWG workshop taking place directly prior to the upcoming EUG meeting in Nice. In the current test phase, two solutions are submitted regularly: one with EOP solutions only (the station coordinates are modeled after ITRF2000), and one which includes both station coordinates and EOPs. The former is foreseen as the official ILRS contribution to the current IERS Bulletin A, whereas the latter will be the ILRS contribution to this IERS Combination Pilot Project. The value of inclusion of other parameters (time-derivatives of x_{pole} and y_{pole} , and UT1-UTC) will be investigated first by the ILRS AWG.

Additional comments (e.g. link to more information etc.):

More information on the ILRS analysis developments can be found on the ILRS webpages

(<http://ilrs.gsfc.nasa.gov>) and in particular on the AWG pages

(http://ilrs.gsfc.nasa.gov/working_groups/awg/index.html).

Part 2: Generation of Combined Weekly Inter-Technique Solutions (Step 2):

List of techniques to be included in the combination (VLBI, GPS, SLR, LLR, DORIS):

Parameter types to be combined:

Additional Parameters set up for the combined solution:

Datum definition strategy:

Weighting method applied:

Short description of combination procedure:

Expertise and capabilities to perform the proposed task:

Additional comments (e.g. link to more information etc.):

Part 3: Validation of Combined Weekly Inter-Technique Solutions (Step 3):

Parameter types to be validated (site coordinates, polar motion, UT1/LOD, nutation, quasar coordinates):

Short description of validation approach:

Expertise and capabilities to perform the proposed task:

Additional comments (e.g. link to more information etc.):

Part 4: Generation of Special Combined Inter-Technique Products:

Techniques included in the combination (GPS, VLBI, SLR, LLR, DORIS):

Parameter type(s) to be combined:

Special product to be delivered:

Short description of combination approach:

Expertise and capabilities to perform the proposed task:

Additional comments (e.g. link to more information etc.):

Place and date:
Delft, February 20, 2004

Name and position of responsible person:
R. Noomen

Signature of the responsible person:

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Participating Organization/Institution/Service:

School of Civil Engineering and Geosciences, University of Newcastle upon Tyne (NCL), UK

Name (primary scientist or person of contact):

Dr. K. Nurutdinov

Organization/institute/service:

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Cooperating organizations / institutes:**Staff members that will contribute to the CPP:**

Dr. P.Clarke

Prof. Ph.Moore

Dr. K. Nurutdinov

Contribution to (see Call for Participation):

Part 1: Generation of "Weekly" Intra-Technique SINEX Files (Step 1):	yes
Part 2: Generation of Combined Weekly Inter-Technique Solutions (Step 2):	yes
Part 3: Validation of Combined Weekly Inter-Technique Solutions (Step 3):	yes
Part 4: Generation of Special Combined Inter-Technique Products:	no

Part 1: Generation of „Weekly“ Intra-Technique SINEX Files (Step 1):

Technique (VLBI, GPS, SLR, LLR, DORIS): GPS, SLR.

In the future, solutions for terrestrial parameters from all space techniques will be used in the combination.

Period covered by each single solution (session or week):

week (Sun 0h – Sat 24h).

Parameter types included and their time resolution:

station coordinates at mid-point of weekly interval;

Earth Orientation Parameters (xpole, ypole, LOD) at 1-day intervals, referred to the middle of each daily interval.

Constraints used: minimal constraints (orientation) will be used during combination; the final combined station coordinates constrained to ITRF2000 for SLR, to IGS realisation of ITRF2000 for GPS using full covariance matrix.

Short description of solution:

The contribution will cover the intra-technique combination of network and EOP solutions computed by individual IGS and ILRS analysis centers. It includes:

1. **Downloading** the solutions from CDDIS and EDC data centres.
2. **Validation.** All Sinex files are checked with TANYA for consistency with SINEX 1.0 and 2.0 format requirements (on-line Sinex checker is on <http://ucscgi2.ncl.ac.uk/~nkn3/> web site). Pole tides effects are added to LODR to obtain LOD (for JPL only). No LOD bias correction is made.
3. **Deconstraining.** Apriori covariance matrices are used to deconstrain constrained A-networks and obtain AC loose solutions.
4. **Estimating** the loose combined solution GNET (full covariance matrix used) consists of exclusion of non-global stations and EOP (appearing less than in three AC solutions) , re-scaling of covariance matrices, combining of normal equations for AC loose solutions, augmentation of corresponding covariance matrix to remove Helmert rotation parameter constraints.
5. **Helmert transformation** from AC loose solutions to GNET solution is made to compute post-residuals of station coordinates and EOP in one reference frame.
6. **Outlier removal** is made from the analysis of the post-residuals.
7. **Variance component estimation** - to balance influence of ACs, to calibrate the outlier hypothesis test. Steps 3-4-5-6 are repeated, if necessary.
8. **Product generation and reporting** to CDDIS and IERS. The final solution is constrained to the CORE-network, which is the subset of ITRF-2000 SLR stations in case of SLR solution and the IGS realisation of ITRF-2000 in case of GPS solution. The resulting G-network is written in the SINEX 1.0 or 2.0 file and sent, along with summary file containing Helmert parameters between AC loose, GNET and CORE networks, to CDDIS/IERS within three days for SLR and eleven days for GPS solutions after the end of the arc.

Expertise and capabilities to perform the proposed task:

The Newcastle University serves as IGS Associated Analysis Centre, starting its activity of combining the GPS solutions in November 1995. NCL participates in the ILRS Analysis Working Group (AWG) workshops starting May 2000, takes part in ILRS Pilot Project "Positioning + Earth Orientation" and in the testing phase of development of an official ILRS product. Currently, NCL submits the combined intra-technique GPS and SLR solutions for station positions, pole coordinates and LOD regularly on weekly basis in a quasi-operational fashion.

Additional comments (e.g. link to more information etc.):

More information on the

1) Geomatics activity within School of Civil Engineering and Geosciences could be found

<http://geomatics.ncl.ac.uk>

2) participation of NCL in IGS could be found in IGS Mail and IGS Reports on web site

<http://igs.cb.jpl.nasa.gov/mail/>.

3) participation of NCL in ILRS analysis developments can be found on the ILRS AWG web pages (http://ilrs.gsfc.nasa.gov/working_groups/awg/index.html).

Part 2: Generation of Combined Weekly Inter-Technique Solutions (Step 2):

Techniques to be included in the combination (VLBI, GPS, SLR, LLR, DORIS): GPS, SLR
In the future, solutions for terrestrial parameters from all space techniques will be used in the combination.

Parameter types to be combined: Station coordinates, pole coordinates and LOD

Additional Parameters set up for the combined solution:

Datum definition strategy: Collocation stations will be used to bring GPS and SLR networks into one reference frame.

Weighting method applied: Full covariance matrices will be used in the combination, variance components will be estimated (the contribution of the technique still to be studied) to scale covariance matrices.

Short description of combination procedure: similar to the combination in Part 1.

Expertise and capabilities to perform the proposed task:
See Part 1.

Additional comments (e.g. link to more information etc.):
See Part 1.

Part 3: Validation of Combined Weekly Inter-Technique Solutions (Step 3):

Parameter types to be validated (site coordinates, polar motion, UT1/LOD, nutation, quasar coordinates): station coordinates, polar coordinates, LOD

Short description of validation approach:

Comparison between solutions of different analysis and combination consisting of:

1. **Deconstraining.** Apriori covariance matrices are used to deconstrain constrained solutions and obtain loose ones.
2. **Helmert transformation** from loose solutions to reference solution is made to compute Helmert parameters and post-residuals of station coordinates and EOP in one reference frame.
3. **Repeatability** of Helmert parameters and station coordinates is studied.

Expertise and capabilities to perform the proposed task:

Steps 1-3 are performed routinely for GPS and SLR intra-technique solutions on weekly basis. The comparison procedure for inter-technique combined solutions is similar to that one.

Additional comments (e.g. link to more information etc.):
See Part 1.

Part 4: Generation of Special Combined Inter-Technique Products:

Techniques included in the combination (GPS, VLBI, SLR, LLR, DORIS): none

Parameter type(s) to be combined: none

Special product to be delivered: none

Short description of combination approach: N/A

Expertise and capabilities to perform the proposed task: N/A

Additional comments (e.g. link to more information etc.): N/A

Place and date:

Newcastle upon Tyne, UK

20 February 2004

Name and position of responsible person:

Dr. P.J.Clarke, Lecturer
School of Civil Engineering & Gesciences
University of Newcastle

Signature of the responsible person:

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Deadline for proposals: **February 22, 2004**

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IERS Central Bureau
Bundesamt fuer Kartographie und Geodaesie
Richard-Strauss-Allee 11
60598 Frankfurt am Main
Germany
fax: ++49-69-6333-425
email: central_bureau@iers.org

and a copy to:

Markus Rothacher
IERS Analysis Coordinator
Forschungseinrichtung Satellitengeodaesie
Technische Universitaet Muenchen
Arcisstr. 21
80333 Muenchen
Germany
fax: ++49-89-289-23178
email: Markus.Rothacher@bv.tum.de

Participating Organization/Institution/Service:

Name (primary scientist or person of contact): Richard S. Gross

Organization/institute/service: Jet Propulsion Laboratory

Mailing address: Mail Stop 238-332
4800 Oak Grove Drive
Pasadena, CA 91109, USA

Phone: +1 818-354-4010

Fax: +1 818-393-6890

Email: Richard.Gross@jpl.nasa.gov

Cooperating organizations / institutes: To be determined

Staff members that will contribute to the CPP: To be determined

Contribution to (see Call for Participation):

Part 1: Generation of "Weekly" Intra-Technique SINEX Files (Step 1):	yes/no
Part 2: Generation of Combined Weekly Inter-Technique Solutions (Step 2):	yes/no
Part 3: Validation of Combined Weekly Inter-Technique Solutions (Step 3):	<u>yes</u> /no
Part 4: Generation of Special Combined Inter-Technique Products:	yes/no

Part 1: Generation of „Weekly“ Intra-Technique SINEX Files (Step 1):

Technique (VLBI, GPS, SLR, LLR, DORIS; Combination on the observation level: list of techniques included in the combination):

Period covered by each single solution (session or week):

Parameter types included and their time resolution:

Constraints used:

Short description of solution:

Expertise and capabilities to perform the proposed task:

Additional comments (e.g. link to more information etc.):

Part 2: Generation of Combined Weekly Inter-Technique Solutions (Step 2):

List of techniques to be included in the combination (VLBI, GPS, SLR, LLR, DORIS):

Parameter types to be combined:

Additional Parameters set up for the combined solution:

Datum definition strategy:

Weighting method applied:

Short description of combination procedure:

Expertise and capabilities to perform the proposed task:

Additional comments (e.g. link to more information etc.):

Part 3: Validation of Combined Weekly Inter-Technique Solutions (Step 3):

Parameter types to be validated (site coordinates, polar motion, UT1/LOD, nutation, quasar coordinates): polar motion, UT1/LOD

Short description of validation approach: By comparison to atmospheric and oceanic angular momentum series

Expertise and capabilities to perform the proposed task: I have extensive experience intercomparing Earth orientation series and comparing them to atmospheric and oceanic angular momentum series.

Additional comments (e.g. link to more information etc.):

Part 4: Generation of Special Combined Inter-Technique Products:

Techniques included in the combination (GPS, VLBI, SLR, LLR, DORIS):

Parameter type(s) to be combined:

Special product to be delivered:

Short description of combination approach:

Expertise and capabilities to perform the proposed task:

Additional comments (e.g. link to more information etc.):

Place and date:

Name and position of responsible person:

Richard S. Gross
Principal Member of Technical Staff
Jet Propulsion Laboratory

Signature of the responsible person:

Proposal for Participation

in the

IERS Combination Pilot Project

SUBMITTED TO:

IERS Central Bureau
Bundesamt fuer Kartographie und Geodaesie
Richard-Strauss-Allee 11
60598 Frankfurt am Main
Germany

cc: Markus Rothacher
IERS Analysis Coordinator
Forschungseinrichtung Satellitengeodaesie
Technische Universitaet Muenchen
Arcisstr. 21
80333 Muenchen
Germany

Participating Organization/Institution/Service: JCET/UMBC - NASA/GSFC

Name (primary scientist or person of contact): Prof. Erricos C. Pavlis

Organization/institute/service: Joint Center for Earth Systems Technology
NASA Goddard ILRS Analysis Center

Mailing address: 1000 Hilltop Circle
Baltimore, Maryland, USA 21250

Phone: +1 410 455 5832
Fax: +1 410 455 5868
Email: epavlis@JCET.umbc.edu

Cooperating organizations / institutes: Space Geodesy Branch
NASA Goddard,
Code 926
Greenbelt, Maryland, USA 20771

Staff members that will contribute to the CPP: Erricos C. Pavlis
Glynn Hulley
Keith Evans
James Kelley

Contribution to:

Part 1: Generation of "Weekly" Intra-Technique SINEX Files (Step 1):	yes
Part 2: Generation of Combined Weekly Inter-Technique Solutions (Step 2):	by summer 2004
Part 3: Validation of Combined Weekly Inter-Technique Solutions (Step 3):	by summer 2004
Part 4: Generation of Special Combined Inter-Technique Products:	by end of 2004

Part 1: Generation of „Weekly“ Intra-Technique SINEX Files (Step 1):

Technique (VLBI, GPS, SLR, LLR, DORIS; Combination on the observation level: list of techniques included in the combination):

SLR

Period covered by each single solution (session or week):

WEEK

Parameter types included and their time resolution:

Site positions (**WEEKLY**)
(x, y)_{POLE}, LOD (**DAILY**)

Constraints used:

Loose Constraints

Short description of solution:

Sunday 00 UTC to
Saturday 00 UTC LAGEOS 1&2
and ETALON 1&2 SLR data
in combined reduction with
GEODYN II, following IERS
Conventions 2000.

Expertise and capabilities to perform the proposed task:

Our group has been always in
a leader's position in the analysis
of SLR data and we are active
participants in the IERS and
ILRS Pilot project for Coordinate,
CoM, and EOP series.

Additional comments (e.g. link to more information etc.):

We have been recently awarded
a NASA project to deliver a state-
of-the-art Reference Frame for
Mean Sea Level studies. Our
contribution to this CPP will be
funded through this project which
has been secured for the next
three years.

Part 2: Generation of Combined Weekly Inter-Technique Solutions (Step 2):

List of techniques to be included in the combination:

SLR & LEO GPS

Parameter types to be combined:

Site positions and EOP

Additional Parameters set up for the combined solution:

None at present

Datum definition strategy:

Loose constraints only

Weighting method applied:

Optimal weighting (VCA)

Short description of combination procedure:

Combined analysis of
GPS and SLR data taken
on LEO targets and the
result combined with our
LAGEOS+ETALON
normal equations.

Expertise and capabilities to perform the proposed task:

We applied successfully
this type of analysis
and data combination in
our development of the
EGM96 gravity model.

Part 3: Validation of Combined Weekly Inter-Technique Solutions (Step 3):

Parameter types to be validated:

Site coordinates, polar motion, & LOD

Short description of validation approach:

Products will be validated during our own product validation process, using tests which will utilize these products in precision orbit determination, coordinate comparisons and spectral analysis of EOP with simultaneous comparisons to independent series and geophysics implied signals, for noise level characterization.

Expertise and capabilities to perform the proposed task: See Parts 1 & 2

Additional comments (e.g. link to more information etc.):

Part 4: Generation of Special Combined Inter-Technique Products:

Techniques included in the combination:

GPS, SLR, DORIS

Parameter type(s) to be combined:

Site coordinates, EOP and Orbits

Special product to be delivered:

Site coordinates, EOP and Orbits

Short description of combination approach:

As in Part 2

Expertise and capabilities to perform the proposed task: See Parts 1 & 2

Additional comments (e.g. link to more information etc.):

Place and date: Baltimore, February 18, 2004

Name and position of responsible person: Erricos C. Pavlis

Signature of the responsible person:



Call for Participation Form

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Technische Universitaet Muenchen
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80333 Muenchen
Germany
fax: ++49-89-289-23178
email: Markus.Rothacher@bv.tum.de

Participating Organization/Institution/Service:

Name (primary scientist or person of contact):
Thomas Johnson

Organization/institute/service: Earth Orientation Department/US Naval Observatory

Mailing address: 3540 Massachusetts Avenue NW, Washington, DC 20392-5420, USA

Phone: (202) 762-1518
Fax: (202) 762-1563
Email: johnson.thomas@usno.navy.mil
Cooperating organizations / institutes:

Staff members that will contribute to the CPP:
Merri Sue Carter, Arvid Myers, Peter Kammeyer, Dennis McCarthy, and William Wooden
We will also use summer interns to assist in data analysis.

Contribution to (see Call for Participation):

Part 1: Generation of "Weekly" Intra-Technique SINEX Files (Step 1):	no
Part 2: Generation of Combined Weekly Inter-Technique Solutions (Step 2):	yes
Part 3: Validation of Combined Weekly Inter-Technique Solutions (Step 3):	yes
Part 4: Generation of Special Combined Inter-Technique Products:	yes

Part 1: Generation of „Weekly“ Intra-Technique SINEX Files (Step 1):

Technique (VLBI, GPS, SLR, LLR, DORIS; Combination on the observation level: list of techniques included in the combination):

Period covered by each single solution (session or week):

Parameter types included and their time resolution:

Constraints used:

Short description of solution:

Expertise and capabilities to perform the proposed task:

Additional comments (e.g. link to more information etc.):

Part 2: Generation of Combined Weekly Inter-Technique Solutions (Step 2):

List of techniques to be included in the combination (VLBI, GPS, SLR, LLR, DORIS):

The combination will examine the use of VLBI, GPS, SLR, LLR, and DORIS.

Parameter types to be combined:

The production of Earth rotation parameters (polar motion, UT1-UTC, and nutation).

Additional Parameters set up for the combined solution:

The additional parameters used in this combination will include: an USNO generated GPS UT1-like quantity, atmospheric angular momentum, and GPS calibration.

Datum definition strategy:

The resulting EOP time series will be aligned with the current C04 EOP time series, which is defined with respect to the current ITRF.

Weighting method applied:

Initially, the weights will be generated using the operational production method for Bulletin A EOP solutions. Currently, the analysis centers of different techniques (GPS, VLBI, and SLR) submit their EOP solutions to USNO with their estimates of formal errors. IERS Rapid Service/Prediction Centre continuously monitors the accuracies of data contributed, tracking changes in bias, rate, and standard deviation of residuals with respect to Bulletin A and C04 as well as the reported formal errors. These rates and biases are then removed. The time series from these different centers are then weighted. Weights in the algorithm may be either a priori values estimated by the standard deviation of the residual of the techniques or values based on the internal precision reported by contributors or by a combination of both. Following this initial approach, we will examine how the method can be improved to make it a more rigorous combination.

Short description of combination procedure:

The study will use the approach currently applied in the operational production IERS Rapid Service/Prediction Centre of Bulletin A EOP solutions. This algorithm is based on a weighted cubic spline with adjustable smoothing fit to the contributed observational data (McCarthy & Luzum, 1991). Contributed data are corrected for possible systematic differences. Biases and rates are determined with respect to the C04 system of the IERS Earth Orientation Centre (EOC). Statistical weighting used in the spline is proportional to the inverse square of the estimated accuracy of the individual techniques and for VLBI and GPS the weight also takes into account the formal errors of each data point. If necessary, minimal smoothing is applied, consistent with the estimated accuracy of the observational data. The center will also examine the modification of its current approach to make it a rigorous combination approach.

Expertise and capabilities to perform the proposed task:

USNO is currently the IERS Rapid Service/Prediction Center and the combined experience of USNO's staff totals over 80 years in the production of Earth orientation parameters. We routinely combine the currently available IGS GPS solutions, VLBI analysis center solutions, IVS VLBI combination solution and SLR analysis center solutions to produce the IERS Bulletin A daily and weekly solutions.

Additional comments (e.g. link to more information etc.):

McCarthy, D.D. and Luzum, B.J., 1991a, Combination of Precise Observations of the Orientation of the Earth, *Bulletin Geodesique*, **65**, 22.

Also see Bulletin A information and documentation on the internet at <http://maia.usno.navy.mil/>.

Part 3: Validation of Combined Weekly Inter-Technique Solutions (Step 3):

Parameter types to be validated (site coordinates, polar motion, UT1/LOD, nutation, quasar coordinates):

We will validate polar motion, UT1/LOD, and nutation parameters.

Short description of validation approach:

The validation will compare the combined weekly inter-technique solutions (from GPS, VLBI, SLR, LLR, and DORIS) to IERS's Bulletin A (rapids), Bulletin B (finals), and C04 time series. These comparisons will allow us to establish the performance of each of these series to all of the currently available IERS EOP combination products. We will also compare the combination solution to EOP time series estimated from geophysical fluids and any improved EOP combination method that may result from our participation in part 2 of this pilot project. Comparisons of the combined solution to the solutions from different techniques will also be made. In addition to simply examining the bias, rate, and distribution of the residuals, we will examine the correlation, coherence, and power spectrum of the different technique solutions.

Expertise and capabilities to perform the proposed task:

USNO is currently the IERS Rapid Service/Prediction Center and the combined experience of USNO's staff totals over 80 years in the production of Earth orientation parameters. We routinely compare the currently available IGS GPS solutions, VLBI analysis center solutions, IVS VLBI combination solution, and SLR analysis center solutions to IERS Bulletin A and C04 EOP solutions.

Additional comments (e.g. link to more information etc.):

Our most recent comparison of different techniques to the IERS Bulletin A solution can be found at <http://maia.usno.navy.mil/plots.html>.

Part 4: Generation of Special Combined Inter-Technique Products:

Techniques included in the combination (GPS, VLBI, SLR, LLR, DORIS):

We will examine the following techniques: GPS, VLBI, SLR, and DORIS (if part 1 participants can reduce the formal errors of DORIS below current levels).

Parameter type(s) to be combined:

We will combine the different techniques to produce polar motion (both x and y) and UT1-UTC, and nutation corrections.

Special product to be delivered:

The production of sub-daily Earth rotation parameters from the abovementioned techniques will be examined as well as daily nutation corrections from VLBI and GPS, if participants to part 1 of this project produce a GPS nutation time series.

Short description of combination approach:

The study will use the approach currently applied in the operational production of Bulletin A EOP solutions as well as any improvements to the process resulting from part 2 of this pilot project. See part 2 of this participation form for more details.

Expertise and capabilities to perform the proposed task:

USNO is currently the IERS Rapid Service/Prediction Center and the combined experience of USNO's staff totals over 80 years in the production of Earth orientation parameters. We produce a daily EOP solution as the IERS rapid service/prediction center using the currently available IGS GPS solutions, VLBI analysis center solutions, IVS VLBI combination solution, and SLR analysis center solutions.

Additional comments (e.g. link to more information etc.):

For more information on USNO's combination process, its accuracies, and comparisons, see <http://maia.usno.navy.mil>.

Place and date:
Washington, DC
February 19, 2004

Name and position of responsible person:
Dennis McCarthy
Director, Directorate of Time

Signature of the responsible person:

Call for Participation Form for the IERS Combination Pilot Project

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and

Markus Rothacher
IERS Analysis Coordinator
Forschungseinrichtung Satellitengeodäsie
Technische Universität München
Narcisstr. 21
80333 München
Germany
fax: ++49-89-289-23178
email: Markus.Rothacher@bv.tum.de

Participating Organization/Institution/Service:

Name (primary scientist or person of contact): J. Vondrák
Organization/institute/service: Astronomical Institute of Czech Academy of Science,
Combination Research Center (CRC)

Mailing address: 141 31 Praha 4, Boční II 1401
Phone: +420 267103043
Fax:

Email: vondrak@ig.cas.cz

Cooperating organizations / institutes: Czech Technical University, Faculty of Civil
Engineering
Thákurova 7, 166 29 Praha 6

Staff members that will contribute to the CPP: J. Vondrák, A. Čepek, J. Kostecký, I. Pešek

Contribution to (see Call for Participation):

Part 1: Generation of "Weekly" Intra-Technique SINEX Files (Step 1): no
Part 2: Generation of Combined Weekly Inter-Technique Solutions (Step 2): no
Part 3: Validation of Combined Weekly Inter-Technique Solutions (Step 3): no
Part 4: Generation of Special Combined Inter-Technique Products: yes

Part 4: Generation of Special Combined Inter-Technique Products:

Techniques included in the combination (GPS, VLBI, SLR, LLR, DORIS): GPS, VLBI, SLR, DORIS

Parameter type(s) to be combined: EOP and Station coordinates

Special product to be delivered: SINEX files, local ties

Short description of combination approach:

- a) EOP and station coordinates from „non-regular combination“ of results of several techniques based on transformation to the celestial system;
- b) Regular combination of SINEX data based on direct use of covariance matrices

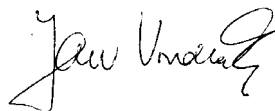
Expertise and capabilities to perform the proposed task: Long term experience with processing astro-geodetic data

Additional comments (e.g. link to more information etc.): <http://www.asu.cas.cz/~ron/ierscrc>

Place and date: Praha, February 26, 2004

Name and position of responsible person: Jan Vondrák, Deputy director, Astronomical Institute

Signature of the responsible person:

A handwritten signature in black ink, appearing to read 'Jan Vondrák', with a stylized, cursive script.

Call for Participation Form

for the

IERS Combination Pilot Project

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Technische Universitaet Muenchen
Arcisstr. 21
80333 Muenchen
Germany
fax: ++49-89-289-23178
email: Markus.Rothacher@bv.tum.de

Participating Organization/Institution/Service:

GRGS

Name of responsible

Michel Kasser, Executive Director of GRGS

Name (primary scientist or person of contact):

*Dr Richard Biancale**

*Dr Daniel Gambis***

Organization/institute/service:

CNES/ GRGS

Mailing addresses:

** CNES*

18 avenue Edouard 31401 Toulouse Cedex 09 , France

Tel : +33 (0)5 61 33 29 78

Fax: +33 (0)5 61 25 30 98

richard.biancale@cnes.fr

*** Observatoire de Paris*

61 Avenue de l'Observatoire

75014 Paris, France

Tel : +33 (0)1 40 51 22 29

*Fax: +33 (0) 1 40 51 22 91
daniel.gambis@obspm.fr*

Cooperating organizations / institutes:

CLS

CNES

Noveltis

Observatoire Côte d'azur

Observatoire de Paris

Observatoire de Bordeaux

IGN

Staff members that will contribute to the CPP:

CNES

Georges Balmino

Dr Richard Biancale

Jean-Michel Lemoine

Noveltis

Sylvain Loyer

CLS

Laurent Soudarin

Observatoire Côte d'azur

David Coulot

Pierre Exertier

Observatoire de Paris

Nicole Capitaine

Anne-Marie Gontier

Daniel Gambis

Gérard Francou

Olivier Becker

Christian Bizouard

Patrick Sillard

Observatoire de Bordeaux

Patrick Charlot

IGN

Zuheir Altamimi

Contribution to (see Call for Participation):

Part 1: Generation of "Weekly" Intra-Technique SINEX Files (Step 1):	no
Part 2: Generation of Combined Weekly Inter-Technique Solutions (Step 2):	no
Part 3: Validation of Combined Weekly Inter-Technique Solutions (Step 3):	no
Part 4: Generation of Special Combined Inter-Technique Products:	yes

Part 1: Generation of „Weekly“ Intra-Technique SINEX Files (Step 1):

Technique (VLBI, GPS, SLR, LLR, DORIS; Combination on the observation level: list of techniques included in the combination):

Period covered by each single solution (session or week):

Parameter types included and their time resolution:

Constraints used:

Short description of solution:

Expertise and capabilities to perform the proposed task:

Additional comments (e.g. link to more information etc.):

Part 2: Generation of Combined Weekly Inter-Technique Solutions (Step 2):

List of techniques to be included in the combination (VLBI, GPS, SLR, LLR, DORIS):

Parameter types to be combined:

Additional Parameters set up for the combined solution:

Datum definition strategy:

Weighting method applied:

Short description of combination procedure:

Expertise and capabilities to perform the proposed task:

Additional comments (e.g. link to more information etc.):

Part 3: Validation of Combined Weekly Inter-Technique Solutions (Step 3):

Parameter types to be validated (site coordinates, polar motion, UT1/LOD, nutation, quasar coordinates):

Short description of validation approach:

Expertise and capabilities to perform the proposed task:

Additional comments (e.g. link to more information etc.):

Part 4: Generation of Special Combined Inter-Technique Products:

Techniques included in the combination

GPS, VLBI, SLR, LLR, DORIS

Parameter type(s) to be combined:

EOPs, TRF, CRF?

Special product to be delivered:

Short description of combination approach:

We propose to study the rigorous combination of five techniques (SLR, LLR, VLBI, GPS and DORIS) in order to obtain a global and homogeneous solution of the Earth Orientation Parameters (EOPs) : universal time UT1, pole motion, nutation corrections as well as station coordinates and radio-sources coordinates. The adopted strategy consists in

*Firstly, to process observations of the different techniques using the GINS software
Secondly to stack normal equations previously obtained using DYNAMO software*

The optimal relative weights between each technique are obtained using the Helmert's optimal variance-covariance method. The obvious main interest of the approach is the homogeneity reached using the same software in the same computational environment for all techniques. Moreover, all correlations will be automatically taken into account between the different techniques, allowing in particular to solve for EOPs and terrestrial parameters simultaneously and possibly the celestial frame.

Expertise and capabilities to perform the proposed task:

In the frame of GRGS, the GINS/DYNAMO software package has been developed since 1962. It has first been used for orbitography studies including Doppler and Laser ranging satellite tracking, DORIS, GPS and more recently it is been extended to LLR and VLBI analyses.

Philippe Yaya in 2002 defended his Phd thesis on the global combination of the various astro-geodetic techniques using this package. He showed the interest of the method. However to reach the highest level of accuracy, it was previously necessary to ensure the best possible processing for all individual techniques in particular for GPS and VLBI which mainly contribute to terrestrial reference frame and EOPs. At present the various teams are involved in a program with the objective of analysing data over 2002 in order to demonstrate the pertinence of the method and our operational capability to do it.

Within an internal GRGS pilot campaign in 2002, we are currently testing in an extensive way. The organization of the processing of the work will be ensured by the various following components under the responsibility of:

GPS : Sylvain Loyer, Noveltis

VLBI : possibly Patrick Charlot (Observatoire de Bordeaux)

SLR : Pierre Exertier, David Coulot, Observatoire de la Côte d'azur,

LLR : Gérard Francou, Observatoire de Paris

DORIS: Laurent Soudarin, CLS

Additional comments (e.g. link to more information etc.):

Since the development of the various techniques implies the involvement of different institutes (CNES, CLS, Observatoires de Paris et Bordeaux et de la Côte d'azur), we are not presently completely ready to fulfil the constraints concerning the schedule of product submissions, we expect to be fully operational during the period of the pilot project.

Place and date:

Paris 26 February 2004

Name and position of responsible persons:

Richard Biancale

Daniel Gambis

Signature of the responsible person:

Michel Kasser

Executive Director of GRGS

A handwritten signature in blue ink, appearing to read "M. Ham", is positioned below the title. The signature is written in a cursive style with a horizontal line at the end.

Proposal for the IERS Combination Pilot Project

Participating Organization/Institution/Service:

Name (primary scientist or person of contact): Jean-François Crétaux

Organization/institute/service: LEGOS/CLS
IDS Analysis Center

Mailing address: CNES/LEGOS
18 Av. Edouard Belin
31401 Toulouse Cedex 4, France

Phone: +33 (0) 1 61 33 29 89
Fax: +33 (0) 1 61 25 32 05
Email: cretaux@cnes.fr

Cooperating organizations / institutes: Collecte Localisation Satellites (CLS)

Staff members that will contribute to the CPP:

CNES/LEGOS:	Jean-François Crétaux
CLS:	Laurent Soudarin

Contribution to (see Call for Participation):

Part 1: Generation of "Weekly" Intra-Technique SINEX Files (Step 1):	yes
Part 2 - Part 4:	no

Part 1: Generation of „Weekly“ Intra-Technique SINEX Files (Step 1):

Technique: DORIS

Period covered by each single solution (session or week): week

Parameter types included and their time resolution: weekly station coordinates
daily x- and y-pole

Constraints used: ITRF2000 (minimum constraints)

Short description of solution: Series of unconstrained solutions (Sinex)

Expertise and capabilities to perform the proposed task: DORIS data Analysis Center for IERS (since 1994) and IDS (since 1999)

Additional comments (e.g. link to more information etc.): We plan to provide solutions directly for the CPP and to the IDS Analysis Coordinator for the intra-technique combination.

Place and date: Toulouse 27 February 2004	Name and position of responsible person: Jean-François Crétaux LEGOS/CLS Analysis Center for IDS
---	--

Signature of the responsible person:

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IERS Combination Pilot Project

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fax: ++49-89-289-23178
email: Markus.Rothacher@bv.tum.de

Participating Organization/Institution/Service:

International GPS Service

Name (primary scientist or person of contact):
Remi Ferland

Organization/institute/service:
Natural Resources Canada

Mailing address:
456 - 615 Booth Street
Ottawa, Ontario, Canada

Phone: (613) 995 - 4002
Fax: (613) 995 - 3215
Email: rferland@nrcan.gc.ca
Cooperating organizations / institutes:

Staff members that will contribute to the CPP:

Contribution to (see Call for Participation):

Part 1: Generation of "Weekly" Intra-Technique SINEX Files (Step 1):	yes
Part 2: Generation of Combined Weekly Inter-Technique Solutions (Step 2):	no
Part 3: Validation of Combined Weekly Inter-Technique Solutions (Step 3):	no
Part 4: Generation of Special Combined Inter-Technique Products:	no

Part 1: Generation of „Weekly“ Intra-Technique SINEX Files (Step 1):

Technique (VLBI, GPS, SLR, LLR, DORIS; Combination on the observation level: list of techniques included in the combination):
GPS

Period covered by each single solution (session or week):
Since 99/02/28

Parameter types included and their time resolution:
Weekly station coordinates and daily pole positions/rates and LOD

Constraints used:
Inner constraints

Short description of solution:
The weekly solutions are combinations of the weekly Analysis Centers (cod, emr, esa, gfz, jpl, ngs, sio) solution. All the available variance/covariance information is used.

Expertise and capabilities to perform the proposed task:
The proposed participation is already operational.

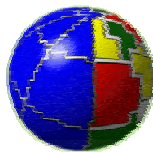
Additional comments (e.g. link to more information etc.):
See weekly summary files for more details.

This commitment is conditional to Natural Resources Canada priorities and to available resources.

Place and date:
11 March 2004

Name and position of responsible person:
Remi Ferland Chair of IGS Reference Frame Working Group
Gerd Gendt IGS Analysis Coordinator

Signature of the responsible person:
Remi Ferland
Gerd Gendt



Istituto Nazionale di
Geofisica e Vulcanologia

PROPOSAL

in response to the
Call for Participation

for the
IERS Combination Pilot Project

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Contribution to:

Part 2: Generation of Combined Weekly Inter-Technique Solutions (Step 2):

List of techniques to be included in the combination (VLBI, GPS, SLR, LLR, DORIS):

VLBI, GPS, SLR, DORIS

We will consider the combination of LLR solutions as soon as the previous four techniques combination has become operational and the LLR and DORIS solutions has proven to be homogeneous in terms of parameter's accuracy.

Parameter types to be combined:

Coordinates, EOP and EOP rates, Quasar coordinates

Additional Parameters set up for the combined solution:

Site eccentricities

We will consider the combination of additional parameters (geocenter, etc.) as soon as the standard combination has become operational.

Datum definition strategy:

Loosely constrained solution (e.g. 1m equivalent constraint to all apriori parameters).

Weighting method applied:

Chi square based criterion to balance the contributing solutions

Short description of combination procedure:

The combination process will consider as input all the technique specific solutions (coordinate & EOP estimates and full covariance matrix) with a loosely defined reference frame (1 m level a priori constraints). The solution's covariance matrices should not have rank deficiencies nor weakly resolved parameters such that the inversion of the matrix is possible. After eventually unconstraining the given covariance, all the contributing solutions are combined using a least squares approach without estimating and removing relative rotations and/or translation between the solutions themselves. The solution's covariance matrices will be weighted according to a chi-squared criteria and outliers will be edited using the [Baarda 1968] methodology. The combined solution will be a loosely constraint solution (unknown reference frame), which can be transformed to any external datum (e.g. ITRF2000).

Expertise and capabilities to perform the proposed task:

ASI-CGS has recently developed a combination procedure to merge weekly SLR solutions within the ILRS "Position+EOP" Pilot Project. The service is now running regularly since mid 2003. During the CRC "SINEX Combination Campaign" the loose combination approach has been generalized to an inter-technique test case, including GPS, SLR, VLBI and DORIS solutions [Devoti et al. 2003].

POLIMI is active in theoretical aspects of geodetic and geophysic sciences; it has developed and currently hosts the IAG International Geoid Service (IGeS)

INGV is cooperating with POLIMI since many years in the IGeS framework, and in the field of geodetic and geophysic sciences.

Additional comments (e.g. link to more information etc.):

See attached technical note.

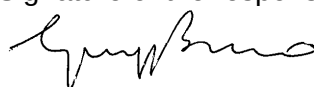
Place and date:

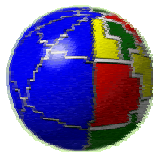
Matera, March 12th, 2004

Name and position of responsible person:

Dr. Giuseppe Bianco

Signature of the responsible person:





Istituto Nazionale di
Geofisica e Vulcanologia

APPENDIX A

Technical Note for the IERS Combination Pilot Project

1	PURPOSE OF THE DOCUMENT	5
2	APPLICABLE AND REFERENCE DOCUMENTS.....	5
3	DEFINITIONS, ACRONYMS AND ABBREVIATIONS.....	5
4	BACKGROUND.....	6
5	PROPOSED ACTIVITIES	6
5.1	PROCESSING STRATEGY	7
5.1.1	Input Data retrieval.....	7
5.1.2	Pre-processing	7
5.1.3	Analysis strategy & models	8
5.1.4	Quality control & Reporting	9
5.1.5	Proposed activity timeline.....	9
6	RESOURCES.....	9
6.1	STAFF.....	9
6.2	HARDWARE & SOFTWARE	ERRORE. IL SEGNALE NON È DEFINITO.
7	FINANCIAL ARRANGEMENTS	10
8	REFERENCES AND SELECTED PUBLICATIONS.....	11
9	CITED REFERENCES.....	12

1 PURPOSE OF THE DOCUMENT

This document outlines the processing model for the simultaneous combination of Earth Orientation Parameters (EOP) and Station Coordinates (SSC) of different inter-technique geodetic solutions. The proposed activity has been stimulated by the call for proposals issued by the IERS-Working Group on Combination: “IERS combination pilot project” [A-1].

2 APPLICABLE AND REFERENCE DOCUMENTS

[A-1] Call for Participation for the “IERS Combination Pilot Project”, IERS Message No. 53, January 22, 2004.

3 DEFINITIONS, ACRONYMS AND ABBREVIATIONS

AAC	Associated Analysis Center
ASI	Agenzia Spaziale Italiana
API	ASI-PoliMi-INGV Consortium
CGS	Centro di Geodesia Spaziale
CRC	Combination Research Center
EOP	Earth Orientation Parameters
EUREF	European Reference Frame
GPS	Global Positioning System
IGS	International GPS Service
IERS	International Earth Rotation Service
ILRS	International Laser Ranging Service
INGV	Istituto Nazionale di Geofisica e Vulcanologia
ITRF	International Terrestrial Reference Frame
IVS	International VLBI Service
MLRO	Matera Laser Ranging Observatory
OC	Operating Center
POLIMI	Politecnico di Milano
RMS	Root Mean Square
RSC	Radio Source Coordinate
SINEX	Solution Independent Exchange
SLR	Satellite Laser Ranging
SSC	Solution Site Coordinates
VLBI	Very Long Baseline Interferometry

BACKGROUND

The Space Geodesy Center of the “Agenzia Spaziale Italiana” (ASI) in Matera, the “Politecnico di Milano” (POLIMI) in Milano, the “Istituto Nazionale di Geofisica e Vulcanologia” (INGV) in Roma and Telespazio SpA (TSPZ), altogether agreed to develop and realize the regular combination of weekly inter-technique geodetic solutions. This agreement foresees a joint effort between the three research institutes (ASI-POLIMI-INGV) and the private company (TSPZ) to design, to implement and to maintain the procedures for the rigorous combination of geodetic solutions. As a consequence an open group of researchers has been formed to study different methods of rigorous combination, and that will be responsible to operate the weekly combination process. The combination process will be operated at the Space Geodesy Center, Matera (CGS), which becomes the seat of the joint ASI-POLIMI-INGV-TSPZ (API) Combination Center.

The ASI-CGS is already participating to different activities promoted by the IERS, as AAC, OC and Combination Center of the ILRS, as EUREF Local Analysis Center, and as contributor to a number of pilot projects, furthermore it is member of the Combination Research Center (CRC) of the IERS.

POLIMI hosts and manage the International Geoid Service (IGeS) and promotes regularly international lectures and symposiums on Geodesy and Geophysics subjects.

INGV is setting up a permanent GPS network in Italy and is responsible for the monitoring of the seismic and volcanic hazard in Italy. It is cooperating with POLIMI since many years in the IGeS framework, and in the field of geodetic and geophysics sciences.

Telespazio SpA has been operating the ASI-CGS since 1983, including the geodetic systems maintenance, data acquisition and archiving, data analysis, under ASI supervision. These activities are enhanced by the company profile, featured by value-added activities in the frame of Earth Observation, with national and international projects/programs managed by a dedicated Business Unit.

4 Proposed activities

The “loose” approach foresees the combination of loosely constrained solutions without estimating and removing any relative rotation, translation nor scale between their respective reference frames. This approach has been already introduced in the framework of the IGS activities by Heflin et al., 1992; Blewitt, 1998; Davies and Blewitt, 2000.

Within the ILRS “Position+EOP” Pilot Project, the ASI-CGS has recently developed a combination procedure to merge SLR input solutions into a consistent combined product; the

combination strategy foresees the simultaneous combination of coordinates and EOPs without estimating and removing relative rigid transformations between reference frames and is based on the assumption that solution's reference frames have large uncertainties (loosely constrained solutions), on the order of a few meters on the surface of Earth.

During the CRC "SINEX Combination Campaign" the loose combination approach has been generalized to an inter-technique test case, combining site coordinates, EOP, EOP rates of GPS, SLR, VLBI and DORIS solutions and including ITRF2000 local ties to connect site domes of different techniques [Devoti et al. 2003].

The API joint research group proposes to develop a fully automated SW procedure to combine inter-technique weekly solutions, based on the loose combination methodology. The API partners will support and promote research activities related to the rigorous combination of geodetic solutions and will also study and develop alternative combination strategies and algorithms.

4.1 Processing strategy

Each input SINEX file is checked against format and consistency, all the non-minimal constraints stated in the *a priori* covariance matrix will be removed and the solution covariance matrix will be augmented such that the errors associated to Helmert parameters become large and homogeneous between each other's. The combined product will be estimated in a least square sense by iteratively fitting the input solutions to a best fit combined solution. Each solution covariance matrix will be multiplied, at each iteration step, by a scaling factor that will balance the inhomogeneous contributions to the individual chi-squares.

4.1.1 Input Data retrieval

The input data of the whole process are the SINEX files containing the contributing solutions. We assume that the SINEX files contain at least the estimated parameters, the full estimated covariance matrix (upper or lower part), the full *a priori* covariance matrix (upper or lower part) written in SINEX ver 2.0 (or ver. 1.0) format. In alternative to the covariance matrices, also the normal equations will be accepted if provided as foreseen by the SINEX v. 2.0 standards. IERS shall define the operational details for the solutions retrieval.

4.1.2 Pre-processing

At this stage the system will move, and eventually uncompress, the incoming files to the processing machine. Each SINEX file will be checked in its content and format, and the degree

of looseness of the covariance will be evaluated. If the covariance matrices are present, then the whole solution will be unconstrained using the well-known equations of information handling in the normal equations:

$$\Sigma_u = \left(\Sigma_{solution}^{-1} - \Sigma_{apriori}^{-1} + (A^T A)^{-1} A^T \Sigma_w^{-1} A (A^T A)^{-1} \right)^{-1}$$

$$X_u = \Sigma_u \Sigma_{solution}^{-1} (X_{solution} - X_{apriori}) + X_{apriori}$$

where Σ_x are the respective covariance matrices, Σ_w is a diagonal matrix chosen in such a way to give a good matrix conditioning, X_x the parameters vector and A the Helmert parameters Jacobi matrix. If the normal equations were provided then it is assumed that the SINEX file contains the reduced normal equation matrix without constraints (i.e. the free original solution).

The second step will check the looseness and eventually augment the given covariance matrix in order to achieve a homogeneous reference frame uncertainty. One of the following equivalent formulations can be used to loosen the covariance matrix [Davies and Blewitt, 2000]

$$\Sigma_{augmented} = \Sigma_u + A^T \Sigma_w A$$

$$\Sigma_{augmented} = \left(\Sigma_u^{-1} - \Sigma_u^{-1} A^T (A \Sigma_u^{-1} A^T + \Sigma_w)^{-1} A \Sigma_u^{-1} \right)^{-1}$$

where Σ_w is the diagonal matrix of the augmented Helmert parameters.

4.1.3 Analysis strategy & models

Denoting with X_i the site and/or Quasar coordinates of the i-th solution and with Y_i the EOPs of the i-th solution at times t_{ij} and being P the time propagation operator, the following equations show the relationship between two different solutions:

$$\begin{pmatrix} X_1 \\ Y_1(t_{1j}) \\ \dot{Y}_1 \end{pmatrix} = P \begin{pmatrix} X_0 \\ Y_0(t_{0j}) \\ \dot{Y}_0 \end{pmatrix} = \begin{pmatrix} \mathbf{I} & 0 & 0 \\ 0 & \mathbf{I} & (t_{1j} - t_{0j}) \mathbf{I} \\ 0 & 0 & \mathbf{I} \end{pmatrix} \begin{pmatrix} X_0 \\ Y_0(t_{0j}) \\ \dot{Y}_0 \end{pmatrix}$$

The current ITRF local ties will be used to connect site domes of the different techniques. The ties will be used to build pseudo-observation equations whose linearized observation equations will be introduced in the normal equations. The combination of the solutions is obtained by solving in a least squares sense the problem design equation.

A scale factor of the covariance matrix of the i-th solution σ_i , is required because the relative scaling may be incorrect. Imposing that each solution contribution to the total a-posteriori variance, evaluated from the residuals R_i , is equally balanced, the relative scaling factors can be obtained.

$$R_1^T (\sigma_1 \Sigma_1)^{-1} R_1 = \dots = R_i^T (\sigma_i \Sigma_i)^{-1} R_i$$

At each iteration step the coordinates/EOP outliers will be edited following the data snooping procedure proposed by *Baarda* [1968].

4.1.4 Quality control & Reporting

The combined product will be checked against ITRF2000 and a number of test statistics will be reported. A full report containing residuals root-mean-square of the input solutions with respect to ITRF2000 and with respect to the combined product, as well as statistical parameters (χ^2 , post-fit rms, biases, etc.) will be available. In addition to the official contribution we maintain all the basic reports and products on the ASI web site (<http://geodaf.mt.asi.it/>) and mirrored on POLIMI and INGV web sites.

4.1.5 Proposed activity timeline

For the proposed activities, two phases are planned:

1. Prototype phase (to be completed by the end of May 2004): the first combination procedure, able to provide an inter-technique weekly solution from the start of the Pilot Project will be set-up taking into account the SSC, EOP and EOPrate parameters from the contributing techniques, including the local system eccentricities as pseudo-observations.
2. Pre-operational phase: additional parameters (RSC, geocenter) will be included in the combination process, refinement of the weighting procedure after exploration of alternative methods. This phase will be gradually completed during the pilot project; preliminary results and the operational scheme will be presented at the IERS Workshop in October 2004.

5 Resources

5.1 Staff

ASI, POLIMI, INGV personnel compose the joint API-team; Telespazio as ASI contractor will also contribute with dedicated personnel.

Dr. Giuseppe Bianco (ASI-CGS, Matera) has the program responsibility for the space geodesy activities at ASI; he is President of the EuroLAS Consortium and member of the Governing Board of the International Laser Ranging Service.

Dr. Francesco Vespe (ASI-CGS, Matera) is an expert of GPS data exploitation.

Prof. Fernando Sansò, full professor at PoliMi, Milano, and actual president of the IAG, is involved in many research programs in the fields of geodesy and geophysics.

Dr. Roberto Devoti, senior researcher at INGV, Roma, since 1990 is involved in global space geodesy research programs.

Dr. Cecilia Sciarretta (Telespazio SpA, Roma, involved since 1988 in space geodesy data analysis, has the technical supervision for the geodetic data analysis at Telespazio SpA.

Dr. Vincenza Luceri (Telespazio SpA), involved since 1990 in SLR data analysis, is official member of the ILRS AWG.

Dr. Roberto Lanotte (Telespazio SpA), involved since 1990 in VLBI data analysis, is official member of the IVS.

Dr. Mauro Pirri (Telespazio SpA), junior analyst involved in geodetic data analysis, he will support the combination process.

Dr. Ludovico Biagi, researcher at PoliMi, Como,

Dr. Federica Riguzzi, senior researcher at INGV, Roma,

Dr. Grazia Pietrantonio, researcher at INGV, Roma,

6 Financial Arrangements

No external funding is required for the proposed activities, which will be fully funded by ASI, POLIMI, INGV and TSPZ as foreseen in the formal agreement.

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- Baarda W., A Testing Procedure for Use in Geodetic Networks, *NGC pub. on Geodesy*, vol.2(5), Netherlands Geodetic Commission, Delft, 1968.

Call for Participation Form

for the

IERS Combination Pilot Project

Deadline for proposals: **February 22, 2004**

Please send the completed form, duly signed, by mail or fax to:

IERS Central Bureau

and a copy to:

IERS Analysis Coordinator

Participating Organization/Institution/Service:

Name (primary scientist or person of contact): Dr. Axel Nothnagel

Organization/institute/service: International VLBI Service for Geodesy and Astrometry

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Cooperating organizations / institutes:

Staff members that will contribute to the CPP: Axel Nothnagel, Markus Vennebusch

Contribution to (see Call for Participation):

Part 1: Generation of "Weekly" Intra-Technique SINEX Files (Step 1):	yes
Part 2: Generation of Combined Weekly Inter-Technique Solutions (Step 2):	no
Part 3: Validation of Combined Weekly Inter-Technique Solutions (Step 3):	no
Part 4: Generation of Special Combined Inter-Technique Products:	no

Part 1: Generation of „Weekly“ Intra-Technique SINEX Files (Step 1):

Technique (VLBI, GPS, SLR, LLR, DORIS; Combination on the observation level: list of techniques included in the combination):

VLBI only

Period covered by each single solution (session or week): one 24-hour session

Parameter types included and their time resolution: station coordinates, xp, yp, UT1-UTC, dpsi, deps, 1 parameter for 24 hours

Constraints used:
none

Short description of solution:

Combination of datum free normal equation matrices reduced to parameters listed above for all IVS VLBI sessions. Product will be datum free normal equation matrices.

Expertise and capabilities to perform the proposed task:

Routine IVS EOP time series combination, investigations in combinations of datum free normal equations

Additional comments (e.g. link to more information etc.):

Place and date:
Bonn, March 16, 2004

Name and position of responsible person:
Dr. Axel Nothnagel, VLBI Group Leader

Signature of the responsible person:

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Please send the completed form, duly signed, by mail or fax to:

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Name (primary scientist or person of contact): Oleg Titov

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Cooperating organizations / institutes:

Staff members that will contribute to the CPP: Oleg Titov, Clement Ogaja

Contribution to (see Call for Participation):

Part 1: Generation of "Weekly" Intra-Technique SINEX Files (Step 1):	yes
Part 2: Generation of Combined Weekly Inter-Technique Solutions (Step 2):	no
Part 3: Validation of Combined Weekly Inter-Technique Solutions (Step 3):	no
Part 4: Generation of Special Combined Inter-Technique Products:	no

Part 1: Generation of „Weekly“ Intra-Technique SINEX Files (Step 1):

Technique (VLBI, GPS, SLR, LLR, DORIS; Combination on the observation level: list of techniques included in the combination): VLBI

Period covered by each single solution (session or week): 24 hour

Parameter types included and their time resolution: EOP, EOP rates, nutation angles, the TRF daily values

Constraints used: NNR, NNT for TRF

Short description of solution: Kalman Filter technique for daily VLBI sessions; ICRF is fixed

Expertise and capabilities to perform the proposed task: The daily EOP values obtained by the way are regularly submitted to the IVS and IERS

Additional comments (e.g. link to more information etc.):

Place and date: 18.03.2004

Name and position of responsible person: Dr. Oleg Titov, Project officer

Signature of the responsible person:

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IERS Central Bureau
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Participating Organization/Institution/Service:

Name (primary scientist or person of contact):

Dr. Chuang Shi

Organization/institute/service:

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Cooperating organizations / institutes:

Staff members that will contribute to the CPP:

Dr. Chuang Shi

Dr. Yibin Yao

Dr. Jia Luo

Jinsong Huang

Rong Zou

Xin Xiang

Contribution to (see Call for Participation):

Part 1: Generation of "Weekly" Intra-Technique SINEX Files (Step 1): no
 Part 2: Generation of Combined Weekly Inter-Technique Solutions (Step 2): yes
 Part 3: Validation of Combined Weekly Inter-Technique Solutions (Step 3): yes
 Part 4: Generation of Special Combined Inter-Technique Products: no

Part 2: Generation of Combined Weekly Inter-Technique Solutions (Step 2):

List of techniques to be included in the combination (VLBI, GPS, SLR, LLR, DORIS): VLBI, GPS, SLR, LLR, DORIS

Parameter types to be combined: Coordinates, polar motion, LOD, nutation, quasar coordinates

Additional Parameters set up for the combined solution: Systematic Parameters between various techniques/ACs/ SINEXs

Datum definition strategy: ITRF2000 core station's coordinates as loose constraints, NNR condition.

Weighting method applied: Reconsider the weighting problem for each AC/solution according the variance component estimate result of techniques/ACs/solutions.

Short description of combination procedure:

- Validation:
 - Checking the SINEX format
 - Naming problems
- Deconstraining
 - Remove the aprior constraints of various techniques/ACs/ solutions
 - Remove the aprior constraints of the combined solutions in intra-technique if necessary
- Local tie validation
 - accuracy analysis and weighting problem
 - Convert into vector observation for the adjustment
- Reconsider the weighting problem for each techniques/AC/solution
- Combination
 - Combine normal equations, include coordinates and EOPs
- Parameterization:
 - Add 7 Helmert transformation parameters for various techniques/ACs/solutions in the combined normal equation, consider the relationship of systematic parameter and the EOP parameters.
- Datum definition
 - Add the global constraints into the combined normal equation
- Solution
 - Residuals check, Outlier detection and processing
 - Statistical information
- Iteration if necessary

Expertise and capabilities to perform the proposed task:

Additional comments (e.g. link to more information etc.):

Part 3: Validation of Combined Weekly Inter-Technique Solutions (Step 3):

Parameter types to be validated (site coordinates, polar motion, UT1/LOD, nutation, quasar coordinates): Coordinates, polar motion, LOD, nutation, quasar coordinates

Short description of validation approach:

- Weighted transformation parameter estimation
- Compare the parameters after transformation
- explanation for the transformation parameters

Expertise and capabilities to perform the proposed task:

Additional comments (e.g. link to more information etc.):

Expertise and capabilities to perform the proposed task:

Additional comments (e.g. link to more information etc.):

Place and date:

Oberpfaffenhofen, 3/29/2004

Name and position of responsible person:

Dr. Chuang Shi

Vice-Director of GPS Engineering Research Center of Wuhan University

Signature of the responsible person:

Chuang Shi

Answer to the Call for Participation Form

for the

IERS Combination Pilot Project

Participating Organization/Institution/Service:

Name (primary scientist or person of contact):

Pascal Willis

Organization/institute/service:

Institut Geographique National

Mailing address:

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Cooperating organizations / institutes:

Jet Propulsion Laboratory

Staff members that will contribute to the CPP:

Contribution to (see Call for Participation):

Generation of weekly DORIS sinex solution in free-network solution
DORIS station positions + EOP + full covariance information

Part 1: Generation of "Weekly" Intra-Technique SINEX Files (Step 1):	no
Part 2: Generation of Combined Weekly Inter-Technique Solutions (Step 2):	no
Part 3: Validation of Combined Weekly Inter-Technique Solutions (Step 3):	no
Part 4: Generation of Special Combined Inter-Technique Products:	no

Part 1: Generation of „Weekly“ Intra-Technique SINEX Files (Step 1):

Technique (VLBI, GPS, SLR, LLR, DORIS; Combination on the observation level: list of techniques included in the combination):

DORIS

Period covered by each single solution (session or week):

week

Parameter types included and their time resolution:

stations positions + EOP

Constraints used:

free-network

Short description of solution:

see complete description at

ftp://cddisa.gsfc.nasa.gov/pub/doris/products/sinex_series/ignwd/ignwd05.snxdsc

some information is also directly available in the SINEX files themselves (stations observations period, Chi2, ...)

software used Gipsy/Oasis from JPL

Expertise and capabilities to perform the proposed task:

Additional comments (e.g. link to more information etc.):

Solutions are put directly at CDDIS data center where IERS should download them.

The present naming convention is the following

ftp://cddisa.gsfc.nasa.gov/pub/doris/products/sinex_series/ignwd/ignYYDDDwd05.snxdsc

YY = year (2 characters)

DDD = day of year of the first day of the considered week (3-characters)

Part 2: Generation of Combined Weekly Inter-Technique Solutions (Step 2):

List of techniques to be included in the combination (VLBI, GPS, SLR, LLR, DORIS):

Parameter types to be combined:

Additional Parameters set up for the combined solution:

Datum definition strategy:

Weighting method applied:

Short description of combination procedure:

Expertise and capabilities to perform the proposed task:

Additional comments (e.g. link to more information etc.):

Part 3: Validation of Combined Weekly Inter-Technique Solutions (Step 3):

Parameter types to be validated (site coordinates, polar motion, UT1/LOD, nutation, quasar coordinates):

Short description of validation approach:

Expertise and capabilities to perform the proposed task:

Additional comments (e.g. link to more information etc.):

Part 4: Generation of Special Combined Inter-Technique Products:

Techniques included in the combination (GPS, VLBI, SLR, LLR, DORIS):

Parameter type(s) to be combined:

Special product to be delivered:

Short description of combination approach:

Expertise and capabilities to perform the proposed task:

Additional comments (e.g. link to more information etc.):

Place and date:

Saint-Mande, le 7 avril

Name and position of responsible person:

Jacques Poulain
Director Technique
Institut Geographique National

Signature of the responsible person: