GPS LEO POD activity at CGS
(SPACE GEODESY CENTRE "G. COLOMBO")

A. Nardi
Telespazio SpA, ASI Space Geodesy Centre, Matera, Italy (e-mail: antonio.nardi@asi.it)
G. Bianco
Agenzia Spaziale Italiana, ASI Space Geodesy Centre, Matera, Italy (e-mail: giuseppe.bianco@asi.it)

Introduction

The ASI-CGS is participating as Associate Analysis Center in the IGS LEO Pilot Project. Participating Centers of the Pilot Project provide POD solution for Low Earth Orbiters (LEOs) carrying spaceborne GPS receivers. The two first IGS Orbit Campaigns have been devoted respectively to CHAMP (2002) and JASON-1 (2003) missions, and overall results and comparison methodology can be found in http://nng.esoc.esa.de/gps/igsleo.html.
ASI has provided POD solutions for both the campaigns. Hereafter, technical details of the dynamic approach adopted, based on the use of the VMSI/MicroCosm and NASA/GEODYN II software, are presented. The highly frequent estimation of empirical parameters to absorb unmodelled dynamic effects, makes the ASI adopted POD strategy an example of reduced dynamic approach.

IGS Orbit Campaigns

	Inclination	Perigee Height	Eccentricity	Campaign data span
CHAMP	87 deg	418 km	0.004422	2001, 140-150 doy
JASON-1	66 deg	1336 km	0.000066	2002, 154-182 doy

GPS Data processing for IGS Orbit Campaigns at CGS

The MicroCosm vs 2002.00 (by Van Martin System, Inc.) software was used for the entire CHAMP data processing. JASON-1 data have been pre-processed by MicroCosm to form the double differences, while the Orbit parameters have been estimated by GEODYN II.

For each campaign, data batches (24 hours for CHAMP, 26 hours for JASON-1) have been analyzed separately; the estimation of clock drift was performed for each receiver using GPS navigation ephemerides and pseudorange data, a preliminary estimation of the carrier phase ambiguites and cycle slip detection and fixing were contemporary carried out.
For each batch, keeping fixed the IGS final orbit, a 'troposphere solution' is produced, with troposphere parameters estimated every 2 hours for each station; then, a 'preliminary Orbit solution', from LEO navigation data is prepared; both the solutions are used to determine the 'final LEO Orbit solution', as depicted in the data processing flow (Fig.1).

A critical feature of the data processing for the 'final LEO Orbit solution' is the estimation strategy for the empirical accelerations. A very frequent estimation of empirical accelerations in along and cross direction has been included in order to compensate dynamic modeling deficiencies for the LEO satellite. This parameterization has permitted to make the estimated Orbit 'follow' the data and to reduce the data residual RMS, but an effective assessment of ASI solution has been obtained only after a wide comparison in the framework of IGS LEO Orbit Campaign by ESOC. In Tab.1 and 2, respectively, the dynamic and measurement a-priori models used for the CHAMP and JASON-1 data processing are reported. In Tab. 3 the estimated parameters relevant to the 'final LEO Orbit solution' phase are listed.

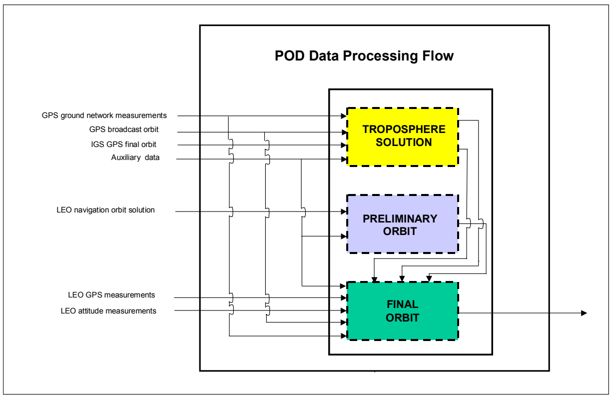

Fig.1

DYNAMIC MODELS	CHAMP	JASON-1
Gravity	TEG4 120 X 120	JGM3 70 X 70
Third Body	JPL DE403	
Solid Earth Tide	EGM 96	
Ocean Tide	EGM 96	
Atmospheric Density Model	Jacchia 1971	MSIS 86
GPS Reference Orbits	Fixed to IGS	

Tab. 2

MEASUREMENTS MODELS	CHAMP & JASON-1
Double-differenced GPS phase observables	Obtained by MicroCosm vs. 2002.00 • Ionosphere-free of L1 and L2 carrier phase • Cut-off: 10 deg. • Sampling rate: 10 sec.
Troposphere	Hopfield Model
Ionosphere	Not modeled
Station Coordinates and Velocities	ITRF 2000
Earth Orientation	IERS EOP C 04
GPS Station Phase Center	IGS_01.PCV
GPS LEO Satellite antenna phase center	Not modeled

Tab. 3

ESTIMATED PARAMETERS	CHAMP	JASON-1
Empirical Force	• Processed using MicroCosm vs 2002.00 • Cd / every ½ orbital period • Along and Cross 1-CPR accelerations / every ½ orbital period	• Processed using GEODYN II vs 0104.00 • Cd / every orbital period • Along and Cross 1-CPR accelerations / every 3 orbital periods

Tab. 4

For each data processing, the SW internal attitude models have been used: 'gravity gradient' for CHAMP in MicroCosm and 'TOPEX' for JASON-1 in GEODYN.

CHAMP satellite has been characterized as a 'cannon ball' model while JASON-1 as a 'box-wing' in order to take into account the more complex shape.

GPS Observables

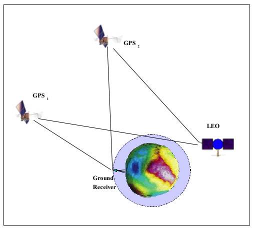

Fig. 2 - Double Differences scheme -

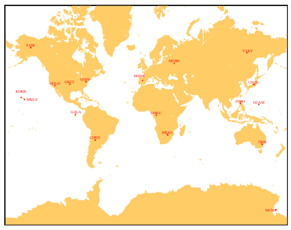

Fig. 3 - GPS ground network -

To generate GPS POD solutions, in order to eliminate/mitigate the LEO satellite clock receiver errors the double difference observables (Fig. 2) have been formed. A network of ground stations (Fig.3) has been chosen according the following criteria:

•High rate acquisition (10 sec) stations;
•Uniform geographical distribution.

The selected stations need to be reliably referenced to ITRF2000; for selected stations with 'weak' ITRF coordinates, a specific coordinates solution was carried out to evaluate them.

CGS CHAMP and JASON-1 POD results

The internal consistency of the produced POD solutions can be provided by several indicators internal to the processing procedure, as the RMS of data residuals, or derived, as the differences of overlapping arc.
Anyway, only an external validation/comparison allows a verification of the POD results, with a realistic estimation of the orbit precision.

The IGS LEO Comparison Campaign has allowed to 'score' the solutions submitted by the various analysis centres, evaluating their precision by crossing the pair-wise orbit errors analysis and the tracking data analysis (SLR for CHAMP, SLR+DORIS for JASON-1) results, as reported in http:// nng.esoc.esa.de/gps/igsleo.html

The **final CGS CHAMP** solution has been evaluated at **13 cm level precision**, while a **preliminary CGS JASON-1 solution**, submitted at the beginning of 2003, has been evaluated at **11 cm precision level**.

Two updated JASON-1 POD solutions have been recently submitted, concerning respectively:
• the removal of some inconsistencies of the transformation from inertial J2000 to ITRF2000 reference system; this update has permitted to remove an anomalous Z rotation of about more than 2 masec with respect to the orbit of the other analysis centers;
• the use of GPS satellites general acceleration estimation parameters along GPS X-axis and GPS Y-axis together with the sine and cosine components (according to the IGS standard) instead of the only Y-bias constant.

Consequently, a better precision level is expected for their evaluation within the IGS LEO Comparison Campaign.

An example of orbit comparison (CHAMP) between ASI and ESOC solutions is reported in Fig. 4.

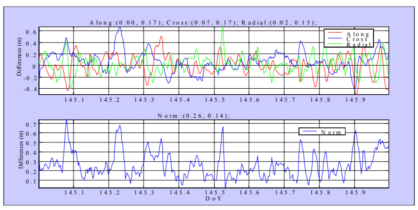

Fig. 4 – CHAMP differences (ASI-ESOC) –

Conclusions

ASI-CGS has been performing several POD analysis activities, within the frame of SLR and GPS geodetic techniques.
In the context of the IGS LEO POD Pilot Project, GPS positioning of CHAMP and JASON-1 has been evaluated by MicroCosm and GEODYN II SW, following a reduced dynamic approach; the POD assessment, performed within the IGS LEO Comparison Campaign, has evaluated CGS CHAMP POD solution at 13 cm precision level, and a preliminary CGS JASON-1 POD solution at 11 cm precision level. Updated versions of the JASON-1 POD solution have been submitted recently: a better 'score' is expected.