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IGN
INSTITUT NATIONAL DE L'INFORMATION GÉOGRAPHIQUE ET FORESTIÈRE

SERVICE
DE GEODESIE
ET DE METROLOGIE

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ITRF local tie survey at Le Lamentin, La Martinique

DIFFUSION OUVERTE

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Résumé / Abstract

The ITRF2020 realization (most recent frame of the International Terrestrial Reference System) computed by the ITRS product Centre (IGN Geodesy research team from IPGP) is the result of the reference frames combination from the four space geodesy techniques (i.e., GNSS, DORIS, SLR and VLBI). One way to achieve a common frame consists in adding to the combination local tie surveys results from co-located sites. The weather station of the Martinique Aimé Césaire International Airport located in Le Lamentin and managed by Météo-France hosts a DORIS and a GNSS station. This report describes the local tie survey carried out in April 2025 after the DORIS station renovation and presents the associated results.

Remerciements / Acknowledgements

On behalf of CNES and IGN, we would like to acknowledge the staff of Météo-France for their essential logistic assistance, their welcome and their help during the survey.

1 Introduction

1.1 Context

The International Terrestrial Reference Frame (ITRF) is the result of a combination of different terrestrial reference frames provided by the four space geodetic techniques (i.e. GNSS, DORIS, SLR and VLBI). To perform this combination between independent reference frames, local tie surveys between co-located space geodetic instruments, precisely measured and expressed in three dimensions are necessary.
One way to improve the ITRS realization consists in adding to the combination tie vectors from new co-located sites or to improve the local tie accuracy on former sites.
To this end, missing or old local ties have to be surveyed. In charge of the DORIS network deployment and maintenance, IGN carries out local tie surveys whenever a DORIS station is co-located with other space geodetic technics.
This document presents the local tie survey performed in Le Lamentin, La Martinique, French West Indies, which took place in April 2025 during the DORIS renovation operation.
The objectives of the survey were as follows:

- Assign coordinates to the reference point of the new DORIS antenna;
- Provide tie vectors between instrument reference points (i.e. DORIS (former and new), GNSS);
- Produce a survey result file in SINEX format.

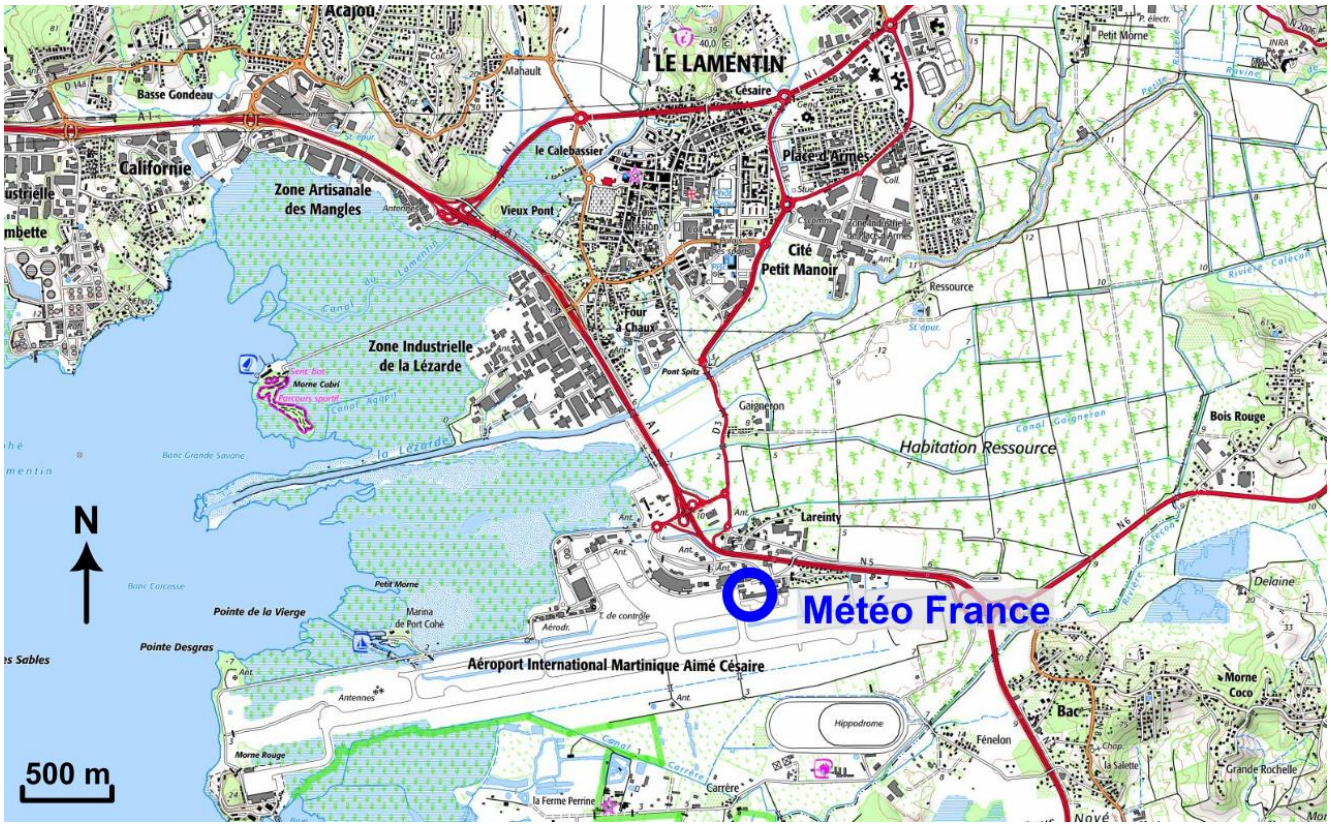
1.2 Glossary

ARP: Antenna Reference Point
CNES: Centre National d'Études Spatiales (France)
DOMES: Directory Of MErit Sites, ITRF product center site numbering
DORIS: Doppler Orbitography and Radiopositioning Integrated by Satellite
GGOS: Global Geodetic Observing System
GNSS: Global Navigation Satellite System
IDS: International DORIS Service
IERS: International Earth Rotation and Reference Systems Service
IGN: Institut National de l'Information Géographique et Forestière (France)
IGS: International GNSS Service
ITRF: International Terrestrial Reference Frame
SINEX: Solution INdependent Exchange
SLR: Satellite Laser Ranging
VLBI: Very Long Baseline Interferometry

2 Co-location site description

2.1 Site information

The geodetic site is located at the weather observation station owned and operated by Météo-France, in Le Lamentin, north of the airport runway. This is the international airport of Martinique, one of the islands of the French West Indies.



Situation map (IGN)

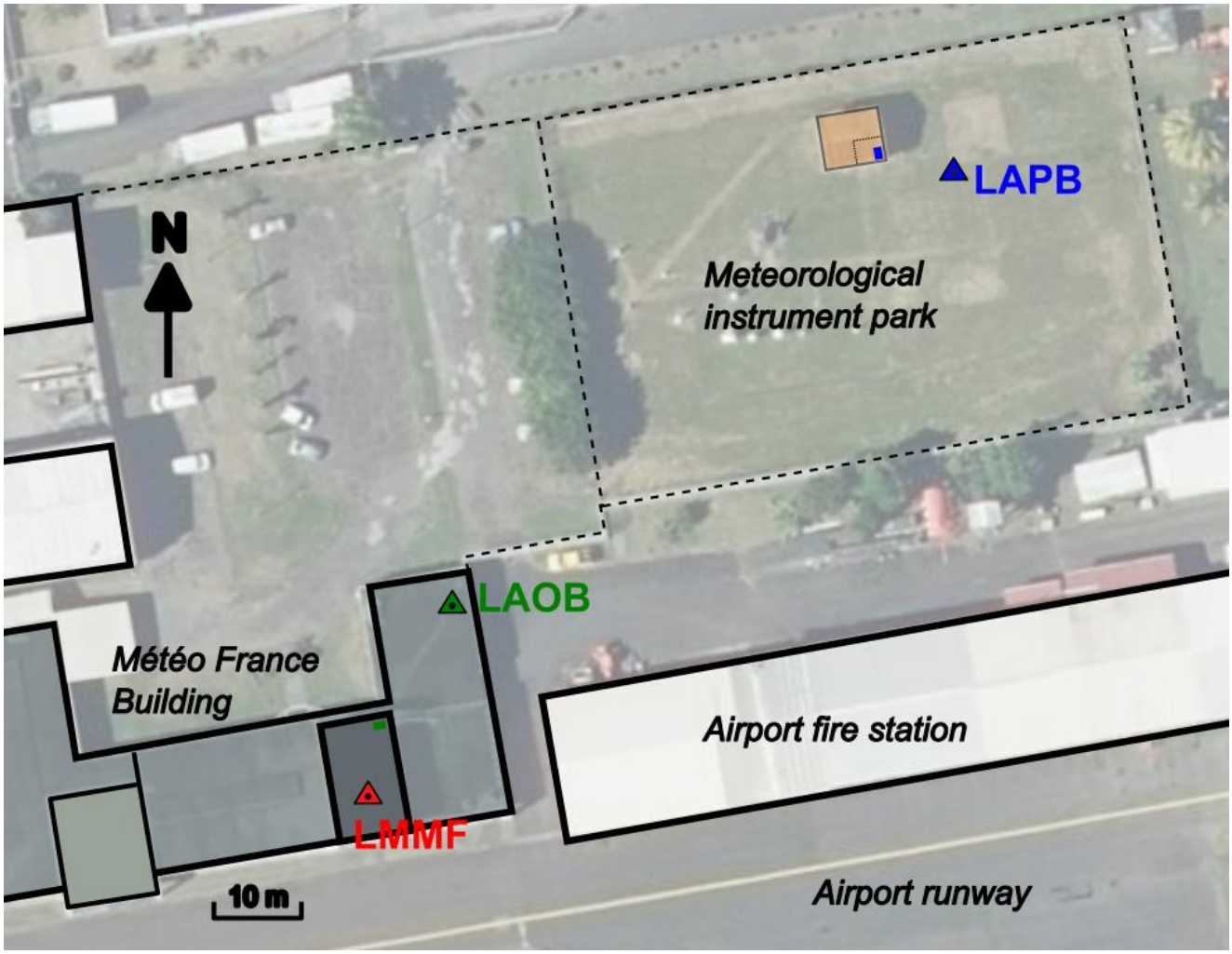
2.2 Co-located points on site

The geodetic site is divided into two parts. The IGS GNSS station and the old DORIS station are located on the roof of the main Météo-France building. The new DORIS station is located in the meteorological instrument park, around 70m from the building.

The following table sums up the geodetic techniques co-located on site.

Technique Name	DOMES n°	Description	Acronym / N°
GNSS	97205M001	Antenna mount reference point / mast	LMMF
DORIS	97205S001	DORIS antenna reference point *dismantled after the survey*	LAOB
DORIS	97205M002	DORIS mark – *antenna LAOB*	-
DORIS	97205S002	DORIS antenna reference point	LAPB
DORIS	97205M003	DORIS mark – *antenna LAPB*	-

For further information about the DORIS station:
https://ids-doris.org/network-stations/sites.html
And for further information about the GNSS station:
https://network.igs.org/



Points location (IGN)

3 Local tie survey description

3.1 Organization

The local tie was performed by Thomas Donal and Damien Pesce (IGN) from April 1st to 4th 2025.

3.2 Equipment – Instruments characteristics

The following section provides the characteristics of the surveying equipment that was used. The surveying instruments belong to IGN. The equipment is regularly checked and calibrated at IGN headquarters.

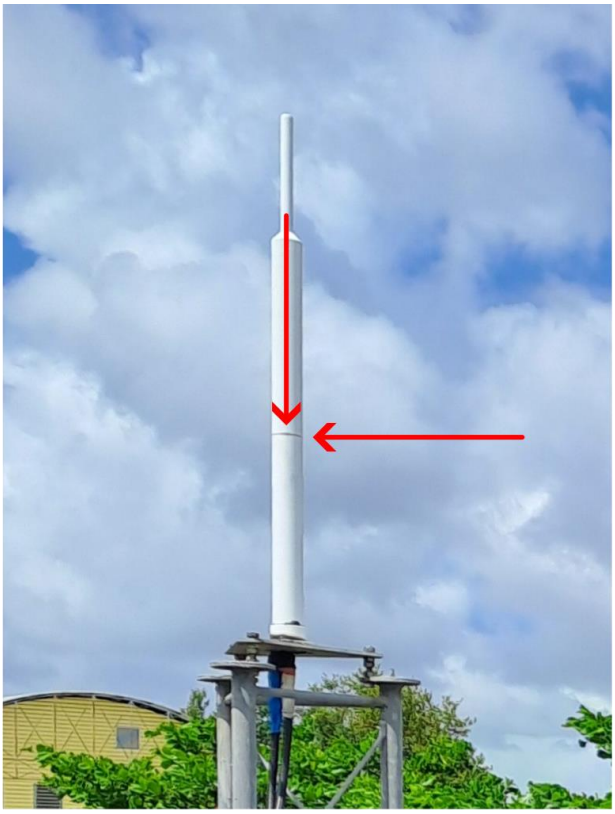
Equipment	Trademark, Serial ref. n°	Specifications, accuracy
Total station	Leica TM50 s/n 368639	Distance measurement: st. dev. 0.6 mm + 1 ppm Angular measurement: st. dev. 0.15 mgon (0.5")
Prism set Reflector & tribrach	Leica GPF121 – Leica GZR3 Leica GPH1P	Distance correction 0.0 mm Centring accuracy 0.3 mm
Reflector mini pole	Leica GLS14	H = 0.200 m
Pocket weather tracker (meteorological station)	Kestrel 4500NV s/n 2020534	Temp. st. dev. 0.5°C Pressure st. dev. 1 hPa
GNSS unit	Receiver: Leica GX 1230+ GNSS Antenna: Leica AX1203+ GNSS	Theoretical static post-processing accuracies: Horiz. 5 mm + 0.5 ppm Vert. 6 mm + 0.5 ppm

NB.: All these survey instruments allow the observations to be recorded electronically on memory cards or storage devices and then downloaded to a laptop PC for on-site checking.

3.3 Co-located points

3.3.1 DORIS former antenna – LAOB

The LAOB DORIS antenna was installed in June 2013 and was removed during the local tie survey right before the installation of the new LAPB DORIS antenna.

Acronym: LAOB	DOMES number: 97205S001
 Overview	 Close-up view
Description: the reference point is located 0.390 m above the antenna base-mounting surface on the antenna vertical axis.	

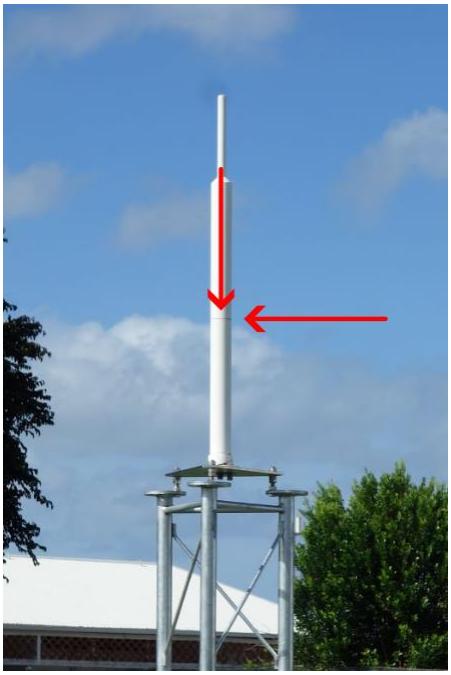
3.3.2 LAOB marker

A domed brass mark embedded vertically down the DORIS reference point (LAOB) on the roof is used as a witness mark.

Acronym: DORIS marker	DOMES number: 97205M002
 Overview	 Close-up view
Description: the marker is located + 2.367 m underneath the antenna reference point (LAOB)	

3.3.3 DORIS antenna – LAPB

The new DORIS antenna was installed during the local tie survey work. The antenna was installed on a 2 m mast about 70 m east from the former LAOB antenna.

Acronym: LAPB	DOMES number: 97205S002
 Overview	 Close-up view
Description: the reference point is located 0.390 m above the antenna base-mounting surface on the antenna vertical axis.	

3.3.4 LAPB marker

A domed brass mark embedded vertically down the DORIS reference point (LAPB) on the concrete block is used as a witness mark.

Acronym: DORIS marker	DOMES number: 97205M003
 Overview	 Close-up view
Description: the marker is located + 2.425 m underneath the antenna reference point (LAPB)	

3.3.5 GNSS station – LMMF

LMMF GNSS station is managed by IGN and is part of the French national CORS network (RGP) and also parts of IGS and REGINA networks. It was installed in 2008.
The antenna is mounted on a 1m stainless steel mast fixed on rooftop of the main building.

Acronym: LMMF	DOMES number: 97205M001
 Overview	 Close-up view
Description: the reference point is the top and centre of the antenna mount plate.	

3.4 Observation Polygon

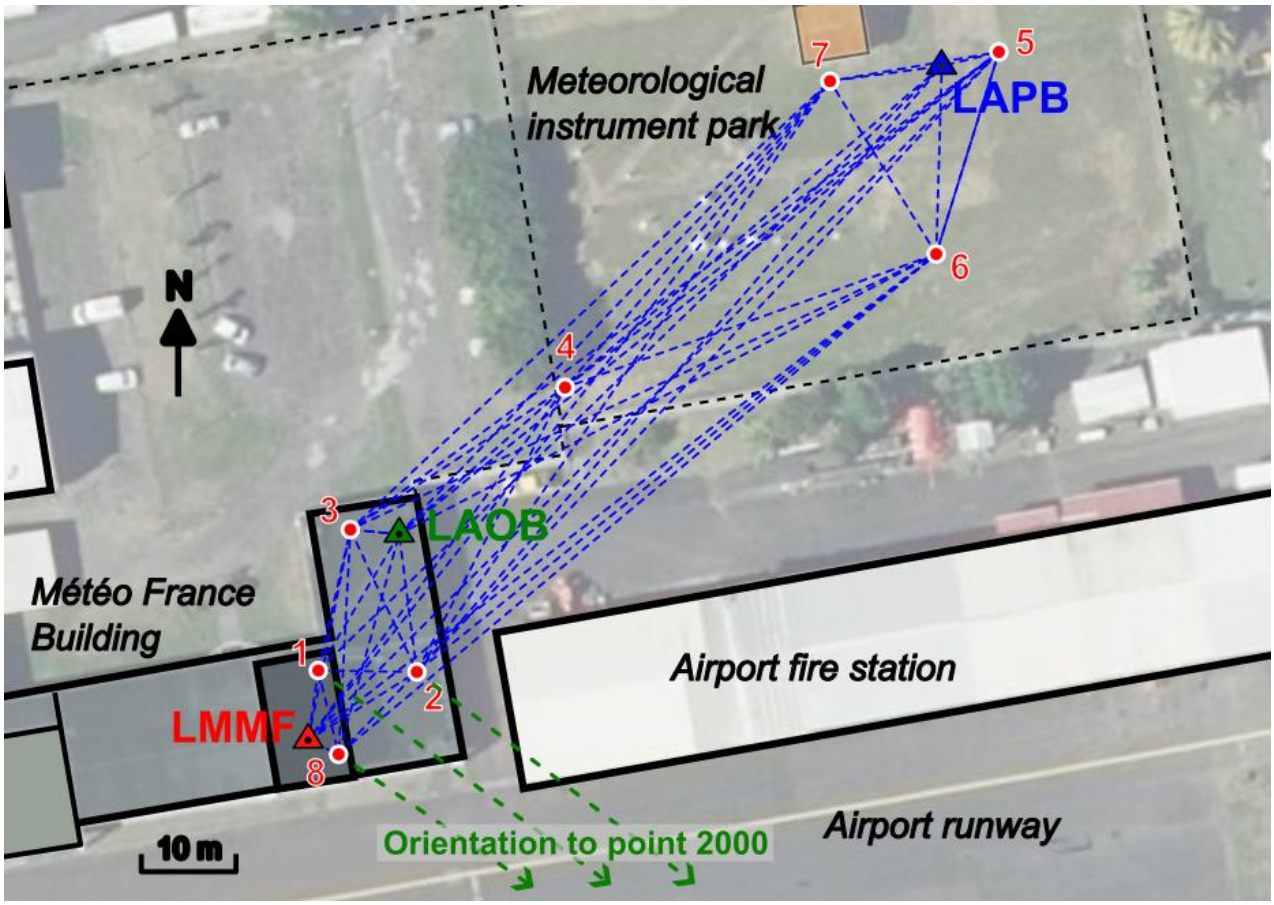
All surveying operations have been carried out in such a way to provide the highest accuracy for the 3D vectors determination between reference points.

3.4.1 Total station figure

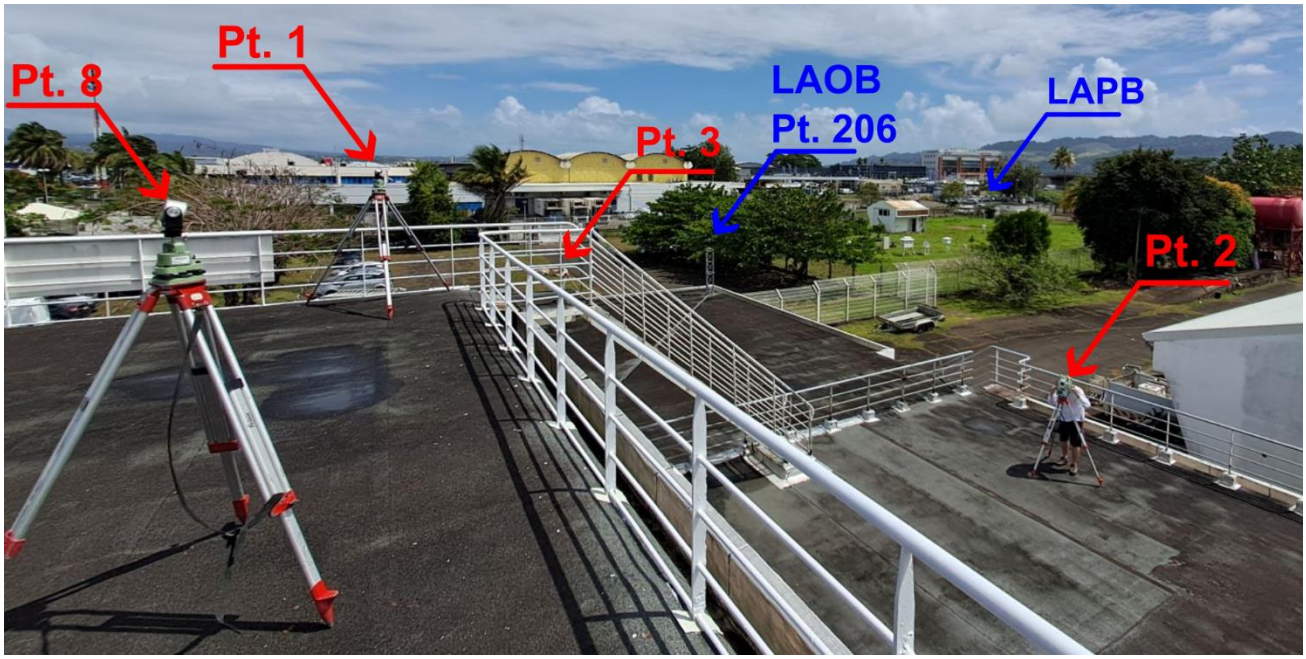
Observations were done using a total station from:

- 4 stations on tripods on the rooftop around stations LMMF and LAOB (numbers 1, 2, 3 and 8),
- 4 stations on tripods in the instrument park around station LAPB (numbers 4 to 7),

After the LAOB antenna was removed, a prism was installed centered on the antenna plate (number 206).
In order to obtain a solution with minimal constraints, all the survey points were non-monumented temporary points except the point 206.
The local tie survey was carried out in two separate sessions, as the DORIS antenna was the same for the old and the new stations. It was not possible to observe both antennas at the same time. In the first session, before removal of the LAOB antenna, stations 1 to 5 were observed. In the second session, after installation of the LAPB, all stations were observed.



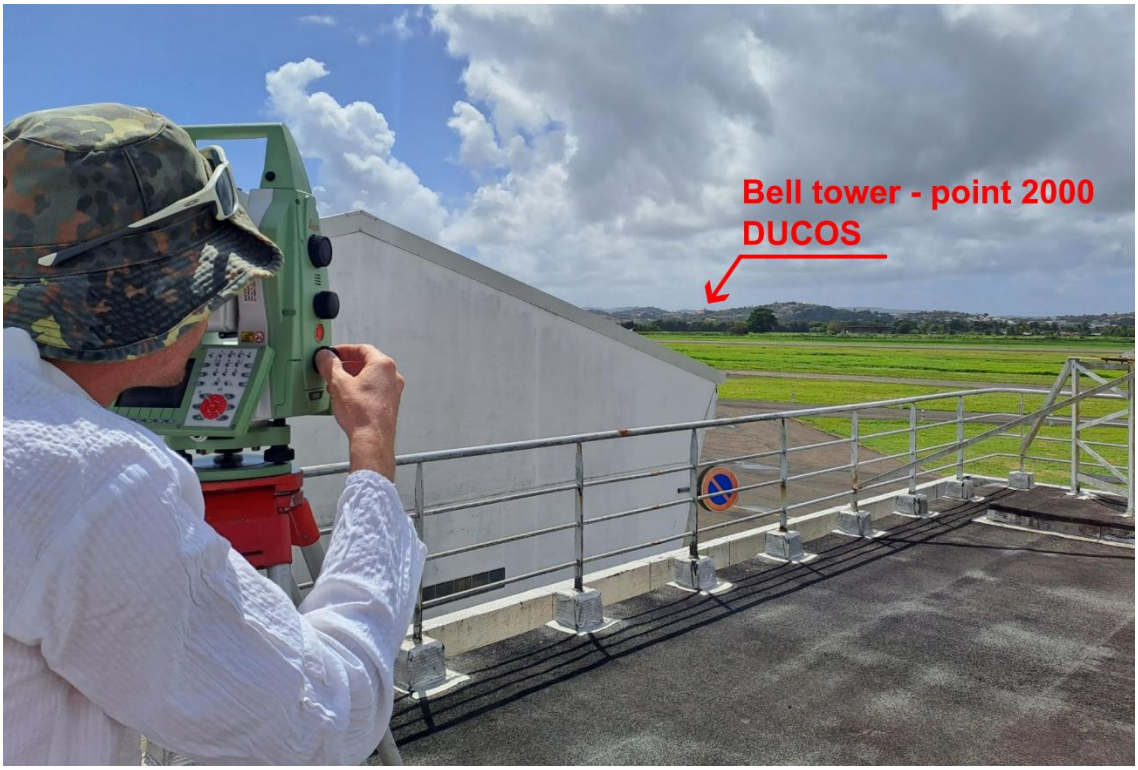
Local tie survey polygon



Overview of the survey stations around the old Doris station (LAOB)

3.4.2 Orientation

In order to constrain the orientation of the survey with north direction, the bell tower of the Ducos town church (point 2000) was observed from stations 1, 2 and 8. It is located about 3 km from station LMMF.



Thomas aiming bell tower from station 2

To assign coordinates to the bell tower axis, a small local tie survey was carried out using 3 temporary stations in the street around the church (point 500 to 502).

Bell tower of Ducos church – point 2000

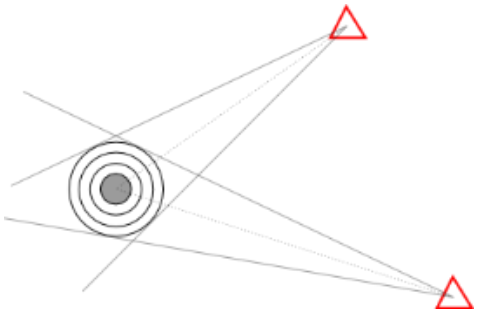
GNSS antenna on station 502 and point 2000

3.5 Survey method

All the visible lines of sight were observed with total station. Horizontal directions and zenith angles were observed in data sets, each set consisting in one reading in both direct and reverse theodolite positions. Distance measurements were observed at least once over each line. Meteorological data (atmospheric pressure and temperature) were recorded at each station and used to correct distances measurements.
For a small figure like this one, conventional terrestrial observations are more accurate than GNSS measurements. The GNSS observations are only used to get the polygon orientation.

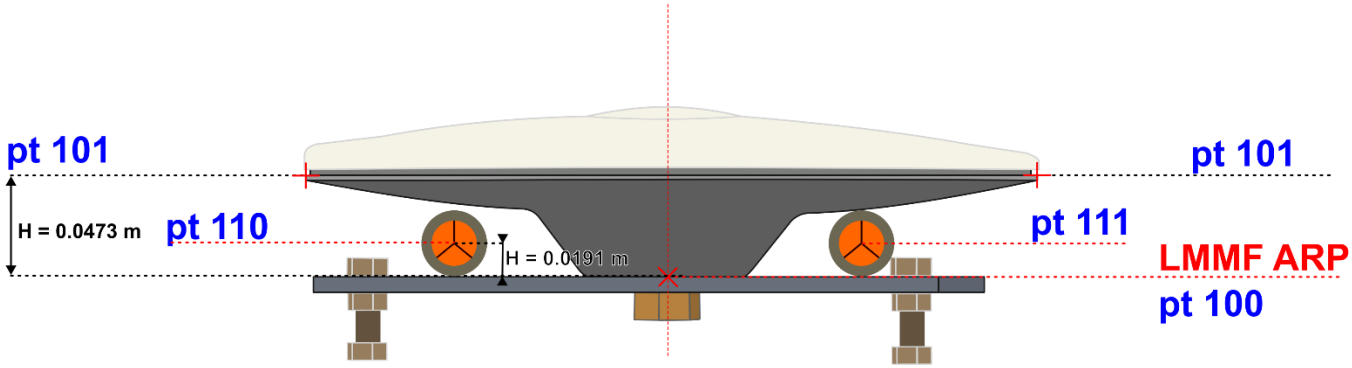
3.5.1 LMMF GNSS antenna reference point

The reference point (point 100) has been determined indirectly for LMMF antenna. From each surveying station aiming at the antenna, right and left tangents on upper edge of the largest part of the antenna (h:47.3 mm up to ARP – point 101) were observed. In the adjustment, horizontal and vertical angle observations were averaged.



Top view

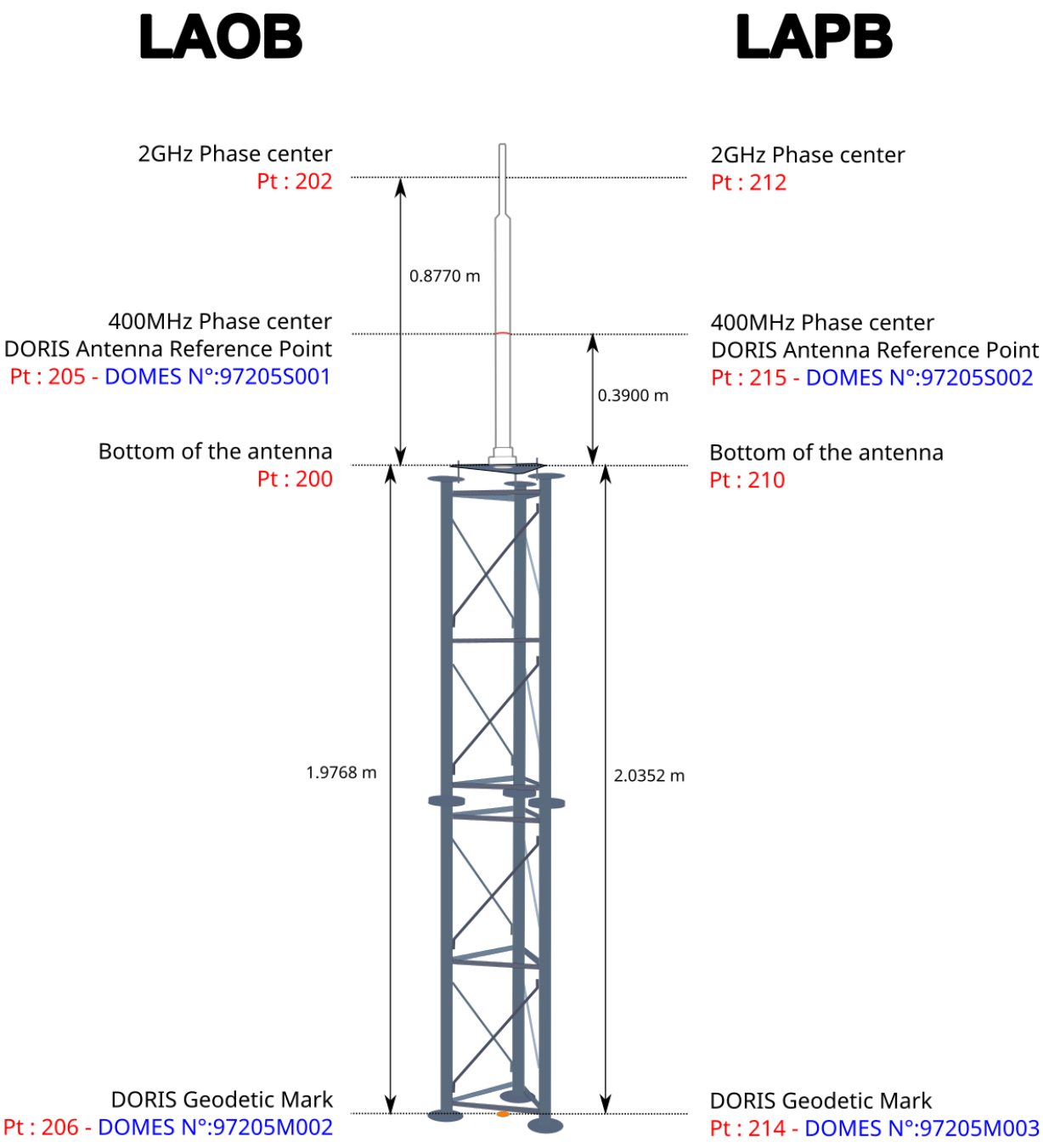
To improve the accuracy of the height component, two 1.5" prisms were placed at top of antenna support plate (points 110 and 111). Horizontal and vertical angles and distances were observed from the surveying stations but in the adjustment these points are considered as levelling ones whose height is identical to that of the ARP.



Drawing of the LMMF antenna

3.5.2 DORIS antenna reference point

An indirect approach was used to determine the reference point for both DORIS antennas. From each surveying station aiming at the DORIS antenna, right and left tangents to the antenna close to the ARP (red circle n°201 and 211), close to 2 GHz phase centre (points 202 and 212) and close to antenna base (n°200 and 210) were observed. In the adjustment, horizontal and vertical angle observations of the red circle were averaged. For the two other points, only horizontal angle observations were averaged because vertical positions of those points are not precisely defined. In the final process, the ARP was determined as the point on the same vertical as the centre of the bottom of the antenna (points 205 and 215) but 0.390 m up of the bottom.
Some 1.5" prisms placed on the top of the support plate were observed from each station to determine with a higher accuracy the elevation of the bottom of antenna (points 230 to 233 and 220 to 223). The heights between antenna bottom and phase centres come from the antenna manufacturer (i.e., 0.390 m from antenna bottom to ARP and 0.877 m from antenna bottom to 2 GHz phase centre).



Sketch of the two antennas

3.5.3 Orientation

The bell tower (point 2000) was observed with angles measurements from 3 temporary stations (points 500 to 502) located around the church. Those stations also observed the other two with angles and distances, as is done at the co-located site.

Then Points 501 and 502 were observed by GNSS during 30 minutes each. GPS and Glonass constellations were recorded with a sampling rate of 30s.

4 Computation and data analysis

4.1 On site validation

Total station observations were checked on site and converted into the adjustment format. GNSS data were validated after a quick baselines calculation.

4.2 IGS alignement

4.2.1 LMMF IGS coordinates

LMMF coordinates used in this process proceed with the IGS0OPSSNX_20250890000_07D_07D_CRD.SNX i.e., IGS20 weekly combined SINEX solution for the week 2360 – IGS20 epoch 2025.25.

4.2.2 Orientation point

The point 2000 was aligned to IGS thanks to a small terrestrial survey (integrated in the final adjustment) tied to LMMF with two GNSS baselines.
The GNSS baselines were processed with Leica Infinity software version 3.3.1. The IGS precise ephemerides were used as well as the IGS antenna phase offset files.
Those baselines and their covariance matrices are used for the final adjustment.

4.3 Final adjustment

The data was processed using 3D least-square adjustment with IGN Comp3D version 5.22 software.
The input file comes from:

- Total station observations: horizontal and zenith angles, distances;
- Height differences between points of the same stations;
- Centring equations: relative position between points;
- GNSS baselines;
- LMMF reference point coordinates, constrained at 0.5 mm to its IGS20 epoch 2025.25 position.

The computation was done in UTM 20N projection.
The terrestrial adjustment was processed taking into account the vertical deflection from the geoid model EGM08.

The a priori standard deviations used for most of the observations with total station are:

- 0.6 mgon + 0.2 mm (SD relative) for horizontal angles
- 1.3 mgon + 0.2 mm (SD relative) for vertical angles,
- 0.5 mm for distances on prism.

The final precision of an observation takes into account its absolute precision and the one relative to the computed distance between the two points coordinates at current iteration.

For angular measurements, the final precision is computed as follows: $\sigma_{abs} + \frac{\sigma_{rel}}{distance}$

The first adjustment provides an azimuth and its standard deviation from LMMF to point 2000.

Analysis of the adjustment shows that station 1,2,3 and 5 have moved slightly between the two observation sessions. Those stations are defined as one distinct point for each sessions named respectively 11, 21, 31, 5 for the first session and 1, 2, 3, 51 for the second session.

A second adjustment with minimal constraints was processed using the same parameters and observations. The LMMF azimuth to 2000 was added to the processing but all the observations used to determine point 2000 (observation from station 500 to 502 and GNSS baselines) were removed.

This adjustment provides final coordinates and a covariance matrix.

5 Results

5.1 Adjusted coordinates and confidence intervals

The results of the adjustment are the coordinates of all points and their confidence ellipsoids in the IGS20 reference frame at epoch of the observations (i.e. epoch 2025.25).
The table below provides the 3D coordinates.

Cartesian Coordinates IGS20 epoch 2025.25			
Point – *process nb*	X (m)	Y (m)	Z (m)
LMMF – *100* 97205M001	2993387.4431	-5399363.7667	1596748.2369
LAOB – *205* 97205S001	2993393.8250	-5399351.4737	1596768.2757
LAPB – *215* 97205S002	2993436.1469	-5399311.4935	1596811.1215

The table below provides confidence ellipsoid (3D) at 2.5σ (that means the results have a probability of 90% to be inside the ellipsoid).

3D confidence regions at 2.5σ (90 percent)			
Point – *process nb*	½ axis (mm)	Azimuth (gr)	Tilt (gr)
LMMF – *100* 97205M001	1.25	-	-
	1.25	-	-
	1.25	-	-
LAOB – *205* 97205S001	3.00	76.65	0.55
	2.95	176.64	198.96
	2.93	7.60	98.82
LAPB – *215* 97205S002	3.90	148.46	0.05
	3.03	48.46	7.04
	2.98	48.02	92.96

The whole covariance matrix was computed. Covariance submatrix for the main points of interest was extracted for the next ITRF solution computation. Finally, this covariance submatrix was converted into SINEX format. The resulting SINEX file (97205_IGN_2025-092_v10.SNX) is provided in appendix 6.1.

5.2 Vectors

The following table shows vectors in Cartesian coordinate system (IGS20 ep.2025.25):

	ΔX (m)	ΔY (m)	ΔZ (m)
LMMF → LAOB	6.3820	12.2930	20.0389
LMMF → LAPB	48.7038	52.2732	62.8847
LAOB → LAPB	42.3219	39.9803	42.8458
LAOB → LAOB mark	-1.1102	2.0031	-0.5972
LAPB → LAPB mark	-1.1373	2.0531	-0.6110

6 Annexes

6.1 Sinex file: 97205_IGN_2025-092_v10.SNX

```
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*-------------------------------------------------------------------------------
+FILE/COMMENT
* File created by COMP3D v5.22-win
* Original computation file: LMMF4.comp
* Matrix Scalling Factor used:          1.0061
-FILE/COMMENT
*-------------------------------------------------------------------------------
+SITE/ID
*CODE PT __DOMES__ T _STATION DESCRIPTION__ APPROX_LON_ APPROX_LAT_ _APP_H_
 LMMF  A 97205M001 P BAM                   299  0 13.8  14 35 41.3   -27.1
 LAOB  A 97205S001 D DORIS ARP             299  0 14.2  14 35 42.0   -29.5
 LAPB  A 97205S002 D DORIS ARP             299  0 16.0  14 35 43.5   -32.7
-SITE/ID
*-------------------------------------------------------------------------------
+SOLUTION/EPOCHS
*Code PT SOLN T Data_start__ Data_end____ Mean_epoch__
-SOLUTION/EPOCHS
*-------------------------------------------------------------------------------
+SOLUTION/ESTIMATE
*INDEX TYPE__ CODE PT SOLN _REF_EPOCH__ UNIT S __ESTIMATED VALUE____ _STD_DEV___
     1 STAX   LMMF  A    1 25:094:50403 m    2 0.299338744305169E+07 0.50153E-03
     2 STAY   LMMF  A    1 25:094:50403 m    2 -.539936376670884E+07 0.50153E-03
     3 STAZ   LMMF  A    1 25:094:50403 m    2 0.159674823686350E+07 0.50153E-03
     4 STAX   LAOB  A    1 25:094:50403 m    2 0.299339382501465E+07 0.11886E-02
     5 STAY   LAOB  A    1 25:094:50403 m    2 -.539935147374475E+07 0.11753E-02
     6 STAZ   LAOB  A    1 25:094:50403 m    2 0.159676827572043E+07 0.11787E-02
     7 STAX   LAPB  A    1 25:094:50403 m    2 0.299343614686573E+07 0.13973E-02
     8 STAY   LAPB  A    1 25:094:50403 m    2 -.539931149348189E+07 0.12097E-02
     9 STAZ   LAPB  A    1 25:094:50403 m    2 0.159681112154101E+07 0.13752E-02
-SOLUTION/ESTIMATE
*-------------------------------------------------------------------------------
+SOLUTION/MATRIX_ESTIMATE L COVA
*PARA1 PARA2 ____PARA2+0__________ ____PARA2+1__________ ____PARA2+2__________
     1     1 0.251535835049953E-06
     2     1 0.464544632009780E-20 0.251535835049953E-06
     3     1 0.733212894967004E-20 0.465868120989865E-20 0.251535835049950E-06
     4     1 0.251535696049147E-06 0.250730988381590E-12 -.746457731085323E-13
     4     4 0.141280983882451E-05
     5     1 -.191073172732496E-12 0.251536179703257E-06 -.102609962453728E-12
     5     4 0.334283392818255E-07 0.138131591889591E-05
     6     1 -.382951788714032E-12 0.690750897137920E-12 0.251535629396877E-06
     6     4 0.128863685961667E-07 0.155210067654238E-07 0.138921718949181E-05
     7     1 0.251534882869540E-06 0.171752793146389E-11 -.511338670510863E-12
     7     4 0.450645190897211E-06 0.704942387641522E-07 -.657823889271013E-07
     7     7 0.195251599788732E-05
     8     1 -.883076339797517E-12 0.251537427916014E-06 -.474229406392159E-12
     8     4 0.494167061415736E-07 0.312060802334985E-06 -.723059564881339E-08
     8     7 0.154812018412750E-06 0.146330621593448E-05
     9     1 -.119303686240051E-11 0.215193710742425E-11 0.251535194363791E-06
     9     4 -.137240732407471E-06 -.464739924206944E-07 0.390047329243017E-06
     9     7 -.470708456952641E-06 -.124021963145010E-06 0.189117766281462E-05
-SOLUTION/MATRIX_ESTIMATE L COVA
%ENDSNX
```

Diffusion interne		
Direction / Service	**Fonction**	**Adresse électronique**
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Mots-clé

DORIS; GNSS; local tie survey; Le Lamentin ; Martinique

Résumé

La réalisation ITRF2020 (dernière en date de l'International Terrestrial Reference System) calculée par l'équipe géodésie IGN de l'IPGP est le résultat de la combinaison des référentiels terrestres issus des quatre techniques de géodésie spatiale (à savoir GNSS, DORIS, SLR et VLBI). Pour réaliser un repère unique, un moyen consiste à ajouter dans la combinaison les résultats de rattachements sur des sites co-localisés. Le site de Météo-France à l'aéroport international du Lamentin est équipé de stations DORIS et GNSS.
Ce rapport décrit le rattachement de précision réalisé en avril 2025 sur ce site lors des travaux de rénovation de la station DORIS et présente les résultats obtenus.

Matériel

Système d'exploitation	Logiciel
Windows 10	Microsoft Word

Validation

	Fonction	Nom	Visa
Relecteur	Expert	Thomas Donal	14/08/2025
Relecteur	Expert	Jérôme Saunier	28/07/2025
Relecteur	Chef d'unité	François L'Ecu	25/07/2025
Approbateur	Chef de service	Bruno Garayt	21/07/2025