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Framework for Measuring mm-Accurate Local Survey Ties over 1km baselines at the McDonald Geodetic Observatory, Texas, USA

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Fig 1: MLRS at McDonald Observatory

We develop a framework for determining the local tie between an SLR station and VLBI antenna at the McDonald Geodetic Observatory in Texas, USA to within 1mm accuracy in a joint effort between The University of Texas at Austin and NASA. The instruments are separated by about 800m horizontally and 120m vertically. This results in distinct spatial and temporal gradients in atmospheric conditions between the valley to the mountain top.

Framework

We apply and combine the state-of-the-art of existing metrology and surveying technology and techniques to minimize the error in determining the local positions of the instrument centers. Data is collected over field campaigns. Six campaigns have been conducted thus far.

Key Equipment

- Leica TS-30 Total Station (Cert: 0.13mm distance, 0.2mgon Hz, 0.26mgon V)
- Leica GPH1P Single-Prism Precision Reflectors (0.3mm accuracy)
- PLX Ball Mounted Hollow Retroreflectors (BMRs) (0.002mm accuracy)

Site Layout

Local Control Networks constructed around each instrument site in ~30m radius

- 6 (semi-)permanent target monuments (TMs) from each LCN (3 constructed)
- LCN around VLBI denoted "VC" for Visitor's Center, LCN around SLR denoted "MF" for Mount Fowlkes
- Each site has two TS-30 instrument positions (IPs), forming a "braced quadrilateral" across the km-baseline. This configuration produces strong error ellipses versus configurations with more or fewer IPs.

Fig 2: (Left) VC LCN (Right) MF LCN
Green Pins represent TMs constructed. Orange Pins represent TMs yet to be constructed.
Yellow Pins represent IPs where the TS-30 or Precision reflectors are mounted on tripods.

Monumentation

Due to limitations in the scope and duration of the project, target monuments are constructed "semi-permanently" using cost-efficient methods and materials.

Components:

- 6ft, 1in dia. Stainless Steel Rod set into ground with epoxy 2-4ft deep
- 0.5-1ft below surface is left free of epoxy to decouple from surface dynamics
- Rod is protected by PVC collar and pipe cemented in ground around rod
- Machined with sleeve to fit mounting nest for BMRs
- GPS antenna can be threaded onto rod with base plate adapter

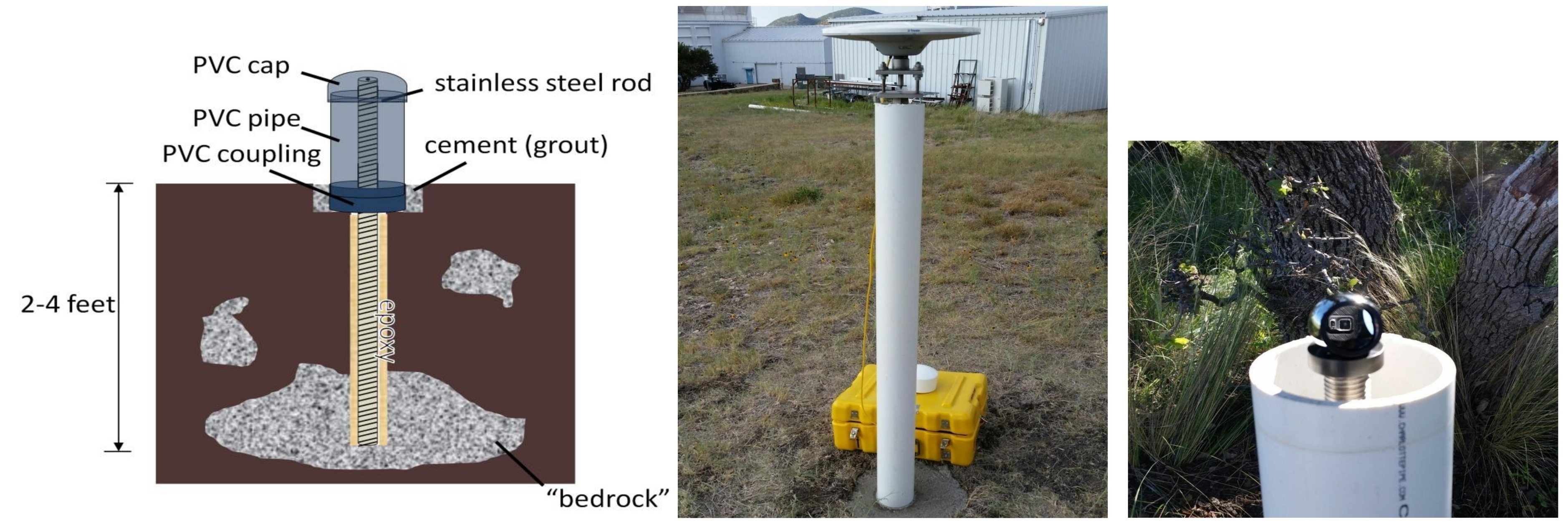

Fig 3: (Left) Diagram of TM Construction (Center) TM with GPS antenna mounted (Right) BMR mounted on TM rod

Survey Session Scheme

The total station is set up on a tripod over one IP location. The other IP locations are fitted with GPH1P Precision reflectors mounted on tripods facing the total station. BMRs are mounted on each of the TMs facing the current location of the total station.

- Settings: Sets-of-Angles Program, Automatic Target Recognition (ATR) on, PPM correction set to 0
- Atmospheric conditions are recorded at each site during entire session.
- At each IP, the TS-30 records distance and (H,V) angle measurements to each TM (4 sets of measurements) and to the other IPs (16 sets of measurements).
- A metrology laser tracker will be used to range from the TMs to the instrument with an accuracy of an order better than the total station (0.01mm).

Analysis and Results

Data collect is processed using an in-house Gauss-Newton Non-Linear Least Squares batch estimator.

- Observables: range, local vertical, and local horizontal distances
- Estimated State: Local (x,y,z) positions of all points in the network (TMs and IPs)
- Corrections for atmospheric refraction and curvature of the Earth applied in the pre-processing[2].
- Solutions were also computed via STAR*NET software[3], yielding similar results.

Table 2: Campaign 05 Estimated Network Position Errors (σ, Standard Deviations)

Target Name	X Coordinate Error	Y Coordinate Error	Z Coordinate Error
IP-1	0.4008mm	0.5486mm	3.1297mm
IP-2	0.5787mm	0.5375mm	3.3553mm
IP-3	0.9091mm	2.0795mm	4.1620mm
IP-4	1.0280mm	1.9775mm	4.1588mm
VC-2 (Origin of Frame)	0.3mm	0.3mm	0.3mm
VC-4	0.7124mm	0.6464mm	4.7046mm
VC-6	0.5697mm	0.7716mm	5.1311mm
MF-1	1.1508mm	2.1718mm	5.3670mm
MF-2	1.0986mm	2.1751mm	5.2234mm
MF-4	1.1611mm	2.1223mm	4.7889mm
STAR*NET Std.Error	0.5mm	0.5mm	1.00mm

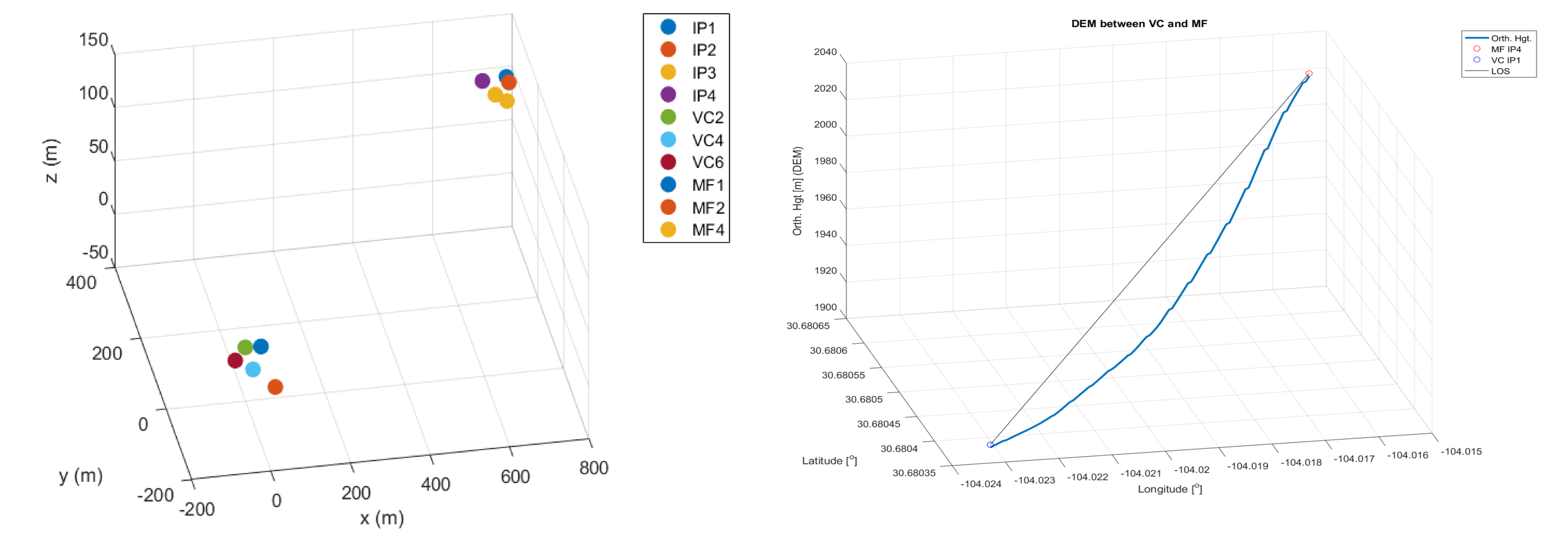

Fig 4: (Left) Plotted Network Positions (Right) Topology of Network using DEM Orth. Ht.[4]

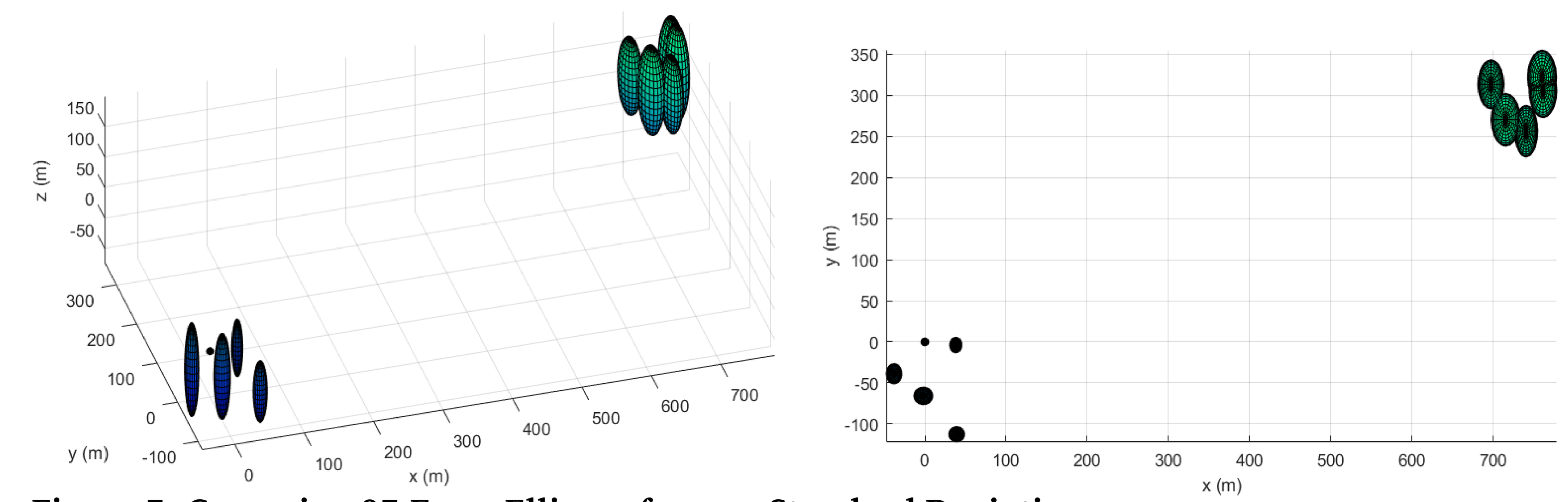

Figure 5: Campaign 05 Error Ellipses from σ, Standard Deviations
(Left) Least Squares Error Ellipsoids (Right) Least Squares Error Ellipses

Conclusion

Through the framework outlined, the km-tie between the VLBI and SLR sites at McDonald Geodetic Observatory can be measured to within <1mm in the horizontal and to within 3-5mm in the vertical. The TM coordinates exhibit larger error than the IP measurements due to fewer sets of observations collected (4 vs. 16).

Next steps:

- Collect 16 or more sets of measurements between the TMs and IPs
- Measure atmospheric refraction conditions along the entire light path
- Implement a 2-way EDM scheme using a second TS-30 to correct for angular errors due to atmospheric refraction[5]
- Correction for Deflection of the Vertical (DoV) between the two sites
- Characterize the consistency from campaign to campaign and to
- Compare the tie estimate from local metrology to the tie estimate from GPS collected simultaneously during each campaign.

Acknowledgements

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