# Local Survey Relationships to System Calibration and Bias Identification

*"Towards Millimeter Accuracy"*

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## Motivation:

A limiting factor in the range bias of an externally calibrated SLR system is the accuracy of the surveyed distance and the stability of that distance. An error in the target distance will map 1:1 into a range bias. By periodic simultaneous ranging to multiple terrestrial targets, at different azimuths and ranges, system biases can be separated from target, system movement or survey errors. These simultaneous ground target tests are commonly referred to as MINI COlocations (MINICO).

Local survey ties are necessary to monitor site stability between geodetic systems; geodetic markers; and terrestrial SLR calibration targets. Currently, state-of-the-art local survey ties are accurate to the 1 to 2 millimeter level using proper equipment, survey procedures, and data reduction techniques.

Maintaining accuracy of local survey ties can be a critical component towards reaching millimeter SLR data.

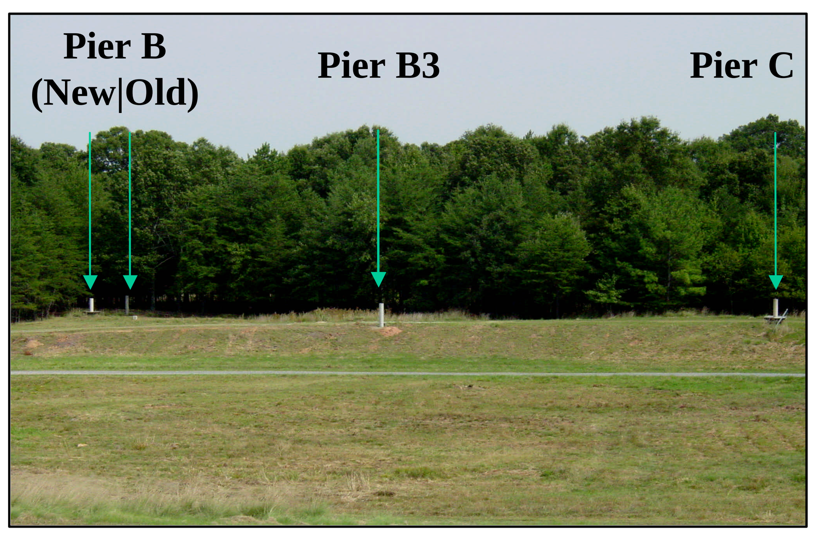



**Figure 1. Calibration Targets at Greenbelt viewed from the mount Station 7105. "Old" Pier B shifted 5.3mm in 1998. "New" Pier shifted 8.1mm in 2001. Pier C has remained stable and is the current operational ground target.**

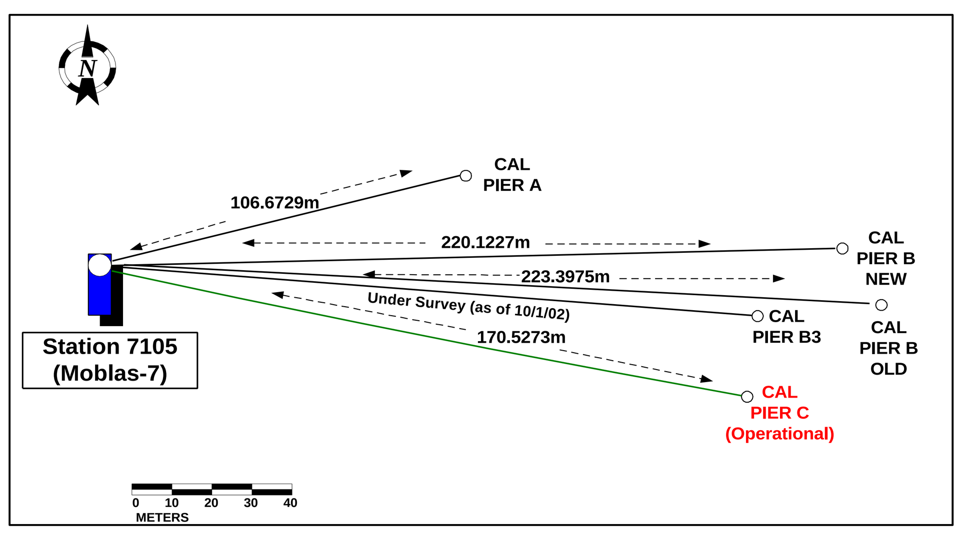



**Figure 2. Calibration Pier Network at Greenbelt Maryland, USA**

## Ground Testing:

MINICO ground tests assist in the identification of any azimuth dependent bias and provide validation of site survey by calculating variations in system delays by laser ranging to multiple ground targets with differing azimuths and ranges. By maintaining data histories and performing trend analysis on bias's between these multiple targets, potential target movements can be detected.

Analysis revealing bias between multiple ground targets ***above 5mm*** should require follow up survey activities to confirm stability of all pier measurements and identify the precise magnitude of any potential movement.

**System Delay =**
**Calibration TOF - 2*Target Range * Fn**
**C**

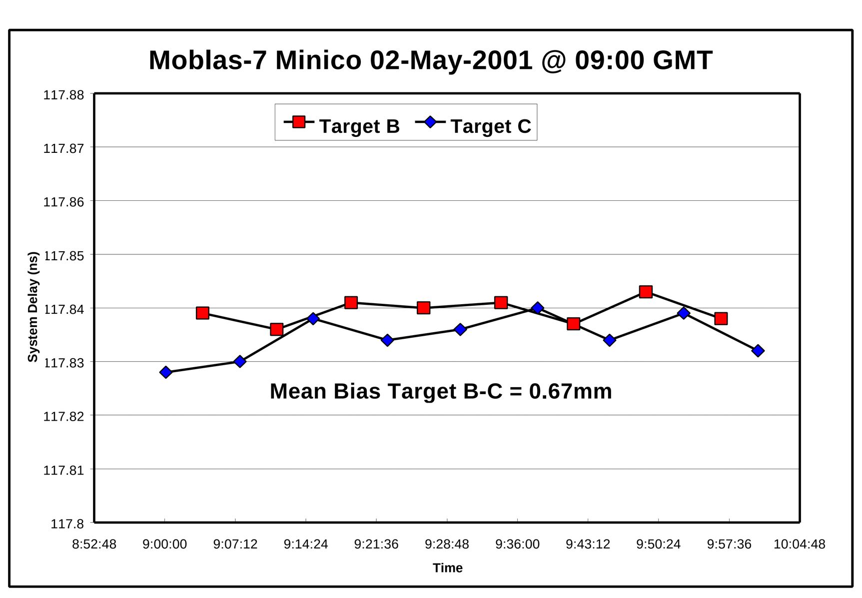



**Fig.3: Ground test data with minimal bias indicating stable agreements of survey distances.**

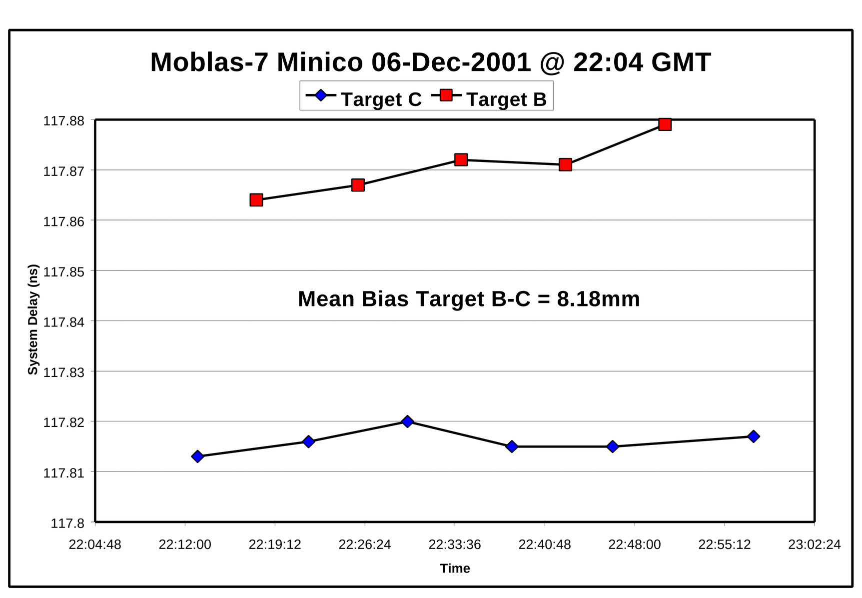



**Fig.4: Ground test data with large bias suggesting instability of target distance**

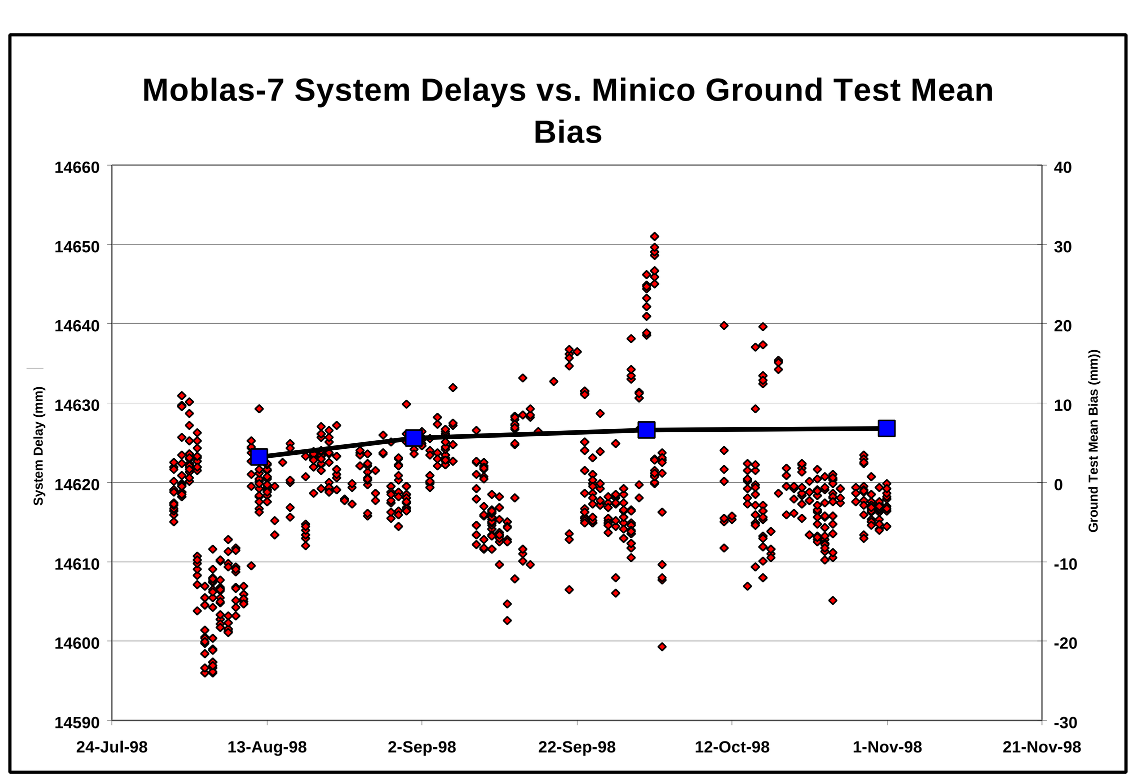



**Figure 5: The standard deviation of system delay over time, absorbs biases (+3 millimeters) identified in MINICO ground test data.**

## History of Recent Movements:

Ground targets movements at Greenbelt have occurred as a result of significant events to the geological composition in which calibration targets reside. Changes to the geological composition can often be tied to severe weather and climate conditions frequently found at SLR site locations.

In 1998 at the Goddard Geological Observatory (GGAO), following an extended period of summer drought conditions, Calibration Target "B" was found to moved 5.3mm in range relative to Station 7105 (Moblas-7) (Figure 1,6).

Once again in 2000, following the construction of a new, more stable calibration Target B, climate and geological conditions contributed to another significant movement of the target (Figure 1,7).

In both 1998 and 2000 at GGAO, laser ranging ground tests provided the initial diagnosis in the identification of pier instability. Formal re-survey's confirmed the suspected movements (Figures: 3,4,5.).

### Calibration Pier Stability
### Relative to SLR Station 7105

**"Old" Pier B**

| Date | Range(mm) | Azimuth (deg.) | Elevation (deg.) |
|---|---|---|---|
| Jun-98 | 223392.2 | 89.4317 | -1.5244 |
| Dec-98 | 223397.5 | 89.4317 | -1.5306 |
| Delta | 5.3 | 0 | 0.0062 |

**Figure 6: Formal survey revealed a large shift in the position of "Old" operational Pier B in relation to the GGAO survey scheme (0.011mm North, 0.003m East, -0.028 Up). The 5.3mm increase in range to Station 7105 would bias satellite data by the same magnitude.**

**"New" Pier B**

| Date | Range(mm) | Azimuth (deg.) | Elevation (deg.) |
|---|---|---|---|
| Mar-00 | 220114.6 | 88.5882 | -1.5915 |
| Dec-01 | 220122.7 | 88.5852 | -1.5915 |
| Delta | 8.1 | -0.003 | 0 |

**Figure 7: Survey results of the "New" Pier B revealed an even larger shift than had occurred in 1998. MINICO ground tests isolated the 8.1mm change in range to within a 4-6 week period in 2001.**

**Operational Pier C**

| Date | Range(mm) | Azimuth (deg.) | Elevation (deg.) |
|---|---|---|---|
| Jun-98 | 170526.7 | 105.0109 | -1.6598 |
| Dec-98 | 170525.9 | 105.0109 | -1.6611 |
| Mar-00 | 170526.4 | 105.0106 | -1.6614 |
| Dec-01 | 170527.3 | 105.0106 | -1.6603 |
| Delta | 0.3 | 0.0003 | 0.0005 |

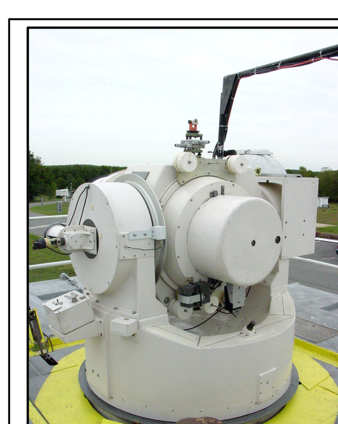
**Figure 8: As a result of the identified instability of Pier B, Station 7105 has been utilizing Pier C as their operational Calibration Pier. Survey values confirm a very stable target.**

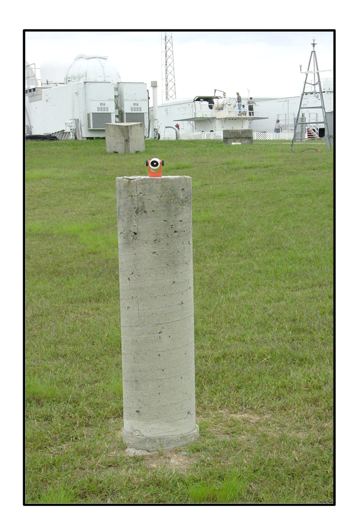
**Short Target A**

| Date | Range(mm) | Azimuth (deg.) | Elevation (deg.) |
|---|---|---|---|
| Jun-98 | 106672.8 | 64.9355 | -3.1326 |
| Dec-98 | 106673.2 | 64.9355 | -3.1316 |
| Mar-00 | 106673.3 | 64.935 | -3.1327 |
| Dec-01 | 106672.9 | 64.9341 | -3.132 |
| Delta | -0.5 | 0.0014 | -0.0006 |

**Figure 9: Survey results have validated the long term stability for Short Target A and is utilized by Station 7105 as the secondary target for MINICO ground tests.**

## ***SOLUTIONS!***





- Increase Formal Survey Activity
- Mandatory Performance of Monthly Ground Tests
- Regular Analysis & Evaluation of Ground Test History
- Identification of Stable Geology for all future Cal Piers