GBT MEMO 224

NRAO Green Bank
Metrology Lab Capabilities
Facilities and Resources

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Contents

Chapter 1

Introduction

Over the course of the research & development of the PSH97 laser rangefinder instrumentation, CST92 panel corner setting tool, NPH6 hydrostatic level, JPL GeoSAR contract, and in support of auxilliary Green Bank Telescope metrology projects, significant metrology instrumentation, skills, and library collection were assimilated–with a particularly strong emphasis on length, angle, and hydrostatic leveling.

The Green Bank Telescope Antenna Metrology Group was disolved in 2003, but the equipment remains in place at this time. This report is intended to document the resources available to the greater NRAO.

The PSH97, CST92, and NPH6 hydrostatic level, are custom-built instruments with unique capabilities for large-scale metrology. The PSH97 has unique electronic distance measurement capabilities. The accuracy and distance range closely matches the top-of-the-line Leica ME5000 Mekometer (no longer manufactured), with the additional features of automated control, speed, and signal processing capabilities. The CST92 corner setting tool, designed for the GBT, was the first-of-kind instrument designed to measure the relative piston offsets between four surface panel corners, with corrections for; instrument gravitational orientation, panel location, and panel coordinate measurement machine profile. The NPH6 is probably the most accurate, and versatile, portable level in the world.

The 1052 square foot metrology lab is located in the basement of the former 300 Foot Telescope control building, on a quiet isolated part of the NRAO property, which is also located far from railroad or heavy highway traffic, and thus extremely attractive for low vibration work. Larger equipment access is provided by an outside freight elevator with a double-door lab entrance. Materials handling is facilitated by a 500 lbf capacity hoist and monorail system extending over a 24" X 96" surface plate, stable concrete monument, and access for a platform truck.

Five stable concrete monuments, with optics jig plates and/or anchor bolts on the tops, are isolated from the floor with dedicated foundations for vibration and temperature stability (distance, elevation, and tilt), and includes a leveled 18.374 m baseline with a rail for laser interferometer calibration and facilities to tension invar wires. There is an indoor optical path of up to 20 meters and an extended outdoor optical path, through an opening in the wall, of up to 85 meters. There is a 6 inch opening through the upstairs concrete floor for sighting down into the lab from above. The lab can easily be converted to darkroom conditions for optics experiments. There is a small shop area with a bench, vice, drill press, and hand tools, and the full Green Bank machine shop is readily available for more complex tasks.

Chapter 2

Standards

2.1 Certificates

The original calibration certificates are filed at the lab, and copies are in the GBT Archive file.

2.2 Dimensional

1. Hewlett Packard laser interferometer†, model 5508A, S/N 3040A02643 with 10753A tripod, linear and angle retroreflectors (inspected and calibrated 7/1994)
2. Mitutoyo gage block set (81 piece), grade 2, set number BE1-81-2, S/N 281739 (certified 3/1993, inspected and calibrated 11/1997)
3. DoAll gage block set (81+1 piece) grade 3, S/N 2076-C (inspected and calibrated 11/1997)
4. 10.0000" gage block
5. Unilamp 5461 Å mercury line (green) lamp
6. Hoover Precision Products, 4.0000 inch steel ball.
7. Hoover Precision Products, 3.5000 inch, grade 200, steel ball. Quantity of 12.
8. Precision Components, assortment of grade 25 chrome steel alloy balls, 0.1250—1.0000" +/- 0.0001" diameter, spherical within 0.000025" (certificate not dated)
9. SPI 7.00012" calibration ring
10. Southern Gage cylinder ring gage 4.200000 +/-0.000025 inches, S/N CRF96-162 (certified 5/1996)
11. Southern Gage, no-go 0.9920-Z
12. Southern Gage, go-gage 1.0000-Z

2.3 Flat, straight, and angle

1. NRAO model NPH6 hydrostatic level†with 30 m (2) and 9 m removable hoses, +/- 0.009 mm/60 m
2. Pellisier H5 hydrostatic level† with 15 m fixed hose
3. Davidson Optronics model D602-101 manual autocollimator S/N 543 (certified 2/1993)
4. DoALL 4 inch optical flat, one side +/- 0.000002", S/N 411 (certified 3/1991)

[1] † indicates computer interface

5. Edmund Scientific 1 inch optical flat, model 43408, one side $\lambda/20$ S/N 056 (certified 8/1993)
6. granite surface plate with stand, 24 X 96" (2)
7. granite surface plate with stand, 24 X 36" (2)
8. Pyramid Granite, 12 X 18 X 2" granite surface plate, grade AA, 2 faces flat and parallel to 0.000050 per 6" (certified 1/2003)
9. Pyramid Granite, 12 X 12 X 3" granite surface plate, grade AA 0.000050 per 6" S/N 4035 (certified 8/1999)
10. Pyramid Granite, 12 X 18 X 3" granite surface plate, grade A 0.0001 per 6" S/N 3758 (certified 5/1999)
11. Tru-Stone granite surface plate, 8 X 12" grade b toolroom, S/N 22022 0.0002 per 6 " (certified 10/1993)
12. Pyramid Granite, 2 X 4 X 36", four face, granite parallels, master grade, 0.000025 per 6" (certified 6/1994)
13. DoALL granite parallels, 3/4 X 1.5 X 9 inches, master grade, 0.000025 per 6" (certified 10/1993)
14. Starrett steel straight edge, 84"
15. Starrett steel straight edge, 2.5" X 36" (2)
16. Starrett steel straight edge, 1.5" X 18"
17. DoALL 8" X 8" X 8" granite master cube, master grade, 0.000025" per 6" (certified 9/1993)
18. Pyramid Granite, granite master square 12 X 12 X 3"–all 6 sides finished and square, w/inserts, master grade, 0.000025 per 6 " (certified 11/1993, recertified 10/1997 and downgraded to 0.000050 per 6" after adding additional inserts)
19. Tru-Stone granite master angle, Grade AA (2 face) 0.000025 per 6", 6 X 9 X 3" S/N 22162 (certified 11/1993)
20. Tru-Stone granite master angle, Grade AA (2 face) 0.000025 per 6", 6 X 9 X 3" S/N 29880 (certified 8/1997)
21. Starrett, Webber Gage Division, model L right angle target S/N TU5 +/-0.3 seconds (certified 7/1993)
22. Starrett CroBlox metal mirror, flat and parallel, 2 inch (4)
23. Melles Griot optical flat and parallel mirror 0.7534" thick, model 02WBK333/011
24. Starrett Webber 12-side optical polygon, Grade 1, +/- 0.5 seconds, S/N 102695.4 (certified 2/1996)
25. DoALL granite sine bar, 22 X 4 X 3 inches (certified 4/1993)
26. Apollo Tool model 10306 sine bar, S/N 92035
27. 4" sine plate
28. 3" sine plate
29. Universal angle block set: 1, 2, 3, 4, 5, 10, 15, 30 +/- 0.5 degree
30. DoALL granite V-block 3 X 3 X 3 inches, 0.0001 per 6" (certified 9/1993
31. Hilger Watts model TB95-3 split-bubble Clinometer, 0–360° range $\approx$ 1 arc second accuracy

2.4 Mass

1. Troemner 5.000 kg mass, Class F (0.5g), S/N 4266 (certified 10/1992)
2. Troemner 5.000 kg mass, Class F (0.5g), S/N 4254 (certified 10/1992)
3. Troemner 2.000 kg mass, Class F (0.2g), S/N 6521 (certified 3/1993)
4. Troemner 2.000 kg mass, Class F (0.2g), S/N 6524 (certified 3/1993)
5. Troemner 2.000 kg mass, Class F (0.2g), S/N 2131 (certified 9/1993)
6. Troemner 2.000 kg mass, Class F (0.2g), S/N 5394 (certified 12/1992)
7. Troemner 1.000 kg mass/hangar, Class F (0.1g), S/N 6094 (certified 2/1993)
8. Troemner 1.000 kg mass/hangar, Class F (0.1g), S/N 6093
9. Troemner 1.000 kg mass, Class F (0.1g), S/N 5499 (certified 12/1993)
10. Troemner 1.000 kg mass, Class F (0.1g), S/N 5501 (certified 12/1993)

2.5 Temperature

1. Miller & Weber precision thermometer S/N 1M1411 (calibrated -37–0 C 1/1993)
2. Miller & Weber precision thermometer S/N 65103 (calibrated -7–30 C 4/1988)
3. Miller & Weber precision thermometer S/N 2E6246 (calibrated -7–30 C 8/1995)
4. Miller & Weber precision thermometer S/N 1S4693 (calibrated -7–30 C 2/1994)
5. Miller & Weber precision thermometer S/N 1N5051 (calibrated -7–30 C 5/1993)
6. Miller & Weber precision thermometer S/N 2L2606 (calibrated 0–30 C 4/1997)

2.6 Humidity

1. General Eastern chilled mirror dew point instrument†, +/- 0.20 C, model M1D-2-SP, S/N 0460794 (repaired and calibrated -23.50–21.60 C 11/1997)

2.7 Pressure

1. Princo model 453 mercury barometer (calibrated 4/3/1995)

2.8 Frequency

1. 100 MHz Maser (from interferometer building)
2. 100 MHz Rubidium (2)

2.9 Optics

1. Newport 8 pc neutral density filter set, 1" dia, 0.04, 0.1, 0.1, 0.3, 0.5, 1.0, 2.0, 3.0
2. See section 2.3 for optical flats

Chapter 3

Metrology Instrumentation

3.1 Dimensional

1. NRAO model PSH97 laser ranging instrument (20)
2. Mitutoyo height gage†model 192-656, 0–18", with 192-001 touch probe
3. Chicago Dial Indicator comparitor stand, 12 X 8 X 2"
4. Mitutoyo digital indicator†, 0.000050" (4)
5. Mitutoyo digital indicator†, 0.0001" (4)
6. Mitutoyo digital indicator†, 0.0001" (3)
7. Mitutoyo digital indicator†, 0.0001", 1" stroke (2)
8. mitutoyo 6"-12" digital micrometer†
9. Mitutoyo 1"-2" digital micrometer†
10. Mitutoyo deep throat 1"-2" digital micrometer†
11. Mitutoyo 0"-1" digital micrometer†
12. Mitutoyo digital depth micrometer†(RANGE???)
13. Starrett 32' long inside micrometer set in fitted wood box, with 2' (17) and 1' extensions and 12", 10", 8", 6", 4", 2", and 1" micrometer tips
14. Starrett model 823A2 inside micrometer, maximum length 32"
15. Mitutoyo 12" digital caliper†
16. Fowler 6" digital caliper
17. Starrett telescoping gage set
18. K&E large bore target holder model 9099-80
19. SPI bore micrometer 6–7"
20. K&E 100' invar tape, model 88-0273, with #4631 spring scale tensioner and pull handles (2)
21. Invar wire stock, storage spools, and fittings.
22. Lufkin 100 ft/30 meter steel tape

3.2 Flat and Angle

1. NRAO model CST92, telescope panel corner setting tool with CMT handheld computer and barcode reader (3)
2. Rank Taylor Hobson Dual Axis Photoelectric Autocollimator DA80, autocollimator 142/67, controller 142/64-143
3. Davidson Optronics model D-523-102 porro prism, S/N 20 (certified 4/1998)
4. Lucas Schaevitz LSRP-30 biaxial inclinometer S/N 42740 & 42742 (calibrated -30, 30 degrees 5/1995)
5. Lucas Schaevitz LSRP-30 biaxial inclinometer S/N 48073 & 48074 (calibrated -30, 30 degrees 2/1999)
6. Lucas Schaevitz LSRP-30 biaxial inclinometer S/N 47393 & 47392 (calibrated -30, 30 degrees 8/1998)
7. Lucas Schaevitz LSRP-30 biaxial inclinometer S/N 45548 & 47395 (calibrated -30, 30 degrees 8/1998)
8. Lucas Schaevitz LSRP-14.5 biaxial inclinometer S/N 38343 & 38342 (calibrated -15.5, 15.5 degrees 7/1992)
9. Starrett 18" machinest level (2)
10. Starrett model 98-4, 4" level (2)
11. Pro 3600 digital protractor/electronic level†
12. Honeywell Compas model HMR3000†

3.3 Force/Strain/Pressure

1. 2,000,000 lbf Geokon Series 3000 compression load cell (2) (rent from Dudgeon Jack, but NRAO has extensive calibration data)
2. 100,000 lbf compression load cell (can borrow from University of Virginia)
3. 50,000 lbf tension load cell (can borrow from Tucson)
4. Wallace and Tiernan model FA185260D aneroid barometer, 560–800 mm Hg (calibrated 3/1995)
5. Setra model 270 pressure instrument, 800-1100 mbar, +/- 0.016% S/N 434767 (certified 7/1994)
6. Dwyer slack tube manometer

3.4 Temperature

1. Fluke model 807-150u universal DMM temperature probe
2. Stoway temperature loggers with waterproof case (6)
3. External mount thermistor for Stoway temperature logger (4)

3.5 Humidity

1. Taylor sling psychrometer
2. Psycho-Dyne battery powered psychrometer

3.6 Frequency

1. 100 MHz crystal oscillator (2)

3.7 Electronics

1. Wavetek arbitrary waveform generator†, model 75A w/option 001 IEEE-488 interface, S/N A92100071
2. Clark Hess Phase Meter†Model 6000 S/N 399
3. Stanford Research Systems Lock-In Amplifier†, model SR830DSP, S/N 36620
4. Racal Instruments model 5001 multimeter S/N 502010 (inspected and recertified 3/1995)
5. Fluke model 97 scope meter
6. Fluke model 87 DMM (2)
7. Fluke model 187 DMM
8. Keithley model 199 DMM†(2) (S/N 477387 & 492052)
9. CMT handheld computer†(2)
10. Dan Gibsom model P-65 parabolic reflector microphone
11. Hewlett Packard model 8478B thermistor microwave power head, S/N 3318A25262 (certified 10/1998)

3.8 Optics

1. Power
   (a) Anritsu optical power meter
2. Imaging
   (a) Titan cathetometer
   (b) Cannon 10 X 30 image stabilizing binoculars
   (c) infrared viewer with IR illuminator
   (d) infrared viewer
   (e) Pulnix model TM-720 monochrome CCD camera without IR filter
   (f) Panasonic monochrome CCTV camera model WV-BP330
   (g) Nikon 50 mm lens
   (h) Nikon 55 mm macro lens (on loan from graphic arts)
   (i) Nikon PK-13 extension rings
   (j) C-mount to Nikon adapter
3. Components
   (a) Replicated hollow retroreflector, 2" (11)
   (b) solid glass retroreflector, 2" (18)
   (c) Custom built attenuated hollow retroreflector (2)
   (d) Physik Instruments type S-330, 2.5" piezo mirror, S/N 34988
   (e) Physik Instruments model P-864.10, piezo mirror controller, S/N 2880792

(f) ??? model 3100 fiber optic light source

(g) Optics bread board, 24" X 36" X 2"

(h) optics bread board, 18" X 36" X 2" with kelvin mount tooling ball base (to fit laser monument)

(i) Thore 1/4-20 X 1"o.c. bread board 12 X 24 X 3/4

(j) Thore 1/4-20 X 1"o.c. bread board 12 X 18 X 3/4

(k) Thore 1/4-20 X 1"o.c. bread board 12 X 12 X 1/2

(l) Thore 1/4-20 X 1"o.c. bread board 10 X 12 X 1/2

(m) Thore 1/4-20 X 1"o.c. bread board 12 X 8 X 1/2

(n) UV light box

Chapter 4

Accessories

1. DoALL gage block clamp set, model AR-11 S/N 423 (certified 11/93)
2. Suburban Tool, ground steel right angle, 16 X 9 X 8", model URA-080916
3. Suburban Tool, ground steel right angle, 6 X 4" (pair)
4. Suburban Tool 2-4-6 blocks (2 matched pairs)
5. 2-3-4 blocks, matched pair
6. Fowler 1-2-3 blocks (1 pair)
7. steel V-blocks, 7 X 5 X 2.5"(pair)
8. steel V-blocks, 6 X 3 X 3.5" (1 pair)
9. steel V-block goniometer, 4 X 2", 0–60°
10. steel V-blocks, 2.5 X 2.75 X 1.75" (1 pair)
11. Starrett V-block set, model 278, 1.25 X 1.75" (4 sets)
12. Starrett model 257B surface gage
13. Fowler bench micrometer stand
14. 2" X 2" magnetic base indicator stand (10)
15. Mighty Mag indicator holder magnet (2)
16. general purpose 1" X 5" magnet (6)
17. Cenco lab jacks, 4.5" X 5.5" (pair)
18. adjustable jack V saddle stand 30"–?? (7)
19. adjustable jack V saddle stand 20"–?? (3)

Chapter 5

Surveying Instruments

5.1 Instruments

1. Topcon model GT3-301 total station† w/90° eyepiece, battery charger, 9 pin RS232 cable
2. Wild T-2 theodolite, 90°, autocollimator eyepiece
3. K&E alignment telescope with optical square penta prism and autocollimator eyepiece
4. Carl Zeiss Ni-2 automatic optical level
5. Wild N3 optical level (repaired 2/2000)
6. Wild model ZBL optical plummit
7. Hilger Watts model TA9059-1/186740 theodolite–rare custom built instrument with alidade bearings for mounting on telescope at inclined elevations
8. Sonin 250 acoustic distance measurement instrument

5.2 Accessories

1. Wild invar level rod
2. Wood level rod kit, 0.1' marks, 4 X 4' pieces (16 foot maximum)
3. Star*net least squares reduction software
4. K&E heavy duty telescoping instrument stand with triangle foot pattern (2)
5. K&E heavy duty telescoping instrument stand–modified for box beam mounting on GBT
6. Topcon tribrach (6)
7. custom built 0.7500" X 3.5000 ball chuck (4)
8. K&E 3.5000" target sphere (7)
9. Leica model GRZ4 omnidirectional retroreflector
10. hollow retroreflector, 2.5", mounted in custom brass block (2)
11. retroreflector target, 2.5" (6)
12. Wild lighted surveying target and tribrach (2)
13. brass plumb bob, 10"

14. Cubic Precision K&E 3 1/2" X 8 thread translator stage
15. tribrach to 5/8" X 8 threaded translator stage
16. Wild trivet X 5/8-11 stud (2)
17. Wild trivet X ball tip for rod stand
18. Topcon battery charger
19. Pop-up utility tent (three)
20. Surveyor's umbrella

Chapter 6

Fixtures and Tools

6.1 Fixtures

1. Thore 1/4-20 X 1"o.c. bread board 12 X 24 X 3/4 with Kelvin mount base and provision for tribrach(2)
2. Calibration of dual axis inclinometers by rotation on a sine plate
3. 10 inch sphere to 3.5 inch sphere, coincident center, adapter
4. 0.75 inch sphere to 3.5 inch sphere with 75.0 mm offset adapter
5. Kelvin mount V angle-to-T2 measurement fixture
6. Hollow retroreflector centering/mounting fixture
7. 5 mm mirror grasping/mounting fixture

6.2 Tools

1. Greenlee panel punchs: 25 pin D, 9 pin D, IEEE 488
2. Greenlee knockout punch set: 1/2, 3/4, 1, 1 1/4" conduit
3. lettering/numbering stamp set, 1/8" letters
4. proto 1/4" socket set in box
5. proto 3/8" socket set in box
6. Ratchet tiedown straps, 9' X 2" (2)
7. chain hoist, 1/2 ton with beam trolley
8. Coleman rechargable air pump
9. Morat gearhead motor, 1" dia shaft
10. Simer 1/2 hp, 85 gpm submersible utility pump
11. ultrasonic cleaner
12. Technitool vaccuum pickup tool
13. propane heater (2)
14. shop vac

Chapter 7

Appendix

In the early days of NRAO, there was an active interest in metrology. People like John Findlay collected some classical, and now hard to find, books in the Green Bank library. The Antenna Metrology Group added some later volumes to bring the collection up to date. A partial list of the metrology holdings are included.

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