Alignment Network Measurement & Adjustment Software Development at FRIB

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Abstract

The alignment group at FRIB has developed software to interface with our Leica AT402 laser trackers to take network measurements and perform real-time least squares network adjustment and statistical analysis. The software is named NETOBS (for Network Observation). NETOBS was written in MATLAB* with the supporting Leica software development toolkit .dll file over the course of several years and compiled to run on any windows computer. NETOBS was written to expedite the time it takes to measure and analyze network measurement data. NETOBS has greatly reduced network measurement monument naming errors and blunders, automates measurements, and does least squares adjustment analysis all in one software solution. Using NETOBS improved the network measurement campaign time to less than half that of previous campaigns.

Network Adjustment & Statistical Analysis Module
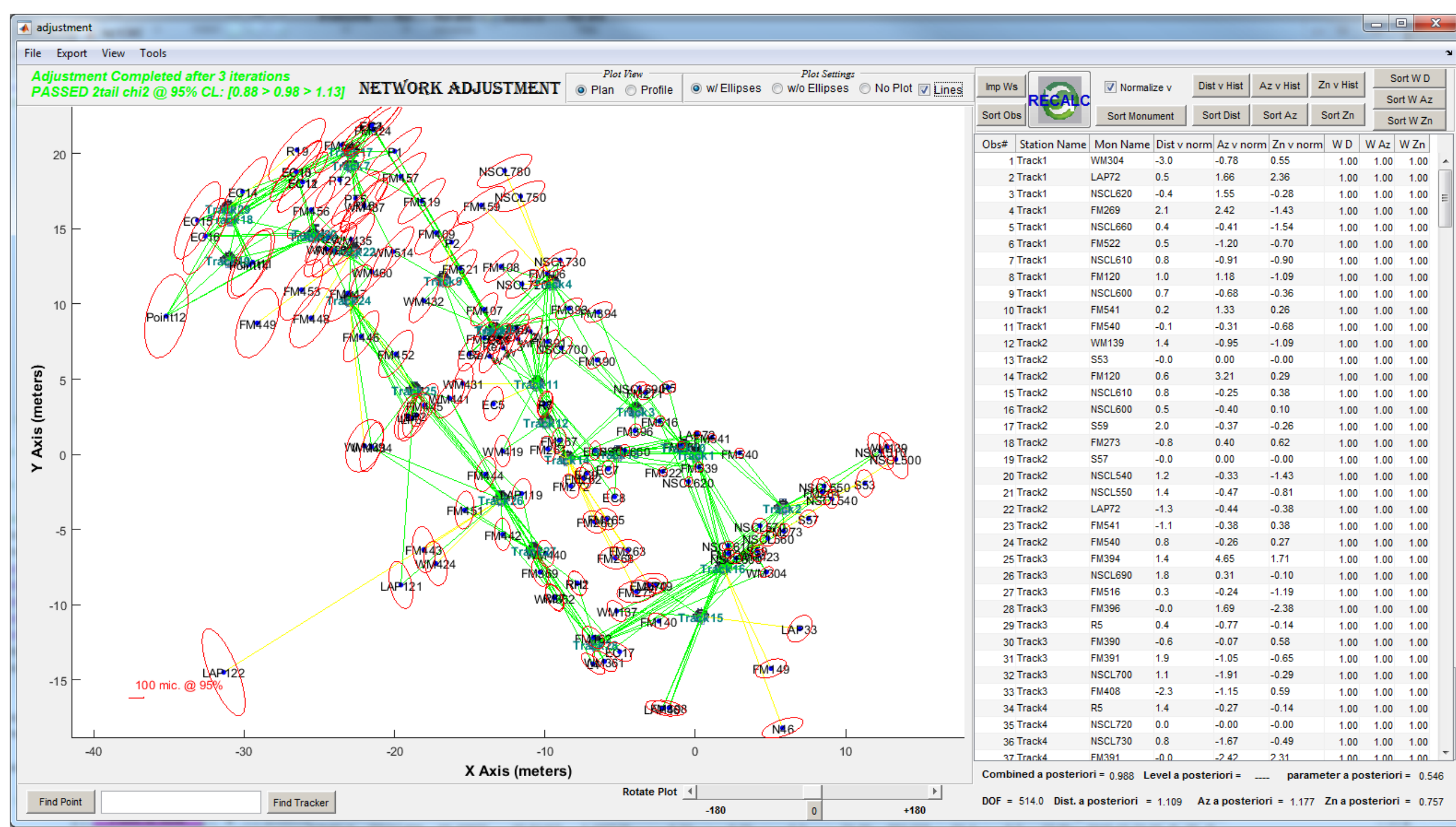
- **Least squares network adjustment**
  - Least squares adjustment of network measurement data can be done quickly in the field on all or a subset of the network measurements. Periodically checking the statistical adjustment of the network in the field can test the quality of measurements and allow environmental or procedural factors to be addressed sooner. Leveling data can be included in the network adjustment.

- **Statistical analysis**
  - Plot normalized measurement residual distributions for azimuth, zenith, and distances
  - Chi Squared tests for total network adjustment and for each measurement type

- **Blunder detection**
  - Sort a posteriori adjusted measurements by magnitude of normalized residuals to identify outliers

- **Flexible datum definition options** (A and B do not require a priori monument coordinates)
  - A: Constrain first tracker position to X = 0, Y = 0, Z = 0, Rx = 0, Ry = 0, Rz = 0
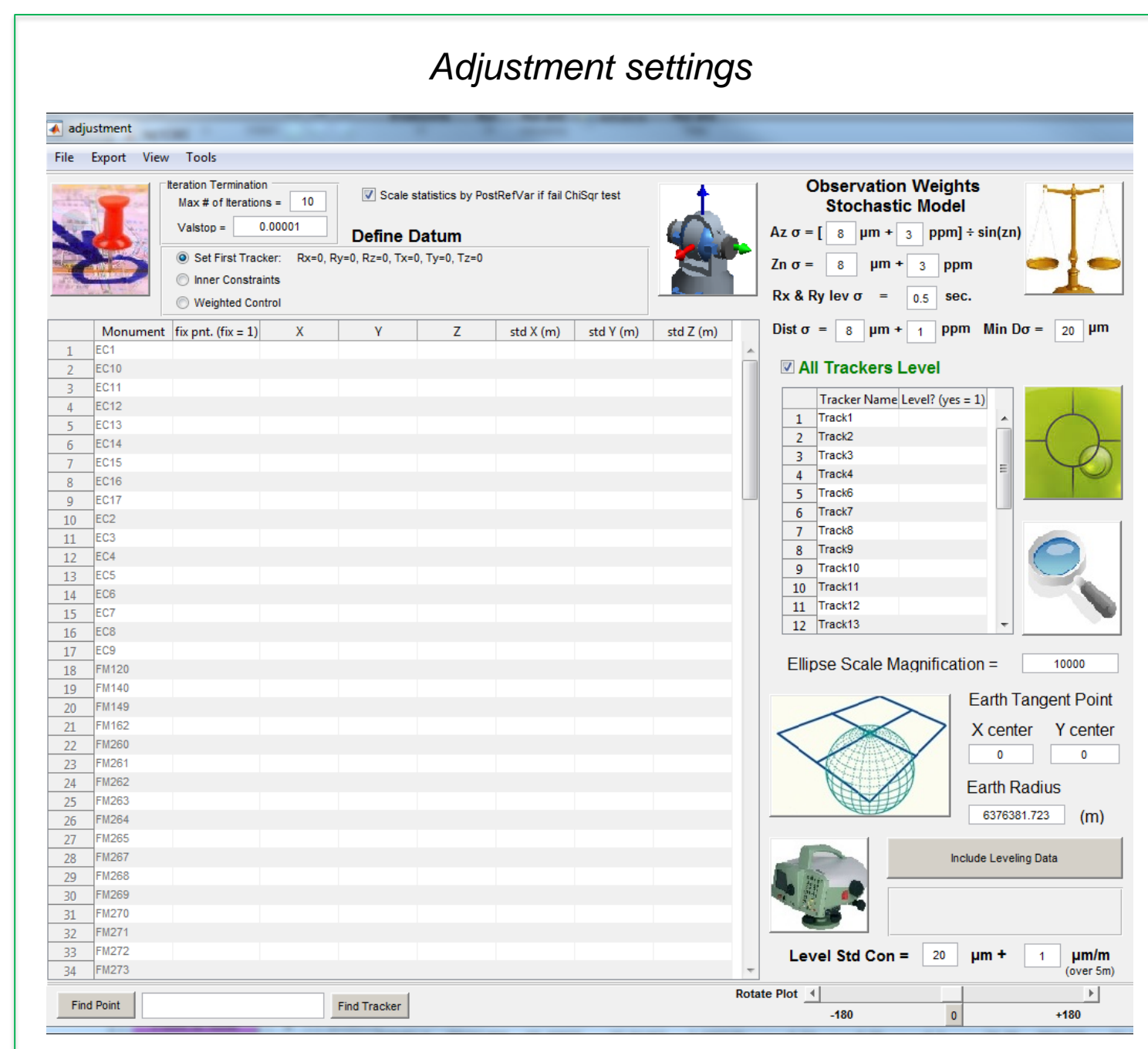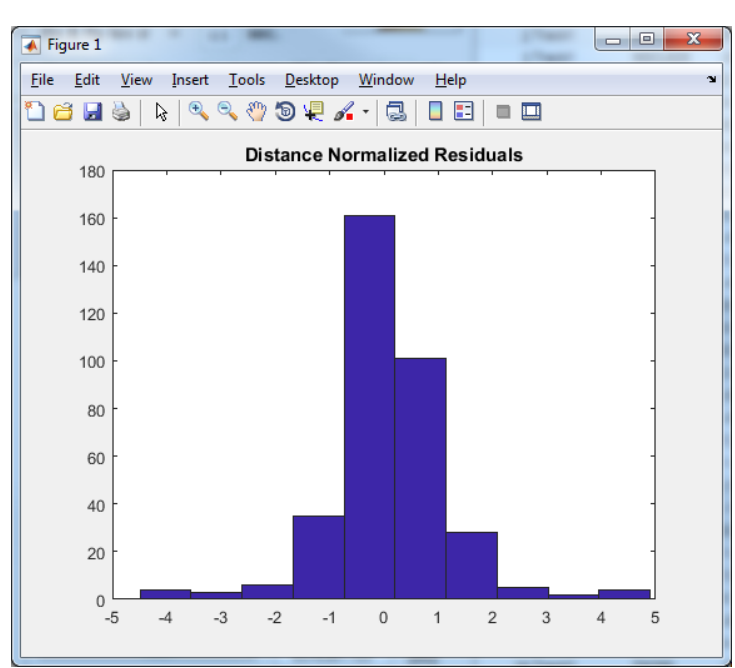 - B: Inner network constraints
  - C: Weighted datum point constraints

- **Flexible stochastic modeling**
  - Set a priori standard deviations for each measurement type
    - Azimuths
    - Zeniths
    - Distances
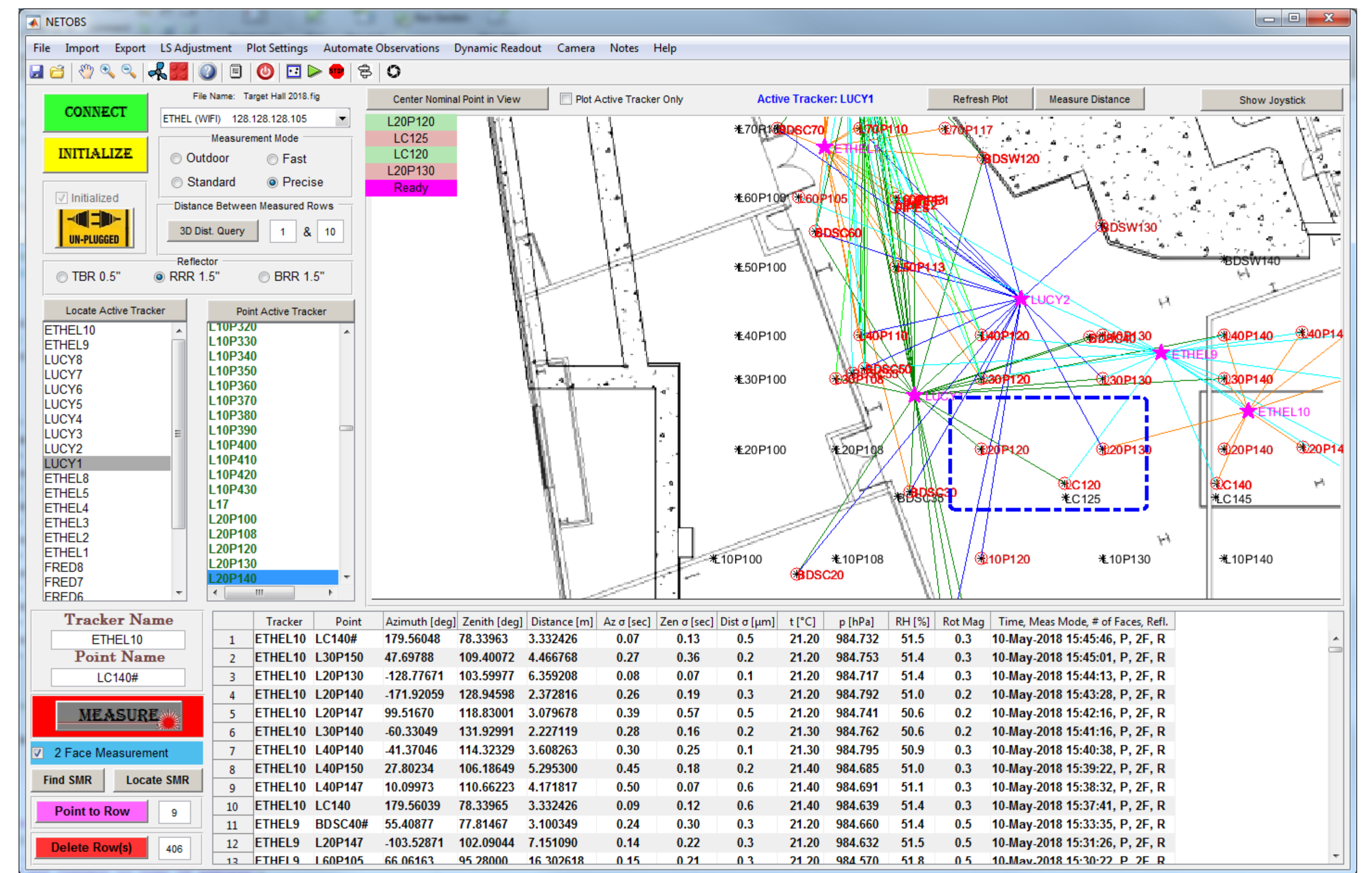   - Tracker Levelness
    - Leveling data

- **Gravity Modeling**
  - Uses localized sphere model

Normalized distance residual distribution plot

Adjustment settings

AT402 Interface Module

- **Complete control of AT402 through Ethernet or Wi-Fi**
  - Measurements in Precise, Outdoor, Standard, and Fast modes
  - Real-time monitoring and display of AT402 status: Locked on SMR, levelness, plugged in, and initialized
  - Display AT402 overhead view camera live color video and capture and save video image
  - Drive AT402 head with overhead view camera NETOBS display or NETOBS joystick
  - Real-time AT402 watch window ΔX, ΔY, ΔZ read-out for component alignment or coordinate layout
  - Smart AT402 search for SMR
  - Power off AT402

- **Automatic measurements**
  - Drives AT402 to measure multiple monuments automatically within a user-drawn perimeter (with an optional left-click-to-continue / right-click-to-retry-previous-measurement pause between measurements)
  - Automatically names monument measurements by nearest neighbor to nominal within user tolerance

- **Dynamic plotting**
  - Display settings include the optional plotting of tracker positions, nominal network points, measurement lines, measured points, point names, and the FRIB building outline

- **Locate AT402** (after minimally measuring 3 network monuments)
  - Interactive least squares best fit transformation routine with the option to fit to a nominal list of network points or measurements from a previous tracker position

- **Records standard deviation of measured angles and distances**
  - Measurement lines with standard deviations above 3 sigma are highlighted in red
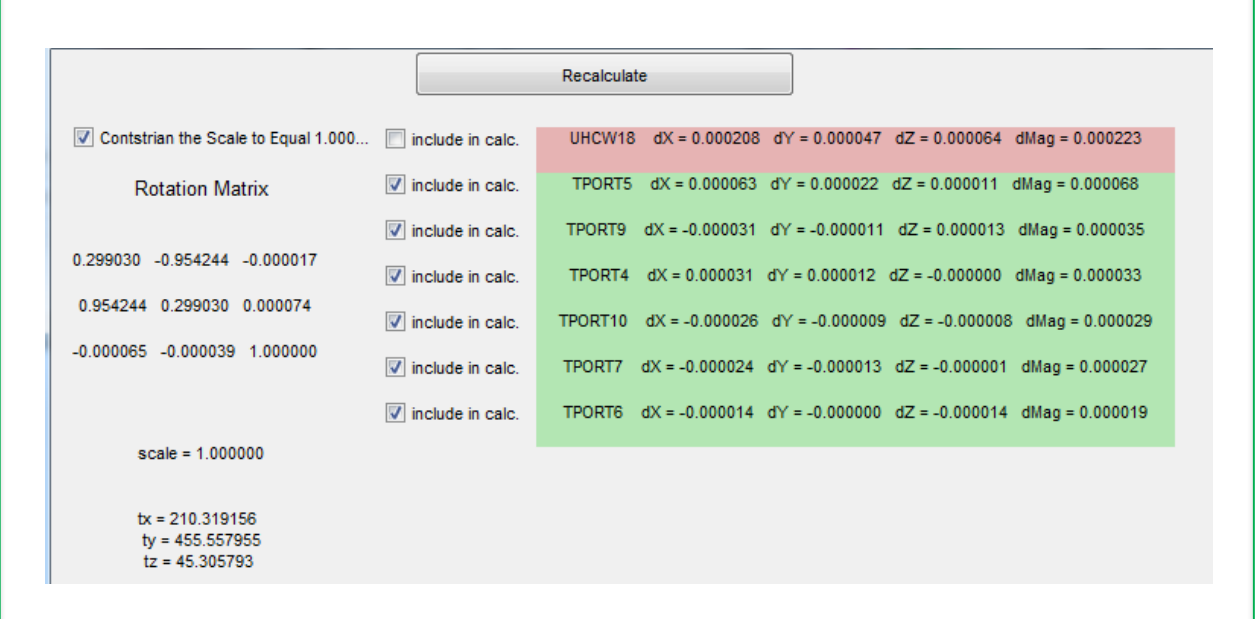
- **Possible future additions to NETOBS**
  - Add more instruments that can interface with NETOBS
  - Record the difference between the backsite and foresite of a 2 face measurement and give a warning if the difference is greater than a user defined tolerance
  - Add magnet mapping equipment interface to work simultaneously with laser tracker measurements
  - Add beamline component as-aligned calculations
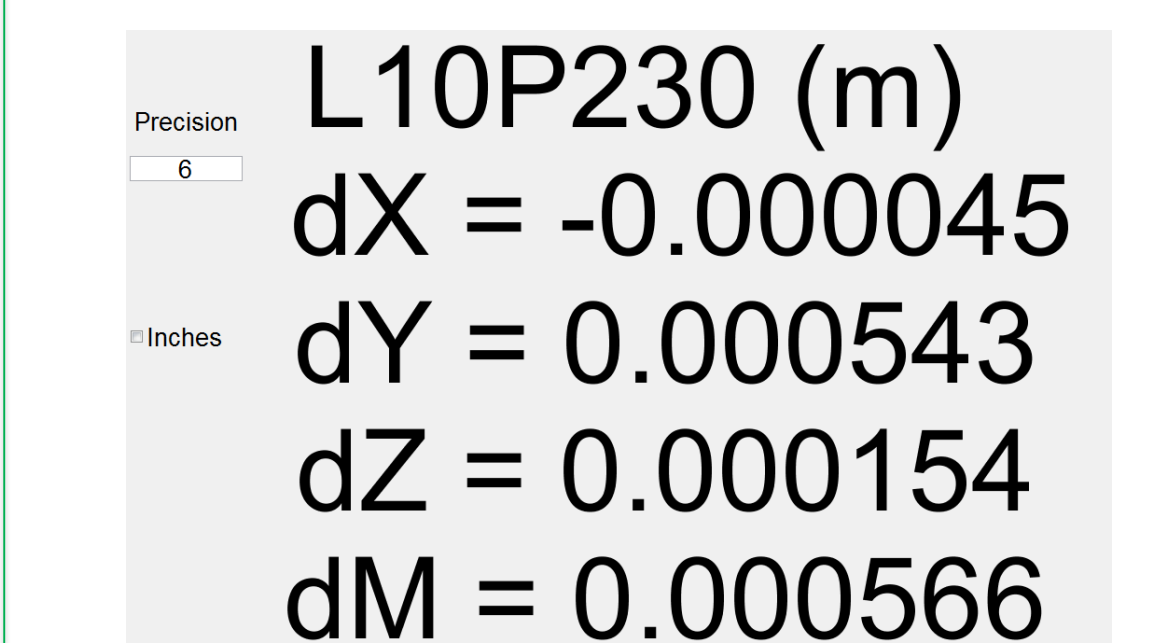 - Add geometric fitting to measurements

Taking monument network campaign measurements with an AT402 controlled by NETOBS software
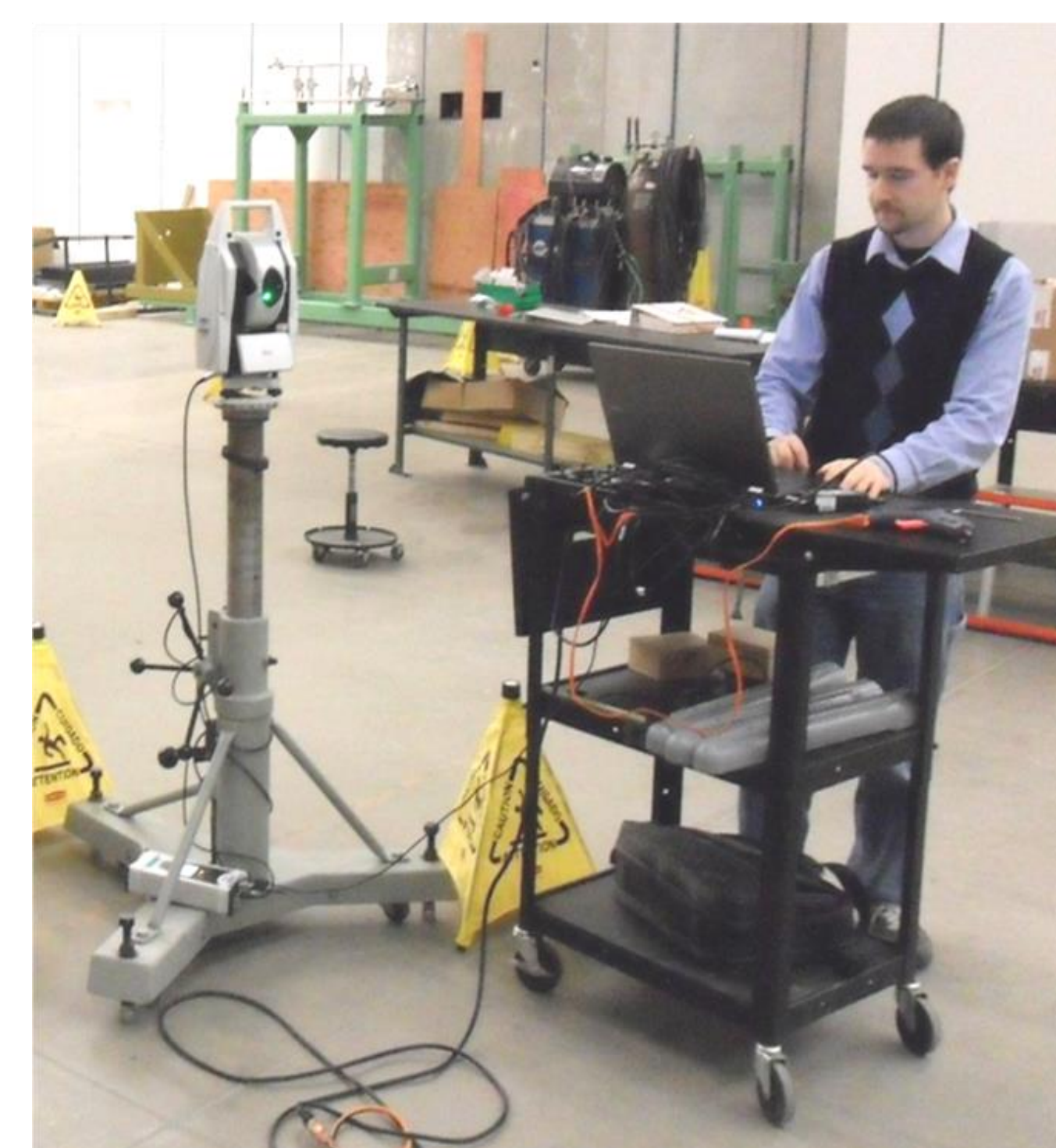
Least squares best fit transformation to locate AT402

Dynamic watch-window for nominal point layout

L10P230 (m)
dX = -0.000045
dY = 0.000543
dZ = 0.000154
dM = 0.000566

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