

INDEX

- A posteriori variance factor, 34, 185, 257, 297, 298
- Absolute confidence ellipse, 223
- Absolute distance meter (ADM), 566
- Absolute network, 272, 307
- Absolutely constrained, 293
- Accuracy
- analysis, 15, 133, 223, 260, 504
 - apparent, 29
 - direction, 25, 120
 - distance, 25, 67, 222, 311, 340, 569–571
 - elevation difference, 62
 - ellipsoidal height, 73, 74
 - horizontal angle, of, 110
 - horizontal coordinate, 73, 74
 - local, 69, 72–77, 85
 - local measure of, 34
 - measurement, of, 30, 48
 - network, 69, 72–77, 85, 211
 - positional, 49, 66, 78, 79, 84, 216, 217, 239, 498, 520
 - positioning, 205, 223, 323, 439, 535, 538
 - setting, 21, 62, 123, 195, 197, 232, 235, 264
 - specifications for vertical control, 54
 - standards, 48–51, 55, 61, 62, 66, 72, 75
 - tilt determination, for the, 439
- Accuracy ratio, relative, 68, 69
- ACSM, *see* American Congress on Surveying and Mapping
- Adit, 445–447, 449
- Adjustment
- constrained, 74, 222, 256
 - free network, 293, 294, 296
 - inner constraint, 293, 294, 302
 - minimal constraint, 51
 - single-epoch, 291, 298, 300, 301
 - two-epoch, 291, 292, 300, 301, 307, 311, 317
- ADM, *see* Absolute distance meter
- Airborne laser scanning system, 258, 259
- Alignment
- accelerator, 537, 565
 - automated, 464
 - axial rotational, 419
 - of a boring machine, 500
 - coarse, 535, 536
 - constant, 470, 472–474
 - diffraction, 528
 - element, 555, 557
 - fine, 535, 536
 - horizontal, 555–557, 573
 - optical plummet, 207
 - option, 556
 - by polar measurement systems, 529, 565

- Alignment (*Continued*)
 quality analysis of, 536
 results, 531, 532, 574
 sensor, 419
 telescope, 8, 447, 464, 536, 540–543, 552, 554
 theodolite, 531
 tunnel, 451, 497, 498, 500, 505
 vertical, 391, 555, 558, 571
- Alignment techniques
 conventional, 531
 diffraction, 528
 direct laser, 528, 530
 hydrostatic, 529
 mechanical, 528
- Alkaline aggregate reaction, 269, 310
- Allowable discrepancy, 48, 54–58, 65, 122, 123, 221, 236
- Alternative hypothesis, 38, 39
- Ambient
 pressure, 145
 temperature, 128, 145, 148, 198, 203, 429, 562
- Ambiguity
 altitude of, 360
 resolution, 334
 signal phase, 375
- American Congress on Surveying and Mapping (ACSM), 48
- American Society for Photogrammetry and Remote Sensing (ASPRS), 49, 77
- American Society of Civil Engineers (ASCE), 392
- Amplitude
 of EM wave, 136
 modulation, 137, 138
- Amplitude and transit method, 469
- Antenna footprint, 350, 351
- Antennas phase center, 71, 72, 204, 260
- ASCE, *see* American Society of Civil Engineers
- ASPRS, *see* American Society for Photogrammetry and Remote Sensing
- Astronomic
 azimuth, 11, 20, 121, 246–249, 473, 482
 latitude, 240, 246, 248
 longitude, 240, 246, 248
 meridian, 241
- Atmospheric refraction
 horizontal, 104, 573
 vertical, 88, 105, 117, 190, 193, 322, 573
- ATR, *see* Automatic target recognition
- Attached method, 553
- Autocollimation, 540, 541, 544, 545, 550–553
- Automatic level
 Leica NA2/NAK2, 21
 Sokkia B20, 21
- Automatic target recognition (ATR), 27, 285, 570
- Auto-reflection, 540–542, 544, 551–553
- Axial errors, 340
- Azimuth
 astronomic, 11, 20, 121, 246–249, 481, 482, 505
 display mode, 478, 479
 geodetic, 20, 246–249, 482
 grid, 20, 472, 473, 482, 523
 gyro, 69, 472–474, 482, 508
 solar observations for, 121
- Baarda, 298
- Baselines
 GNSS, 205, 208
 GPS, 285, 323
 mine, 442, 444
- Best linear unbiased estimates, 296
- BLUE, 296
- Blunder detection, 62, 84, 298, 299
- Bragg
 condition, 408
 equation, 408
 gratings, 407, 409
 wavelength, 408, 409
- Breakthrough error, total
 lateral component of, 505
 longitudinal component of, 505
- Breakthrough points, 497, 506, 511, 512, 514, 516
- Bubble sensitivity, 21, 110, 111, 118, 225, 234, 264
- Bucking in procedure, 553
- C/A code, 9, 10, 205
- Calibrated scale bars, 535
- Calibration
 antenna, 207
 baseline, 166, 170, 181, 183, 184, 205, 287
 correction, 472, 473
 of EDM, 167, 170, 175, 180
 geodetic leveling equipment, 201
 instrument, 85, 173, 180, 192, 474, 538
 parameters, 84, 85, 171, 180, 260, 415
 refractivity, 153
 value, 482
- Canadian Active Control System (CACS), 69, 73
- Canadian Base Network (CBN), 73
- Canadian Spatial Reference System (CSRS), 73
- Carrier wave, 137, 140, 333, 561
- Cartesian
 coordinates, 244, 262, 528, 529, 566, 567
 reference frame, 291
- CCR, *see* Corner cube reflector
- Central meridian, 239, 472, 481, 518

- CERN Distinvar, 389
- C-factor, 61, 64, 192
- Channel Tunnel, 7, 517, 518
- Channel Tunnel Grid (CTG), 518
- Check points, 346, 347
- Chi-square
 - distribution, 41, 42, 81, 82, 197, 308, 309
 - test, 203, 298
- Closing the section, 56
- Closure
 - loop, 53, 62, 63, 195, 196
 - section, 53, 62, 195, 196
- CLR, *see* Coherent laser radar
- Cofactor matrix, 35, 184, 220, 292, 296, 301–303, 309
- Coherency, 330
- Coherent laser radar (CLR), 572
- Collimation
 - axis, 88, 198, 340
 - error, 57, 60, 88
 - factor, 61
 - horizontal, 88–90
- Collinear array of points, 175
- Combined design, 213
- Compass, 8, 271
- Compensator index error, 89, 95, 107
 - alongside error, 95
 - crosswise error, 95
- Compensator, reversible, 192, 193
- Computer simulation, 210, 218, 220
- Confidence ellipse
 - absolute, 223
 - for horizontal coordinate accuracy, 74
 - relative, 223
 - representing the network accuracy, 73
 - standard, 216
- Confidence interval, 33, 65, 74, 197, 201
 - for ellipsoidal height accuracy, 74
- Confidence region, 34, 51, 66, 307
 - estimation, 51
 - for population mean, 32
- Confidence-error curve, 505
- Constant
 - additive, 158, 165–167, 173, 180, 183–187, 254, 344
 - alignment, 470, 472–474
 - calibration, 525
 - instrumental, 474
 - system, 153, 171, 172, 174–177, 179–182
 - torque ratio, 474
 - zero, 178
- Constraint
 - equations, 292–294
 - inner, 293, 294, 300, 302
 - minimal, 51, 52, 293, 303, 313, 507, 508
 - weight, 293
- Contour interval, 80, 82, 242, 363
- Conventional Terrestrial Reference System (CTRS), 240
- Convergence of meridian, 248, 472, 481, 524
- Coordinate differencing, 291, 301
- Coordinate reference systems
 - one-dimensional, 238
 - three-dimensional, 238, 240
 - two-dimensional, 238, 239
- Coordinate system
 - geocentric natural, 240
 - one-dimensional, 238, 239
 - origin of the, 69, 294, 525, 571
 - reference, 213, 238, 249, 277, 293
 - topographic, 242
 - two-dimensional, 239, 240
- Coordination
 - three-dimensional, 569
 - wall target, 252
- Coplaning method, 449, 450, 457
- Corner cube reflector (CCR), 565
- Correction
 - earth curvature, 290, 469
 - eye-to-object, 289
 - first velocity, 148, 149, 152, 156, 226
 - second velocity, 149, 150, 156
- Correlation, in mining, 444, 447–449
- Critical value, 32, 33, 40–42, 313
 - from the Chi-square distribution, 42
 - from the normal distribution, 41
- Crosscut, 446
- CSRS, *see* Canadian Spatial Reference System
- CTG, *see* Channel Tunnel Grid
- CTRS, *see* Conventional Terrestrial Reference System
- Curvature of subsidence bowl, 325
- Cyclic
 - error, 153, 154, 158, 165, 168
 - function, 389, 430
- Cylindrical Orthomorphic Transverse Mercator, 518
- Dam, embankment, 269, 309, 310
- DamSmart software, 423
- Datum
 - constraints, 293, 301, 302
 - defect, 292
 - deficiencies, 295, 297
 - definition, 293, 294, 299
 - dynamic, 240
 - elements, 291, 293
 - geodetic, 69, 73, 244, 291, 299, 345

- Datum (*Continued*)
 invariant, 307
 mine, 444
 reference, 23, 157, 215, 270, 272, 274, 396,
 519, 535, 558
 vertical, 290, 519
- Deflection of the vertical, 98, 246–248, 251, 482,
 516, 517, 519, 530, 538
- Deformation
 analysis, 4, 5, 217, 268, 270, 272, 293, 298,
 300, 306, 307, 311, 317, 345, 349, 350,
 367, 430, 431, 438
 geometrical, 306, 307
 graphical trend analysis of, 308
 localization of, 307, 308
 modeling, 308
 statistical trend analysis of, 307
- Deformation monitoring
 automated real-time, 318
 basic problems of, 437
 integrated, 437
 schemes, 273, 420
 with terrestrial scanners, 345
- Degrees of freedom, 127, 131, 172, 177, 187, 197,
 216, 309
- Design
 Aarau, 168
 combined, 213
 EDM baseline, 168
 first-order, 212, 213
 of geotechnical deformation monitoring, 420
 Heerbrugg, 168
 Hobart, 168
 optimum, 212
 second-order, 212, 213
 third-order, 212, 213
 zero-order, 212, 213
- Design matrix
 first, 172, 212, 220, 292, 296
 second, 172
- Detached method, 553
- Deterministic, 305
- Dial indicator, 380, 382
- Digiquartz pressure sensor, 168
- Digital levels, 12, 21, 25, 322
 Leica DNA03, 21
 Sokkia SDL30, 21
 Topcon DL-101C, 21
- Digital terrain model (DTM), 260, 349
- DIN, 45, 46, 50, 131, 183, 202
- D-InSAR, 360, 367, 368, 375
- Dip, 425–427
- Directional
 method, 18, 19, 108–110, 116, 124, 228
 theodolites, 17, 18
- Displacement ellipse, 309, 313
- Distribution
 χ^2 , 41, 42, 81, 82, 197, 308, 309
 F-, 43, 301, 303, 307
 Fisher (*see* Distribution, F-)
 normal (z), 33, 34, 41, 51, 53, 81, 217
 t , 34
- Diversion sluiceway, 309, 310, 315, 393
- Doppler
 counts, 560, 561
 effects, 352, 559, 560
 frequency, 559, 560
 signal, 559
- Double-centering, 96, 97, 106, 340, 569
- Double-run leveling, 56, 197, 200, 202
- Double-scale rod, 194
- Drift, 446
- DTM, *see* Digital terrain model
- Dual-axis compensators, 27, 99, 101, 221
- Dynamic
 height difference, 23
 height systems, 22–24
 models, 305, 306
 process, 305
 system, 305
- Earth curvature, 150, 154, 155, 190, 193, 290
- EDM, *see* Electromagnetic distance measurement
- EDM system constant determination, 175, 177,
 179
 approximate approach of, 179
 modified standard approach of, 177
 standard approach of, 175, 177
- Eigenvalues, maximum and minimum, 35, 38,
 220, 309, 507
- Electromagnetic distance measurement (EDM), 8,
 11, 24, 133, 205, 276, 439, 445, 528, 561
 accuracy of, 134
 calibration, 166, 167, 170, 180, 205
 Geomensor 204DME precision, 25, 287
 internal phase measurement of an, 154
 modulation frequency, 153–156
 phase measurement principle, 139
 reflectorless, 26, 318
 standardization, 175, 179, 180
 two-color, 26
- Electronic digital theodolites, 17, 19, 24
- Electro-optical instrument, 145, 154
- Elevation differences, 21, 22, 56, 61, 62, 189, 236,
 509
- EM spectrum, 136
- EM waves, 134, 136, 137
- Equipotential surface, 290, 529

- Error**
 analysis of tunneling surveys, 504
 axial, 340
 breakthrough, 504–508, 511–513, 515, 516
 centering, 98, 112–115, 118, 252
 collimation, 57, 58, 60, 88–91, 93, 94, 96, 107, 190, 192, 193, 537
 compensator-index, 95
 cyclic, 154, 158, 168
 external, 190
 gross, 28, 298
 instrument, 99, 101
 instrument leveling, 110, 189, 191, 192, 235
 instrument miscentering, 113, 114
 laser beam divergence, 340
 lateral breakthrough, 2, 505, 506, 508, 512, 513, 516
 leveling, 89, 110, 111, 117, 119, 120, 191, 192, 225, 465
 margin of, 32, 33, 81
 maximum allowable, 63, 71, 257
 phase measurement, 153, 154, 158
 plate bubble, 101, 107
 plummet, 98, 99, 107
 pointing, 106–190, 194, 221, 263, 264, 548
 random, 53, 56, 115, 164, 178, 264, 453, 522, 558
 reading, 108–110, 191, 194, 195, 273
 relative positional, 71, 505
 standard, 32, 34, 40, 41, 51, 53, 54, 115, 165, 507
 standing axis, 88, 95, 96, 99–101, 107
 systematic scale, 144
 target miscentering, 112, 113
 vertical index, 90, 95
 zero, 153, 154, 158, 165, 340
- Error ellipse**
 absolute, 35, 73
 confidence, 35, 36, 51, 216, 506
 point displacement, 308
 relative, 36, 38, 70, 220, 222, 506–508
 standard, 70, 218, 507
- Error propagation**
 for alignment elements, 557
 for angle measurements, 115, 233
 of the average value of refractive correction, 226
 on the azimuth, 264
 on the difference of two distances, 41, 161
 on the discrepancy, 197
 of the misclosure, 230
 on sine law equation, 453
 on traverse surveys, 522
- ETRS89, *see* European Terrestrial Reference System of 1989
- European Terrestrial Reference System of 1989 (ETRS89), 73, 530
- Extensometer**
 borehole, 326, 383, 385, 421, 430
 fixed borehole rod, 383
 multipoint, 383, 384, 424
 observation equation, 425
 portable wire line, 383
 single-point rod, 383, 384
 tape, 281, 387–390, 423, 428–431
- External errors, 88**
- Fiber Bragg gratings (FBGs), 407**
- Fiber optic sensor (FOS), 406**
 application of, 407
 intensity modulated, 407
 long base, 409
 phase modulated, 407, 409
- Field reconnaissance, 218, 219, 274**
- Finite element method, 215, 305**
- First velocity correction, 148, 149, 152, 226**
- First-order design (FOD), 213, 215**
- Flattening the earth, 357**
- FOD, *see* First-order design**
- Follow-up method, 471–474, 477**
- Footprint, antenna, 350, 351**
- Forced-centering, 112, 169, 170, 173, 276, 286, 567**
- Four-pin gauge, 389, 391**
- Frequency correction, 154, 156**
- Fringe**
 counter, 560, 561, 563
 counts, 560, 563
- Fully distributed sensors, 407**
- Galileo, 8, 271**
- Gauss mid-latitude method, 20**
- GB-InSAR, advantages of, 374**
- General model equations, 172**
- Geodesy, 1**
- Geodetic**
 control, 3, 4, 49, 66, 69, 71, 272, 497, 509
 coordinates, 72, 239, 243
 datum, 69, 73, 244, 291, 299, 345
 deformation, 4, 268, 270, 272, 276
 engineering surveying, 5, 305
 latitude, 20, 246, 247
 leveling, 22, 23, 56, 190, 191, 194–196, 322–324, 439
 local, 240, 243
 longitude, 20, 246
 receivers, 9, 203

- Geodetic network
 - absolute, 271, 315
 - relative, 270
- Geodetic reference system 1980 (GRS80), 530
- Geographic information system (GIS), 6, 372, 424, 443
- Geoid undulations, 531, 538
- Geometrical models, 306
- Geopotential
 - differences, 22, 23
 - numbers, 22, 23, 517
- Georeferenced object space coordinates, 263
- Georeferencing
 - direct, 262–264, 335, 336
 - indirect, 335
 - two-step approach of, 335
- Geotechnical instrumentation, 268, 270, 318, 379, 380, 419, 422, 440
- GIS, *see* Geographic information system
- Global Navigation Satellite System (GNSS)
 - antenna phase center variations, 204
 - derived orthometric heights, 204
 - ellipsoidal height differences, 204
 - measurement validation, 204, 205
 - network design, 214
 - performance, 204
 - receivers, 9, 20, 25
 - specifications, 214
 - three-dimensional test network, 204
 - validation network, 205, 206
 - zero-baseline, 204, 206
- Global Navigation Satellite System (GNSS), 17, 20, 71, 213, 238
- Global positioning system (GPS), 6, 244, 259, 530
- GLONASS, 8, 271, 284
- GNSS, *see* Global Navigation Satellite System
- GP-1 gyro, 468, 474, 477
- GPS, *see* Global positioning system
- GPS three-baseline surveys, 285
- Graphical analysis, 313
- Gravity potential, 240
- Greenwich, meridian plane of, 241
- Grid
 - azimuth, 20, 472, 473, 482
 - north, 524
- Ground reference system, 346, 347
- Ground truth, 206
- Group refractive index, 137, 144, 145, 162
- GRS80, *see* Geodetic reference system 1980
- Gyro azimuth
 - corrected, 472
 - measurements, 69
 - uncorrected, 472
- Gyro mark, 468–471
- Gyro station, 16, 17, 467
 - Sokkia GP1–2A, 121
 - Sokkia GP3X, 20, 467, 469, 475
- Gyro unit, Sokkia GP-1, 467, 468
- GYROMAT 2000, 11, 20
- GYROMAT 3000, 467, 538
- GYROMAT 5000, 538
- Gyrotheodolite
 - azimuth, 293
 - equipment, 467
 - fieldsheet, 472, 473
 - traversing, 443, 447, 512
- Head gate, 310
- Headframe, 446
- Heading, 260
- Headpond area, 310
- Heights
 - differences, 20–23, 30, 61, 277, 528, 529
 - dynamic, 22
 - ellipsoidal, 16, 73, 531
 - Helmert orthometric, 23, 517
 - normal, 22
 - normal orthometric, 23
 - orthometric, 22, 239, 290
- High definition survey, 270, 330
- Horizontal control surveys, 8, 51, 66, 67, 498
- Horizontal index error, 95
- Hybrid system, 320
- Hydrographic surveying, 518
- Hydrostatic alignment, 529
- Identity matrix, 302, 303
- IFM, *see* Interferometer
- In situ instrumentation, 438
- Inclinometer
 - in situ, 402, 403
 - MEMS, 381, 413, 418
 - probe, 401, 413
 - sensors, 401
 - servo-accelerometer-based, 416
 - traditional, 401, 416
- In-context testing, 299
- In-context value, 309
- Industrial metrology, 7, 238, 243, 246, 248, 251, 252, 533, 535, 565, 571
- Inertial measurement unit (IMU), 259
- Inertial Navigation System, 16
- InSAR, *see* Interferometric synthetic aperture radar
- Instrument's proportionality factor, 474
- Intake structure, 310, 316, 317, 387–400
- Integer ambiguity, 140

- Integrated model, 305
- Interferogram
 differential, 359, 362
 D-InSAR, 360
 flattened, 356, 362
- Interferometer (IFM)
 angular, 563, 564
 angular measurement with, 563
 displacement, 566, 568
 laser, 44, 529, 559, 562, 569
 operational principle of an, 560
 straightness (measurement with), 564
- Interferometric
 coherence, 362, 364
 phase, 355–359, 361–363, 367
 phase shift, 358, 363
- Interferometric synthetic aperture radar (InSAR),
 330
 applications of, 367
 CR-, 365
 GB-, 330, 342, 368–372, 374, 375
 limitations of, 330, 366
 permanent scatterer, 364, 365
 persistent scatterer, 364
 space-borne, 368, 369
- Interferometry
 concept of, 559
 differential, 360, 367
 imaging principle of, 354
 repeat-pass, 353
 single-pass, 353
- Internal accuracy, 85, 215, 216
- Internal/instrumental errors, 88
- International Commission of Large Dams, 275,
 310
- International Organization for Standardization
 (ISO), 45, 50, 84
 17123– 2, 61
 17123– 3, 232, 311
 17123– 4, 169, 183
- International society of mine surveying (ISM), 442
- International Terrestrial Reference Frame (ITRF),
 240
- International Terrestrial Reference System (ITRS),
 240
- Interval estimate, 32, 33
- Invar scale bar, 534, 538
- Inverted plumbline, 316, 391, 393, 396–400, 439,
 440
- ISM, *see* International society of mine surveying
- ISO, *see* International Organization for
 Standardization
- Iterative weighted similarity transformation
 (IWST), 268, 281, 302
- ITRF, *see* International Terrestrial Reference
 Frame
- ITRF2000, 244
- ITRS, *see* International Terrestrial Reference
 System
- Jacobian matrix, 31, 127, 130, 199
- Jig transit, 539, 542, 544, 545, 550, 553–555
- Joint meter, 390, 392, 432
- Kern distometer, 389, 439
- Kinematic models, 306
- LA system, *see* Local astronomic system
- LADAR, *see* Laser detection and ranging
- Land surveying, 5
- Laplace correction, 247
- Large scale metrology (LSM), 527, 529
- Laser
 alignment, 528, 530
 application of, 333
 coherency property of, 332
 degradation of, 332
 directional property of, 331
 interferometry, 7, 559
 monochromatic property of, 331
 output intensity property of, 332
 plummet, 112, 221, 447, 464
 profiler, 258
 scanner, 259, 262
 trackers, 529, 565–569
 triangulation technique, 334
- Laser detection and ranging (LADAR), 572
- Laser scanners
 ground-based, 333
 terrestrial, 262, 330
- Lateral adjuster, 540, 554
- Lateral breakthrough, 2, 504–506, 508, 512, 513,
 515, 516
- Least squares
 adjustment, 32, 35, 37, 62, 67, 74, 171,
 176–178, 184, 199, 212, 219, 256, 291,
 292, 298, 301, 303, 304, 307, 425,
 506–508, 535
 equations, 176, 177, 298
 method, 127, 130, 172, 175
 parametric model, 291
- Leica DNA03, 21, 61
- Leica ScanStation P20, 264, 265, 337
- Leveling
 closure, 62, 63, 195, 196
 differential, 12, 20, 21, 24, 56, 58, 310
 double-run, 56, 197, 200, 202

- Leveling (*Continued*)
 - electronic, 61
 - first-order, 55–58, 64
 - rejection test, 56
 - section, 56, 60, 61, 192, 195, 236, 509
 - single-run, 53, 509
 - special-order, 55, 235, 236
 - three-wire, 58, 59
 - trigonometric, 16, 21, 253, 289, 323, 483
- LG system, *see* Local geodetic System
- LiDAR, *see* Light detection and ranging
- Light detection and ranging (LiDAR), 16, 333, 572
- Limitations to the accuracy of measurements, 25
 - atmospheric condition, 25
 - design and precision of equipment, 26
 - instrument operator factor, 27
- Line of sight (LoS), 346, 351
- Linear potentiometer, 382
- Linear regression, 171, 173, 183, 184
- Linear variable differential/displacement transformer (LVDT), 382, 390
- LLR, *see* Lunar laser ranging
- Local astronomic (LA) system, 240
- Local geodetic (LG) system, 240, 243
- Long base sensors, 407, 409
- Longitudinal waves, 134
- Loop traverse, 51, 68, 69, 227, 232, 257
- LSM, *see* Large scale metrology
- Lunar laser ranging (LLR), 139
- LVDT, *see* Linear variable differential/displacement transformer

- Main spillway, 310
- Map projection, 239, 240, 277, 284, 481, 518
- Mark-to-mark
 - distance, 171, 256, 288, 290
 - reductions, 277
- Matrix
 - identity (*see* Identity matrix)
 - symmetric (*see* Symmetric matrix)
 - weight (*see* Weight matrix)
- Mechanical alignment, 528
- Mechanical correlation technique, 448
- Mechanical plumbing, 447, 449
- MEMS, *see* Micro-electro-mechanical sensors
- Metrology, industrial, 7, 238, 243, 246, 248, 251, 252, 533, 535, 565, 571
- Michelson interferometric procedures, 560
- Microbarometers, 168
- Micro-electro-mechanical sensors (MEMS), 412
 - accelerometers, 414, 418
 - inclinometer probe, 413
 - inclinometer system, 413
- Micro-electro-mechanical systems, 412

- Micromachines, 412
- Micrometer
 - depth, 382–385, 390
 - gauge, 387, 389, 390, 392, 428
 - optical, 8, 359, 540, 543, 545–548, 554
 - parallel glass plate, 58, 322
 - parallel-plate, 21, 58, 65, 235
- Micro-network
 - datum for the, 535
 - geodetic, 533–535
 - reference, 533, 535
- Microsystems technology, 412
- Mine surveyor
 - main activities expected of a, 442
 - skills, 443
- Mining
 - claim, 442
 - open-pit, 318, 442
 - strip, 442
 - surface, 442, 491
 - underground, 442, 443, 446, 463
- Mining surveying
 - definition of, 442
 - specific and peculiar circumstances in underground, 443
- Misclosure
 - allowable angular, 230
 - ratio of, 68, 222
 - traverse, 68
- Models
 - dynamic, 305, 306
 - geometric, 306
 - kinematic, 306
 - static, 306
- Modulating signal, 137
- Modulation
 - amplitude, 137, 138
 - frequency, 137, 158
 - phase, 137
- Monitoring
 - automated, 318–321, 383
 - network, 272, 311, 313, 316, 438
- Monochromatic source, 331
- Monument
 - dam crest, 282, 283
 - dam slope, 282
 - design, 278, 282
- Monumentation and targeting, 273, 278
- Multiple reversal point, 470, 471
- Multiple transit, 470
- Multiplexing
 - time division, 409
 - wavelength division, 409

- NAD83, *see* North American Datum of 1983
- National Map Accuracy Standards (NMAS), 49, 77
- National Spatial Reference System (NSRS), 3, 73
- National Standard for Spatial Data Accuracy (NSSDA), 49, 77
- Natural coordinate system, 240
- Network
- accuracy, 69, 72–76
 - design, 206, 209, 211–214, 217, 218, 220
 - free-, 293, 296
 - metrology, 252, 253
 - monitoring, 216, 217, 268, 272, 306, 311, 312, 316, 438
 - reference, 270, 275, 277, 278, 303, 311, 315, 317, 438, 500, 571
 - surface, 270, 498, 507, 508, 512–514, 517, 537, 538, 571
 - underground, 446, 447, 496, 504, 507, 515, 516
- Network geometry
- external, 292
 - internal, 292
- Nivellement Transmanche Datum 1988 (NTM88), 519
- NMAS, *see* National Map Accuracy Standards
- North American Datum of 1983 (NAD83), 239, 530
- NSRS, *see* National Spatial Reference System
- NSSDA, *see* National Standard for Spatial Data Accuracy
- NTM88, *see* Nivellement Transmanche Datum 1988
- Nuisance parameters, 293, 296–298, 303
- Object point, 253, 262, 311
- Observation
- differencing approach, 291, 304, 305
 - equations, 220, 245, 304, 425, 434
- Open pit mine, 427
- Optical
- alignment, 7, 277
 - directional theodolites, 17
 - fibers, 406, 407, 410, 411
 - micrometers, 7, 228, 541, 543
 - plummet, 98, 112
 - repeating theodolites, 17
 - square, 540, 549
- Optical-tooling
- bars, 549
 - scales, 546, 547, 554–557
 - stand, 542
 - techniques, 538–557
 - transits, 539
- Ordnance Datum Newlyn, 519
- Origin of the coordinate system, 69
- local astronomic, 248
 - local geodetic, 249
 - map grid rectangular, 481
 - one-dimensional, 239
 - terrestrial laser scanning system, 261
 - two-dimensional, 239
- Orthometric correction, 22, 23, 190
- Oscillation amplitude value, 473
- Outlier detection, 256, 298, 305
- Out-of-context testing, 299
- Parameters
- adjusted, 173, 184
 - datum, 302
 - population, 33
- Parametric least squares equations, 176, 177
- Partial derivatives, 145, 151, 161–163
- Partially distributed sensors, 407
- Pattern wavelength, 137
- Pendulum
- inverted, 278, 397, 398, 400, 403, 432–434
 - suspended, 387, 393
- Phase
- angle, 143, 429, 430
 - center variation, 10, 207
 - delay, 140, 143
 - measurement error, 153, 154, 158
 - measurement principle, 139
 - unwrapped, 358, 369
 - wrapped, 358
- Phase measurement accuracy
- carrier, 9
 - code, 10
- Phase measurement principle, 139
- Phase shift technique, 334
- Photogrammetry, 1, 16
- aerial, 443
 - close-range, 16
 - terrestrial, 491
- Photonic stopband, 408
- Pitch, 259, 260
- Planimetric, 78, 242, 260, 528
- Plate level bubble, 99
- Plumbline
- inverted, 391, 393, 396–400, 439, 440
 - suspended, 326, 393
 - weighted, 393, 394, 397, 399
- Plummet
- laser, 98, 112, 221, 230, 447, 457, 464
 - zenith, 444, 463, 465, 466, 486
- PMS, *see* Polar measurement systems
- Point cloud to point cloud method, 348
- Point cloud to surface model method, 349

- Point clouds
 - segmentation of the registered, 347
- Point estimate, 32
- Point sensors, 407, 411
- Polar measurement systems (PMS), 565
- Polar measurement techniques, 529
- Polaris observation, 120
- Pope, 298, 299
- Population mean, 32, 33, 39
- POS, *see* Position and orientation system
- Position and orientation system (POS), 259
- Powerhouse, 309, 310
- Precision
 - barometer, 168
 - of estimate, 32, 33, 53, 63
 - hygro-thermometer, 167
 - measure of, 31, 33, 123, 165, 197
 - of measurements, 27, 31, 211
 - psychrometer, 167
 - thermometer, 167
- Prism
 - holders, 282
 - pentagonal, 551
 - rod, 338
 - targets, 28
 - triangular, 567
 - Wollaston, 564
- Prolonging a line, 97
- Pseudo-inverse, 296, 297
- Pseudolites, 271, 272
- Pseudo-satellites, 272
- Published distances, 171
- Pulse measurement principle, 138
- Pulsed laser, 338, 339

- Quadrilateral method, 457, 460, 497
- Quality
 - assurance, 47, 82–85, 202, 253
 - control, 47, 82–85, 202, 253
 - of end results, 49
 - of instrument operation, 48
- Quarter time method, 469

- Radar, *see* Radio detection and ranging
- Radio detection and ranging (Radar), 139
 - real-beam aperture, 370, 373
 - slope stability, 370
 - synthetic aperture, 350, 370
- Random error propagation, 30, 31, 164, 182, 557
- Rank deficiency, 293
- Ratio of misclosure (ROM), 68
- Reconnaissance surveys, 6, 221
- Redundancy, 2, 56, 344–346, 375

- Reference
 - ellipsoid, 238–241, 246, 247, 250, 251, 288, 482, 530, 538
 - invar rod, 428
 - network stations, 275
 - refractive index, 144, 152
 - wavelength, 144, 155, 180
- Reference system
 - Canadian Spatial, 73
 - conventional terrestrial, 240
 - coordinate, 238, 239
 - European Terrestrial, 73, 530
 - International Terrestrial, 240
 - National Spatial, 3, 73
- Refraction
 - coefficient of, 104, 105, 150, 157, 289, 469
 - correction, 574
 - effect, 500, 502, 518
 - horizontal, 120, 288, 503, 571, 573
 - vertical, 103, 115, 193, 255, 289, 323
- Refractive index
 - effective, 408, 409
 - group, 137, 144, 145, 162
 - reference, 144, 152
- Refractive number, 146
- Refractivity, 102, 146, 149, 153, 226
- Relative accuracy ratio, 68, 69
- Relative error bar, 511, 512
- Relative network, 270, 306, 307
- Relative positional tolerance, 510
- Reliability, 76, 167, 211, 215, 217, 220, 378, 419, 459
- Remote sensing, 1, 16
- Repeatability, 29, 48, 282
- Repeating theodolites, 17
- Repetition method, 17, 18, 109
- Reproducibility, 48
- Reversal point method, 469–471
- Robotic surveying system, 27
- Robotic total station, 270, 319
- Roctest RxTx telependulum, 397, 400
- Rod index error, 190, 193
- Roll, 259, 260
- ROM, *see* Ratio of misclosure
- Root mean square error (RMSE), 79
- Rotating laser instruments, 332
- RTM87, 518
- RTS/GPS hybrid system, 320

- SAA, *see* ShapeAccelArray
- SAR, *see* Synthetic aperture radar
- Satellite laser ranging and tracking (SLRT), 139
- Satellite radar altimeter, 139

- Scanners
 - camera-type, 336
 - hybrid-type, 336
 - laser triangulation based, 336
 - long-range, 336
 - medium-range, 336
 - panoramic-type, 336
 - phase-based, 336
 - short-range, 336
 - time-of-flight, 336
- Scattering
 - Brillouin, 407, 411, 412
 - Raman, 407, 411, 412
 - Rayleigh, 411
- Schuler Mean, 470–472, 474
- SE, 32–34, 39–41, 51, 53, 54, 63, 106, 164, 165, 182
- Second-order design (SOD), 213, 215
- Self-aligning centering detectors, 530
- Sensors
 - active, 333
 - biaxial, 19
 - FBG, 409
 - fiber-optic, 406
 - inclinometer, 401
 - long-base, 407
 - LVDT, 382, 386, 387
 - MEMS, 378, 418
 - partially distributed, 407
 - point, 407
- Separability, 215, 217
- Shaft
 - collar, 446, 466, 486
 - inclined, 446, 447, 496
 - plumbing, 448, 449, 453, 462, 464, 465, 467
 - shallow, 486
 - sinking, 446, 448, 464, 465
 - ventilation, 516
 - vertical, 446–450, 457, 462, 463, 485, 487, 489, 496
- ShapeAccelArray (SAA), 413
 - construction, 413
 - design property of, 418
 - important properties of, 414
 - installations, 416
 - measurements, 415, 416
 - typical package of, 413
- Significance level, 32, 38, 39, 41, 43, 122, 123, 197, 257, 258, 298, 307–309
- Single look complex (SLC), 353
 - images, 358, 361
- Single point movement, 306, 343
- Single-run leveling, 53, 63
- Single-valued (leveling) systems, 24
- SLC, *see* Single look complex
- Slope indicator stations, 278
- SLRT, *see* Satellite laser ranging and tracking
- SMR, *see* Spherically mounted reflector
- SNCOLD, *see* Swiss National Committee on Large Dams
- SOD, *see* Second-order design
- SOFO system, 410
- SOKKIA GP3X, 20, 467
- Solar observations, 119
 - altitude, 120
 - hour angle, 120
- Sources of EDM errors
 - external, 154
 - internal, 153, 154
- Spatial continuity, 273, 274
 - design criterion, 274
- Spatial trend, 308
- Specifications
 - advantages of, 50
 - survey, 50, 51
- Spherical cup, 541, 542, 549
- Spherically mounted reflector (SMR), 529, 572
- Spiral shape, 392, 393, 440, 488–490
- Spirit leveling, 52, 484, 510, 517
- Stadia
 - distance, 59, 60, 64
 - factor, 59, 64
 - interval, 59, 64
- Standard deviation
 - of the mean, 32, 33, 39, 123
 - population, 32, 42
 - sample, 32, 41, 42, 127, 130, 131
- Standard factor of unit weight, 172, 309, 313
- Standards
 - accuracy, 48–51, 55, 61, 62, 66–68, 70–72, 75, 77–82, 86, 213, 214, 243
 - ASPRS, 78, 82
 - circular map accuracy, 81
 - classification, 62, 75
 - content, 48, 49
 - GNSS accuracy, 213
 - map and geospatial data accuracy, 77
 - National map accuracy, 49
 - performance, 48–50
 - precision, 48, 50, 82
 - USA accuracy, 61
 - vertical map accuracy, 82
- Statistical
 - analysis, 292, 297, 308, 312, 313, 459
 - testing, 85, 183, 307, 435
 - trend analysis, 307
- Statistical test
 - of the difference of the means, 39

- Statistical test (*Continued*)
 of the mean, 39
 on the variance of the observations, 41
 Stereographic double projection, 239
 Strain
 component, 325, 424, 435, 436
 rate, 327
 Subsidence, 5, 8, 216, 268, 269, 274, 282, 323, 325, 368, 433, 434
 Sump, 446, 465
 Superconducting super collider, 7, 503, 531
 Surface model to surface model method, 349
 Survey network
 triangulation, 10
 trilateration, 10
 Swing time, 469
 Swiss National Committee on Large Dams (SNCOLD), 422
 Symmetric matrix, 32, 37, 511
 Synthetic aperture, 350, 352, 369, 370
 Synthetic aperture radar (SAR), 350, 352
 concepts of, 350
 ground-based interferometric, 330
 images, 353, 355, 362, 366, 367
 interferometric, 16, 330
 satellite-based interferometric, 330
 sensors, 352
 Systematic error propagation, 30, 31, 161
- Tailrace, 310
 Tape corrections, height transfer in the mine
 effect of air current, 488
 sag, 389, 488
 spiral shape, 488
 standardization, 487
 stretching of tape under its weight, 488
 temperature variation, 487
 tension, 488
- Targets
 auto-reflection, 552
 concentric circle patterned, 534
 double-V, 548
 paired-line, 548
 wall, 245, 252, 253, 445, 533, 534, 536, 570
- Tau, 298, 299
 Taylor Hobson sphere, 466, 484, 486
 TBM, *see* Tunnel boring machines
 Tellurometer, 138
 MA-100, 223
 MA200, 287
 Temperature gradient, 102–104, 115, 190, 502, 573
 Temporal continuity, 274
- Test
 Chi-square, 203, 298
 F-, 301, 307
 global, 298, 299
 in-context, 299
 local, 298
 one-tailed, 39, 40, 42
 rejection, 56, 57
 zero-baseline, 206, 207
- Test statistic, 42, 128
- Theodolites
 directional, 17, 18
 electronic digital, 17, 19, 24
 nonelectronic, 17
 optical, 17, 19, 26, 110, 288
 repeating, 17
- Thinning filter, 340
- Third-order design (THOD), 213, 215
 THOD, *see* Third-order design
- Three-wire leveling, 58, 59
- Tilt
 angle, 92, 324
 measurement, 435, 437
 rate, 327
- Tilting axis, 88, 89, 92–95, 97, 99, 100, 107
- Tilting level, Sokkia PL1, 21
- Tiltmeter
 biaxial, 405
 important advantages of using, 406
 in situ, 405
 MEMS, 405
 portable, 405
 uniaxial, 405
- Time
 method, 473–475, 478, 480
 series, 369, 438
- Time of flight
 measurement principle (*see* Phase measurement principle)
 method, 334
- Tolerance
 absolute positioning, 537
 limit, 218, 287, 516
 relative, 538
- Topographic map, 82, 239, 242, 497
- Total station
 industrial, 25, 570
 reflectorless, 26, 263, 333, 444, 491
 robotic, 270, 319
- Township surveying, 69
- Trans Mountain Pipeline (TMPL), 6
- Transducer
 electrical resistance, 380, 383

- linear variable displacement, 382, 390
 - mechanical, 380
- Transit
 - jig, 539, 540, 542, 544, 545, 550, 553–556
 - method, 469, 473, 478
 - surveyor's, 542
- Traverse
 - braced, 497
 - closed, 222, 531, 532
 - connecting, 68
 - fitted, 462, 504, 530
 - loop, 51, 68, 227, 257, 444
 - mine, 444
 - misclosure, 68, 257
 - open, 11, 285, 444, 447, 503, 504, 520, 532
 - separate-point-included angle, 530, 531
 - zigzag, 497, 503, 518, 520
- Trend analysis, 307, 308, 312, 313, 317
- Triangulation network, 245, 302
- Trigonometric leveling, 16, 21, 253, 289, 323, 483
- Trilateration network, 10, 302, 315–317, 530
- Trivet, 555
- True north, 241, 467, 469, 473, 524
- Tunnel
 - The Channel, 517
 - Rogers Pass, 512, 516
- Tunnel boring machines (TBM), 504, 517
- Tunneling machine control, 499
- Tunneling surveys
 - The Channel Tunnel, 517
 - for scientific research, 7
 - for the Superconducting super collider, 7
- Turning point method, 469–471
- Two-shaft method, 465

- Unit length, 140–142, 155, 168, 169
- Unit weight
 - standard factor of, 172, 309, 313
 - variance factor of, 34, 35, 52, 185, 297, 298, 300, 308, 309, 313, 317, 507
- Universal Transverse Mercator (UTM), 239, 284
- Unwrapping, 358, 363, 367, 369, 373, 375
- Upper-tail areas, 41, 257, 258, 301

- Validation network, 205, 206
- Validation survey, 205

- Variance factor
 - a posteriori, 34, 52, 185, 297, 298
 - a priori, 34, 35, 52, 298, 299, 308, 309, 313, 314, 317, 507
- Variance-covariance
 - matrix, 32, 36, 37, 52, 185, 263, 350
 - propagation, 32, 37, 40, 41, 53, 147, 160, 163, 184, 212, 226, 263, 506, 511, 520, 559
- Velocity correction, second, 149, 150, 156
- Vertical alignment, 391, 555, 558, 571
- Vertical axis
 - error, 95
 - of the laser equipment, 464, 465
 - of the theodolite, 88
- Vertical collimation, 89–91, 94
- Vertical control surveys, 48, 51, 52, 55, 497, 519
- Vertical index error, 90, 95
- Vertical refraction, 103, 115, 193, 255, 289, 323, 538
- Very long baseline interferometry (VLBI), 244
- VLBI, *see* Very long baseline interferometry
- Volume determination, 443, 491, 492
- V-shaped index, 470, 471, 473, 474

- Waves, 134–137
 - electromagnetic (EM), 134, 559
 - longitudinal, 134
 - transverse, 134
- Weight matrix, 171, 212, 220, 292, 296, 303
- Weisbach method, 451, 452, 457, 459, 497
- Weiss quadrilateral method, 449, 457
- WGS84, *see* World Geodetic System of 1984
- World Geodetic System of 1984 (WGS84), 244, 530

- Yaw, 259

- Zenith angle reading, 90, 482
- Zero error, 153, 154, 158, 165
- Zero index, 89, 109, 126
- Zero-baseline test, 206, 207
- Zeroing targets, 530
- Zero-order design (ZOD), 213, 214
- Zero-point offsets, 57, 199, 200, 203
- ZOD, *see* Zero-order design

