

**CN561 Navigation Systems Integration II – GNSS: Aided or Autonomous**  
**September 15, 2008, 1:30 am-5:00 pm, CEU: 3.0, prior to ION GNSS 2008**  
**Marriott Savannah Riverfront, Savannah, GA**

**Instructor:** Dr. James L. Farrell, VIGIL Inc.

**Prerequisite:** Vectors and small matrices (*e.g.*  $4 \times 4$ ); familiarity with estimation important; some familiarity with GPS quite helpful though not strictly essential.

**Intended Audience:** Management and technical staff members responsible for developing capability to use GNSS data, either alone or to update a strapdown inertial navigation system.

**Notes Provided:** Slides presented will be professionally spiral bound, with clear plastic cover, including color to add clarity where needed. (See Part IV for 2007 book).

**Reference List:** To augment material presented herein, references to be cited were chosen to provide thorough coverage from a manageable (compact) set of sources.

**Course Overview:** Review of fundamentals (relation of elapsed time to phase/frequency; distance/speed); line-of-position intersections; 2D, 3D, 4D solutions in appropriate coordinate frames; error state updating; segmented estimation with differencing with major impact on corrections (*e.g.*, clock, propagation); state-of-the-art flight results with or without low-cost IMU.

**Course Content:** The main topics to be covered by this course are:

- Review
  - 1-dimensional example – overhead satellite with no clock error
  - 2-dimensional example – two satellites seen by ship with no clock error
  - expansion to 3D and 4D cases; role of geometry and coordinate frames
  - all requisite pseudorange corrections
- Immediate departures from custom
  - robust updating techniques
  - differencing
    - across satellites (cancellation of user clock error)
    - sequential changes in carrier phase
  - simplifications offered in implementation
  - segmentation; separation of position from dynamics
  - full exploitation of recent technology advances
  - combination with major changes in receiver configuration
  - vastly improved robustness
- Validation of all methods
  - illustration of basic points by simulation
  - proof by flight test results
    - cm/sec velocity and tenths-mrad verticality with low-cost IMU
    - dm/sec velocity without IMU
    - switching of subtraction-reference satellite – no problem

**Course Outcomes:** Material presented in this course will enable attendees to use frequent (not necessarily continuous) GNSS carrier phase and pseudorange updates to:

- obtain state-of-the-art dynamic accuracies from a low-cost strapdown IMU
- obtain dm/sec RMS velocity accuracy from GNSS alone with no IMU
- continue operation in the presence of multiple repeated breaks in GNSS signals