Office of the Registrar
FORM 40G REV. 07/13

PURDUE UNIVERSITY

REQUEST FOR ADDITION, EXPIRATION, OR REVISION OF A GRADUATE COURSE (50000-60000 LEVEL)

Print Form

DEPARTMENT Aeronautics and Astronautics

EFFECTIVE SESSION 2015 Spring

INSTRUCTIONS: Please check the items below which describe the purpose of this request.

- [X] 1. New course with supporting documents (complete proposal form)
- [ ] 2. Add existing course offered at another campus
- [ ] 3. Expiration of a course
- [ ] 4. Change in course number
- [ ] 5. Change in course title
- [ ] 6. Change in course credit/type
- [ ] 7. Change in course attributes
- [ ] 8. Change in instructional hours
- [ ] 9. Change in course description
- [ ] 10. Change in course requisites
- [ ] 11. Change in semesters offered
- [ ] 12. Transfer from one department to another

	PROPOSED:	EXISTING:
Subject Abbreviation	AAE	AAE
Course Number	67500	69000

Long Title Advanced Signals and Systems for Satellite Navigation

Short Title Adv. Sig. & Sys. Satellite Nav

Abbreviated title will be entered by the Office of the Registrar if omitted. (30 CHARACTERS ONLY)

TERMS OFFERED
Check All That Apply:
- [ ] Fall
- [X] Spring
- [ ] Summer

CAMPUS(ES) INVOLVED
- [ ] Calumet
- [X] Cont Ed
- [ ] Ft. Wayne
- [ ] Indianapolis
- [ ] N. Central
- [ ] Tech Statewide
- [X] W. Lafayette

CREDIT TYPE
1. Fixed Credit: Cr. Hrs. 3
2. Variable Credit Range:
   Minimum Cr. Hrs
   (Check One) To [ ] Or [ ]
   Maximum Cr. Hrs.
3. Equivalent Credit: Yes [ ] No [X]
4. Thesis Credit: Yes [ ] No [X]

COURSE ATTRIBUTES: Check All That Apply
1. Pass/Not Pass Only [ ]
2. Satisfactory/Unsatisfactory Only [ ]
3. Repeatable [ ]
   Maximum Repeatable Credit:
4. Credit by Examination [ ]
5. Fees: [ ] Coop [ ] Lab [ ] Rate Request
   Include comment to explain fee
6. Registration Approval Type
   Department [ ] Instructor [ ]
7. Variable Title [ ]
8. Honors [ ]
9. Full Time Privilege [ ]
10. Off Campus Experience [ ]

Schedule Type	Minutes Per Mtg	Meetings Per Week	Weeks Offered	% of Credit Allocated
Lecture	50	3	15	100
Recitation				
Presentation				
Laboratory				
Lab Prep				
Studio				
Distance				
Clinic				
Experiential				
Research				
Ind. Study				
Pract/Observ				

Cross-Listed Courses

COURSE DESCRIPTION (INCLUDE REQUISITES/RESTRICTIONS):

Fundamental theory of ranging signal design. Generation of pseudorandom noise. Methods for detecting, tracking, and estimating delay using ranging signals. Probability of detection, probability of false alarm, and tracking threshold derived from a stochastic signal model. Models for multiple access, quantization, clock and multipath errors. Examples drawn from present-day Global Navigation Satellite Systems (GNSS)

*COURSE LEARNING OUTCOMES

On completing this course the student shall be able to: 1) Understand current literature in radio navigation signal processing. 2) Develop signal processing algorithms for radio navigation applications. 3) Predict performance of radio navigation signal processing algorithms. 4) Implement radio navigation signal processing algorithms in a

Calumet Department Head	Date	Calumet School Dean	Date	Calumet Director of Graduate Studies	Date
Fort Wayne Department Head	Date	Fort Wayne School Dean	Date	Fort Wayne Director of Graduate Studies	Date
Indianapolis Department Head	Date	Indianapolis School Dean	Date	IUPUI Associate Dean for Graduate Education	Date
North Central Department Head	Date	North Central School Dean	Date	North Central Director of Graduate Studies	Date
[signature] West Lafayette Department Head	8/20/14 Date	[signature] West Lafayette College/School Dean	9/25/14 Date	Date Approved by Graduate Council	Date
Graduate Area Committee Convener	Date	Graduate Dean	Date	Graduate Council Secretary	Date
				West Lafayette Registrar	Date

OFFICE OF THE REGISTRAR

Supporting Document
to accompany the Registrar's FORM 40G when:

1. Requesting a New Graduate Course (Complete Section I)

or

2. Adding Distance as an Additional Schedule Type (Complete Section II)

For Reviewer's comments only (Select One)
Reviewer:
Comments:

To: Purdue University Graduate Council

From:

Faculty Member: James L Garrison

Department: School of Aeronautics and Astronaut

Campus: West Lafayette

Date:

Subject: Supporting Document to the Registrar's Form 40G

Contact for information if questions arise:

Name: Prof. James L Garrison

Phone Number: (765)-486-7482 (X67482)

E-mail: jgarriso@ecn.purdue.edu

Campus Address: 701. West Stadium Ave.

Course Subject Abbreviation and Number: AAE67500

Course Title: Advanced Signals and Systems for Satellite Navigation

SECTION I

A. Justification for the Course:

- Provide a complete and detailed explanation of the need for the course (e. g., in the preparation of students, in providing new knowledge/training in one or more topics, in meeting degree requirements, etc.), how the course contributes to existing majors and/or concentrations, and how the course relates to other graduate courses offered by the department, other departments, or interdisciplinary programs.

Historically, much of the development of radio navigation has been very closely integrated with that of radio communications. Basic navigation measurements, range and range-rate, arise as byproducts of tracking a communications signal, for example, telemetry from an interplanetary probe. The basic approach to navigation has been to take these available measurements, as provided, incorporating the geometric constraints, to determine an optimal estimate of the position and velocity of the receiver or transmitter. In this framework, generation of the basic measurements, a signal processing problem, is for the most part decoupled from the navigation solution, an estimation problem. Such an approach had generally been the standard practice during the development of GPS and Glonass, and can be thought of as the "classical" radio navigation problem.

- Justify the level of the proposed graduate course (50000- or 60000-level) including statements on, but not limited to: (1) the target audience, including the anticipated number of undergraduate and graduate students who will enroll in the course; and (2) the rigor of the course.

This course has been offered the temporary number AAE690S four (4) times from Spring 2006 to Spring 2013 with the following enrollments: Spring 2006: 3, Spring 2009: 7, Spring 2011: 7, Spring 2013: 9 (4 on campus, 5 ProEd). It was offered for the first time via distance learning in Spring 2013. The expected enrollment for a course offered every 2 to 3 years will be 4-10 students at the PhD or advanced Master's level.

B. Learning Outcomes and Method of Evaluation or Assessment:

- Describe the course objectives and student learning outcomes that address the objectives (i.e., knowledge, communication, critical thinking, ethical research, etc.).

See attached document.

- Describe the methods of evaluation or assessment of student learning outcomes. (Include evidence for both direct and indirect methods.)

See attached document.

- Grading criteria (select from drop down boxes); include a statement describing the criteria that will be used to assess students and how the final grade will be determined.

Criteria	Homework	Criteria	Papers and Projects	Criteria	
Criteria		Criteria		Criteria	

- Identify the method(s) of instruction (select from drop down box) and describe how the methods promote the likely success of the desired student learning outcomes.

Method of Instruction	Lecture	Method of Instruction	Distance	Method of Instruction	
Method of Instruction		Method of Instruction		Method of Instruction	
Method of Instruction		Method of Instruction		Method of Instruction	

C. Prerequisite(s):

- List prerequisite courses by subject abbreviation, number, and title.

ECE600, AAE567, or equivalent (Random variables and stochastic processes)

- List other prerequisites and/or experiences/background required. If no prerequisites are indicated, provide an explanation for their absence.

Students should be competent with a computer language (MATLAB preferred).

D. Course Instructor(s):

- Provide the name, rank, and department/program affiliation of the instructor(s).

James L. Garrison, Associate Professor, AAE

- Is the instructor currently a member of the Graduate Faculty? X Yes __ No
  (If the answer is no, indicate when it is expected that a request will be submitted.)

E. Course Outline:

- Provide an outline of topics to be covered and indicate the relative amount of time or emphasis devoted to each topic. If laboratory or field experiences are used to supplement a lecture course, explain the value of the experience(s) to enhance the quality of the course and student learning. For special topics courses, include a sample outline of a course that would be offered under the proposed course.

See attached document.

F. Reading List (including course text):

- A primary reading list or bibliography should be limited to material the students will be required to read in order to successfully complete the course. It should not be a compilation of general reference material.

See attached document.

G. Library Resources

- Describe the library resources that are currently available or the resources needed to support this proposed course.

Students should have access to Purdue Library's electronic Journal collection for use in their literature review and some of the assigned readings.

H. Example of a Course Syllabus (While not a necessary component of this supporting document, an example of a course syllabus is available, for information, by clicking on the link below, which goes to the *Graduate School's Policies and Procedures Manual for Administering Graduate Student Programs*. See Appendix K.)

http://www.gradschool.purdue.edu/downloads/Graduate_School_Policies_and_Procedures_Manual.pdf

SECTION II

New graduate degree program policies and guidelines, approved by the Indiana Commission for Higher Education on August 10, 2012, require additional documentation regarding modes of delivery. Please complete Section II when adding an additional mode of delivery to an existing graduate course.

A. Justification for New Proposed Mode of Delivery (Complete)

B. Learning Outcomes and Method of Evaluation or Assessment:
(Complete if different from approved mode of delivery)

- Describe the course objectives and student learning outcomes that address the objectives (i.e., knowledge, communication, critical thinking, ethical research, etc.).

- Describe the methods of evaluation or assessment of student learning outcomes. (Include evidence for both direct and indirect methods.)

- Grading criteria (select from drop down boxes); include a statement describing the criteria that will be used to assess students and how the final grade will be determined.

Criteria | Criteria | Criteria

Criteria | Criteria | Criteria

- Identify the method(s) of instruction (select from drop down box) and describe how the methods promote the likely success of the desired student learning outcomes.

Method of Instruction | Method of Instruction | Method of Instruction

Method of Instruction | Method of Instruction | Method of Instruction

Method of Instruction | Method of Instruction | Method of Instruction

C. Prerequisite(s):

(Complete if different from approved mode of delivery)

- List prerequisite courses by subject abbreviation, number, and title.

- List other prerequisites and/or experiences /background required. If no prerequisites are indicated, provide and explanation for their absence.

D. Course Instructor(s):

- Provide the name, rank, and department/program affiliation of the instructor(s).

- Is the instructor currently a member of the Graduate Faculty? __ Yes __ No
  (If the answer is no, indicate when it is expected that a request will be submitted.)

E. Course Outline:

(Complete if different from approved mode of delivery)

- Provide an outline of topics to be covered and indicate the relative amount of time or emphasis devoted to each topic. If laboratory of field experiences are used to supplement a lecture course, explain the value of the experience(s) to enhance the quality of the course and student learning. For specials topic courses, include a sample outline of a course that would be offered under the proposed course.

F. Reading List (including course text):

(Complete if different from approved mode of delivery)

- A primary reading list or bibliography should be limited to material the students will be required to read in order to successfully complete the course. It should not be a compilation of general reference material.

- A secondary reading list or bibliography should include material students may use as background information.

G. Library Resources

(Complete if different from approved mode of delivery)

- Describe the library resources that are currently available or the resources needed to support this proposed course.

TO: The Faculty of the College of Engineering

FROM: School of Aeronautics and Astronautics

RE: New Graduate Course, AAE 67500 Advanced Signals and Systems for Satellite Navigation

The faculty of the School of Aeronautics and Astronautics have approved the following new course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

AAE 67500 Advanced Signals and Systems for Satellite Navigation
Sem. 2. Lecture 3, Cr. 3.
Prerequisites: AAE 56700, ECE 60000 or equivalent (Random Variables and Stochastic Processes)

Description: Fundamental theory of ranging signal design. Generation of pseudorandom noise. Methods for detecting, tracking, and estimating delay using ranging signals. Probability of detection, probability of false alarm, and tracking threshold derived from a stochastic signal model. Models for multiple access, quantization, clock and multipath errors. Examples drawn from present-day Global Navigation Satellite Systems (GNSS).

Reason: Historically, much of the development of radio navigation has been very closely integrated with that of radio communications. Basic navigation measurements, range and range-rate, arise as byproducts of tracking a communications signal, for example, telemetry from an interplanetary probe. The basic approach to navigation has been to take these available measurements, as provided, incorporating the geometric constraints, to determine an optimal estimate of the position and velocity of the receiver or transmitter. In this framework, generation of the basic measurements, a signal processing problem, is for the most part decoupled from the navigation solution, an estimation problem. Such an approach had generally been the standard practice during the development of GPS and Glonass, and can be thought of as the "classical" radio navigation problem.

Starting in the late 1990's, studies to modernize GPS were conducted in the United States. Around the same time, the European Union began preliminary design studies to develop an independent system, which would become Galileo. It was recognized that new signal designs, optimized specifically for navigation not communications, had to be developed in order to meet the increased performance requirements of these modernized systems. One outcome of these studies was a set of metrics for evaluating and optimizing navigation signal and system performance, and a new set of signal designs based upon these metrics. The unique requirement for a navigation signal design is to estimate the delay of a signal with the minimal error, in the presence of multiple transmitters, as necessary for a well-conditioned navigation problem. Other considerations in navigation signal design and processing are the effect of Multipath error and clock jitter.

With the continual expansion in the breadth of applications for satellite navigation signals and the increased expectations on their performance in more challenging environments, the separation between the signal processing layer and the navigation layer has became less distinct. Some applications, particularly in the sciences, extract useful data directly from the baseband signal, bypassing the separate steps of tracking and estimation entirely.

With this background in mind, the time is right to integrate this material, drawn from a variety of sources, into the framework of an academic course. The audience for this course would be doctoral-level students, primarily in AAE and ECE, although students from Civil and the College of Science have successfully taken it in the past. Through the Engineering Professional Education program, it is expected that a larger audience would be found for this course in practicing engineers at government laboratories and contractors (NASA, JPL, NRL, MITRE, etc...) as well as private companies involved in GNSS system development (Rockwell Collins, Trimble, Garmin, etc ...)

This course is proposed at the 60000-level as it is intended for doctoral students in engineering or the sciences. It will present a rigorous mathematical development of the principles of navigation signal design and processing.

This course has been offered the temporary number AAE690S four (4) times from Spring 2006 to Spring 2013 with the following enrollments: Spring 2006: 3, Spring 2009: 7, Spring 2011: 7, Spring 2013: 9 (4 on campus, 5 ProEd). It was offered for the first time via distance learning in Spring 2013. The expected enrollment for a course offered every 2 to 3 years will be 4-10 students at the PhD or advanced Master's level.

Tom I-P. Shih, Professor and Head

School of Aeronautics and Astronautics

APPROVED FOR THE FACULTY
OF THE SCHOOLS OF ENGINEERING
BY THE ENGINEERING
CURRICULUM COMMITTEE

ECC Minutes 9/19/14

Date 9/19/14

Chairman ECC

AAE 67500, Advanced Signals and Systems for Satellite Navigation

Supplemental Material for Form 40G.

B. Learning Outcomes and Method of Evaluation or Assessment:

Course Objectives: On completing this course, the student shall be able to: 1) Understand current literature in radio navigation signal processing. 2) Develop signal processing algorithms for radio navigation applications. 3) Predict performance of radio navigation signal processing algorithms. 4) Implement radio navigation signal processing algorithms in a software-defined radio, using a programming language such as MATLAB.

Student Learning Outcomes:

Student learning outcomes (knowledge, skills, communication, critical thinking, and ethical research) that address the four (4) objectives above, are listed in the following table:

- Objective 1: Understand current literature in radio navigation signal processing (course literature review and project)
  - **Knowledge**: In depth understanding of the topic of a student's choice. Standards for scientific and technical writing. Organization of a technical paper and proper acknowledgement of sources. Available tools for literature search.
  - **Skills:** Scientific and technical writing. Literature reviews.
  - **Communication**: Writing of a technical paper in the style, format and standard of a peer-reviewed journal article.
  - **Critical Thinking:** Evaluation of published results. Inter-comparison of results from multiple authors.
  - **Ethical Research:** Proper citation and attribution of sources in publication.

- Objective 2: Develop signal processing algorithms for radio navigation applications.
  - **Knowledge**: Fundamentals of radio navigation and requirements on navigation signal design. Stochastic models for navigation signals. Maximum likelihood estimation of delay. Pseudorandom noise code generators. Delay-, phase- and frequency-lock loops. Signal acquisition through cross-correlation, circular correlation and matched filters. Application of the Kalman filter to signal tracking.
  - **Skills**: Stochastic signal modeling. Continuous and discrete-time signal processing. Estimation theory.

- Objective 3: Predict performance of radio navigation signal processing algorithms.
  - **Knowledge**: Models for signal tracking noise variance and mean time to lose lock. Allan variance and clock models. Acquisition threshold, probability of detection and probability of false alarm. Acquisition time models. Multipath error models. Radio-frequency front-end considerations: sample rate, bandwidth, noise figure, etc.
  - **Skills**: Stochastic signal modeling. Continuous and discrete-time signal processing. Estimation theory. Cramer-Rao lower bound analysis.

- Objective 4: Implement radio navigation signal processing algorithms in a software-defined radio, using a programming language such as MATLAB.
  - **Knowledge**: Nyquist-Shannon sampling theorem and aliasing. Fast-Fourier transform (FFT) and zoom-FFT. Available functions and tools in MATLAB.
  - **Skills**: Programming for digital signal processing.
  - **Ethical Research:** Acknowledgement of code obtained from other sources.

Methods of Evaluation or Assessment

Grading criteria: Extended homework assignments and an individual research project.

A final numerical score will be computed by averaging the numerical scores for the homework and project, weighted equally (50% each). The distribution of numerical scores over the entire class will be used to set the thresholds for each letter grade. It is expected, however that the letter grades will not deviate much from the "uncurved" values, i.e. A=90%+, B=80-90%, C=70-80%, etc.

Task 1: Homework
4-5 homework assignments will be given for a total of 50% of the course grade.
Homework assignments are evenly spaced throughout the course, due approximately once every 3 weeks. These assignments may contain a few "text book" problems, but the majority of the work will involve some computer programming for analysis, or processing of experimental or simulated data. Students are expected to write a complete description of the problem, in their own words, a clear explanation of their solution, and an interpretation of their results. Students must create their own code or properly acknowledge code obtained from other sources. All code must be commented. Most problems will have an "open-ended" component in which students will be required to extend the application of their work beyond the question asked.

Homework will be graded on a scale of 100 points. Shorter, "text book" problems will count for 10-20% each. Longer problems involving computer programming and processing of data will count for 40-60% each. Approximately 20-30% of the total score will be allocated to the student's insight into the problem, interpretation of the results and extension of their results to more "open-ended" questions.

Task 2: Individual Research Project

An independent research project, completed incrementally throughout the semester and due on the last day of class, will count for 50% of the final grade.

The project will be based upon a topic selected by the student and approved by the instructor, on some current research problem in navigation signals and systems. The project must show an application of the course material to the selected topic.

The minimum requirement for a grade of B- (75%) is a thorough, clearly written, review of the literature related to the specific topic selected, presented in the style and format of a journal article, with proper citations and a complete bibliography. In order to earn a grade of B+ or better (85%), the student project must present some "original contribution" in which they demonstrate the application of course material to some aspect of the topic that they have selected. In most cases this will involve some combination of: 1) Re-deriving theoretical models presented in a reference, 2) Extending published theory to a new or different problem 3) Application of published methods to synthetic or experimental data 4) Inter—comparison of alternative approaches to solving a problem.

Three incremental deadlines are provided for the instructor to provide feedback to the student throughout the term.

- Abstract with 7 references – due week 4
- Preliminary literature review (15+ peer reviewed references) and project plan – due week 8
- Project draft – due week 13
- Final project – due last day of class.

These incremental deliverables will not be used to compute the project score. Only the final project will contribute to the final grade. The incremental due dates are provided to give feedback to students to help them in developing their project.

Method of Instruction:

Lecture

Lectures are the preferred method of instruction, mostly involving derivations of mathematical models. Some demonstrations of numerical results using instructor provided code may also be incorporated into the lectures.

Distance

Lectures will be designed for both in-class and distance students.

E. Course Outline:

1) Introduction and background (1 week)
2) Navigation signal structure (3 weeks)
3) Hardware considerations (1.5 weeks)
4) Signal propagation (1.5 weeks)
5) Satellite search and acquisition (3 weeks)
6) Satellite tracking (3 weeks)
7) Advanced signal processing techniques (2 weeks)

F. Reading List:

Course Text: Prepared notes by Instructor

Assigned Readings from other texts:

(The reading list may be varied on subsequent offerings of the course, in order to follow the most recent research in the field as it is published.)

Akos, D., Stockmaster, M., Tsui, J.B.Y., and Caschera, J., "Direct Bandpass Sampling of Multiple Distinct RF Signals," *IEEE Transactions on Communications,* Vol. 47, No. 7, July 1999, pp 983-988

Betz, J.W., "Binary Offset Carrier Modulations for Radionavigation," *Navigation,* Vol. 48, No. 4,Winter 2001–2002, pp 227-246

Betz, J. W. and K. R. Kolodziejski, "Generalized Theory of Code Tracking with an Early-Late Discriminator, Part I: Lower Bound and Coherent Processing," *IEEE Transactions on Aerospace and Electronic Systems,* Vol. 45, No. 4, Oct. 2009, pp 1538-1550, DOI: 10.1109/TAES.2009.5310316

Betz, J. W. and K. R. Kolodziejski, "Generalized Theory of Code Tracking with an Early-Late Discriminator, Part II: Noncoherent Processing and Numerical Results," *IEEE Transactions on Aerospace and Electronic Systems,* Vol. 45, No. 4, Oct. 2009, pp 1551-1564, DOI: 10.1109/TAES.2009.5310317

Heckler, G.W., and Garrison, J. L., "Implementation and Testing of an Unaided Method for the Acquisition of Weak GPS C/A Code Signals," *Navigation: Journal of the Institute of Navigation*, V. 56, No. 4, pp 241-259, Winter 2009.

Lohan, E.S., "Analysis of Filter-Bank-BasedMethods for Fast Serial Acquisition of BOC-Modulated Signals," *EURASIP Journal on Wireless Communications and Networking*, Volume 2007, Article ID 25178, 11 pages, DOI:10.1155/2007/25178

Polydoros, Andreas, and Charles L. Weber. "A unified approach to serial search spread-spectrum code acquisition--part I: general theory." *Communications, IEEE Transactions on* Vol. 32, No. 5, 1984, pp 542-549.

Polydoros, Andreas, and Charles L. Weber. "A unified approach to serial search spread-spectrum code acquisition--part II: A Matched-Filter Receiver." *Communications, IEEE Transactions on* 32.5 (1984): 550-560.

Rubiola, E., *Phase noise and frequency stability in oscillators,* Cambridge University Press, 2009, ISBN 978-0-521-88677-2, pp 22-33.

Soellner, M., and Ph Erhard. "Comparison of AWGN code tracking accuracy for Alternative-BOC, Complex-LOC and Complex-BOC modulation options in Galileo E5-Band." *Proceedings of GNSS.* 2003.

Van Nee, R.D.J., *Multipath and multi-transmitter interference in spread-spectrum communication and navigation systems*, PhD Thesis, Delft University of Technology, The Netherlands, 1995.

Ziedan, N.* and Garrison, J. L., "Bit Synchronization and Doppler Frequency Removal at Very Low Carrier to Noise Ratio Using a Combination of the Viterbi Algorithm with and Extended Kalman Filter," ION-GPS/GNSS 2003, Portland Oregon, September 9-12, 2003

Ziedan, N.* and Garrison, J. L., "Unaided Acquisition of Weak GPS Signals Using Circular Correlation and Double-Block Zero Padding," IEEE Position, Location and Navigation Symposium (PLANS), Monterey, CA, April 26-29, 2004

Ziedan, N.* and Garrison, J.L., "Extended Kalman Filter-Based Tracking of Weak GPS Signals Under High Dynamic Conditions," *ION GNSS 2004*, September 21-24, 2004, Long Beach, CA.