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

**DEPARTMENT** Aeronautics and Astronautics

**EFFECTIVE SESSION** 2015 Spring

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

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:**

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<th>Subject Abbreviation</th>
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<th>Course Number</th>
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<td>67500</td>
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<tr>
<th>Long Title</th>
<th>Advanced Signals and Systems for Satellite Navigation</th>
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<td>Abbreviated title will be entered by the Office of the Registrar if omitted. (50 CHARACTERS ONLY)</td>
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**COURSE ATTRIBUTES:** Check All That Apply

1. Pass/Not Pass Only
2. Satisfactory/Unsatisfactory Only
3. Repeatable
4. Credit by Examination
5. Fees: [ ] Coop [ ] Lab [ ] Rate Request
6. Registration Approval Type
   - Department
   - Instructor
7. Variable Title
8. Honors
9. Full Time Privilege
10. Off Campus Experience

**COURSE DESCRIPTION:**


Example drawn from recent did 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...
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)

To: Purdue University Graduate Council
From: Faculty Member: James L Garrison
Department: School of Aeronautics and Astronautics
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.

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- 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.

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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?  
  Yes — No

(If the answer is no, indicate when it is expected that a request will be submitted.)

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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.)


(Revised and Approved by the Graduate Council 2/13)
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.

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• 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.

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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 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 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)


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 become 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)
  - 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.
• **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.

• **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.)


