Curriculum Enhancement to the Mechanical Engineering Graduate Program and Undergraduate Aerospace Option by Including Contemporary Issues of Integrating Unmanned Aircraft Systems into the National Airspace System

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In this paper, curriculum modifications to enhance and support Unmanned Aircraft Systems (UAS) integration into the National Airspace System (NAS) (along with other related UAS and unmanned system missions such as technologies that reduce environmental noise and emissions; increased aircraft and traffic safety; advanced sensor UAS sensor development; etc.) as well as the formation of a regional student UAS competition to be held at the Rochester Institute of Technology's (RIT's) is outlined. The curriculum modifications focus on RIT's Mechanical Engineering (ME) department related to the ME Aerospace Option and ME Graduate program. The proposed curriculum enhancements include the development of a new UAS related course; updates to two undergraduate aerospace courses transitioning the course as dual-listed undergraduate/graduate courses; the formation of a new ME Graduate Focus area in UAS; the development of an Advanced Certificate in the UAS; and updates to our Graduate Seminar series for inclusion of UAS related concepts. The new UAS course has direct benefits to students exposing them to UASs where a new pool of potential undergraduate/graduate students can be recruited for research related activities in UAS. Two RIT courses (Flight Dynamics and Orbital Mechanics) are to be updated and offered as both a terminal undergraduate course and an introductory graduate course for increasing enrollment in the ME's aerospace undergraduate option and newly developed Graduate Focus area. The updated courses will give higher exposure to a greater number of students for related subjects to UASs. The new Aerospace Graduate Focus area benefits students directly by allowing them to focus on an up-and-coming area, i.e., UAS that may be included in resume building and future projects related to UASs. We also outline a foundation for a regional UAS student competition to be housed at RIT's existing outdoor UAS netted closure facility and, in the future, a student UAS related conference. In particular, we consider the development of a final capstone requirement for the new proposed UAS related dual-listed course for mandatory participation in the proposed UAS student competition and student conference as part of the curriculum enhancement effort. A new lecture for presentation to RIT's graduate seminar series was developed in the topic of commercial applications and societal benefits of UASs. This will be a valuable recruiting tool for new graduate research students by exposing new graduates to new and exciting UAS research possibilities. RIT will also benefit since regional industry leaders will be recruited to attend the seminar and will be able to converse with faculty and students for possible research collaborations. The Engineering Education efforts presented here were funded by a NASA/New York Space Consortium STEM Curriculum Higher Education Curriculum Enhancement grant.

In this work, a curriculum enhancement to the Rochester Institute of Technology's Mechanical Engineering department's undergraduate and graduate program was completed. The curriculum enhancement included incorporating, within our current curriculum, a NASA priority area, i.e., integrating unmanned aircraft systems into the national airspace system that had direct benefit to the RIT faculty and students. In particular, several enhancements to our current curriculum were completed including:

1. the development of a new undergraduate/graduate dual-listed course related to unmanned aircraft systems. The new course has direct benefits to students exposing them to UASs and to RIT faculty where a new pool of potential graduate students can be recruited for research related activities RIT faculty who have area of expertise in UAS along with a benefit to the RIT for recruiting new students and soliciting external grants related to one of RIT's signature research area, UASs.
2. updates to two existing undergraduate courses to be offered as dual-listed courses. Two RIT courses (Flight Dynamics and Orbital Mechanics) were updated to be offered as both an terminal undergraduate course and an introductory graduate course. The updated courses will give higher exposure to a greater number of students for related subjects to UASs. This will also benefit RIT by the ability to recruit more graduate students and for a higher enrollment in our aerospace undergraduate option and newly developed Graduate Focus area.
3. the development of a new Graduate Focus and undergraduate aerospace option area related to unmanned aircraft systems. The new Aerospace Graduate Focus area benefits students directly by allowing them to focus on an up-and-coming area, i.e., UAS that may be included in resume building and future projects related to UASs. Again, this will also benefit RIT and RIT facultyby the ability to recruit more graduate students and for a higher enrollment in our aerospace undergraduate option.
4. updates to the; development of a new lecture presentation for the graduate seminar series. A new lecture for presentation to RIT's graduate seminar series was developed in topic of commercial applications and societal benefits of UASs. This will be a valuable recruiting tool for new graduate research students for the RIT along with getting new graduates excited about UAS research possibilities. RIT will also benefit since regional industry leaders will be recruited to attend the seminar and will be able to converse with RIT faculty and students for possible research collaborations.
5. the researching of developing an advanced certificate program related to unmanned aircraft systems. The benefits of the new advanced certificate to the RIT faculty, RIT, and the students are the same as developing the new UAS course, graduate focus area, and graduate seminar.
6. the formation of a unmanned aircraft systems student competition (first at a regional level then at a national and international level) to be used for the student capstone project of the new proposed course. This will give students exposure to UASs and get them excited about UASs moving forward in a real-world type application that can be used for resume building and other future projects. RIT faculty and RIT will benefit by placing them in the forefront of this new technology first at a regional level then on an international level.

1.1 Development of a New UAS Course

A new UAS course (MECE-5xx/6xx Unmanned Aircraft Systems) related to educational outcomes for integrating UASs into the NAS was developed as part of the curriculum development. The new course is an enhancement to RIT's MECE-411 Flight Dynamics basis course by focusing solely on UAS. The overall goal of this course is to provide students a fundamental understanding of unmanned aircraft systems with sufficient knowledge to design, construct, and perform flight testing of a small unmanned aircraft system. The students will obtain knowledge to develop a complete end-to-end flight unmanned aircraft flight simulator including full nonlinear flight dynamics, sensor models, autopilot integration, and path planning methods. In addition, students will be exposed to contemporary issues related to unmanned aircraft systems such as current FAA regulations, societal benefits of unmanned aircraft systems, commercial applications, etc. A capstone project was developed for participation in a UAS Regional Student competition (to be described later). The capstone project is team based and we expect teams of 5 students to work on the capstone project for the course. The new dual-listed course was fully developed and completed, i.e., course outline, learning and educational outcomes, course notes, class book selection, pre-requisite requirements, homework and project problems, etc. The intended **course learning outcomes** and associated assessment methods are shown below:

Course Learning Outcome	Assessment Method
Fundamental understanding of UAS system architecture and design models	Homework
Introduction to system coordinate frames including differences in UAS velocity components	Homework, Test
Full understanding of UAS rigid-body kinematics and dynamics equations of motion	Homework, Project, Test
Full understanding of UAS of applied forces and moments including atmospheric disturbance models	Homework, Project, Test
Full understanding of linear design models including transfer functions and linearized state-space models	Homework, Test
Introduction to UAS autopilot design including lateral-directional and longitudinal autonomous control	Homework, Project, Test
Introduction to sensors typically used in UAS flight	Homework
Introduction to state estimation theory with applications to attitude estimation and GPS smoothing	Homework, Test
Full understanding of UAS guidance design and straight-line and orbit following algorithms	Homework, Test
Full understanding of path planning design and management	Homework, Project, Test
Introduction to vision-guided navigation with applications to UAS precision landing and target motion estimation	Homework, Project, Test
Introduction to UAS contemporary issues	Homework

The **program outcomes** and **goals** supported by the new UAS course are as follows:

Program Outcome	Instructional Level
an ability to apply knowledge of mathematics, science, and engineering	
an ability to design and conduct experiments, as well as to analyze and interpret data	
an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	
an ability to function on multidisciplinary teams	
an ability to identify, formulate, and solve engineering problems	
an understanding of professional and ethical responsibility	
an ability to communicate effectively	
the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	
a recognition of the need for, and an ability to engage in life-long learning	
a knowledge of contemporary issues	
an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	

1.2 Updates for MECE-410 Flight Dynamics and MECE-411 Orbital Mechanics

Two undergraduate courses (MECE-410 Flight Dynamics and MECE-411 Orbital Mechanics) that are being taught by the authors were updated to meet requirements for the Mechanical Engineering Graduate program. The original new course proposal forms for each of these courses were modified to update these courses for listing them as dual-listed courses (undergraduate/ graduate courses). The new course names and numbers are: MECE-510/610 Flight Dynamics and MECE-511/611 Orbital. The course content for each course was modified and updated to an appropriate level required for use as dual-listed courses including aspects of UASs. For example, additional homework was developed for each course along with an additional test. Also, an additional project was developed for each course to include newly develop graduate level topics such as Lagrange's approach in developing kinematical equations of motions, quaternion models, orbital perturbations, Gibbs method of orbital determination from three position vectors, Gauss method of preliminary orbit determination, linearization of flight dynamics equations-of-motion and comparison to full nonlinear simulation models, etc. For example, a newly developed computer project was developed for the updated Flight Dynamics course related to linearization of nonlinear equations-of-motions and comparison to full nonlinear models. The updated courses were used to form a cluster for the new proposed Graduate UAS Focus area outlined in the next subtask.

1.3 New ME Graduate Focus Area and Updates to the ME UG Aerospace Option

The authoes investigated the formation of a new Mechanical Engineering Graduate Curriculum Focus area and updates to the Mechanical Engineering Undergraduate Aerospace Option as part of the curriculum enhancement effort was performed. The Aerospace Engineering Option allows for specialized study in the engineering aspects of air- and space-borne vehicles and starts with a course introducing students to the aerospace field. The sequence starts in the third year with students taking a variety of electives focused on aerospace. In addition, students choosing this option are expected to work on an aerospace engineering design project in Senior Design I and II

capstone courses and to pursue co-op employment in a related field. The Mechanical Engineering undergraduate Aerospace Option was updated to include the new proposed UAS course and the updated Flight Dynamics and Orbital Mechanics courses as shown below:

Extended Core	
REQUIRED COURSES - pick 1 from this list	
MECE-350	Strengths of Materials II
MECE-360	Advanced Computational Techniques
Applied Electives	
REQUIRED COURSES - pick 2 from this list	
MECE-403	Propulsion
MECE-409	Aerodynamics
MECE-412	Aerostructures
MECE-510/610	Flight Dynamics
MECE-511/611	Orbital Mechanics
MECE-512/612	Unmanned Aircraft Systems
MECE-543/643	Continuous Control Systems
MECE-544/644	Intro to Composite Materials
MECE-558/658	Introduction to Engineering Vibrations

All students in the Mechanical Engineering Graduate Program are required to develop a concentration/focus area by completing 9 credits of study in an area. Current Focus Areas include: automotive systems, business, controls, manufacturing, mechanics-design/materials, product development, sustainability, thermo/fluids engineering, vibrations engineering. Also, students with a specific career interest may develop an individually customized concentration based on mutual agreement between the student and the department. The current Graduate Focus areas consist of 9 sub-disciplines but none related to aerospace systems and UAS. In this curriculum update, the relevant courses required to complete the three course sequence for the new Aerospace/UAS Graduate Focus area was finalized and is shown below:

Aerospace/UAS (choose 1 of 4)		**9**
MECE-610	Flight Dynamics-X	3
MECE-611	Orbital Mechanics-X	3
MECE-612	Unmanned Aircraft Systems-X	3
MECE-643	Classical Controls-X	3

"X" indicated dual-listed undergraduate/graduate course

The necessary proposal paperwork required for updating the undergraduate Aerospace Option and Graduate Focus area (including the new UAS course and updates to Flight Dynamics and Orbital Mechanics) was completed. The updated Aerospace Option and new Graduate

Aerospace/UAS Focus Area received ME faculty and Mechanical Engineering curriculum committee approval and will be incorporated into the 2020-2021 RIT Course Bulletin. In addition, updates to the ABET and Middle States learning outcomes and corresponding documentation were performed and documented.

1.4 Graduate Seminar Lecture

A lecture for the Mechanical Engineering and college wide Graduate Seminar series was fully developed for exposing the general population Masters and Ph.D. students to the topic of integrating UASs into the NAS thus giving students a direct benefit. The seminar series presents topics of contemporary interest to graduate students enrolled in the program and is ideal for introducing contemporary issues of UAS. The seminar also benefits the RIT faculty as a possible recruiting tool for Masters and Ph.D. students for research opportunities related to the RIT faculty who have research interest in UASs.

1.5 Advanced Certificate in Unmanned Aircraft Systems

The authors have worked with other departments in RIT performing UAS research and course offerings to investigate the possibility of developing an Advanced Certificate in UAS. The certificate could be made more attractive by allowing students to take courses from a broader selection of courses and explicitly to allow them to take advantage of directly applying the courses required for the Advanced Certificate degree program towards course work completion of either the two Master's programs within Mechanical Engineering. This will make the Advanced Certificate attractive to a broader audience of students interested in not only a certificate in unmanned aircraft systems but working towards a Master's degree in Mechanical Engineering. The new Advanced Certificate will thus be a better feeder for the Master's program for students who are not ready at the onset to commit to complete Master of Science degree. Furthermore, students who complete the Aerospace/UAS Graduate Focus area part of the Master's program may be directly eligible for the Advanced Certificate in Unmanned Aircraft Systems. It is expected that the majority of students will be practicing engineers from the Rochester and surrounding communities, or students ultimately interested in obtaining a Master of Science or Master of Engineering degree. Students seeking to earn a Master's degree can use the courses taken within the proposed new Advanced Certificate program towards degree requirements for the Master of Science or Master of Engineering degree and thus has a direct benefit to students and the RIT community for attracting higher graduate level student cohorts. The initial stages of the new Advanced Certificate program were developed. The courses required for the Advanced Certificate program have been selected and are shown below:

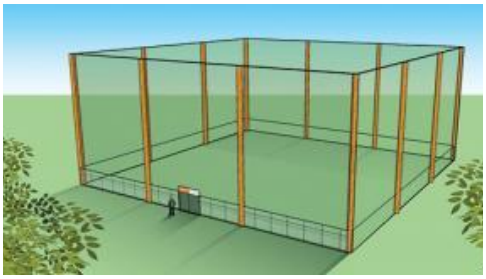
Proposed UAS Advanced Certificate		**15**
MECE-707	Engineering Analysis	3
MECE-709	Advanced Engineering Mathematics	3
MECE-610	Flight Dynamics -X	3
MECE-612	Unmanned Aircraft Systems-X	3
MECE-643	Classical Controls-X	3

"X" indicated dual-listed undergraduate/graduate course

The Advanced Certificate will also benefit RIT faculty in attracting possible graduate research students for research related to UAS. A proposal to RIT was completed for RIT governance approval of the Advanced Certificate program. The new MECE-612 Unmanned Aircraft Systems course must be approved prior to the approval process for an Advanced Certificate in Unmanned Aircraft Systems. Once the new course is approved the authors will seek RIT governance approval for Advanced Certificate in Unmanned Aircraft Systems after which all necessary documents (i.e., NYSED New Program Form, Table 1, Table 3, and Outcome Form) will be sent to NYSED for NYS approval with the goal of offering the Advanced Certificate during the 2021-2022 Academic Year.

1.6 UAS Student Competition

A new team-based UAS student competition is proposed to be researched in this curriculum development project. The student competition focuses on FAA and NASA priority areas such as technologies related to integrating UAS into the NAS and design of UAS with reduced emissions and noise. For example, the student teams are required to implement autonomous sense and avoid and technologies used to detect and avoid obstacles of various sizes while integrating autonomous navigation and control technologies; design for minimal fuel consumption and reduced noise output; overall cost; aesthetics of the UAS design; etc. The competition utilizes RIT's existing outdoor UAS research netted enclosure for showcasing operation in outdoor environments. A plan for implementing the student-based team UAS completion was investigated and finalized in this curriculum update project. Items completed in this task include:



RIT's Netted Enclosure

1. the development of an outline of the competition emphasizing FAS and NASA related priority areas; the rules for the competition; competition scoring; time frame; etc.
2. The authors will coordinate with Monroe Community College (MCC) to combine MCC's UAS student competition with the competition proposed here.
3. Students enrolled in the new UAS course are required to participate in the UAS student completion as part of the culminating effort for the course.

We envision opening the student competition to all RIT and MCC students in the first year then opening the competition to all universities (and outreach high schools). The first competition will be held during the first week of June, 2021 at RIT's UAS Netted Enclosure site. The solicitation will be distributed to regional universities (through NUAIR's University Partnership) including schools in New York, Massachusetts, and Michigan. NUAIR manages one of seven FAA UAS Test Sites in the United States consisting of a highly instrumented UAS test ecosystem with functionality. NUAIR is also responsible for the continued development and advancement of New York's 50-mile UAS corridor between Syracuse and Rome, facilitating beyond visual line of sight testing, commercial operations, and the safe integration of UAS into the national airspace. Dr. Crassidis is a the Academic Director for NUAIR and has contacted several participating universities though email and phone conversations, within the NUAIR alliance, and local high schools to solicit interest for the competition and future framework of the competition in the following years. All universities and high school responded that they would be sending students to the competition. The authors have also contacted several potential sponsors for the planned UAS student competition.