NE 591-007  Probabilistic Risk Assessment and Management  Fall 2020

COURSE INFORMATION

1. **Instructor:** Dr. Mihai A. Diaconeasa  
   1110D Burlington Engineering Labs (BU), (919) 515-3768  
   e-mail (typical response within 12 hours): madiacon@ncsu.edu  
   Zoom Office hours: Monday 5:00pm – 7:00pm  
   or by appointment (use e-mail to request a time)

2. **Schedule:**
   - Class: Monday, Wednesday 3:00pm – 4:15pm.  
     Location: 125 Withers Hall  
   - Possible make-up classes: Friday 3:00pm – 4:15pm. Location: 125 Withers Hall  
   - Online **class evaluations** will be available for students to complete during the last 2 weeks of the semester then become unavailable at 8am on the first day of finals:  
     8am November 2\textsuperscript{nd} through 8am November 16\textsuperscript{th}  
   Students will receive an email message directing them to a website where they can login using their Unity ID and complete evaluations. All evaluations are confidential; instructors will not know how any one student responded to any question, and students will not know the ratings for any instructors. Results of the evaluation is revealed to the instructor after the grades are assigned.  
   Evaluation website: [http://go.ncsu.edu/cesurvey](http://go.ncsu.edu/cesurvey)

3. **Description:** This course is focused on the principles of probabilistic risk assessment and management of complex engineering systems, with a particular focus on nuclear power applications. Topics include fundamental safety and risk concepts, accidents and risk management, a review of major probabilistic risk assessment studies, hazard analysis, qualitative and quantitative systems analysis, human and software reliability, and uncertainty quantification. Emphasis will be placed on the risk-informed and performance-based design and licensing of advanced nuclear reactors under development.

4. **Recommended Prerequisites:**
   - ST 370 “Probability and Statistics for Engineers”, or  
   - MA 421: “Introduction to Probability” or equivalent
   Contact the instructor if you don’t have the exact pre-requisite course to discuss your background.

5. **Objectives:**
   The students completing this course will be able to:
   - **Define** and **explain** the general safety and risk concepts  
   - **Explain** the nuclear plant regulation and licensing key rules and **judge** their importance  
   - **Interpret** the principles of risk and reliability analysis and **implement** them for simple engineered systems  
   - **Explain** deterministic safety analysis of nuclear power plants and **compare** it to probabilistic safety analysis  
   - **Interpret** the critical events and lessons learnt of the major accidents and incidents for commercial nuclear power plants over the past thirty years  
   - **Contrast** the major probabilistic risk assessment studies of nuclear power plants  
   - **Explain** advanced simulation methods for risk assessment  
   - **Predict** the safety of complex engineered systems and **choose** appropriate risk management strategies
6. **Test Schedule**

<table>
<thead>
<tr>
<th>Exam</th>
<th>Date/Time/Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test #1</td>
<td>Wednesday, TBD (online or take-home)</td>
</tr>
<tr>
<td>Test #2</td>
<td>Wednesday, TBD (online or take-home)</td>
</tr>
<tr>
<td>Final</td>
<td>Wednesday, November 18, 3:30pm – 6:00pm (online or take-home)</td>
</tr>
</tbody>
</table>

https://studentservices.ncsu.edu/calendars/exam/#fall

7. **Homework**: Homework will be assigned periodically throughout the semester. The last homework assignment may be due during the last week of classes. Moodle is used to post lecture notes, homework and other materials:

**Late Assignments**: Unless stated otherwise, assignments are due at the beginning of class on the designated due date. Assignments turned in within 24 hours of this time are considered LATE and will be assessed a 25% penalty. Assignments turned in after 24 hours will be marked and returned to the student, but no credit will be assigned. To allow for unforeseen circumstances, students are granted a one-time exemption if an assignment is turned in by 5:00 PM on the designated due date. Exceptions to this policy may be granted for documented medical or family emergencies.

8. **Attendance**: Required; Active class participation is strongly encouraged. University policy on definition of excused absences:

https://policies.ncsu.edu/regulation/reg-02-20-03-attendance-regulations/

**Personal Problems**: We understand that sometimes life makes it difficult to focus on schoolwork. If you are having a personal problem that affects your participation in this course, please talk to us to create a plan. Please do not wait until the end of the semester to share any challenges that have negatively impacted your engagement and academic performance. The sooner we connect, the more options we will have available to us to support your overall academic success. If you are not comfortable speaking with us directly, please utilize the other student resources provided below in order to understand how to best approach success in this course given your personal needs as soon as possible.

**Providing feedback to us**: We encourage your feedback at any time throughout the semester about things that are helping you learn, or things that aren’t helping. Please let us know if there are ways that we can improve the course to better support your learning.

9. **Text and Selected References**

Lecture notes will be provided for each class.

**Required text**:

**Recommended texts**:

10. **Grading**:

<table>
<thead>
<tr>
<th>NE 591-007</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Classwork</td>
<td>3%</td>
</tr>
<tr>
<td>Midterm</td>
<td>20%</td>
</tr>
<tr>
<td>Homework</td>
<td>22%</td>
</tr>
<tr>
<td>Project</td>
<td>35%</td>
</tr>
<tr>
<td>Grade</td>
<td>Percentage</td>
</tr>
<tr>
<td>-------</td>
<td>------------</td>
</tr>
<tr>
<td>A+</td>
<td>≥ 96%</td>
</tr>
<tr>
<td>A</td>
<td>92 – 95%</td>
</tr>
<tr>
<td>A-</td>
<td>89 – 91%</td>
</tr>
<tr>
<td>B+</td>
<td>86 – 88%</td>
</tr>
<tr>
<td>B</td>
<td>82 – 85%</td>
</tr>
<tr>
<td>B-</td>
<td>79 – 81%</td>
</tr>
<tr>
<td>C+</td>
<td>76 – 78%</td>
</tr>
<tr>
<td>C</td>
<td>72 – 75%</td>
</tr>
<tr>
<td>C-</td>
<td>69 – 71%</td>
</tr>
<tr>
<td>D+</td>
<td>65 – 68%</td>
</tr>
<tr>
<td>D</td>
<td>61 – 64%</td>
</tr>
<tr>
<td>D-</td>
<td>56 – 60%</td>
</tr>
<tr>
<td>F</td>
<td>&lt; 56%</td>
</tr>
</tbody>
</table>

*Must be top 5% student in the class as well to earn the “A+”.

11. **Academic Integrity:**
   - University policy on academic integrity: [Code of Student Conduct Policy](https://policies.ncsu.edu/policy/pol-11-35-01/)
   - By signing your name on either test or homework for this course every student implies the following statement: "I have neither given nor received unauthorized aid on this test or assignment."
   - Absolutely no collaboration is permitted during the tests. All the tests are closed book.
   - Collaboration on homework assignments is allowed, but the submitted work must be your own individual work. Homework assignments must not be treated as group assignments. Zero grade will be assigned for particular homework for the first offence. Second offense will be reported to the Office of Student Conduct.
   - Alternatives to Academic Dishonesty:
     i. Seek out help – connect with your instructor and teaching assistant, ask if there is special tutoring available.
     ii. Drop the course – can you take it next semester it is offered when you might feel more prepared and less pressured?
     iii. Ask for an extension – if you explain your situation to your instructor, an extended deadline may be granted.
     iv. See a counselor at the Counseling Center, and/or your school, college or department – NC State has many resources for students who are feeling the stresses of academic and personal pressures.

12. **Supporting Fellow Students in Distress:** As members of the NC State Wolfpack community, we each share a personal responsibility to express concern for one another and to ensure that this classroom and the campus as a whole remains a safe environment for learning. Occasionally, you may come across a fellow classmate whose personal behavior concerns or worries you. When this is the case, I would encourage you to report this behavior by making a referral on the [NC State Cares](https://prevention.dasa.ncsu.edu/nc-state-cares/about/) website. Although you can report anonymously, it is preferred that you share your contact information so they can follow-up with you personally.

13. **Students with Disabilities:** Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, students must register with Disability Services for Students at 1900 Student Health Center, Campus Box 7509, 515-7653. For more information on NC State's policy on working with students with disabilities, please see the [Academic Accommodations for Students with Disabilities Regulation](https://policies.ncsu.edu/regulation/reg-02-20-01/).

14. **Use of electronic devices in class:** Communication devices are to be turned on silent prior to entering the classroom. No exceptions. Use of electronic devices during class for purposes other than taking notes is prohibited. Tablets may be used in the lay-flat position on the desk for following the posted lecture materials or taking electronic notes only.

15. **Health and Participation in Class:** We are most concerned about your health and the health of your classmates and instructors. The course is delivered in a studio classroom; thus, the
students can actively participate online as well when needed and the recordings will be available after each lecture.

- If you test positive for COVID-19, or are told by a healthcare provider that you are presumed positive for the virus, please work with your instructor on health accommodations and follow other university guidelines, including self-reporting: [https://healthypack.dasa.ncsu.edu/coronavirus/](https://healthypack.dasa.ncsu.edu/coronavirus/). Self-reporting is not only to help provide support to you, but also to assist in contact tracing for containing the spread of the virus.
- If you feel unwell, even if you have not been knowingly exposed to COVID-19, please do not come to class.
- If you are in quarantine, have been notified that you may have been exposed to COVID-19, or have a personal or family situation related to COVID-19 that prevents you from attending this course in person (or synchronously), please connect with your instructor to discuss the situation and make alternative plans, as necessary.
- If you need to make a request for an academic consideration related to COVID-19, such as a discussion about possible options for remote learning, please talk with your instructor for the appropriate process to make a COVID-19 request.

16. **Course Delivery Changes Related to COVID-19**: Please be aware that the situation regarding COVID-19 is frequently changing, and the delivery mode of this course may need to change accordingly, including from in-person to online. Regardless of the delivery method, we will strive to provide a high-quality learning experience.

**COURSE TOPICS**

1. **Basic Risk Concepts (2 lectures)**
   1.1. Formal definition of risk (L1)
   1.2. Sources of debates (L1)
   1.3. Risk-aversion mechanisms (L2)
   1.4. Safety goals (L2)

2. **Accident Mechanisms and Risk Management (2 lectures)**
   2.1. Accident-causing mechanisms (L1)
   2.2. Risk management (L2)
   2.3. Preproduction QA program (L2)

3. **Probabilistic Risk Assessment (3 lectures)**
   3.1. Nuclear PRA (L1)
       3.1.1. Plants with hazardous materials
       3.1.2. WASH-1400 and NUREG-1150
       3.1.3. Benefits, detriments, and successes of PRA
   3.2. Initiating Event Search (L2)
       3.2.1. Hazard analysis
       3.2.2. Master logic diagram
   3.3. Risk Calculations (L3)
       3.3.1. Conditional Probabilities
       3.3.2. PRA levels
       3.3.3. Risk profile

4. **Fault Tree Analysis (3 lectures)**
   4.1. Fault tree building blocks (L1)
   4.2. Top event search (L2)
   4.3. Fault tree construction (L2)
   4.4. Automated fault tree synthesis (L3)

5. **Qualitative System Analysis (4 lectures)**
   5.1. Cut sets and path sets (L1)
   5.2. Common-cause failure analysis (L2)
   5.3. Fault tree linking (L3)
   5.4. Noncoherent fault trees (L4)

6. **Quantification of Basic Events (5 lectures)**
   6.1. Probabilistic distributions (L1)
   6.2. Probabilistic parameters (L2)
   6.3. Failure and repair models (L3)
   6.4. Estimation of distributions parameters (L4)
6.5. Components with multiple failure modes (L5)

7. Confidence Intervals (2 lectures)
   7.1. Classical confidence limits (L1)
   7.2. Bayesian confidence limits (L2)

8. Quantitative System Analysis (2 lectures)
   8.1. Truth table approach (L1)
   8.2. Structure function approach (L1)
   8.3. Minimal cuts or minimal paths approach (L1)
   8.4. Kinetic tree theory approach (L1)
   8.5. Binary decision diagram approach (L2)
   8.6. Dependent failure analysis (L2)

9. Human and Software Reliability (1 lecture)

10. Uncertainty Quantification (3 lectures)
   10.1. Parametric uncertainty (L1)
   10.2. Analytical moment propagation (L2)
   10.3. Monte Carlo propagation (L3)

COURSE PROJECT

The semester long project guidelines/options/details will be posted during the first week of the semester on Moodle.

**Project deliverables** (mark your calendar, all via Moodle Turnitin):

- Choose the project option, or propose a suitable alternative – due TDB (see project options in separate document available on Moodle)
- Specific plan (2-5 pages) on executing the project, including theoretical framework report (proposed equations to be used) and possible issues with the project formulation – due TDB.
- Proposal on specific set of values to be used with the numerical code and justification – due TBD. Include any progress made so far in this report.
- Working model and code demonstration for specific set of parameters accompanied by analytical proof (when possible) that the results are trustworthy – due TBD.
- Final report, which includes the electronic version of the model and code, and the detailed results section and conclusions on what is the best design choice based on the risk studies – due TBD.

Please keep this syllabus easily accessible so that you can refer to it throughout the semester. Contact us with any clarifying questions in advance of the semester or within the first week. We look forward to supporting your learning in this course.