Proposed

# Masters of Science in Engineering with Certificate of Specialization in Reliability Engineering

Reliability Engineering is an established field of engineering offering an interdisciplinary approach to the development of reliable and safe engineered systems. The discipline's roots are found in the efforts during and shortly after WWII to improve reliability of electronics. Reliability Engineering is now an integral part of development and life cycle management of nearly all engineered systems, products, and services. Formal education programs in Reliability Engineering were introduced in early 80's and have witnessed a steady growth in number and scope worldwide, with more than frothy MS/PhD programs being currently offered at many prestigious universities around the globe. The first and most comprehensive MS-PhD program was developed at the University of Maryland in 1988 with both distance and on-campus course offerings. There is a proven and solid demand for a more modern and comprehensive online program in reliability engineering and related disciplines such as risk analysis, system safety, resilience, and security. The proposed program as part of the UCLA School of engineering MSOL is a timely response to this market. Faculty from multiple departments will be involved in this new area.

**Degree Requirements:** At least nine courses are required (36 Units), 5 core courses in Reliability Engineering plus 3-4 courses from a list of electives.

**Core:**

- MAER174: Reliability Engineering Fundamentals
- MSE298: Risk Analysis for Engineers and Scientists
- Probabilistic Physics of Failure (new)
- Design for Reliability and Resilience (new)
- System Level Prognostics and Health Management (new)

**Partial listing of Electives (all exiting course):**

- CEE 244, Structural Reliability
- ENGR 201, Introduction to Systems Engineering
- ENGR 200, Project Management Principles for Engineers
- ENGR 202, Systems Reliability and Safety
- ENGR 205, Model-Based Systems Engineering
- ENGR 206, Engineering for Systems Assurance
- ENGR 204, Trusted Systems Engineering

## Course Descriptions

## PROPOSED CORE

### MAE174: Reliability Engineering Fundamentals

This course provides a semi-intensive survey of the field of reliability engineering. It is designed to give a thorough philosophical base for reliability engineering along with examples of application. Topics include the fundamental understanding of how engineered systems and processes fail, basic material degradation processes, probabilistic models of failure phenomena and life-models, statistical analysis of data for reliability prediction, methods for reliability analysis of complex systems (including fault tree analysis and Markov models for dynamic systems), network reliability, hybrid systems (hardware, software and human operators,) design for reliability, accelerated life testing, reliability growth, reliability in manufacturing, reliability program management (and its relationship with quality), safety, and risk. Examples will cover a range of engineering applications

### MSAE298: Risk Analysis for Engineers and Scientists

This course provides a graduate level survey of the field of risk analysis with applications in engineering and applied sciences. It is designed to give a thorough philosophical base for risk analysis, main methods and tools along with examples of application. Students completing the courses will have a good understanding of the actions and goals of a state-of-the-art risk analysis and will become familiar with current techniques and their use in producing high quality risk assessment as a basis for rational decision-making and risk management.

### Probabilistic Physics of Failure

All failures are caused by failure mechanisms. Understanding failure mechanisms permits reliability and maintainability analysis. This course will provide an understanding of the physics of failure (PoF) and degradation mechanisms such as crack propagation, diffusion, creep, yield, charge creation and migration, electromigration, defects and wear. The course covers how these mechanisms inform activities such as deterministic and probabilistic PoF modeling, diagnostics and prognostics, Failure Mode, Effect and Criticality Analysis (FMECA). Further, this course will provide the theoretical underpinnings for the successful undertaking of failure analysis or Root Cause Analysis (RCA) more broadly.

### Design for Reliability and Resilience

All systems are the manifestation of design. System reliability depends on design and must be an active design consideration throughout all stages of the system's life cycle. Resilience is a system's ability to maintain or recover functionality in response to errors, faults, disturbances and external threats. This course covers how reliability and resilience can be incorporated in the design process. This includes understanding user requirements and how to allocate program goals to meet them. Specific activities include reliability/resilience apportionment and tradespace exploration (TSE) in a value-driven design (VDD) framework. Key reliability and resilience topics will be covered as they relate to the software and human domains of complex systems.

### System Level Prognostics and Health Management

This course provides the concepts and methods of prognostics and health management (PHM). The course describes PHM techniques and their applications in various areas including structural health monitoring (SHM), Integrated Vehicle Health Monitoring (IVHM), Software Health Management (SWHM), and other health monitoring technologies. Various methods and techniques for developing health management and monitoring of components and systems will be discussed. This course also includes machine learning concepts that identify causal factors to both inform models and the identification of precursors. Students will develop a good understanding of system health monitoring, optimum sensor placement for health assessment, and current challenges and opportunities in the PHM field.

## POSSIBLE FUTURE ADDITONS as ELECTIVES

### Advanced Methods for Systems Reliability Analysis

This course covers advanced topics in system reliability modeling. These topics include modeling and solution methods for complex logic diagrams (reliability block diagrams, fault and event trees) along with influence diagrams such as Bayesian belief networks. The course will expand on these modeling methodologies to cover static, dynamic, and repairable systems. This includes Markov models, Petri Nets, and simulation techniques. Also covered are modeling of complex interdependencies including dependent failure analysis, and methods for reliability analysis of "X-ware systems" (systems of interacting hardware, software and human operators). The course also covers advanced techniques for reliability parameter estimation based on different types of information, and methods of uncertainty assessment for reliability models and parameters

### Human Reliability Analysis

This course is an introduction to human reliability analysis, incorporating human factors that govern performance. Complex system performance depends on hardware, software and humans – numerous disastrous failures are attributable to human performance. The course covers relevant subjects from ergonomics, cognitive sciences, experimental psychology, management and organizational factors. Theories and technique that relate such subjects to human reliability analysis are discussed, including methods for identifying and characterizing human errors modes and corresponding causes and influencing factors. A number of exciting and emerging methods for human reliability analysis will be discussed and applied to various filed such as nuclear power, petrochemical installations, space mission, and healthcare.

### Methods of Reliability Testing and Growth

Course revolves around exploiting (1) a detailed understanding of the physics of failure (PoF) to accelerate the reliability analysis of systems through the design of reliability tests, and (2) leveraging testing and design modification to facilitate 'reliability growth.' This involves modeling system reliability to predict reliability performance, and inform reliability analysis and testing activities such as accelerated life testing (ALT). These models involve probabilistic, deterministic and hybrid modelling approaches. Basic data analysis techniques will be covered, including 'upwards' (or predictive) and 'downwards' (or investigative) approaches. These techniques will be both parametric and non-parametric. The development of these models leads into accelerated life modelling (to enable ALT) of identified failure mechanisms in compressed timeframes. The course compressively covers various techniques for reliability growth assessment and projection.

### Software Reliability

This course provides an overview of contemporary research, techniques and tools whose aims are to improve software reliability. Systems are increasingly reliant on software and software-controlled elements – including those with safety-critical applications. This course covers manual and automated techniques and frameworks for improving software reliability as part of the development and release process. This includes code verification and software model checking. Key software reliability prediction models will be introduced, including those that inform software reliability growth. Key topics include N-version programing and the development of fault tolerant software.

**Bayesian Inference for Reliability and Risk Applications**

This course provides students with an overview of methods and tools for collecting and analyzing data to estimate parameters of probabilistic models. While the fundamentals covered in the course are applicable to many domains of science and engineering, the focus will be risk and reliability applications. This course provides an overview of relevant foundational topics in probability and statistics (both Bayesian and classical) followed by a comprehensive coverage of specific inference and estimation techniques for different types of data such as field data and data collected from testing or under laboratory conditions. Also covered are cases involving 'soft' evidence (uncertain, partially applicable information, and expert opinion). Both parametric and non-parametric methods are explained. Also covered are methods for collecting and categorizing data from field observations and tests.

**Reliability Engineering Management**

This course covers the organizational and behavioral approaches necessary for the adequate incorporation and subsequent management of reliability performance characteristic into systems. The course revolves around the reliability framework triad that links organizational value with personnel behavior and system performance. Developing and implementing organizational reliability programs will be covered, along with routine systemic evaluations and risk mitigation. This course will include qualitative and quantitative techniques for improving reliability performance, and the implementation of approaches such as Failure Reporting and Corrective Action Systems (FRACAS). The course will include Design for Reliability (DFR) activities, including the analytic allocation of sub-system and component reliability goals.