
SIE 496/596 – Fall 2025

Smart Manufacturing Systems

MW: 1:30 PM -2:45 PM

R P Harvill Bldg, Rm 452

<https://d2l.arizona.edu/d2l/home/1663851>

INSTRUCTOR

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Office Hours: By appointment only. Please send an email to schedule a meeting.

COURSE DESCRIPTION

The rapid evolution of **Industry 4.0** is transforming not only manufacturing but also a wide range of **industrial systems** such as energy, healthcare, water, aerospace, and transportation. These **Smart Industrial Systems** integrate physical assets with digital intelligence through the **digital thread, advanced analytics, machine learning, automation, and cybersecurity**, enabling higher productivity, resilience, and sustainability.

This course provides students with both the **conceptual foundations** and the **hands-on skills** needed to understand, evaluate, and apply smart manufacturing technologies. Students will learn about the building blocks of smart systems (digital thread, advanced analytics, intelligent processes, cybersecurity), explore product design and realization in a digital environment, and gain practical experience implementing the **industrial machine learning pipeline** on real-world datasets (e.g., water treatment systems, metal 3D printing). The course also covers cyber-physical systems cybersecurity challenges and defense strategies, ensuring students appreciate both the opportunities and risks of digital transformation. While the primary focus is on manufacturing, many of the methods and tools introduced generalize to other industrial sectors, enhancing the broader relevance of the course.

By the end of the course, students will be equipped to critically assess smart manufacturing practices, design and analyze digital products and processes, and apply data-driven methods to solve industrial problems.

Prerequisite(S):

SIE 383 Integrated Manufacturing Systems.

Advanced standing is required before taking this course. For Advanced Standing of undergraduate students, please visit the webpage for detail information to obtain the advanced standing: <http://sie.engr.arizona.edu/advanced-standing>.

COURSE OBJECTIVES

1. Introduce students to the **principles and building blocks of Smart Manufacturing Systems**, situating them in the context of Industry 4.0.
2. Develop understanding of the **digital thread and digital transformation strategies**, including their role in enabling enterprise-wide connectivity and innovation.
3. Provide exposure to **digital product ideation, design, and realization**, including simulation-driven design, Multiphysics analysis, industrial control, and automation.

4. Train students in the **end-to-end industrial machine learning pipeline**, from problem definition to deployment, with applications in manufacturing and supply chain contexts.
5. Engage students in **hands-on workshops using real industrial datasets** (e.g., water treatment monitoring, additive manufacturing process monitoring) to reinforce applied learning.
6. Raise awareness of **cybersecurity challenges in manufacturing CPS** and introduce defense-in-depth approaches for building resilient systems.
7. Equip students with the ability to **critically reflect on workforce, organizational, and societal implications** of smart manufacturing adoption.
8. **Encourage reflection on cross-sector adoption of smart systems**, comparing how concepts such as the digital thread, analytics, and machine learning apply in other industrial domains (e.g., energy, water, healthcare, aerospace).

EXPECTED LEARNING OUTCOMES

By successfully completing this course, all students in this course should be able to:

1. Explain the foundations of Industry 4.0 and Smart Manufacturing Systems, including the digital thread, advanced analytics, intelligent processes, and cybersecurity.
2. Analyze and compare digital transformation strategies.
3. Apply design thinking, QFD, simulation-driven design, and Multiphysics tools to translate user needs into requirements, generate alternatives, and justify design choices.
4. Describe industrial control systems and automation hierarchies and apply concepts to design simple control strategies and anomaly-recovery approaches.
5. Implement the machine learning pipeline in industrial contexts, including data collection (MTConnect, OPC UA, MQTT), feature engineering (statistical and spectral methods), model training, evaluation, and tuning.
6. Use real industrial datasets (e.g., water treatment, LPBF additive manufacturing) to build, evaluate, and interpret ML models for anomaly detection, predictive analytics, and quality monitoring.
7. Describe cybersecurity risks and defenses in manufacturing CPS.
8. Critically reflect on workforce, organizational, and societal implications of adopting smart manufacturing systems.
9. Reflect on cross-sector adoption of smart system concepts, recognizing how tools such as the digital thread, ML pipelines, and cybersecurity frameworks can be applied beyond manufacturing in other industrial domains (e.g., energy, healthcare, water, aerospace).

Additional Outcomes for Graduate Students:

In addition to the abovementioned learning outcomes, graduate students should be able:

1. Review and synthesize relevant literature in smart manufacturing and industrial ML.
2. Learn the basics of academic writing and deliver a final report in the form of an academic paper.

Accountability Statement:

You may expect to achieve these outcomes only if you honor all course policies, attend classes regularly, complete all assigned work in good faith and on time, and meet all other course expectations.

COURSE MATERIALS

- Lecture notes are the primary source materials for this course.
- Other supplemental readings and resources – available through university’s libraries and online subscriptions or otherwise “free”.

CLASS STRUCTURE PARTICIPATION POLICY

The format of the course is a combination of lecture, in-class discussion, individual projects, and group projects. Student attendance and active participation in class discussions and team projects is vital to the learning process. As such, in-person attendance is required and graded for on-campus students while fully watching the recorded classes is required and graded for remote students. A Zoom link will be provided to remote students for optional attendance of the class live.

General Policies

- The UA's policy concerning Class Attendance, Participation, and Administrative Drops is available at: <http://catalog.arizona.edu/policy/class-attendance-participation-and-administrative-drop>.
- The UA policy regarding absences for any sincerely held religious belief, observance or practice will be accommodated where reasonable, <http://policy.arizona.edu/human-resources/religious-accommodation-policy>. The calendar of religious holidays can be found at <https://registrar.arizona.edu/calendar-religious-holidays>.
- Absences for groups of more than three students that are pre-approved by the UA Dean of Students (or Dean Designee) will be honored. See: <http://policy.arizona.edu/employmenthuman-resources/attendance>.
- Non-attendance for any reason does **not** guarantee an automatic extension of due date or rescheduling of examinations/assessments. Please communicate and coordinate any request directly with your instructor.

Course-Specific Policies

- If a student needs to miss less than three classes in a row for ANY reason, the student **DOES NOT** need to contact the course instructor because the class has a “**three absent classes with NO penalty**” policy; that is three absent classes of course attendance points will be dropped for all students (no questions asked) to account for short-term absences for ANY reason. However, it is the student's responsibility to be aware of all the materials covered in the missed class as it will absolutely affect your progress towards the following classes.
- If you must miss three or more classes in a row, please directly contact the Dean of Students Office DOS-deanofstudents@email.arizona.edu to share documentation about the challenges you are facing. The Dean of Students Office will communicate the situation to the course instructor, and then the student can communicate with the course instructor to discuss what needs to be done to receive attendance points for the missed classes.
- On-campus students must attend the **full** 75-minute lecture in-person while remote students must fully watch the 75-minute lectures.

CLASS SCHEDULE

The tentative course schedule is available on D2L. It lists all material to be covered by date and includes references to the textbook chapters.

ASSIGNMENTS AND EXAMINATIONS

Class Attendance

- Class attendance is required in all classes for on-campus students and accounts for 5% of the course grade.
- Fully watching each week's class recordings before the following week is required for remote students and accounts for 5% of the course grade.
- Attendance checks may not be collected every class and will be collected randomly throughout the semester.
- The class has a **“three absent classes with NO penalty”** policy; that is three absent classes of course attendance points will be dropped for all students (no questions asked) to account for short-term absences for ANY reason. However, it is the student's responsibility to be aware of all the materials covered in the missed class as it will absolutely affect your progress towards the following classes.

Quizzes

- Quizzes will be administered online.
- The quizzes will focus on concepts and material discussed in class, homework, and/or extra work assignments to ensure achievement of learning outcomes of the course.
- Their purpose is mainly to give you an indication of your understanding of the class material throughout the semester.

Homework and Discussions

- This includes assignments related to class lectures, take-home exercises, in-class exercises, and discussion topics on D2L where students will reflect on their learning and be asked to read and interact with other students' reflections.
- The purpose of those assignments is to prepare you for the quizzes and projects, provide additional opportunity to practice and deepen your understanding of the material, and give you an indication of your understanding of the class material throughout the semester.

Course Project

- All students will be asked to work individually and in groups on two course projects covering the topics of “Simulation-Driven Design” and “Industrial Machine Learning”.
- Graduate students will be required to work on a third individual project to read and analyze a research paper and then present it.
- More details on the course projects' scope, deliverables, and timeline will be shared during the semester.

GRADING POLICY

The final course grade will be based on the total weighted points and the following scale. Final scores will be calculated to the hundredth decimal and rounded to the nearest whole number (e.g., 89.50 = A and 89.49 = B, no exceptions).

A: 100-90%; **B:** 80-90%; **C:** 70-80%; **D:** 60-70%; **E:** below 60%

For undergraduate students, grades will be assigned based on performance using the following percentages:

Course Requirement	Percentage of Grade
Class Attendance	5%
Quizzes	20%
Homework and Discussions	25%
Course Projects	50%

For graduate students, grades will be assigned based on performance using the following percentages:

Course Requirement	Percentage of Grade
Class Attendance	5%
Quizzes	20%
Homework and Discussions	20%
Course Project	55%

CLASSROOM BEHAVIOR POLICY

To foster a positive learning environment, students and instructors have a shared responsibility. We want a safe, welcoming, and inclusive environment where all of us feel comfortable with each other and where we can challenge ourselves to succeed. To that end, our focus is on the tasks at hand and not on extraneous activities (e.g., texting, chatting, reading a newspaper, making phone calls, web surfing, etc.).

THREATENING BEHAVIOR POLICY

The UA Threatening Behavior by Students Policy prohibits threats of physical harm to any member of the University community, including to oneself. See <http://policy.arizona.edu/education-and-student-affairs/threatening-behavior-students>.

ACCESSIBILITY AND ACCOMMODATIONS

At the University of Arizona, we strive to make learning experiences as accessible as possible. If you anticipate or experience barriers based on disability or pregnancy, please contact the Disability Resource Center (520-621-3268, <https://drc.arizona.edu/>) to establish reasonable accommodations.

CODE OF ACADEMIC INTEGRITY

Students are encouraged to share intellectual views and discuss freely the principles and applications of course materials. However, graded work/exercises must be the product of independent effort unless otherwise instructed. Students are expected to adhere to the UA Code of Academic Integrity as described in the UA General Catalog. See: <https://deanofstudents.arizona.edu/policies/code-academic-integrity>.

UA NONDISCRIMINATION AND ANTI-HARASSMENT POLICY

The University of Arizona is committed to creating and maintaining an environment free of discrimination. In support of this commitment, the University prohibits discrimination, including harassment and retaliation,

based on a protected classification, including race, color, religion, sex (including pregnancy), national origin, age, disability, veteran status, sexual orientation, gender identity, or genetic information. For more information, including how to report a concern, please see <https://policy.arizona.edu/employment-human-resources/nondiscrimination-and-anti-harassment-policy>.

SAFETY ON CAMPUS AND IN THE CLASSROOM

For a list of emergency procedures for all types of incidents, please visit the website of the Critical Incident Response Team (CIRT): <https://cirt.arizona.edu/case-emergency/overview>.

Also watch the video available at

https://arizona.sabacloud.com/Saba/Web_spf/NA7P1PRD161/common/learningeventdetail/crtfy0000000000003560.

ADDITIONAL RESOURCES FOR STUDENTS

UA Academic policies and procedures are available at <http://catalog.arizona.edu/policies>

Campus Pantry

Any student who has difficulty affording groceries or accessing sufficient food to eat every day, or who lacks a safe and stable place to live and believes this may affect their performance in the course, is urged to contact the Dean of Students for support. In addition, the University of Arizona Campus Pantry is open for students to receive supplemental groceries at no cost. Please see their website at: campuspantry.arizona.edu for open times.

Campus Health

<http://www.health.arizona.edu/>

Campus Health provides quality medical and mental health care services through virtual and in-person care. Phone: 520-621-9202

Counseling and Psych Services (CAPS)

<https://health.arizona.edu/counseling-psych-services>

CAPS provides mental health care, including short-term counseling services. Phone: 520-621-3334

The Dean of Students Office's Student Assistance Program

<http://deanofstudents.arizona.edu/student-assistance/students/student-assistance>

Student Assistance helps students manage crises, life traumas, and other barriers that impede success. The staff addresses the needs of students who experience issues related to social adjustment, academic challenges, psychological health, physical health, victimization, and relationship issues, through a variety of interventions, referrals, and follow up services.

Email: DOS-deanofstudents@email.arizona.edu

Phone: 520-621-7057.

Survivor Advocacy Program

<https://survivoradvocacy.arizona.edu/>

The Survivor Advocacy Program provides confidential support and advocacy services to student survivors of sexual and gender-based violence. The Program can also advise students about relevant non-UA resources available within the local community for support.

Email: survivoradvocacy@email.arizona.edu

Phone: 520-621-5767

SUBJECT TO CHANGE STATEMENT

Information contained in the course syllabus, other than the grade and absence policy, may be subject to change with advance notice, as deemed appropriate by the instructor.

Students are responsible for all the policies above and for any announcements, assignments, or changes to the syllabus that are announced in class, by e-mail, and/or posted on D2L.