OVERVIEW

In our everyday life, we rely on a multitude of systems controlling critical aspects of our life, such as transportation (e.g., airplanes, trains, and cars), medical devices (e.g., pacemakers, and insulin pumps), and infrastructure (e.g., smart electrical grid). Such *Cyber-Physical Systems (CPS)* are formed by digital components interacting with the physical environment.

The modeling, design, and implementation of reliable, secure, and optimal CPS are fundamental but challenging tasks due to the interplay of the software with the physical environment. Moreover, the complexity of designing a CPS will increase significantly in the future, for example requiring more autonomy (i.e., less human intervention).

The CPS program focuses on courses in Computer Science and Applied Mathematics providing the theory and tools to rigorously model, design, and implement the software of the CPS we use in core domains like aerospace, automotive, robotics, and medical devices.

**Language of instruction:** English  
**ECTS:** 120 (60 ECTS obtained in the 1st year and 60 ECTS in the 2nd year)  
**Oriented:** Research  
**Duration:** 2 years  
**Courses Location:** Palaiseau

EDUCATIONAL OBJECTIVES

The main objective of the program is to form the next generation of researchers that will lead the innovation in the field of Cyber-Physical Systems.
The program is multidisciplinary and provides both basic and advanced knowledge in fundamental areas in the design of CPS. The basic topics span Computer Science, Embedded Systems, and Control Theory, to cover the principles of modeling CPS. The advanced topics cover the tools used to rigorously design and analyze CPS and further other relevant areas, like Artificial Intelligence and Robotics.

The program further aims at developing the skills required to pursue a research career. The program achieves such goals through advanced, more research-oriented, courses and a research internship in one of the IP-Paris laboratories.

**PROGRAM STRUCTURE**

The program is structured over 2 years, M1 and M2, and the courses are classified as “Core CPS”, “Elective CPS”, and “Optional”.

During the first year (M1) the students acquire the basic competencies and concepts to work in the area of CPS, while in the second year (M2) the students should specialize their knowledge and interest to a specific research area (e.g., formal methods, real-time systems, robotics).

The students will acquire 60 ECTS credits during the first year (M1). The 60 ECTS credits are divided into 15.5 ECTS credits of compulsory “Core CPS” courses, 15 ECTS credits of a compulsory research project, and 29.5 ECTS credits of “Optional” courses or “Elective CPS” courses.

The research project is a semester-long project that amounts to 15 ECTS credits and will take place in one of the IPP laboratories: Laboratoire d'Informatique de l'École Polytechnique (LIX), Laboratoire de Traitement et Communication de l’Information (LTCI), and Computer Science and Systems Engineering Laboratory (U2IS). The goal of this project is to investigate a research problem in one of the research topics of interest for the CPS track.

The “Core CPS” courses are the following (compulsory, for a total of 15.5 ECTS):
- A Programmer’s Introduction to Computer Architectures and Operating Systems
- Compilation
- Concurrent Programming
- Numerical methods for dynamical systems
- Principes fondamentaux de l’Automatique: dynamique et contrôle des systèmes
- Safe Intelligent Systems
- Tolérance aux fautes

The “Optional” courses recommended for the first program’s year are:
- Algorithmique parallèle et distribuée
- Fondements des algorithmes répartis
- From the Internet to the IoT: Fundamentals of Modern Computer Networking
The “Elective CPS” courses are listed next and are recommended for the second year. However, a student can attend one of such courses during its first year, provided all the student's curriculum already satisfies the requirements for the “Elective CPS” course and after approval of his study plan.

The free choices of “Optional” and “Elective CPS” will amount to a total of 29.5 ECTS credits in the first year.

During the second year (M2) the students will acquire a total of 60 ECTS credits to choose among a list of “Elective CPS” courses, “Optional” courses, and a compulsory research project.

The research project is organized similarly to the first year: it amounts to 15 ECTS credits, it lasts for an entire semester, and is held in one of the laboratories (LIX, LTCI, and U2IS). The main requirement for the research project is that each student should perform the M2 research project in a different institution from the one that hosted the student's M1 research project.

The “Elective CPS” courses are:
- Data-based Modeling
- Real-time Systems Scheduling
- Modeling Physics with Differential Algebraic Equations
- Modélisation et analyse des risques de sécurité dans les systèmes complexes
- Navigation pour les systèmes autonomes
- Procédures de décisions SAT/SMT
- Real-Time Systems Design
- Research Seminar in CPS (from invited professors)
- Réseaux de capteurs
- Réseaux pour l'internet des objets
- Systèmes réactifs et synchrones
- Systèmes répartis et autonomiques
- Validation inductive de programmes et de systèmes hybrides

The “Optional” CPS courses recommended for the second year are:
- Advanced Cryptology
- Advanced Topics in Artificial Intelligence
- Algorithmic Basis for BlockChain
- Architectures logicielles pour la robotique
- Automatique: commande avancée des systèmes
- Computational Logic
- Distributed Computing
- Large scale mathematical optimization
- Perception pour les systèmes autonomes
The choices of “Elective CPS” and “Optional” courses should amount to a total of 45 ECTS credits.

**INVOLED LABORATORIES**

- LIX
- LTCI
- U2IS

**CAREER**

The graduates from the master program will have the ideal skills to further pursue a Ph.D. degree in Computer Science or Computer Engineering and to work in the Research and Development sector.

The program engages students with world-leading researchers working in the IP-Paris laboratories, preparing them for the research activities in the multi-disciplinary and increasingly important area of CPS. Thus, a graduate from the master’s program will be able to continue his academic career and apply for a Ph.D. program at a highly ranked University.

A graduate from the program will also have the necessary background to join the R&D department in industries from various sectors (e.g., aerospace, automotive, robotics, and manufacturing) and of various sizes (from multinational companies to start-up) to foster innovation in the exciting field of CPS. Since CPS are becoming more complex, autonomous, and distributed, they require industries to continuously develop innovative and disruptive solutions. Thus, such industries are increasingly searching for qualified personnel to develop complex systems that are able to safely and securely interact with the physical environments.

**INSTITUTIONAL PARTNERS**

- ENSTA Paris
- École Polytechnique
- Télécom Paris
- Télécom SudParis

**INDUSTRIAL PARTNERS**
CHAIRS AND PARTNERSHIPS

- "Complex Systems Engineering" Chair

ADMISSIONS

Academic Prerequisites
- Year 1: Candidates for the Master program should hold at least a Bachelor’s degree in Computer Science, Electrical Engineering, or Applied Mathematics, and have an outstanding academic record.
- Year 2: Admission can be granted directly into the 2nd year (M2), provided that necessary prerequisites have been met, and are documented. Any student (from France or abroad) who has completed at least an M1 (first year of a Masters program) in computer science, electronic engineering, applied mathematics, and other related disciplines.

Language prerequisites
- English

TUITION FEES


CONTACT
Alexandre Chapoulot
alexandre.chapoutot@ensta-paristech.fr

Goran Frehse
goran.frehse@ensta-paristech.fr

Eric Goubault
goubault@lix.polytechnique.fr

Sergio mover
sergio.mover@lix.polytechnique.fr

Laurent Pautet
pautet@telecom-paristech.fr

Gaël Thomas
gaël.thomas@telecom-sudparis.eu