Ecole Polytechnique
Course syllabus – extracts

- Name – First name of the student: GENIN Aurélien

- Academic years completed: first year (2021-2022), second year (2022-2023), third year (2023-2024)
- Major (third year): Science and Space Challenges

- Full course catalogue available here: https://moodle.polytechnique.fr/

Legend:

INF	Computer science
MAP	Applied mathematics
MAT	Mathematics
PHY	Physics
MEC	Mechanics
BIO	Biology
LAN	Language
HSS	Humanities and Social Sciences
ECO	Economics
MIE	Management and Innovation of Entrepreneurship

First year (Core curriculum):

INF371 Mechanisms of object-oriented programming **Professor: Benjamin Werner**	This course presents the advanced features of programming languages, and in particular the object-oriented constructs of Java. These features are extensively presented and then used in programming classes. The way they function is detailed by showing how they are translated, or compiled, to an abstract machine. This last point allows also an opening towards computer architecture. This course is for first year engineering students who already know some programming and basic algorithmics. The course is graded through a two hours final exam, with some modulation by the work done in the programming classes.
MAP361 Random **Professor: Josselin Garnier**	This course introduces the basic concepts of probability theory, i.e. the mathematical analysis of phenomena in which chance is involved. Particular emphasis will be placed on the two major concepts that underpin this theory: conditioning and the law of large numbers. The aim of the course is to develop probabilistic reasoning, probabilistic modeling and simulation. This modeling is fundamental in many fields of application. The course is illustrated by examples and numerical experiments. It also introduces a few notions of measurement theory (which is the axiomatic foundation of probability theory) and provides an introduction to statistics. During the course, students will complete a simulation project in pairs, which will count towards the module grade.
MAT361 Introduction to real analysis	MAT361 is one of the two core courses offered by the Mathematics Department at École Polytechnique. It is designed for students from streams where mathematics has been given less emphasis. This is an analysis course, divided into four successive parts:

Professor: Yvan Martel	1. Topology of normed vector spaces 2. Differential equations 3. Integration complements 4. Hilbert spaces and applications.
PHY361 Quantum mechanics **Professor: Manuel Joffre**	Quantum mechanics is probably one of mankind's most fertile intellectual adventures of humankind. It has made it possible to determine the structure of nuclei, atoms and molecules, elucidate the nature of light, and is an indispensable tool for understanding modern physics, from elementary particles to the stars and the Big Bang. Its economic impact is just as important: most of the world's high-tech products (electronics, lasers and optronics, nanotechnologies telecommunications) are directly derived from quantum concepts. The aim of PHY361 is to provide all students with an introduction to introduction to quantum mechanics and some of its applications. It begins with wave mechanics. After the basics of the theory, we'll study a few one-dimensional problems one-dimensional problems, such as the motion of a particle in a square-well and the harmonic oscillator. This will introduce the notion of quantum states and introduce the general principles of quantum mechanics, using the using Dirac's formalism. The operation of masers and quantum cryptography will serve to illustrate these principles. This course will have close links with both mathematics and probability.
HSS/BIO361 Cognitive sciences **Professor: Stanislas Dehaene**	1. Introduction to questions and methods of cognitive sciences: the example of decision-taking 2. The baby statistician: cerebral development and early intuitions 3. Cerebral mechanisms for acquiring reading skills 4. Cerebral mechanisms for mathematical operations 5. Modern analysis of the conscience question 6. The big principles of learning
ECO361 Introduction to economics **Professor: Olivier Gossner**	This course presents the basic principles of economic sciences.

Second year:

INF421 Design and analysis of algorithms **Professor: Benjamin Doerr**	Algorithms are the heart of all computation. This course, building on the algorithmic foundations laid in the first computer science courses (INF321 or INF311+INF411), equips the student with a solid background in modern algorithmics. Having followed this course, the student will have a profound knowledge of the most central algorithms, both understanding how and why they work and being able to solve a wide range of computational problems with these building blocks. This is material that everyone aiming to work in a computer science or computing related context needs to know, let it be in a research or industrial environment. In addition to this, we shall also give a brief introduction to several more recent topics like randomized algorithms, evolutionary algorithms, online algorithms, or algorithmic game theory, which had a significant impact on how we understand computing today.The course is taught in English (amphis, poly), for all the rest including the exam both French and English are offered.
INF442 Algorithms for data science in C++ **Professors: Guillaume Février / Pierre Aguié**	Modern data analysis relies on high-level languages such as Python or R for data manipulation and processing. However, behind standard libraries like Scikit-Learn lie implementations in low-level languages like C or C++ for optimized execution and efficient management of memory or computing resources. Hence the interest of this course, which has a dual objective: on the one hand, to familiarize students with some of the standard data analysis and machine learning techniques; on the other, to acquire C/C++ programming skills that will enable students to adapt existing low-level implementations to their specific needs. It should be noted that the programming paradigms covered in the course are almost exclusively sequential, with concurrent programming barely touched on

	in the last session and reserved for other courses.
INF443 **3D Computer graphics** **Professor: Damien Rohmer**	In addition to its importance for digital entertainment (video games, special effects, 3D animated films), 3D computer graphics is indispensable for industrial virtual prototyping (design of objects or mechanisms intended for manufacture), learning simulators and other "serious games", as well as scientific visualization, for example for visual exploration of data or simulation results. This course covers all aspects of computer graphics, focusing on the interactive side. In particular, it covers geometric modelling techniques, projective rendering and the basics of 3D animation.
INF472R **Robots and drones** **Professor: David Filliat**	Robots are complex systems comprising a variety of sensors, actuators and algorithms that link them together to interpret the environment, model it, plan movements or manipulate it. Developing software for these systems is therefore difficult, and approaches that abstract from specific hardware or reuse existing components are being developed to simplify the task. Algorithms and their proof of correct operation, in the presence of the many uncertainties due to sensors and actuators, are also a major issue in UAV development. In this modal, we'll look at some programming basics (python, C++), the basic principles of a middleware used in many laboratories and industries (Robot Operating System, ROS), some notions of image processing, 3D point cloud processing, control, mapping, planning and navigation for robotics, as well as associated open-source libraries (OpenCV, PCL) and guaranteed simulation methods to ensure the correct operation of the chosen algorithms. Various robotic platforms (quad-rotor drones, wheeled mobile robots, humanoid robots) and sensors (RGB cameras, depth cameras, laser rangefinders) will be made available to develop projects in pairs or trios.
MAP433 **Statistics** **Professor: Eric Moulines**	This course has three objectives. The first is to introduce the tools of mathematical statistics and machine learning. We will describe everything from the choice of a statistical model to parameter estimation, inference and model selection. We'll learn how to build estimators, tests and classification rules, and how to evaluate the performance of these rules. We will introduce a number of theoretical tools - decision theory, empirical processes. The last two courses will be devoted to an introduction to statistical learning. The second objective is to describe, in the course and in small classes, concrete examples of modelling in various fields (signal and image processing, econometrics, environmental sciences, shape classification, etc.). The third objective is to develop a well-founded practical know-how enabling students to understand how theoretical tools can be implemented in concrete applications (use of R or Python).
MAP435 **Optimization and Control** **Professor: Grégoire Allaire**	This course is an introduction to optimization and control of dynamical systems which are instrumental in the design and management of systems arising in science, technology, industry or services. The first part of the course is devoted to optimization, including or not constraints, in finite or infinite dimensions. After introducing some theoretical results on optimality conditions, the main focus will be on gradient-type numerical algorithms. Special attention will be paid on some important classes of problems, like linear programming or sequential quadratic programming. The second part of the course is concerned with the control of differential equations, modelling time evolution problems. The notions of controllability, adjoint state and the minimum principle of Pontryaguine are the key ingredients introduced here. Beyond these technical tools, this course is also intended to illustrate the typical approach of applied mathematics which mixes modelization, mathematical analysis and numerical simulation, all these aspects being crucial in any innovative processes.
MEC430 **Deformable continuum mechanics** **Professor: Basile Audoly / Jean-Jacques**	This course introduces the fundamental concepts of deformable continuum mechanics within the simplified framework of slender structures. The aim is to introduce all the concepts within this restricted geometrical framework, so as to quickly arrive at applications and deal with numerous phenomena with a simplified mathematical formalism. The approach used is similar to that of other more specialized courses, and in particular to that of MEC431 for the case of three-dimensional structures: we will cover the notions of internal and external forces, equilibrium equations, boundary conditions, deformations,

Marigo	behavior laws and boundary problems. Once this framework has been introduced, we'll focus on solving the problems obtained and highlighting the resulting phenomena in both statics and dynamics, and in both small and large displacements. Static problems involving elastic wires, rods, beams or arches will be studied, enabling us to deal not only with the classic problems of strength of materials, but also with more advanced problems such as buckling instabilities or boundary layers. Finally, we will introduce the variational approach, which on the one hand offers a different view of the physical laws governing structural mechanics, and on the other provides mathematical and numerical tools for solving the equations. In particular, this will enable us to obtain fundamental energy properties, define stability concepts and provide an introduction to the finite element method.
MEC432 Fluid mechanics **Professor: Laurent Jacquin**	The MEC432 fluid mechanics course lays the fundamental foundations of this discipline. The course begins by putting the notion of fluid into perspective with regard to physics and thermodynamics: what distinguishes a fluid from a solid? What distinguishes different fluids? What is a Newtonian fluid? We then go on to explain the fundamental principles of fluid flow kinematics, followed by those of dynamics and energetics, to arrive at the fundamental equations of Newtonian fluid mechanics: the Navier-Stokes equations. These equations, although reputed to be among the most difficult in physics, are analyzed and calculated by engineers and researchers on a daily basis. We'll then look at how the complexity of these problems can be further reduced, sometimes to the point of no mathematical resolution at all, thanks to dimensional analysis and the principles of similarity on which fluid mechanics experimentation is based. We will then take a closer look at the perfect-fluid approximation that underpins many of the historical applications of fluid mechanics. Analysis of perfect-fluid flows highlights the special role of vorticity, and we'll explore "vorticity dynamics", which can be considered a discipline in its own right. We will then show how the perfect-fluid approximation can be connected to another approximation that concentrates most of the effects of viscosity, the boundary-layer approximation, in order to obtain a uniformly valid description of any flow. Finally, we conclude this course with an introduction to turbulence, which today represents one of the main frontiers in our understanding of fluid mechanics.
PHY431 Relativity and variational principles **Professors: David Langlois / Christophe Kopper**	The objectives of this course are diverse. Firstly, this course provides the necessary prerequisites for all those who wish to continue with fundamental physics ("from particles to stars") in their third year and beyond. Secondly, for students interested in aspects of the conceptual progress of twentieth-century physics, without necessarily wishing to continue teaching physics afterwards. This course will enable them to broaden their knowledge of physics while integrating it into a more fundamental general framework. Finally, it is a useful tool, as other disciplines, such as pure and applied mathematics or mechanics, call on the concepts we will be covering in this course.
BIO452 Molecular Biology and genetic information **Professor: Arnaud Echard**	This course provides a broad introduction to an essential field and prepares for several other 2nd year biology courses, as well as for more advanced, 3rd year programs. This course will reveal the logic of life and will show how biology, an expanding scientific discipline, is developing more and more at the interface with physics, chemistry, informatics, mathematics and engineer sciences. The structure and function of the main biological macromolecules (DNA, RNA and proteins) are presented, along with the regulation systems that control their production and adapt it to cellular needs.
LAN481xANG / LAN482xANG Model United Nations **Professor: Dwayne Johnson**	This is not a normal course. In the span of a few weeks, students will be challenged not only to speak publically, to network and strategize in a group context, to be aware of group dynamics and to modify their own positions, thus, also to think and to react in ways that they are often unprepared for. They will also get a glimpse of their own strengths, their shortcomings, and their incredible capacities on so many levels. What are really doing? In short, we will prepare to attend a Model United Nations conference where you'll represent a country in debates around a specific theme. You'll debate, meet new people, explore a city... go to the socials. In short, have a great time and not realize how much you're getting done!

LAN483kANG **Science Fiction** **Professor:** **Christopher** **Robinson**	In this class we will read stories by Isaac Asimov, Arthur C. Clark, H.P. Lovecraft, and excerpts from novels by Philip K. Dick, Ursula K. Le Guin, H.G. Wells, and others. We will also examine films such as 2001: A Space Odyssey, Blade Runner, Alien, Children of Men, Arrival and Ex Machina. This body of literature and cinema will be placed in its social and historical context, as we trace the links between science fiction and the western literary and artistic tradition from antiquity to the 20th century. We will also address a number of current social, philosophical and linguistic issues, especially posthumanism and the defining principle of the genre: cognitive estrangement. Finally, we will look at the three major techniques that authors employ in the construction of an imaginary space and time: analogy, extrapolation, and world reduction.
LAN412RUS **Russian for** **beginners** **Professor:** **Tatyana** **Shukan**	Russian, an Indo-European language, has many similarities with the languages generally studied in France. However, it is an extremely original language for a Westerner. The way of thinking is not the same, and it responds to values that are totally unusual for this same Westerner. The Russian for Beginners course is based on principles and a method that are valid for all three semesters at the Ecole. The Polytechnicien leaves the school having seen the whole of the grammar, "chatting" fluently, and with all the means to continue studying the language on his own if he so wishes.
HSS422 **The power of** **numbers in the** **economic and** **social world.** **Socio-history of** **quantification** **Professor:** **Arthur Jatteau**	The aim of this course is to provide the means for thinking about the quantification of economic and social facts. It proposes theoretical concepts, inspired by the work of Alain Desrosières, to analyze quantification. Several quantitative objects will be examined, with the aim of revealing their socio-historical construction process.
HSS431 **Can one still be** **modern?** **Professor:** **Michael** **Foessel**	This course will draw on the resources of philosophy (as well as the social sciences) to put to the test the diagnosis that our age no longer has the means (political, scientific, ecological) to be modern. To do this, we'll start by asking what exactly modernity means, a term that is more often invoked than defined. We'll then look at some questions whose resolution seems urgent today: are the achievements of reason always reasonable? Having believed in progress, are we condemned to wait for catastrophe? If we can no longer bank on the future, should we rediscover a sense of tradition? Is the individualistic freedom of the modern age the cause of identity problems and a new solitude? Is the taste for novelty nothing more than an incantation to be "disruptive"?...
HSS415F **History of** **science and** **technology** **Professor:** **Frederic** **Brechenmacher**	Does science have a history? Often celebrated for their universality, the sciences can seem timeless. Yet scientific and technological knowledge is developed by men and women; it evolves in social times and spaces, interacting with other cultural, social, economic and other activities. The aim of the seminar is to develop a reflective approach to science, while providing an introduction to research in the history of science. The presentation of major contemporary research themes will enable participants to discover the richness of highly interdisciplinary approaches, including history, philosophy and sociology.
HSS413G **The** **sketchbook,** **from drawing** **to movement** **Professor:** **Renaud** **Chabrier**	This seminar is meant to be a trip from drawing on paper to modern digital animation tools. We will focus on how to make an information accessible, wether it is for students, scientifics, general public, or even children. A series of workshop will allow us to adress different thematics: - fundamental aspects of drawing (the "stroke") - composition of drawings (on paper, and with a software) - animation approaches in the so-called "2D" family (frame by frame, stop-motion, warping...) - compositing softwares and short film-making. Students will have to develop a narration through text and images, in order to produce the "sketch" of a short scientific movie. Warning: vector animation and 3D animation will not be adressed in this course. However,

	student who are already skilled in such domains are welcome to use them in their movie.
MIE431 Fundamentals of organizations **Professor: Véronique Steyer**	Organizations (companies, research laboratories, public services, etc.) are omnipresent in our daily and professional lives. They shape our lifestyles and our societies. Powerful tools for organizing and sustaining collective action, they will be the focus of your professional life, whatever career you choose. Although seemingly familiar, they are nevertheless complex in their dynamics and in the multiple dimensions, both technical and human, that make them up. For more than a century, management science - the science of the "company", in the sense of the undertaking and the result of this dynamic - has sought to better understand how they work, and to provide managers with benchmarks and tools to steer their internal and external complexities. The aim of this course is to give you a few keys to understanding the logic of this new territory, and to increase your ability to act within it, both during your internship at the end of this second year, and later in your professional life.

Third year:

MEC552A Numerical methods for fluid mechanics **Professor: Lutz Lesshafft**	Numerical simulation has long become an indispensable tool in all areas of mechanical engineering. In research, numerical simulation allows us to obtain information of mechanical systems in a level of detail that is usually inaccessible from experiments. In applications, it is used for parameter studies, optimisation and virtual prototyping. This course provides a thorough introduction to numerical techniques for the solution of linear systems, ordinary and partial differential equations, as needed for computational fluid dynamics. The fundamental issues of consistency, stability and convergence of numerical methods are treated, while maintaining a focus on their practical application. The course is taught in English, integrating lectures with practical exercises. Numerical methods will be implemented in Python, using the Jupyter notebook format.
MEC554 Compressible aerodynamics **Professor: Antoine Sellier / Benjamin Leclaire**	Shock wave? You probably already heard this term but what it means? What are the laws of physicsgoverning such a wave and its properties? In which basic fields of fluid mechanics such wares areencountered and play a key role? What are a so-called compressible flow and the usual fundamental properties of such flows? This course brings answers to the above issues. Upon adopting a few simple assumptions (which are quite relevant for most of the applications in this field),it derives the main properties of compressible flows. More precisely, it successively dealswith shock waves (birth and properties, either plane or curved ones), shock-boundary interactions, one-dimensional unsteady and two-dimensional steady compressible flows, steady compressible flows about a thin airfoil (with subsonic, supersonic and transonic regimes),… On the theoretical side, the course also examines the nature (elliptic, hyperbolic,parabolic) of the Euler equations (unsteady one-dimensional or steady two-dimensional ones) and also introduces in a more general frame work the useful method of characteristics. Such a method is illustrated in this course for some encountered compressible flows.
MEC560 Propulsion **Professor: Christophe Clanet**	Study of the different types of animal propulsion and comparison with human systems. The first part of the course is dedicated to the swimming (low and high Reynolds numbers). The second part is about flight (gliding flapping, steady). The last part of the course covers human propulsion (planes, helicopters, boats),
PHY550 Plasmas in space science and technology **Professor: Pascal Chabert**	This course deals with the physics of ionized environments, or plasma physics, from the space science and industry point of view. Plasma is by far the most common state of matter in the visible universe and therefore nearly all astrophysical objects are in fact plasmas. Plasmas are also present on Earth, either created by nature in the form of lightnings or auroras or generated by human beings in a wide range of industrial applications. They play a central role in microelectronics since etching and deposition of thin films relies mostly on plasma processing. They are also used as air purifiers or to treat wounds in medicine. They might be used in the coming years to treat cancer or to achieve nuclear fusion, which would

	give humanity an almost unlimited source of energy. As we shall see in details in this lecture, they are now successfully used as efficient engines for satellite and spacecraft propulsion. Thus, plasmas are fundamental in space science and technology. Satellites and spacecrafts mainly operate around Earth, or in the solar system in environments that are almost always significantly or fully ionized. The Sun continuously emits a magnetized plasma, mainly composed of electrons and protons, called the solar wind. This plasma interacts with the planets of the solar system, leading to complex phenomenon that are essential to understand the life and the dynamics of planets and their atmospheres. Planets that generate their own magnetic field, like Earth, are partially protected from the solar wind by a magnetosphere, which acts as a magnetic shield. Nevertheless, the higher atmosphere remains ionized by the solar wind (the ionosphere), particularly in the aurora regions. This course will therefore require a detailed description of the fundamental principles governing the solar environment, the solar wind, the magnetosphere and the Earth ionosphere. The lecture will then describe in details the interaction between plasmas and satellites or spacecrafts. These are immersed in space plasmas and are subject to charged particles bombardment (electrons and ions). We will study the structure of the potential surrounding a satellite in a plasma and the variety of interactions between charged particles and parts of a satellite. The conductivity of its dielectric coating, also subjected to radiation, determines the charge differential or charge risk. The secondary emission of electrons resulting of the impact of the plasma electrons controls the sign of the electrostatic discharge, impacts the multipactor discharges which limit the power of telecom satellites, and modify the abnormal electronic conductivity in Hall effect thrusters. In the last part of this course, we will describe the fundamental mechanisms at play in plasmas thrusters, that are now routinely used as satellite engines, and that will be essential for future space exploration missions. The principle of plasma thrusters is to ionize the gas propellant to achieve much higher exhaust velocities than conventional hydrodynamic nozzles. For the same thrust, the mass flow of the propellant is then drastically reduced, and the plasma thruster has a much better mass efficiency than conventional chemical engines. We will study in details two flight-proven engines, the gridded-ion thruster and the Hall effect thruster. Different types of plasma thrusters based on advanced concepts currently under development will also be discussed.
PHY569B Astrophysical plasmas and space missions **Professor: Fouad Sahraoui**	The solar system provide an ideal laboratory to investigate fundamental physical processes (e.g., turbulence, magnetic reconnection, shocks) that underlie longstanding problems of heliophysics, such as the solar corona and solar wind heating problems, particle acceleration and radio emissions in planetary magnetospheres (e.g., aurora). The main reason is the availability of high quality in-situ data measured by various spacecraft that have been exploring these media for about a half century. These include the solar wind exploration by Voyager since the 1970s to the more recent ones, the NASA/Parker Solar Probe (launched in 2018) and the ESA/Solar Orbiter (launched in 2020), the near-Earth space exploration (ionosphere and magnetosphere) by multi-satellites missions such as the ESA/Cluster (2000) and NASA/MMS (2015), planetary exploration: NASA/Jupiter by Galileo, Juno (2016) and "soon" ESA/JUICE (launched in 2022, orbit insertion in 2030), NASA-ESA/Saturn (Cassini 1997-2017), Mercury by NASA/Messenger (2004) and ESA-JAXA/BepiColombo (launched in 2018, orbit insertion in December 2025). The achievements accomplished in the solar system allow us to extrapolate the results to other challenging problems of distant astrophysical objects, which are not (or much less) accessible to measurements. Examples are star formation in the interstellar medium (ISM), cosmic rays acceleration and magnetic field generation in galaxies and inter-cluster galaxy (ICG), angular momentum transport and accretion flows around compact objects (e.g., black holes). In this lecture we will first introduce some major questions of astrophysical plasmas and explain how they can be tackled using the solar system as a laboratory to test modern existing theories. In the second part, we will recall some basic equations of plasma physics (kinetic and fluid-like descriptions, i.e. MHD and its extensions to small scales, e.g. Hall-MHD), before discussing examples of universal plasma processes such as turbulence and magnetic reconnection. We will expose the underlying theories of such processes and explain how they can help solving some of the questions addressed in the introduction of the course, with a particular focus on how the theoretical predictions can be tested in

	spacecraft observations. The second part of the lecture we will deal with the description and design of space missions dedicated to space plasmas. We will describe the main in-situ instruments embedded on orbiting spacecraft (e.g., AC & DC magnetometers, Langmuir probes, plasma spectrometers –electrons and ions). We will explain their functioning principle, their constraints and limitations inherent to space exploration (cost, mass, power, telemetry). We will also introduce some signal processing techniques and methods used to analyze (single and multi-)spacecraft data and discuss their strengths and weaknesses. In the last part we will present some current trends in space exploration dedicated to plasma physics (both in the solar wind and planetary magnetospheres). We will introduce new scientific questions that emerged in light of recent progress achieved from the current orbiting spacecraft, discuss the new concepts of space missions under preparation and highlight the new technical challenges faced.
PHY569C Orbital dynamics and multidisciplinary optimization **Professor: Fabien Gachet / Mathieu Balesdent / Loïc Brevault**	The recent advent of nanosatellites, the announcement of new mega-constellations of satellites including thousands of units, along with the contemporary awareness of the risk posed by space debris, have all in common the need to understand the behavior of bodies in orbit around Earth, in the short and long-term range. This issue falls under a field called astrodynamics, or more generally orbital dynamics. This domain being a branch of celestial mechanics possesses therefore a long history, and proceeds from dynamical systems theory and analytical mechanics in its mathematical and physical foundations. It is still an active field of research, with for instance the recent use of tools stemming from chaos theory to study the long-term stability of orbits: we can mention the computations of chaos indicators in order to determine the best solutions for satellites' end of life (reentry or graveyard orbits), or also the study of orbital resonances present in some regions of space so that satellites naturally end up reentering. In this part of the class we will study the Hamiltonian formulation of orbital dynamics, the resolution of its equations, either analytically using series expansions, or numerically using specific numerical integration schemes, we will develop the perturbation approach and we will analyze the different orbital perturbations at play, we will take up averaging theory, along with the chaos detection tools previously mentioned, and we will examine a cartography of the dynamics in the different orbital regimes used for Earth orbiting satellites, as well as the management of the space debris problem and the risks of collisions. Aerospace vehicle design is a complex process involving numerous disciplines such as aerodynamics, structure, propulsion and trajectory. These disciplines are tightly coupled and may involve antagonistic objectives that require the use of specific methodologies in order to assess trade-offs between the disciplines and to obtain the global optimal configuration. Generally, there are two ways to handle the system design. On the one hand, the design may be considered from a disciplinary point of view (a.k.a. Disciplinary Design Optimization): the designer of each discipline has to design its subsystem (e.g. engine) taking the interactions between its discipline and the others (interdisciplinary couplings) into account. On the other hand, the design may also be considered as a whole: the design team addresses the global architecture of the space vehicle, taking all the disciplinary design variables and constraints into account at the same time. This methodology is known as Multidisciplinary Design Optimization (MDO). The course draws a panorama of the specific mathematical tools used to handle space vehicle design problem complexity: formulations of the MDO problem, choice of the adapted optimization algorithms, use of machine learning techniques to reduce the computational costs and the integration of high-fidelity simulations, etc.
HSS522 Big Data sociology **Professor: Etienne Olion**	For two decades, the number of digital available skyrocketed. Collected by sensors installed in our daily life, this information is a digital record of individual and society. This evolution, combined to the use of technologies to treat them (first and foremost AI), has caused intense debates. How do they change our lives? From social science work that invested various fields going through these big data, the aim of this course is to provide precise answers to the questions that have been raised in the public debate. Rather than giving a too general overview, we will cover specific topics. Among those: work (are we witnessing a labor market urbanisation?), privacy (are we witnessing a feeling, meeting commodification), science (do we really know more today?) and techniques (what can AI do?), political organization and

	public debate (is democracy possible with mass surveillance and social media?). From these examples, this course will study the transformations involved in this new disponibility of data, and the structures that collect, transport and store them.
HSS512F **Brain and cognition: The consciousness** **Professor: Jérôme Sackur**	Consciousness is still a new notion in cognitive science. It was considered to be a notion too vague or subjective to be rigorously and empirically studied with psychological, neuroscience and modeling methods. The situation changed in the last 25 years with the implementation of experimental protocols allowing the systematical comparison of supraliminal (where a stimulus gives rise to a perception associated with consciousness) and subliminal (where a stimulus is dealt without the subjects reporting having perceived anything) perceptions. These protocols enabled implementing cognitive and neuronal models that given legitimacy to empirical sudy of consciousness. In this seminar, we will start with the study of model of perceptive consciousness that are now classic, which without being completely consensual form a solid base for discussion. I will present basic methods and concepts of the empirical study of consciousness, experimental psychology, neuroscience and modeling. Then, we will look at the boundaries of the field, because of course our consciousness of our perceptions is only one aspect of the question.
MIE524 **Collaborative consumption and participative models** **Professor: David Massé**	Blablacar or AirBnB are initiatives that belong to the daily life of the French. The popularity for these new platforms illustrates the success of these initiatives and to think that "collaborative economy" - to use the concept put forward by many authors - has conquered the heart and mind of the French consumers. Despite the lack of conceptual clarity which is still behind the concept of collaborative economy, the first analyses - from or think thanks - hold many promises. For some people, this economy is a sustainable solution. This course offers a review on existing analyses around this emerging study object that is collaborative economy. It presents the diversity of collaborative practices, tension points of this economy, the observed changes in the consumers' behaviour and how large traditional companies are taking these collaborative logics to renew their affair models and activities.
LAN573kANG **Geopolitics** **Professor: Elsa Sen**	C1/C2-level English course on the topic of geopolitics covering various aspects : geography, strategic resources, sports, culture, soft-power…