Course Information

Code	AR3CP120
Course Title	Lunar Architecture and Infrastructure Graduation Studio
EC points	55
Organization	Architecture and the Built Environment

Content

Mirroring the interdisciplinary nature of space colonization projects where architects, roboticists, and space scientists work together to achieve common goals, this new inter-faculties graduation course, Lunar Architecture and Infrastructure (LA&I), is designed to foster collaboration and shared objectives among students from various faculties. It is open to all graduating TU Delft students interested in addressing challenges of space colonization.

To survive in outer space, humans need protection from radiation. Such protection requires architecture and infrastructure to ensure habitation and accommodate various activities ranging from living and working (e.g., habitat, roads), to generating energy (e.g., equipment, storage), and facilitating communication (e.g., base stations), while relying heavily on in-situ resource utilization and a high degree of automation. In this regard, the automation scale and use of robots plays an important role in minimizing the risks for humans. Robots stand out in operating within harsh environments, such as those with extreme temperatures, radiation, and low gravity, which are typically inhospitable to humans. Their capacity to perform tasks that are repetitive, dangerous, or demand high precision makes them a perfect fit for activities like excavation,

construction, maintenance, and other critical off-Earth tasks. Additionally, use of robots significantly mitigates the cost and risk associated with human missions by preparing the lunar surface and infrastructure even prior to the arrival of astronauts. They can be utilized to mine local materials, construct structures, and extract essential resources like fuel, water, and oxygen, thereby facilitating human habitation in extraterrestrial environments.

Lunar architecture and infrastructure are designed by computational means and are constructed by robotic means involving Robot-Robot and Human-Robot Interaction (R/ HRI) supported Design-to-Robotic-Production-Assembly and -Operation (D2RPA&O). The construction of habitats underground on the Moon offers natural protection from radiation and lesser temperature fluctuations, changing the solicitations on the structure. The construction relies on a swarm of mobile robots equipped with various end-effectors that are deployed to map the terrain and mine for materials used to 3D print building components. These are then assembled using R/ HRI-supported methods. The assembled structure is equipped with a Life Support System (LLS), which relies on D2RO processes. Both habitat construction and inhabitation are powered by an energy system involving space-based solar power. The ultimate goal is to develop an autarkic R/ HRI-supported D2RPA&O system employing In-situ Resource Utilisation (ISRU) for building habitats and to transfer developed technology to terrestrial applications in due time.

Study Goals

The LA&I graduation project is implemented in two consecutive semesters with study goals aligned with the respective stages of design. The goal in the first semester is to extract from the analysis and problem statement phase a clear design task formulated as a design brief, in which design assignment, program, site and ambition of the project are identified. While general knowledge in space colonisation will be developed in lectures with invited speakers from a.o. ESA, knowledge and skills in HRI-supported D2RPA&O will be developed in workshops. The overall goal is to develop necessary knowledge and skills to advance the design in the second semester up to materialization level by addressing the requirements formulated in the brief.

In this context, students develop:
• knowledge and skills in architectural design to satisfy both aesthetic and functional requirements within the larger architectural history, theory, technology, and human sciences context;
• knowledge and skills related to understanding the design process concerning the relationship between natural and constructed spaces and societal needs, including sustainability requirements;
• knowledge and skills in computational design, robotic construction, and building technology;
• ability to understand the design process inclusive of structural and materialization requirements for buildings with integrated climate control;
• competence to employ analysis, judgment, creativity, innovativeness, decision, and argumentation skills regarding architectural ethics and the future role as an architect;
• competence to identify the societal and disciplinary relevance of their project and address, where relevant, intercultural issues;
• ability to present adequately and coherently significant results that are correct, thorough, and complete with all relevant aspects elaborated in greater depth;
• ability to present with a degree of clarity, intelligibility, and reflection.

Education Method

The pedagogical methodology relies on a problem-based learning approach that involves defining problem(s), brainstorming, structuring, hypothesizing, and synthesizing. This implies that students identify what they already know, what they need to know, and how and where to access new information that may lead to the resolution of the design and engineering problem(s). With this approach, students learn how to deal with complex design assignments, process and organize large amounts of data, meet deadlines and prioritize milestones.

Collaboration involving group and individual work with corresponding deliverables is strongly promoted. Through group and individual work, students learn how to discuss, divide work, and compromise while relying on personal autonomy and accountability to produce deliverables on time. Deliverables require advancing methods of representing, presenting, and communicating the architectural project using various media (sketches, models, simulations, prototypes, videos, presentations, reports, etc.).

The workflow methodology relies on Design-to-Robotic-Production-Assembly and -Operation (D2RPA&O) methods that integrate computational design with robotic construction and operation of buildings. These involve the use of various Artificial Intelligence (AI) and Human/ Robot-Robot-Interaction (H/ RRI) supported computational and robotic processes that fundamentally change the architectural project, which increasingly emerges from human and non-human interaction. In this context, the H/ RRI-supported D2RPA&O process is implemented by ABE students in collaboration with students and tutors from ME, EEMCS, and AE. For instance, ABE students develop habitat designs, while ME and EEMCS students develop robots for constructing the habitat, and AE energy generation systems for constructing and operating the habitat.

Assessment

Evaluation is based on the group and individual performance of each student. The student’s performance will be determined by the quality of his/ her work, commitment, effort, and improvement over the entire course of each semester. In both semesters, the assessment is implemented at midterm and final review, with a pre-final or go/no go review scheduled a month before graduation. Examinations schedule and formal requirements are described in the Graduation Manual.

Assessment is implemented by reviewing following deliverables:
• presentations showing analysis, concept, parametric models, and prototypes;
• 3-4D parametric models showing the design within the site at the phase of concept design, schematic design, design development and construction design;
• structure and materialization design for robotic production, assembly, and operation;
• from 3D model obtained sections, plans, and views at appropriate scales ranging from 1:1000 to 1:1;
• physical models and 1:1 prototypes developed from the 3D parametric model; photos/ videos documenting production, assembly process, and final result;
• digital documentation of all above including 300 words abstract describing project on the LA&I wiki (http://cpa.roboticbuilding.eu/) and TU Delft repository.

Enrolment / Application

Students are required to register for courses and exams in both the Bachelor's and Master's programmes. For more information, see: https://www.tudelft.nl/en/student/a-be-student-portal/practical-affairs/enrolment-education-exams.

Additional enrolment information for non-BK students:

• Course enrolment via Brightspace only is not considered a valid registration.
• Enrolment in the BK-enrolment system BIS (https://bis.bk.tudelft.nl/) does not guarantee placement; there may be a maximum number of non-BK participants for this course (see below).
• The course can be taken only after confirmation of placement in BIS by BK-enrolment

Period of Education

Graduation projects start in the fall semester and are implemented in two semesters, where each semester is divided into four phases, each of them lasting for five weeks. At the end of each phase, the group and individual presentations take place.

Course evaluation

For the course evaluations, see the Brightspace page 'Evaluations TUD' (requires enrolment). However, since this course is offered for the first time in 2024 there are no evaluations available.