Intelligent Robotics for Assembly & Design

Spring 2027 Syllabus

Georgia Institute of Technology | Vertically Integrated Projects (VIP)

Course Numbers: VIP 6601 / 6602 / 6603 / 3601 / 3602 / 2601 / 4601 / 4602
Term: Spring 2027 (202702)
Sections / CRNs: To be confirmed
Credits: Variable, according to enrollment
Meeting: Friday, 8:25–9:15 AM (tentative)
Location: Digital Fabrication Lab (DFL), Mezzanine, AI-rLAB

Instructor Information

Instructor	Email	Office Hours & Location
Patrick Danahy	--	ARCH West, Room 355; hours TBA
Edvard Bruun (Co-Instructor)	--	By appointment

General Course Information

Description

Intelligent Robotics for Assembly & Design is a research-focused Vertically Integrated Project investigating the development of intelligent robotic systems for architectural fabrication, construction, and physical automation. The course examines a critical transition in robotics and artificial intelligence: the shift from pre-programmed automation toward systems capable of physical intelligence—machines that can perceive their environment, evaluate changing conditions, and adapt their actions during physical tasks.

Most robotic fabrication workflows in architecture and construction remain deterministic, relying on predefined toolpaths, controlled environments, and limited feedback. While these approaches are effective in conventional manufacturing, they are less suited to construction environments where material variation, tolerance accumulation, imperfect positioning, and changing physical conditions are unavoidable. This gap between digital precision and physical uncertainty forms the central research problem of the course.

Building upon the robotic platforms, laboratory infrastructure, and simulation environments developed during Fall 2026, the Spring 2027 semester will emphasize the integration of sensing, computer vision, calibration, motion planning, and adaptive control into functional robotic systems. Students will investigate how information gathered from cameras, sensors, and the physical environment can directly inform robotic behavior,

allowing systems to respond to actual physical conditions rather than simply executing predetermined instructions.

Research will progress from the calibration and characterization of individual robotic platforms toward increasingly integrated experiments in vision-guided manipulation, pick-and-place operations, coordinated assembly, and adaptive material-processing workflows. Students will connect digital design and simulation environments, including Rhino/Grasshopper, ROS2, and NVIDIA Isaac Sim/Isaac Lab, with physical robotic systems, investigating the translation between simulated behavior and physical execution.

The course also emphasizes the development of shared, reproducible research infrastructure. Advanced robotics laboratories often depend on tacit knowledge held by individual researchers, making systems difficult to maintain, reproduce, or transfer between student cohorts. Students will document hardware configurations, calibration methods, software environments, experiments, failures, and results. Each semester will build upon previous work rather than beginning again, establishing a cumulative body of technical knowledge for the Architectural Intelligence and Robotics Lab (AI-rLAB) and collaborating research environments.

Through this work, students will critically examine the broader implications of automation within architecture and construction. Robotics can transform how buildings are designed and produced, but it also raises questions concerning labor, skill, safety, accessibility, and the distribution of technological expertise. The course approaches these technologies not simply as tools to be adopted, but as systems that architects, engineers, designers, and researchers have an opportunity—and responsibility—to shape.

Spring 2027 Research Priorities

The Spring 2027 semester will focus on extending existing robotic infrastructure into integrated and experimentally validated systems. Research priorities will be developed through several interconnected areas:

1. **Robotic Platform Integration and Calibration.** Continue improving Annin AR4 robotic platforms, including mechanical calibration, joint accuracy, repeatability, camera integration, end-effectors, linear rails, and system reliability. Establish standardized testing and operating procedures that can be transferred between robots.
2. **Simulation and Physical Deployment.** Develop reproducible simulation environments using NVIDIA Isaac Sim, Isaac Lab, ROS2, and related tools. Investigate the translation of simulated motion and robot behaviors into physical

operations, including the effects of calibration, collision geometry, positioning errors, and physical tolerances.

3. **Computer Vision and Perception.** Develop camera calibration, object detection, localization, tracking, and scene interpretation workflows. Integrate perception systems with robotic motion planning to support manipulation and assembly tasks that respond to observed physical conditions.
4. **Adaptive Control and Intelligent Manipulation.** Investigate workflows in which sensing and feedback can modify robotic behavior during task execution. Research will address pick-and-place operations, visual servoing, adaptive toolpath generation, error correction, and potentially learned control strategies.
5. **Interfaces, Tooling, and System Development.** Continue improving robotic hardware and software interfaces, including teach-pendant tools, enclosures, end-effectors, wiring, user interfaces, and robot simulation models. Explore how standardized components and interfaces can improve accessibility, scalability, and reliability.
6. **Integrated Demonstrations and Construction Applications.** Translate technical developments into repeatable robotic demonstrations relevant to architectural fabrication and construction. Longer-term research will investigate multi-robot coordination, assembly automation, and material processing in collaboration with the BAR Lab and other research partners.
7. **Research Documentation and Knowledge Transfer.** Maintain shared technical documentation, source code, datasets, experimental records, and reproducible demonstrations. Establish clear pathways for transferring knowledge between new and continuing students, research teams, and future semesters.

These priorities provide a shared research framework rather than a fixed sequence of identical assignments for all students. Individual responsibilities will depend on experience, academic discipline, project needs, and credit-hour enrollment.

Pre- and/or Co-Requisites

There are no formal prerequisites or co-requisites for this course.

Students from architecture, engineering, computer science, and related fields are encouraged to participate. Prior experience with robotics, programming, computational design, or fabrication is beneficial but not required.

New students will begin with introductory technical modules and guided research activities. Returning students will be expected to demonstrate greater independence and technical responsibility.

Course Goals and Learning Outcomes

By the end of this course sequence, students will be able to:

1. **Understand robotic systems from the ground up.** Develop working knowledge of robotic hardware, mechanical assemblies, motors, controllers, sensors, communication systems, calibration procedures, and software architectures.
2. **Develop perception-driven robotic workflows.** Integrate computer vision, sensing, and environmental feedback into robotic systems so that machines can evaluate physical conditions and respond during fabrication and assembly.
3. **Move from fixed automation toward adaptive behavior.** Explore generative and adaptive toolpath strategies that allow robotic actions to change in response to material variation, tolerances, positioning error, and environmental uncertainty.
4. **Connect simulation to physical deployment.** Develop methods for translating digitally planned robotic behaviors into reliable physical operations while understanding calibration, accuracy, latency, tolerances, and sources of error.
5. **Design and evaluate robotic interfaces and components.** Improve robotic hardware, tooling, enclosures, wire management, user interfaces, teach-pendant systems, and other elements influencing usability, maintainability, and performance.
6. **Develop rigorous experimental methods.** Establish repeatable procedures for testing robotic accuracy, sensing, manipulation, assembly, and fabrication processes, using quantitative and qualitative evidence to evaluate results.
7. **Build reproducible research infrastructure.** Create clear documentation, standardized procedures, datasets, code, diagrams, and technical resources that allow future student teams to reproduce, maintain, and extend previous research.
8. **Work cumulatively across teams and semesters.** Treat each project as part of a longer research trajectory in which students inherit existing systems, identify limitations, improve them, and contribute new capabilities for subsequent cohorts.
9. **Demonstrate physical intelligence through fabrication and assembly.** Develop increasingly complex robotic demonstrations ranging from vision-guided

manipulation and pick-and-place operations to adaptive assembly and material-processing workflows.

10. **Engage critically with automation and construction labor.** Consider how intelligent robotic systems may transform construction practices, technical expertise, safety, workforce roles, and access to emerging technologies.
11. **Collaborate across disciplines.** Work at the intersection of architecture, robotics, artificial intelligence, sensing, computation, and engineering, developing the communication and teamwork necessary for complex interdisciplinary research.

Course Requirements and Grading

VIP teams function like real-world research and development teams. Members work on different aspects of a shared project, ranging from undergraduate to graduate students and from first-time participants to researchers with multiple semesters of experience.

Students may enroll for variable credit hours, which are considered in determining the scope and expectations of their contributions.

Zero-credit enrollment is reserved for eligible paid participants and follows the same general assessment criteria.

Grading Overview

Each student is evaluated across three equally weighted areas. Regardless of role or experience, students must demonstrate achievement in all three categories.

1. Documentation and Records — 33⅓%

- Maintain ongoing individual research documentation (required).
- Contribute to shared team documentation through the VIP Wiki and/or GitHub.
- Record technical development, testing, experimental outcomes, and unresolved issues.
- Provide reproducible procedures, source files, drawings, photographs, datasets, and other relevant materials.
- Clearly identify individual contributions within collaborative work.

2. Personal Contributions — 33⅓%

- Complete assigned research modules, experiments, prototypes, or reports.
- Engage actively and consistently in project development.

- Independently pursue technical knowledge relevant to assigned tasks.
- Make meaningful contributions to research progress and system development.
- Demonstrate initiative in identifying and resolving technical problems.
- Experienced members may also contribute to system integration, project management, and mentoring.

3. Teamwork and Interaction — 33⅓%

- Complete required peer evaluations. Failure to submit a required evaluation results in a full letter-grade deduction.
- Attend team meetings on time and participate actively.
- Collaborate toward established research objectives.
- Coordinate work with teammates and communicate progress.
- Assist other members with technical problems and knowledge transfer.
- Contribute to team presentations, demonstrations, and research discussions.

Rubric

Performance Standards

Performance Level	Description
Excellent — A	Consistently makes substantial and well-developed contributions to the research. Demonstrates initiative, independence, technical rigor, strong collaboration, and thoughtful experimentation. Documentation is clear, reproducible, and valuable to future teams. Work frequently extends beyond minimum requirements and meaningfully advances the larger project.
Good — B	Makes consistent and meaningful contributions to assigned research objectives. Demonstrates good technical development, participation, documentation, and collaboration. Work is generally complete and reliable, although some areas may require greater depth, initiative, testing, or refinement.

Satisfactory — C	Completes basic assigned responsibilities, but contributions may be inconsistent, limited in depth, or dependent upon substantial guidance. Documentation or experimentation may be incomplete, and participation may not consistently support team progress.
Limited — D	Makes minimal or inconsistent contributions to the project. Assigned work is frequently incomplete, poorly documented, or insufficiently tested. Demonstrates limited engagement with team responsibilities, research objectives, or technical development.
Unsatisfactory — F	Fails to participate meaningfully in the research effort or complete assigned responsibilities. Contributions, documentation, attendance, and/or teamwork are insufficient to demonstrate achievement of the course objectives.

Research Process and Failure

Experimental research does not always produce a successful technical outcome. A failed prototype, unsuccessful experiment, or technical problem will not inherently result in a lower grade. Students will instead be evaluated on how rigorously the problem was approached, tested, analyzed, documented, and communicated.

A well-designed experiment that reveals why an approach does not work can represent a significant research contribution.

Conversely, a functioning system without sufficient documentation, testing, explanation, or evidence of individual contribution should not be considered complete research work.

Individual and Team Assessment

Many course activities will be completed collaboratively, but grades are assigned individually. Team outcomes provide evidence of collective progress, while individual assessment considers each student's identifiable contributions, research documentation, participation, technical responsibilities, and ability to communicate their work.

Students should maintain an ongoing record of contributions through project documentation, research logs, code repositories, drawings, photographs, test results, and other appropriate records.

At major milestones, students may be asked to identify:

- Work completed individually and collaboratively.
- Technical or research problems encountered.

- Experimental methods and tests conducted.
- Changes made in response to testing.
- Results, evidence, and conclusions.
- Unresolved issues and recommended next steps.

Continuing VIP Students

Students returning for subsequent semesters are expected to demonstrate increasing independence, technical depth, and research responsibility.

Spring 2027 will build upon the systems, research, and documentation established during Fall 2026. Returning students should take a more active role in integrating existing infrastructure, improving reliability, designing experiments, guiding new students, and identifying opportunities for meaningful technical advancement.

Expectations may include responsibility for system integration, experimental design, technical leadership, mentoring, documentation standards, and development of research demonstrations or publishable outcomes.

The objective is not simply to accumulate hours working with robotic systems, but to progressively move from learning and reproducing existing systems toward improving, integrating, and ultimately developing new robotic capabilities.

Grading Scale

Letter Grade	Percentage
A	90–100%
B	80–89%
C	70–79%
D	60–69%
F	0–59%

Course Materials

Materials and Resources

Students will have access to shared robotic hardware, fabrication equipment, sensors, and computational resources through the AI-rLAB and collaborating research facilities, subject to appropriate training and authorization.

Resources may include:

- Annin AR4 robotic arms, linear rails, pneumatic grippers, and associated control systems.
- Intel RealSense cameras and other sensing equipment.
- Rhino and Grasshopper for computational design and robotic workflow development.
- ROS2 and related robot communication and control tools.
- NVIDIA Isaac Sim and Isaac Lab for simulation and robot learning.
- Python, GitHub, and relevant machine-learning and computer-vision libraries.
- Shared CAD models, robot descriptions, datasets, and technical documentation.

Required software and hardware access will depend on the assigned research module. Students are not expected to personally purchase robotic equipment.

Individual teams may be assigned additional technical references, tutorials, or research papers as appropriate.

Course Website and Classroom Management Tools

The course uses:

- **Canvas:** Primary platform for course information, assignments, grading, and announcements.
- **Microsoft Teams:** Primary platform for communication, file sharing, coordination, and collaborative project management.
- **GitHub:** Primary repository for source code, technical documentation, software environments, and reproducible research materials.

Students are expected to maintain appropriate documentation and keep their assigned project resources organized and accessible to the research team.

Peer Evaluations

Peer evaluations are administered through the VIP Program. Students must complete both the midterm and final evaluation during the published evaluation windows.

- VIP Peer Evaluation — On Campus
- VIP Peer Evaluation — Off Campus / VPN

Students must be on campus or connected through the Georgia Tech VPN to access the evaluation system. Evaluations are only available during active evaluation periods.

Course Policies, Expectations, and Guidelines

Your Role in the Learning Process

VIP is a collaborative, multidisciplinary, project-based learning and research experience. Success depends not only on individual technical contributions but also on active engagement with the team and broader research process.

Students are expected to:

- Take initiative in exploring and applying knowledge relevant to their projects.
- Collaborate effectively across disciplines and experience levels.
- Document technical work thoroughly and reproducibly.
- Reflect critically on research progress, experiments, and results.
- Communicate difficulties, uncertainties, and technical problems as they arise.
- Contribute to the continuity and development of the broader research initiative.

This course operates as a real-world research environment in which learning is dynamic, self-directed, and collaborative.

Team Meetings and Participation

Attendance and active participation in scheduled team meetings and sub-team meetings are required.

These meetings are essential for coordinating research tasks, communicating results, reviewing experiments, learning from peers, and establishing project priorities.

Students are expected to arrive prepared to discuss progress, explain technical decisions, demonstrate work where appropriate, and identify next steps.

If a student anticipates missing a meeting, they should communicate with the team and instructor in advance.

Use of External Resources

Students are encouraged to consult external sources, software libraries, tutorials, open-source repositories, and technical publications to support their learning and research.

However:

- Do not present someone else's work as your own.
- Clearly distinguish original work from adapted or externally sourced content.
- Cite external sources, code, models, datasets, and other technical materials.
- Document substantial modifications made to existing code or hardware designs.
- Maintain appropriate attribution in notebooks, repositories, presentations, and deliverables.

Proper attribution is essential to transparent and reproducible research.

Academic Integrity

Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards.

Students should review:

- Georgia Tech Honor Code
- Student Code of Conduct

Students suspected of academic misconduct will be referred to the Office of Student Integrity for investigation and determination of appropriate consequences.

Accommodations for Students with Disabilities

Students requiring academic accommodations should contact the Office of Disability Services at 404-894-2563 to discuss their needs and obtain an accommodations letter.

Students should also contact the instructor as early as possible to coordinate appropriate accommodations within the course and laboratory environment.

Attendance and Participation

Attendance is expected at each scheduled class meeting. Additional individual or sub-team meetings may be arranged according to project needs and group availability.

Meetings outside scheduled class time are intended to support project development and are optional unless otherwise specified through an agreed project responsibility.

Advance notice is expected when a student anticipates missing a class meeting. Appropriate documentation may be requested.

Students are allowed three unexcused absences before a deduction of up to one-half letter grade for each additional unexcused absence.

Extensions, Late Assignments, and Missed Milestones

Long-term research projects may encounter unexpected technical problems, equipment limitations, or experimental failures.

With appropriate notice and planning, extensions or adjustments to intermediate milestones may be permitted. Students are expected to communicate delays promptly, identify alternative research tasks when necessary, and maintain progress toward major semester deliverables.

Major presentation, evaluation, and final documentation deadlines remain important to the overall research schedule.

Inclement Weather and Digital Learning Days

The course follows Georgia Tech policies regarding inclement weather and digital learning days.

When remote work is feasible, teams may transition to virtual meetings, simulation, programming, documentation, or other appropriate research activities.

Student–Faculty Expectations Agreement

Georgia Tech promotes an atmosphere of mutual respect, acknowledgment, and responsibility between faculty and students.

The Student–Faculty Expectations outline the basic responsibilities shared by students and instructors.

Professional communication, respect for others, intellectual curiosity, and a commitment to collaborative work are central expectations of this course.

Mobile Devices and Computing

Use of personal mobile devices for unrelated activities during class meetings is prohibited and may be treated as nonparticipation.

Laptops and other computing devices used to support research, programming, note-taking, simulation, and documentation are encouraged.

Laboratory and Robotic Equipment Safety

All students must follow laboratory safety procedures and obtain appropriate training before independently operating robotic systems or fabrication equipment.

Students must:

- Receive authorization before operating robotic hardware.
- Understand the relevant emergency-stop procedures and operating boundaries.
- Keep robot workspaces clear of unauthorized personnel and obstructions.
- Confirm equipment condition, software configuration, and intended motion before physical deployment.
- Use appropriate supervision and precautions when testing unfamiliar or experimental robotic behaviors.
- Report equipment damage, unsafe conditions, and unexpected system behavior.
- Never bypass safety procedures to accelerate experiments or demonstrations.

Simulation does not guarantee that a physical operation is safe. Robot trajectories, tooling, payloads, collisions, and environmental conditions must be evaluated before physical execution.

Additional Course Policies

VIP Room and Equipment Use Policy

VIP rooms and equipment are shared resources used by multiple teams. The following policies support a productive and respectful working environment.

1. Room Usage Priorities

Room usage is prioritized as follows:

1. Scheduled team meetings, lectures, and learning modules.
2. Weekly sub-team meetings.
3. Video conferences or special meetings with VIP stakeholders.
4. Other project-related work.

Room schedules are available through the VIP Program.

A good-neighbor policy applies: students may use shared rooms during other activities provided they do not cause disruption. Multiple groups may occupy shared spaces when appropriate.

2. Cleanliness and Conduct

- Everyone is responsible for keeping shared rooms clean.
- Food is allowed where permitted, but spills must be cleaned immediately.
- Dispose of gum and other waste properly.
- Respect equipment, furniture, and shared research materials.
- Rooms may be monitored by security cameras, and violations may be reviewed.

3. Equipment Use

Equipment may be designated for general use or assigned to specific teams.

- Equipment assignments and availability may change each semester.
- Use equipment only for its intended purpose.
- Do not remove equipment from VIP rooms without an approved loan agreement signed by a VIP Director.
- Students may be held financially responsible for equipment not returned in good condition.
- Authorization to access equipment does not substitute for the training required to operate it safely.

For questions concerning VIP equipment access, contact vip-request@ece.gatech.edu.

4. Computer Accounts

- Computer accounts are for individual use and must not be shared.
- All activity must comply with Georgia Tech, University System of Georgia, and State of Georgia policies.
- Respect privacy, intellectual property, and data integrity.
- Access to a file or system does not automatically grant permission to modify or distribute its contents.

5. BuzzCard Access

- Access to VIP and laboratory spaces is a privilege and may be logged.
- Do not admit unauthorized individuals into restricted spaces.
- Secure rooms and equipment when leaving.
- Report access or security concerns to the appropriate laboratory or VIP personnel.

Campus Resources for Students

Undergraduate Academic Success

Georgia Tech provides academic advising and student support resources through Success at Tech.

Students seeking additional academic support may access tutoring through Knack, which connects students with qualified peer tutors.

Graduate Academic and Professional Success

Graduate students can access resources through the Office of Graduate and Postdoctoral Education.

Available resources include:

- Academic Resources, including research support, communications resources, the Library, academic policies, and student advocacy.
- Student Resources, including campus services, child care and family programs, health and wellness, and the Student Resource Guide.
- Professional Development, including research development, career planning, and professional opportunities.

Student Well-Being

Georgia Tech supports students' physical, social, and mental well-being. A comprehensive collection of resources is available through the Student Resource Guide.

Spring 2027 Course Schedule

The following schedule outlines the anticipated progression of the semester. Technical topics, research milestones, and presentation dates may be adjusted in response to project development.

Week	Date	Activity / Event
1	Jan 11–15	Course introductions; review of Fall 2026 research; overview of existing robotic systems, infrastructure, and Spring 2027 research priorities.
2	Jan 18–22	Team onboarding; laboratory safety; identification of research workstreams; introduction to hardware, software, and documentation resources. MLK Day: Jan 18.
3	Jan 25–29	Finalize sub-team assignments, responsibilities, and meeting schedules. Establish individual research plans and documentation.
4	Feb 1–5	Research development: robotic calibration, simulation environments, system characterization, and baseline testing.
5	Feb 8–12	Research development: camera calibration, sensing, perception pipelines, and robot–environment coordination.
6	Feb 15–19	Research development: motion planning, manipulation, simulation-to-physical workflows, and experimental protocols.
7	Feb 22–26	Preliminary testing; integration of individual technical systems; preparation for midterm research presentations.
8	Mar 1–5	**Midterm presentations and demonstrations.** Submit individual documentation and research progress reports. Complete midterm peer evaluations during the VIP Program's designated window.
9	Mar 8–12	Review midterm feedback; refine research questions and project milestones; begin second-phase development.
10	Mar 15–19	Integrated system development; adaptive control, vision-guided manipulation, and physical testing.
11	Mar 22–26	**Spring Break — No Class** (provisional; confirm Registrar dates).

12	Mar 29–Apr 2	Resume research development; system integration and repeatability testing; evaluate experimental results.
13	Apr 5–9	Advanced experimentation; debugging, comparative testing, and refinement of integrated demonstrations.
14	Apr 12–16	Final demonstration development; complete technical evaluations, documentation, and research findings.
15	Apr 19–23	**Final research presentations and demonstrations.** Submit final individual documentation, code, datasets, and project handoff materials. Complete final peer evaluations during the designated window.
16	Apr 26–27	Final institutional instructional days; remaining handoff or course-closeout activities as needed. No regular Friday meeting.
Final Exam Period	Apr 29–May 6 (provisional)	No scheduled final exam or additional assignments.

Semester Milestones

Initial Research Plan — Week 3

Each student establishes an assigned research direction, identifies the relevant systems and previous work, and outlines objectives and expected contributions.

Midterm Research Review — Week 8

Each sub-team presents its progress, including research objectives, technical development, experiments, preliminary results, difficulties, and planned next steps. Individual documentation and required peer evaluations support midterm assessment.

Final Research Demonstrations — Week 15

Each sub-team presents the resulting work through physical demonstrations, simulations, experimental findings, or other appropriate research outputs.

Final documentation must clearly communicate:

- Research objectives and methods.
- Hardware and software configurations.

- Experimental procedures and results.
- Working code, CAD files, datasets, and technical resources.
- Known limitations and unresolved issues.
- Recommendations for subsequent research and future VIP cohorts.

Semester Handoff

Students are responsible for ensuring that work can be reproduced, maintained, and extended by subsequent participants.

Where applicable, project repositories and technical documentation should be updated to reflect the final state of the research.

Important Academic Dates

- **January 11, 2027:** Anticipated first day of spring classes.
- **January 18, 2027:** Martin Luther King Jr. Day.
- **March 22–26, 2027:** Provisional spring break.
- **April 26–27, 2027:** Anticipated final instructional class days.
- **Late April–Early May 2027:** Final examination period; no additional VIP final exam.
- **VIP peer evaluations, progress reports, and withdrawal deadline:** Refer to the VIP Program and Georgia Tech Registrar for confirmed dates.

Dates and assignments are subject to revision based on official Institute announcements and research progress. The most current course announcements and requirements will be communicated through Canvas.