Department of Aeronautics and Astronautics
School of Engineering
Massachusetts Institute of Technology

Graduate Program (S.M., Ph.D., Sc.D.)

Field: *Autonomy*
Date: *November 24, 2020*

Introduction and Purpose

The graduate program in the Department of Aeronautics and Astronautics at M.I.T. provides educational opportunities in a wide variety of aerospace-related topics through academic subjects and research. The purpose of this document is to provide incoming masters and doctoral level students guidance in planning the subjects they will take during their graduate program. The suggestions outlined here are to be understood as guidance and not as a mandatory, rigid framework. The final decision as to which subjects are taken and in what sequence is to be decided between each student and their academic advisor and/or doctoral committee. In addition to these recommendations, the official S.M. and doctoral degree completion requirements must be taken into account during the design of a graduate program[1].

What is Autonomy ?

The field of Autonomy focuses on developing embodied intelligent systems, ranging from autonomous drones to self-driving cars and robots, that can physically operate in complex environments with minimal human supervision. Therefore, it includes foundational disciplines including planning and decision-making, control and estimation, sensor fusion and perception, and human-robot interaction, among others. Ongoing research in autonomy aims at designing algorithms and systems that are able

- to perceive and build their own models of the world around them,
- use those models for making complex decisions over long time and length scales,
- to maintain those models as the systems move around and as the world changes,
- to act in ways that are trustworthy and reliable when deployed in safety-critical and high-integrity applications,
- enable more effective human-robot teaming.

The goal of this research is to build systems that can assist with dangerous or repetitive tasks, explore remote environments and benefit society.

Educational Goals of the Graduate Program in Autonomy

A student completing a degree in the area of autonomy will obtain solid knowledge of planning, decision making, estimation and inference. In addition, a student will obtain

knowledge in a number of closely related fields, such as control, perception or human-robot interaction. The specific educational plan would depend on the student's research interests. To achieve this goal each student should develop an educational plan in discussion with their academic advisor.

Educational Plan

Core Courses in Autonomy, Control and Estimation

16.413	Principles of Autonomy and Decision Making
16.412	Cognitive Robotics
16.31	Feedback Control Systems
16.32	Principles of Optimal Control and Estimation
16.485	Visual Navigation for Autonomous Vehicles
16.420	Planning under Uncertainty
6.231	Dynamic Programming and Reinforcement Learning

Autonomy Specializations

6.867	Machine Learning
6.824	Distributed Computer Systems Engineering
6.801 / 6.866	Machine Vision
16.453	Human Factors Engineering
16.422	Human Supervisory Control of Automated Systems
6.832	Underactuated Robotics
6.804 / 9.660J	Computational Cognitive Science
6.437	Inference and Information
6.438	Algorithms for Inference

Discrete Mathematics, Probability and Statistics:

6.431	Introduction to Probability
16.391/6.434	Statistics for Engineers & Scientists
18.404J / 6.840J	Theory of Computation
6.436/15.085	Fundamentals of Probability

Continuous Math, Algorithms and Optimization:

18.100B	Analysis
6.852J/18.437J	Distributed Algorithm
6.854J/18.415J	Advanced Algorithms
6.856J/18.416J	Randomized Algorithms
6.255/15.093/ IDS.200J	Optimization Methods
6.252/15.084	Nonlinear Optimization
6.256[J]	Algebraic Techniques and Semidefinite Optimization

A typical program of study for a student in Autonomy would be 6 courses taken as a Master's student and 6 courses taken as a doctoral student. The following sample schedules illustrate possible combinations of subjects, with focus for example on (1)

machine learning for autonomy or (2) cognitive robotics.

M.Sc.: 2 Autonomy courses, 16.413 and 16.412
2 Controls courses, 16.31 and 16. 32
1 Discrete Math and Probability course, 6.431
1 Continuous Math, Algorithms and Optimization course, 6.255

Ph. D.: 2 Autonomy courses in the specialization of machine learning, 6.867 and 6.231
1 Control course, e.g., 16.32
1 Estimation course, e.g., 6.438
1 Discrete Math and Probability course, e.g., 6.435
1 Continuous Math, Algorithms and Optimization course, e.g., 6.252

Faculty and Staff with Interest in Autonomy

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Research area: Navigation and control; design and implementation of distributed robust planning algorithms to coordinate multiple autonomous vehicles in dynamic uncertain environments; adaptive flight control to enable autonomous agile flight and aerobatics; experimental and theoretical robust control

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Research area: Robotics, embedded systems, autonomous vehicles, robotic networks, information theory, integrated circuits

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Research area: Model-based programming and cooperative robotics, cognitive robotics, artificial intelligence, operations research, robot coordination, energy management