Space Instrumentation for Life Detection

AE/EAS 4803/8803 SLD, 3 credit hours, letter or S/U grading

Spring 2024, Guggenheim 246, Mon/Wed 2:00 – 3:15 PM

Instructor Information

Instructor	Email	Drop-in Hours & Location
Grace Ni	zni47@gatech.edu	[TBD]
Teaching Assistant(s)	**Email**	**Drop-in Hours & Location**
[TBD]	[TBD]	[TBD]

General Information

Description

This course will cover the interdisciplinary foundations of space instrument development focusing on the search for life beyond Earth. This course will introduce various non-contact and destructive methods of handling and analyzing gas, fluid, solid samples for detecting life as we know it and don't know it beyond Earth.

This course is composed of three modules; each of the modules contain lectures, in-class activities, and individual assignments to discuss the WHY, HOW, and WHAT'S NEEDED to propose, design, or build life detection instrument(s) to targeted planetary environment(s). Synopsis about planetary habitability, chemical evolution of organics, and biosignature measurements will be covered to propose instrumentation(s) and define objectives. Various sample acquisition and sample handling techniques will be introduced. Environmental and engineering challenges for spaceflight instrumentation will be discussed to define thermal, mechanical, and electrical designs and radiation controls within the constraint of mass, power, and volume of instruments outlined by the solicitation.

This course has a strong focus on group projects. At the beginning of the class, students will form groups of five to propose instrumentation(s) for life detection missions on Mars, Enceladus, and Titan. Each planetary target will be investigated by three separate student groups, which form a cohort to provide collaborative feedback during the peer review processes. Project progress reports and peer review processes will occur at the end of each course modules during class sessions. These assignments ultimately contribute to the final presentation projects.

Enrollment is restricted via permits. Please contact the course instructor for more information.

Course Topics

- Planetary habitability, & coevolution of planet and life
- The origin, distribution, and evolution of organics in Space
- Signs of life and how to search for them
- Destructive and non-destructive analytical methods for life detection science
- The requirements for life detection measurements via space instrumentation
- Mechanical and electrical requirements
- Space instrument development process: mission science to flight hardware
- Planetary Protection and contamination control
- Thermal control and regulation
- Radiation resistance: hardware, software, reagents
- Prototyping for space instrumentations
- Other interesting topics upon requested.

Course Pre-requisites

This course is intended for experienced undergraduates or graduate students. Specialized engineering knowledge and/or a wide range of planetary science, astrobiology, and astronautics, or other background knowledge is helpful.

Course Text

There is no textbook for this course. All materials will be provided via Canvas. Students are responsible for checking Canvas regularly.

Course Goals and Learning Outcomes

- By the end of this course, you will
    - Propose and/or design a virtual or physical life detection instrument(s) to a targeted planet/moon as a part of your team.
    - Identify driving questions of your investigation and build Science Traceability Matrices (STM) to outline your measurements to the science objectives.
    - Define mechanical, thermal, electrical designs within the constraint of mass, power, and volume outlined by the solicitation.
    - Argue optimal CONOPS to run your instrument(s) and data handling scheme for science returns.
    - Outline feasible timeline and resources needed to test and integrate your instrument(s).
- Learn how to communicate questions, concerns, and requests between scientists and engineers to work on a highly interdisciplinary project.
- Learn how to provide constructive feedback between groups.
- Demonstrate critical thinking, and capability to learn new fields of knowledge.
- Experience the role of an investigator of a scientific instrument, a reviewer of other groups' instruments, and a decision maker of the proposal.

Course Requirements & Grading

Course assignments (last updated: Oct.17th, subject to change)

- Class Participation (15%)
    - Attendance, participation in discussions, and the completion of in-class exercise
- Individual Assignment (20%)
    - Four individual assignments (4*5%) will be created to constitute a total 20% towards the final grades.
- Final group projects (65%)
    - Project progress assignments: (3*5% = 15%)
        - Three group assignments will be created after each module of the class. Each team will be asked to plan and propose different aspects of instrumentation early on during the semester.
        - Each assignment will include (1) complete PPT slides and (2) answer questions in word document.
        - The assignment will be graded based on completion. Feedback will be provided.
    - External peer reviews (3*5% = 15%)
        - Teams of the same planetary targets will meet at the end of each module and provide critical review of other group's work during class time.
    - Final group presentation (35%)
        - Final project presentation (15%)
        - Final project report (15%)
        - Team member contribution report (5%)

Grading Scale

Your final grade will be assigned as a letter grade according to the following scale:

A	90-100%
B	80-89%
C	70-79%
D	60-69%
F	0-59%

Course Website and Other Classroom Management Tools

- Assignments and course announcement will be posted on and submitted through Canvas.
- Assignment must be posed by the due date and time to be eligible for full credit. A late period for late assignments will last until 6pm the day after the due date, with a 10% deduction applied to any assignment turned in during this late period. Any assignments turned in after the late period will receive a 0.

Course Expectations & Guidelines

Academic Integrity

Academic dishonesty is not tolerated in any form. Students are expected to uphold high ethical standards including adherence to the Georgia Institute of Technology Honor Code (https://osi.gatech.edu/content/honor-code), Academic Regulations and Student Regulations.

Below are some guidelines to help you understand what constitutes appropriate academic behavior:

- Students are not permitted to review or use materials from previous semesters. This includes the use of old assignments.
- Students are permitted and encouraged to work collaboratively on assignments and seek help from one another, but the work that is turned in as an individual assignment must be the student's own work. Copying another student's work is not permitted.
- On group assignments, students are expected to do their fair share of the work. If there is an instance where a student is not contributing to a group project, the team members should notify the instructor as soon as possible.
- Plagiarism of any kind is not permitted. Plagiarism includes reproducing the words or visual/graphical expressions of others without clear attribution and citation.

Accommodations for Students with Disabilities

Your experience in this class is important to me. If you have already established accommodations with the Office of Disability Services, please communicate your approved accommodations to me at your earliest convenience so we can discuss your needs in this course.

If you have not yet established services through Disability Services, but have a temporary health condition or permanent disability that requires accommodations (conditions include but not limited to; mental health, attention-related, learning, vision, hearing, physical or health impacts), please contact the Office of Disability Services at (404)894-2563 or http://disabilityservices.gatech.edu/, as soon as possible, to make an appointment to discuss your special needs and to obtain an accommodations letter.

Extensions, Late Assignments, & Re-Scheduled/Missed Exams

Extensions may be granted in cases where extenuating circumstances prevented the student from reasonably completing an assignment on time. Examples include illness, emergencies, family situations, and institute excused absences. The Office of the Vice President and Dean of Students can assist students with documented emergencies by contacting professors on behalf of the students. You can get more information on this process here: https://studentlife.gatech.edu/content/class-attendance.

If you have internet or technical difficulties that prevent you from uploading to Canvas on time, please send a text message or email to the TA and instructor immediately to document this, and then upload as soon as you are able.

Group projects (report and presentation) due dates may include the final two instructional days of the Semester.

Student-Faculty Expectations Agreement

At Georgia Tech we believe that it is important to strive for an atmosphere of mutual respect, acknowledgement, and responsibility between faculty members and the student body. See http://www.catalog.gatech.edu/rules/22/ for an articulation of some basic expectation that you can have of me and that I have of you. In the end, simple respect for knowledge, hard work, and cordial interactions will help build the environment we seek. Therefore, I encourage you to remain committed to the ideals of Georgia Tech while in this class.

Tips for Success

I will do my part to make this course a success. However, being successful will require you to do your part as well. Here are a few tips to help you be successful in this course.

- Participate fully in all activities!
- Use the office hours. If you are not available at one of these times, contact us and we will find an alternate time. Office hours are a great time to get help with homework, ask questions about the material covered in class, discuss your own performance in the course, or just to come and chat. These are a resource for you, and I encourage you to use it!
- Your peers are a resource – talking out an assignment with a classmate can be a fantastic tool to enhance learning for all parties. Explaining your thought process to someone else is often helps your brain organize and synthesize information.
- Make sure you contribute to your group projects. These are designed to help you learn the material. Plus, your peers are the first of your future professional network. Don't start off with a bad impression!

Preliminary Course Schedule
(last update: Oct.17th 2023, subject to change)

#	Topic
	Course Entrance
1	Introduction to Astrobiology and Life detection
2	Life detection techniques, instrumentation, and measurements
HW	Individual assignment 01: Your favorite spaceflight instrumentation
	Module 1: WHY choose these instrument(s)?
3	Birth of the Universe and evolution of planets *"The emergence of life requires a right amount of ingredients react in a right way in the right planetary environment that located in the right astronomical setting over a right period of time."*
HW	Individual assignment 02: Your favorite planetary target

#	Topic
4	The origin, evolution, and distribution of organics in Space *"Organics is not unique to living systems."*
5	Life on Earth: the diversity and the extremes *"Our understanding of life is biased by what we see, what we can reach, and our short longevity."*
6	Analytical measurements, error analysis, and instrument calibration *"Life detection measurements need to be robust, reproducible, and reliable."*
7	Group work time (in person) for project progress report 01
8	External peer review (online) of project progress report 01
9	Guest lecture: solid state single molecule detection
HW	Project progress report 01: Draft science traceability matrices of your winning instrument(s) to targeted planetary environments
	Module 2: HOW to build and operate these instrument(s)?
10	Sample acquisition mechanisms, sample handling, storage, and delivery to payloads
HW	Individual assignment 03: Your favorite sample acquisition mechanisms
11	Instrument miniaturization and ruggedization
12	Bits and bytes: command, control, and data handling
13	In-class activities: build a simple microcontroller system
14	Group work time (in person) for project progress report 02
15	External peer review (online) of project progress report 02
16	Towards autonomy: AI and ML algorithms
HW	Project progress report 02: Define mechanical and electrical requirements of the instrument(s) to operate in planetary environments
	Module 3: WHAT is needed to build these instrument(s)?
17	Space instrument development: concept to mission
HW	Individual assignment 04: the future of life detection
19	Planetary protection and space policy
20	Rapid prototyping processes, benefits, and future perspectives
21	Group work time (in person) for project progress report 03

#	Topic
22	External peer review (online) of project progress report 03
23	Space entrepreneurship using life detection instruments
HW	Project progress report 03: Work plan and timeline to mature, integrate, test your instruments
	Course Exit
23	The future of space instruments for life detection missions
24	Group work time for final project
25	Final group project presentation
26	Final group project presentation
HW	Final group project report, team member contribution report