MAE 3145: Orbital Mechanics & Space Dynamics

Fall 2016, MW 12:45-2:00pm, SEH 3040

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Office Hour: TBD or by appointments at SEH 2200

Prerequisites APSC 2058 Analytical Mechanics II

Course Description This course covers the motion of spacecraft under gravity. Included are the derivation and the analyses of the two-body problem and their applications for real world missions. Extensive use of scientific programming languages is required to simulate orbital dynamics and solve real-world astrodynamics problems.

Textbook

- H. Curtis, *Orbital Mechanics: for Engineering Students*, 2nd Edition, Elsevier 2010
  (Ebook is available through the Gelman Library.)
- R. Bate, *Fundamentals of Astrodynamics*, Dover Publication, 1971

Contents

- Astrodynamic Fundamentals
  - Time
  - Coordinate Systems
  - Coordinate Transformations
  - COMFIX
- Orbital Mechanics
  - Dynamics of Point Masses [Chap. 1]
  - Two-Body Problem [Chap. 2,3]
  - Orbital Elements [Chap. 4]
  - Groundtracks
  - RV2COE
  - PROPOGATE
- Orbital Maneuvers
  - Hohmann Transfers
  - Plane Changes
  - Orbital Rendezvous and Phasing
- Perturbations
  - Geopotential
  - Drag
  - PREDICT

Software Projects A major focus of this course will be the application of sound scientific programming skills. You will apply the theoretical tools of astrodynamics to solve realistic problems by implementing your own library of tools.

- COMFIX - determine the orbital elements of a satellite given ground based radar observations
- RV2COE - convert position and velocity vectors of a spacecraft to classical orbital elements
- PREDICT - predict satellite passes for any location on the Earth
- PROPOGATE - determine the position of a satellite as a function of time

Additional Readings

- David A Vallado. *Fundamentals of Astrodynamics and Applications*. 3rd ed. Microcosm Press, 2007
- Richard H Battin. *An Introduction to the Mathematics and Methods of Astrodynamics*. AIAA, 1999
- J. Danby, *Fundamentals of Celestial Mechanics*, Willmann-Bell, 1988
- J. Prussing, *Orbital Mechanics*, Oxford University Press, 1993
- V. Chobotov, *Orbital Mechanics*, AIAA, 2002
- T. Logsdon, *Orbital Mechanics: Theory and Applications*, Wiley, 1997
- MATLAB Tutorial by Mathworks: `http://www.mathworks.com/academia/student_center/tutorials/`
- Scipy Tutorial: http://www.scipy-lectures.org/

Grading Homework 35%, Attendance 5%, Midterm Exam 20% (TBD), Final Exam 20%, Projects 20%

Course Learning Objectives At the end of this course, students will be able to:

1: Explain the Newtonian gravitational force and gravitational potential between particles
2: Analyze the characteristics of circular, elliptic, parabolic and hyperbolic orbits in a two-dimensional plane
3: Describe the geometry of an orbit in a three-dimensional space from orbital elements
4: Apply numerical/analytical techniques to propogate orbits.
5: Choose and apply the approprite orbital maneuvering method to move spacecraft between orbits.
6: Develop personal software tools to solve practical astrodynamic problems:

   - Determine orbital parameters from ground based observations.
   - Predict satellite passes and determine observation angles to view satellites overhead.

Course Calendar[1]

Month	Week	**M**	Tu	**W**	Th	F
August	1	28 §1.3-1.4	29	30 §1.5	31	1
Sept	2	4 Labor day	5	6 Matlab	7	8
	3	11 Matlab	12	13 §2.3	14	15
	4	18 §2.4	19	20 §2.6	21	22
	5	25 §2.7-2.9	26	27 §2.9-3.2	28	29
Oct	6	2 §3.3-3.6	3	4 §4.2-4.3	5	6
	7	9 Fall Break §4.4	10 Fall Break	11 §4.7	12	13
	8	16 §6.2-6.3	17	18 **Midterm**	19	20
	9	23	24	25 §6.4	26	27
Nov	10	30 §6.5-6.6	31	1 §6.7	2	3
	11	6 §6.8	7	8 §6.10	9	10
	12	13 §8.2	14	15 §8.3	16	17
	13	20 §8.4-8.5	21	22 Thanksgiving	23 Thanksgiving	24 Thanksgiving
Dec	14	27 §8.6-8.8	28	29 §2.12	30	1
	15	4 §2.12	5	6 §2.12	7	8
	16	11 Something is due	12 Reading Day	13 Finals begin	14	15

[1]This calendar is subject to revision. In particular, the section references are only a guide, and your instructor may deviate from it.

General Policy

1: **Check your GW email account daily**. All of the important announcements of this class will be made through your email.
2: All examinations, papers, and other graded work products and assignments are to be completed in conformance with The George Washington University Code of Academic Integrity (available at `http://www.gwu.edu/~ntegrity/code.html`).
3: If you do not have a computer account for accessing MATLAB, you should contact SEAS Computing Facility
4: You may need to take notes during class apart from the viewgraphs handed out. Make sure to carry a notebook or a laptop for this purpose.
5: Class attendance is required. Be punctual and follow the class rules. Students are encouraged to ask questions but talking while the lecture is being delivered is prohibited.
6: Homework assignments should be prepared in a neat and professional manner. Discussion of assignments and collaboration among students is encouraged; however, each student is expected to prepare each assignment problem solution by himself/herself. Do not copy. Use of solutions manuals is prohibited.
7: Late homework assignment will not be accepted. Your lowest homework grade will be dropped and not count towards the final grade.
8: No excuse on missing exams will be accepted. Make-up exams will not be given, except under extraordinary circumstances such as documented illness. If an exam is simply missed, then a grade of zero will be recorded. If you shall have a conflict of schedule, you must inform Dr. Lee in writing with supporting documents at least a week ahead of time.
9: If you shall have any questions regarding grading, you must attach to your paper a written explanation and give them to Dr. Lee within one week after the paper is returned.
10: If you shall have any questions regarding the course, you should see Dr. Nigam during his office hours or contact him via email.
11: Set cell phone to silent mode in the classroom and refrain from texting.
12: Class/Lab cancellation due to weather or special event: Call 202-994-5050 or visit the Campus Advisories Website (`campusadvisories.gwu.edu`) or `www.gwu.edu/~bygeorge/100703/closingpolicy.html` for GW operating status.
13: Disability Support Services (DSS): If a student is to use DSS for testing, he/she should submit the letter from DSS during the first week. Any student who may need an accommodation based on the potential impact of a disability should contact the Disability Support Services office (`http://gwired.gwu.edu/dss/`) during the first week.
14: Students requiring special accommodations for testing through DSS must provide Dr. Lee with the appropriate forms or documents and confirm the approval at least two weeks before the test or exam.

To Report an Emergency or Suspicious Activity Call the GW Police Department at 202-994-6111 (Foggy Bottom). If the line is unavailable or you are calling from another University location or off campus, dial 911.

Shelter in Place - General Guidance Your first reaction in an emergency should be to stay where you are. Evacuate only if you hear the fire alarm or someone instructs you to evacuate. If you are outdoors during an incident, proceed into the closest GW building unless you are told to do otherwise. No matter where you are on campus, the basic steps of ?sheltering in place? are:

1: Shelter-in-place in an interior room, above ground level, and with the fewest windows. If there is a large group of people inside a particular building, several rooms may be necessary.
2: Shut and lock all windows (locking will form a tighter seal), close exterior doors, and stay away from glass doors and windows.
3: Turn off air conditioners, heaters, and fans. Close vents to ventilation systems as you are able (Facilities staff will turn off ventilation systems as quickly as possible).
4: Make a list of the people with you and call the list in to GWPD (see numbers above) so they know where you are.
5: Visit GW Campus Advisories `http://CampusAdvisories.gwu.edu` or call the GW Information Line at 202-994-5050 for incident updates. If possible, turn on a radio or television and listen for further instructions. If your e?mail address or mobile device is registered with Alert DC, check for alert notifications.
6: Make yourself comfortable and look after one other. You will get word as soon as it is safe to come out.

Evacuation We will always evacuate if the fire alarm sounds or if the building we are in becomes unsafe. In the event of an evacuation, please quickly gather your personal belongings (purse, keys, cell phone, GWorld card, etc.) and proceed to the nearest exit. Do not use the elevator.

Once we have evacuated the building, proceed to the east entrance of SEH. If the first location is not available, we will meet at Marvin Center (800 21st Street, in the lobby)

Alert DC & GW Alert Alert DC provides free notification by e-mail or text message during an emergency. Visit GW Campus Advisories for a link and instructions on how to sign up for alerts pertaining to GW. If you receive an Alert DC notification during class, please share the information immediately.

GW Alert provides popup notification to desktop and laptop computers during an emergency. In the event that we receive an alert to the computer in our classroom, we will follow the instructions given. You are also encouraged to download this application to your personal computer. Visit GW Campus Advisories to learn how. Additional information about emergency preparedness at GW can be found on GW Campus Advisories `http://CampusAdvisories.gwu.edu`.

University Policy on Religious Holidays

1: Students should notify faculty during the first week of the semester of their intention to be absent from class on their day(s) of religious observance.
2: Faculty should extend to these students the courtesy of absence without penalty on such occasions, including permission to make up examinations.
3: Faculty who intend to observe a religious holiday should arrange at the beginning of the semester to reschedule missed classes or to make other provisions for their course-related activities

Support for Students Outside the Classroom

- Disability Support Services (DSS)

  Any student who may need an accommodation based on the potential impact of a disability should contact the Disability Support Services office at 202-994-8250 in the Rome Hall, Suite 102, to establish eligibility and to coordinate reasonable accommodations. For additional information please refer to: `http://disabilitysupport.gwu.edu`

- Mental Health Services 202-994-5300

  The University's Mental Health Services offers 24/7 assistance and referral to address students' personal, social, career, and study skills problems. Services for students include: crisis and emergency mental health consultations confidential assessment, counseling services (individual and small group), and referrals. `http://counselingcenter.gwu.edu`

Academic Expectations for University Courses[2]

- You are no longer in high school. The great majority of you, not having done so already, will have to discard high school notions of teaching and learning and replace them by university-level notions. Our goal is more than just getting you to reproduce what was told to you in the classroom.
- Expect to have material covered at two to three times the pace of high school. Above that, we aim for greater command of the material, especially the ability to apply what you have learned to new situations (when relevant).
- Lecture time is at a premium, so it must be used efficiently. You cannot be *taught* everything in the classroom. It is your responsibility to learn the material. Most of this learning must take place outside the classroom. You should be willing to put in two hours outside the classroom for each hour of class.
- The instructor's job is primarily to provide a framework, with some of the particulars, to guide you in doing your learning of the concepts and methods that comprise the material of the course. It is not to *program* you with isolated facts and problem types nor to monitor your progress.
- You are expected to read the textbook for comprehension. It gives the detailed account of the material of the course. It also contains many examples of problems worked out, and these should be used to supplement those you see in the lecture.
- Exams will consist largely of *fresh* problems that fall within the material that is being tested.

[2]Zucker, Steven, *Teaching at the University Level*, AMS Notices (43), 1996, pp 863-865. Available at `http://www.ams.org/notices/199608/comm-zucker.pdf`

EMERGENCY PREPAREDNESS INFORMATION – SYLLABUS INSERT

Instructor: Taeyoung Lee
Course: MAE3145
Building/Room#: SEH3040

READY GW
MAKE A PLAN. BUILD A KIT. STAY INFORMED.
CampusAdvisories.gwu.edu

EMERGENCY NUMBERS	
Foggy Bottom (GWPD)	202-994-6111
Mount Vernon (GWPD)	202-242-6111
VSTC (Loudoun County)	911
Other Locations	911

NON-EMERGENCY NUMBERS	
Foggy Bottom (GWPD)	202-994-6110
Mount Vernon (GWPD)	202-242-6110
GW Information Line	202-994-5050
VSTC Information Line	571-553-8333

Fire

□ Pull the fire alarm
□ Leave the building immediately using the closest emergency exit, closing doors behind you
□ Call GWPD (202-994-6111) or 911 when safe to do so
□ Assemble in a designated area
□ Re-enter the building only when instructed by emergency officials

- Do not assume an alarm is false
- USE STAIRS, do not use elevators
- If unable to exit the building, go to the nearest exit stairwell or safe area of refuge and call GWPD (202-994-6111) or 911 to report your location
- If trained, use a fire extinguisher if the fire is small and contained and the room is not fill with smoke

Two emergency exits are located: Behind classroom Southwest corner of the floor

Primary meeting area (near): East entrance of SEH

Secondary meeting area (far): Wests entrance of Academic Center

Severe Weather

Thunderstorms are the most common type of severe weather in the Washington, DC metropolitan area. However, winter storms, extreme hot/cold temperatures, flooding, tornadoes and hurricanes can occur. Check **CampusAdvisories.gwu.edu** for up-to-date weather advisories and information.

Shelter-in-place for severe weather events:

□ Seek shelter indoors in a low part of the building
□ Move to a windowless interior room away from hazardous materials
□ Take cover under a sturdy object or against an interior wall
□ Monitor **Campus Advisories** and local media
□ Wait for the *all clear* before leaving your safe space

Violence/Active Shooter

If an active shooter is in your vicinity, call GWPD (202-994-6111) or 911 when it is safe to do so and provide information, including the location and number of shooter(s), description of shooter(s), weapons used and number of potential victims.

Evacuate: If there is an accessible escape path, attempt to evacuate the premises

- Have an escape route and plan in mind; leave your belongings behind; follow instructions of police officers

Hide Out: If evacuation is not possible, find a place to hide where the active shooter is less likely to find you

- Hide in an area out of the shooter's view; provide protection; lock the doors; block entry to your hiding place; silence your phone; wait for law enforcement

Take Action: As a last resort and only when your life is in imminent danger, attempt to disrupt and/or incapacitate the shooter by:

- Acting as aggressively as possible against him/her; yelling; throwing items and improvising weapons; and commit to your actions

Emergency Communications

CampusAdvisories.gwu.edu is the university's primary website used for communicating emergency preparedness and incident-related information (including class cancellations) to the GW community.
GW Alert is a notification system that sends emergency alerts to email addresses and mobile devices. Students, faculty and staff are requested to maintain current contact information and campus location information by logging into the GWeb Information System (banweb.gwu.edu). In emergency situations, alerts may also appear at the top of university webpages.
Media Outlets, such as 103.5FM or WTOP, may be contact with emergency information, such as weather-related delays and closing.