Spacecraft Dynamics and Control

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Lecture 0: Introduction

Understanding and Controlling Motion in Space

Aspects of Orbital Motion:

- Universal Gravitation
- Geometry of Orbits
- Motion in Space
- Navigation
  - Delta-V manuevers
- Orbit Maintenance
- Interplanetary travel
- Attitude Control

Trends in Space: Navigation and GPS

Currently, almost all navigation on Earth is based on satellites,

Figure: The GPS Constellation

CAPSTONE provides GPS on the moon.

Trends in Space: Communications

Increasingly, communications are routed through space

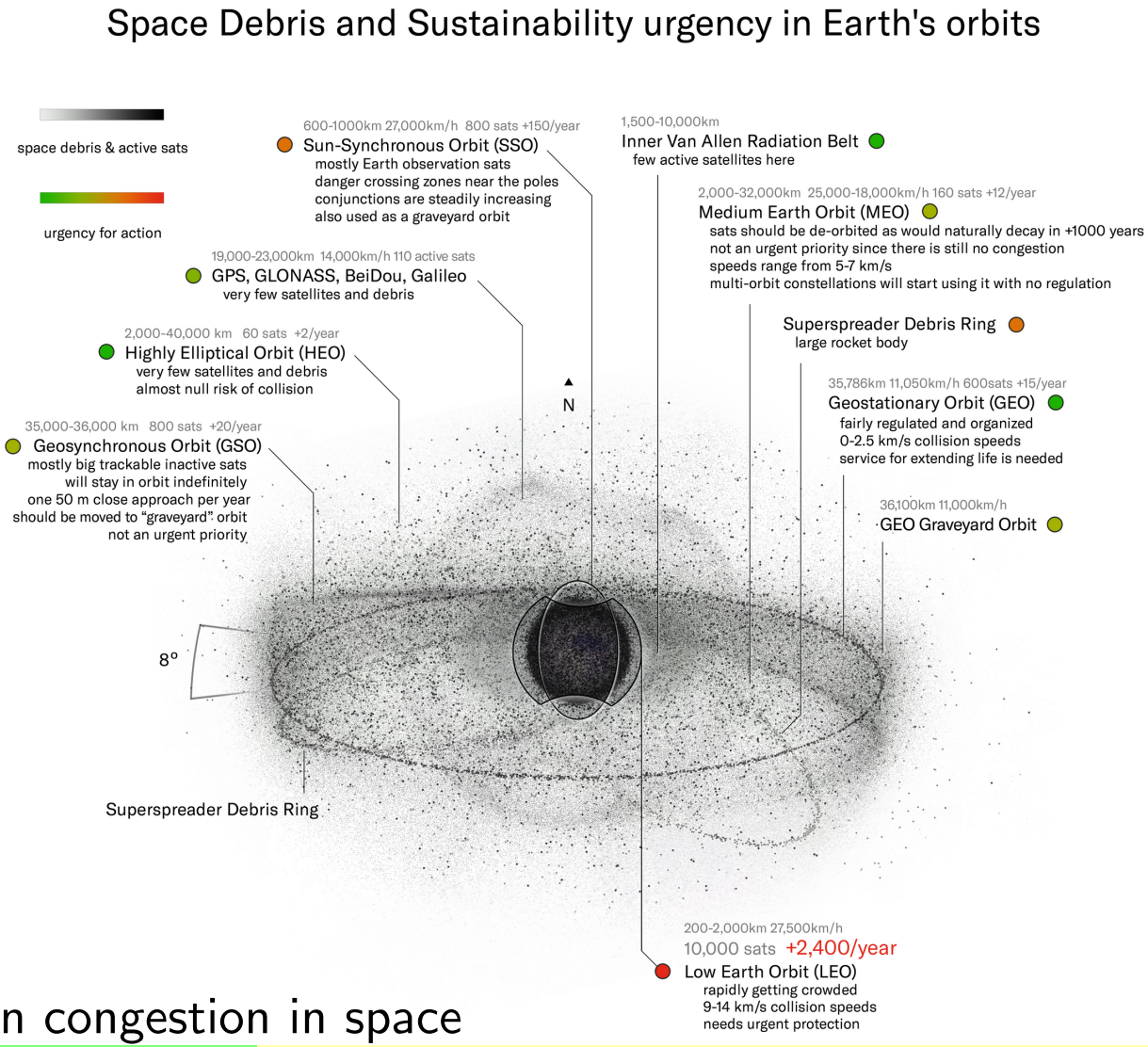
- Phone lines
- Cell towers already use satellites
- Globalstar/Viasat/Starlink/Oneweb
- NASA Deep Space Network

Figure: ECHO I (1960)

Figure: The Starlink Constellation (2024)

Trends in Space: Congestion and Debris

- Currently around 11,000 satellites
- 71,000 launch requests waiting approval



NYT article on congestion in space

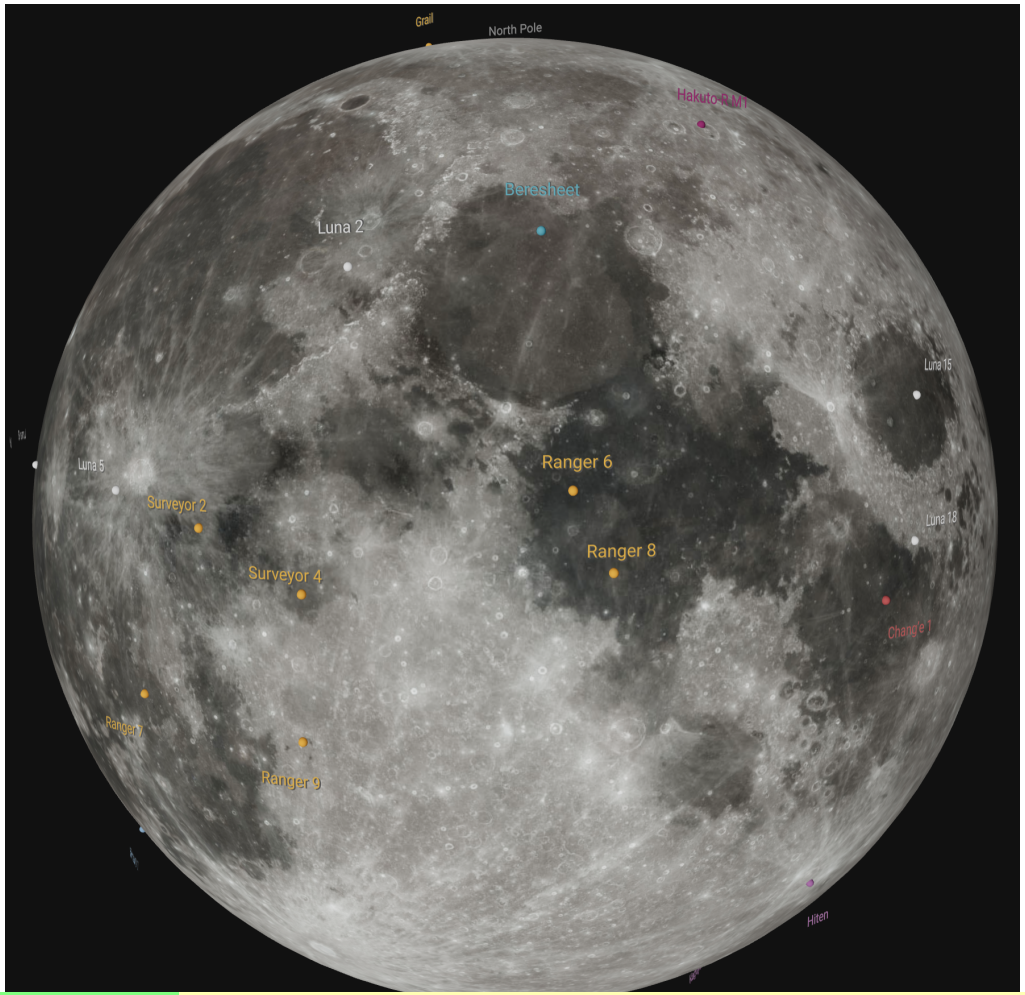
Trends in Space: A 21st Century Race to the Moon

USA: 0(1); Russia: 0(1); China: 3(0); India: 1(1); Japan: 0(0); Israel 0(1)

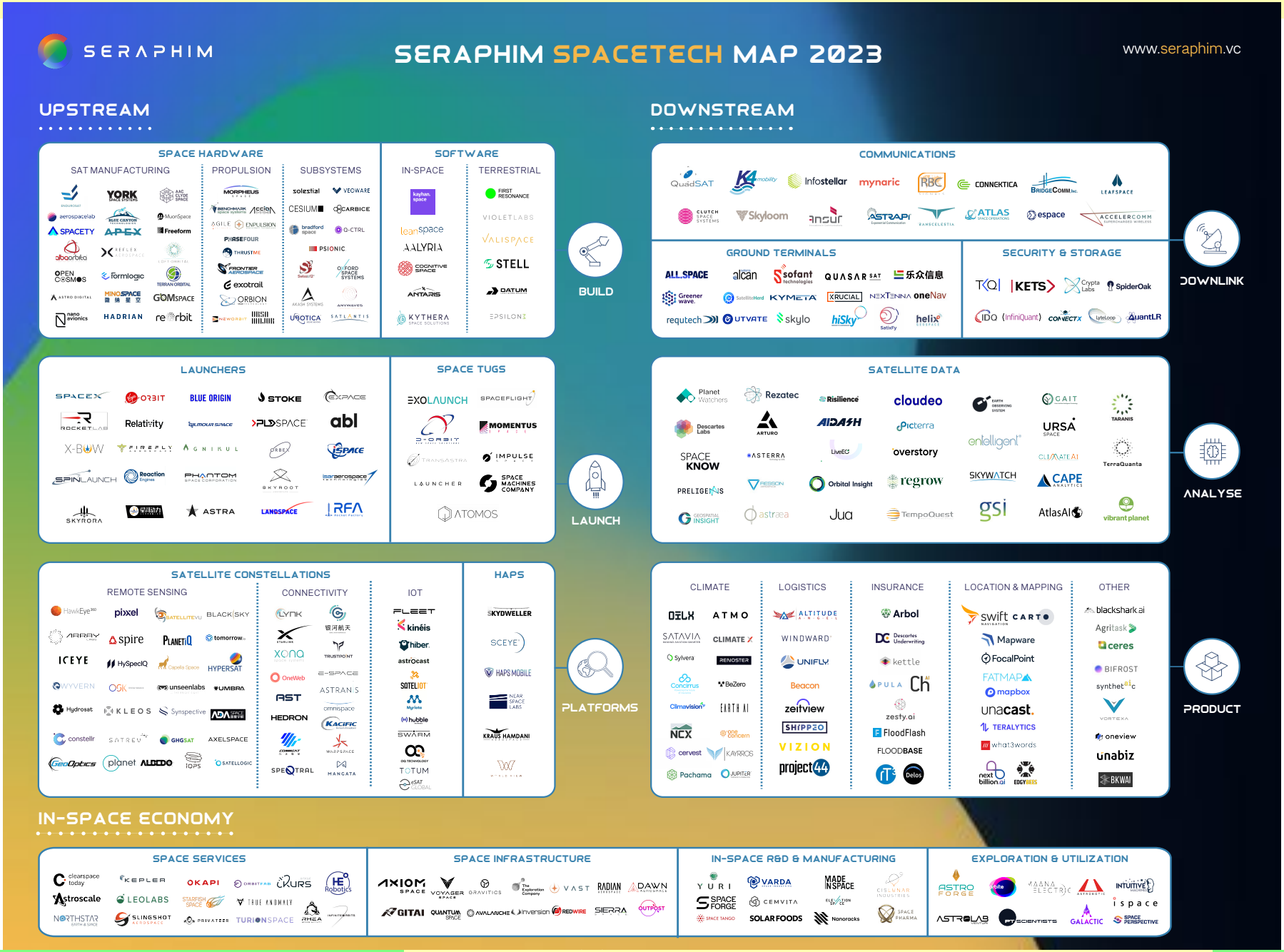
Anticipated Permanent Lunar Presences:

Artemis (USA, ESA, JPN, ISR, CAN): 28 missions; Lunar Gateway/Base Station

International Lunar Research Station (China, Russia, Venezuela, Pakistan, UAE)



Trends in Space: Commercialization of space



Who Am I?

Website: http://control.asu.edu

Research Faculty: Computation, Optimization and Control

Applications:

- Nuclear Fusion Energy
- Spacecraft Navigation
- Communication Networks

Theory:

- Control of Delayed Systems
- Control of PDE Systems
- Control of Nonlinear Systems
- Optimization/AI/Machine Learning

My Background:

- B.Sc. Aerospace Engineering and B.Sc. Physics, University of Texas at Austin
- Ph.D. Aeronautics and Astronautics, Stanford University
- Worked at ARL(GPS), NASA Johnston, Gravity Probe B, and SNAP

Office: ERC 253; Lab: GWC 531

Introduction to Spacecraft Dynamics

Overview of Course Objectives

- Determining Orbital Elements
  - Know Kepler's Laws of motion, Frames of Reference (ECI, ECEF, etc.)
  - Given position and velocity, determine orbital elements.
  - Given orbital elements and time, determine position + velocity.
- Satellite Orbital Maneuvers
  - Identify Required Orbit.
  - Find Optimal Transfer.
  - Determine Thrust and Timing.
- Interplanetary Mission Planning
  - Design Gravity-Assist Maneuvers.
  - Use Patched-Conics.
- Linear Orbit Theory (Perturbations)
  - Earth-Oblateness
  - Drag
  - Solar Wind
- Orbit Estimation

More things we will cover.

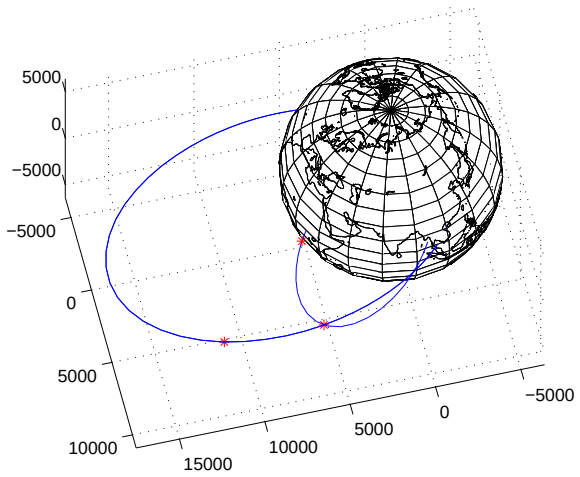


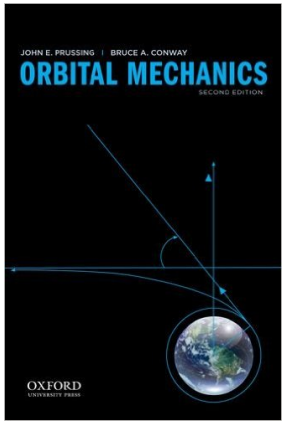
Figure: Intercept Trajectory

- Attitude Dynamics
  - Pointing, Tracking Problems
  - Vibration Damping
  - 6 DOF motion

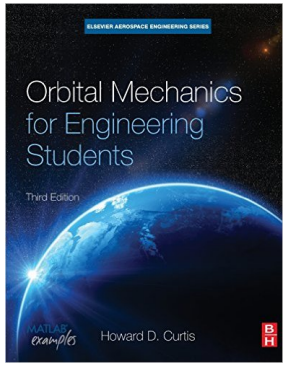
- Propulsion
  - Staging
  - Chemical Rockets
  - Nuclear Rockets
  - Solar Sails
  - Ion engines
  - Gravity Assist
- Attitude Controllers
  - Control Moment Gyros
  - Spin Stabilization
  - Gravity-Gradient Stabilization
  - Attitude Thrusters

Class Resources

Required:
Orbital Mechanics, 2nd edition
by Prussing and Conway



Optional:
Orbital Mechanics for Engineering Students, 4th edition
by Curtis



Non-Traditional Resources:
Kerbel Space Program
Universe Sandbox
Sky Safari Mobile App

Matlab code will be posted on Canvas at the appropriate time.

Expectations

Space is HARD. So is this class.

1. Pay attention to Lectures.
   - This is not TikTok
   - If you need to miss a lecture, watch it online.
2. Participate
   - Ask questions, contribute to group projects, complete polls/quizzes.
3. Do the homework (yourself)
4. Complete the practice final and midterm (yourself)
   - You can use an equation sheet on exams (make it yourself)
5. No grade inflation here
   - If you get an A, you will have earned it.
   - If you pass, you can calculate basic orbital maneuvers correctly.