

Spaceflight since Apollo

Astronomy 101
Syracuse University, Fall 2022
Walter Freeman

December 6, 2022

Announcements: makeups/retakes

See email/Blackboard for announcements about lab makeups and quiz retakes.

Turn your homework (due today) in when you leave class today.

Please write your name and your TA's name at the top.

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Remember that creative projects should include a brief artist’s statement linking your creative work to the stuff of astronomy or science.

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Selfie by the Curiosity rover, on the Martian surface

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- I've heard a lot of fantastic ideas for final projects already (and seen a few completed ones)
- Remember, your projects are due on the day of the final
 - We'll have a box there for you to submit things
 - If your project is something best submitted electronically, email it to suast101projects@gmail.com
 - If your project is something complicated (artwork, etc.), come talk to me; we'll make arrangements
 - If you take your exams at CDR, get your project to me before/after (I'll be around, and will be in the Physics Clinic after the exam)

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- To a box in front of my office, Physics Building 215, on December 10
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Doing something creative and awesome and running out of time? Contact me for an extension; we will grant these for ambitious and creative projects depending on what you're doing and what you need.

Announcements: take-home lab

The take-home lab is due this Friday, 9 December.

I accidentally wrote “10 December” in one place, which is of course a Saturday. So, if you turn it in Monday morning, that’s okay too. Put it in your TA’s mailbox in the Physics Building.

If you didn’t do it, it is far too late to do it now. It requires actual measurements of the real Sun or Moon; you cannot do it with simulated or borrowed data.

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If you didn’t do it, we will make a correction so that missing it doesn’t affect your grade too badly.

Preparing for the final exam

- The final exam is next Tuesday, 3PM - 5PM, 13 December
- Section 1 (12:30): Stolkin Auditorium (here)
- Section 2 (2:00): (not here)
- Bring your final projects to the final to submit them

Preparing for the final exam: review sessions

- I'll be holding usual office hours tomorrow and extra help Friday in Holden or the Physics Clinic (12-4 pm).
- The best things to study and how to use them:
 - Previous exercises and homework

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 - The study guides – as a narration of all the course content in one place
 - Your labs – the high points from them will also be on the final, but *there will not be detailed math*
- Next Monday: I'll be in the Physics Clinic as often as I can; so will Clinic TA's
 - I'll send out a note Monday morning/Sunday night with the expected schedule
- Next Tuesday: will be in and out of the Physics Clinic from 10AM until your exam starts

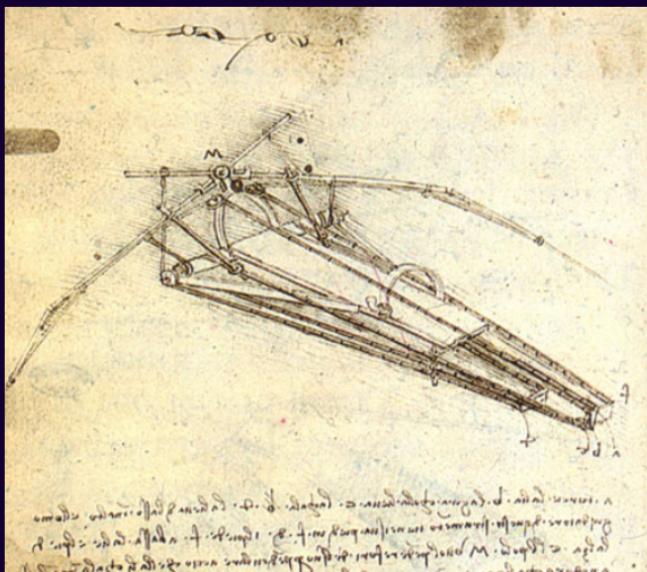
300 BCE: The dream of flight

The ancients; flight as hubris...



1450 CE: The dream of flight

Humanism and the Renaissance: flight as a dream...



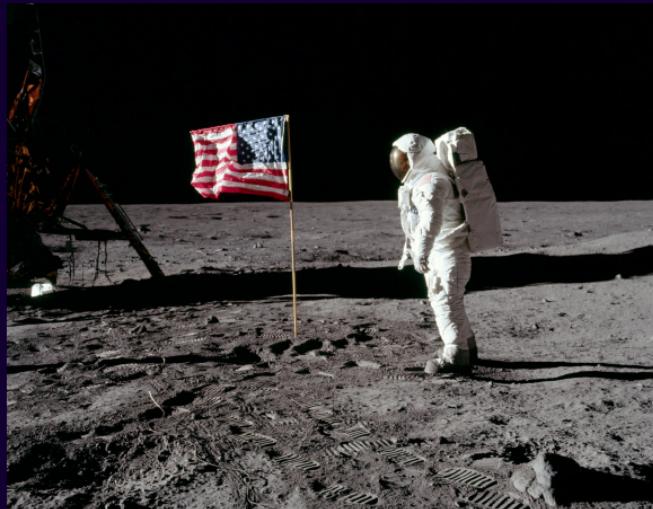
1850-1900: The reality of flight

The Industrial Revolution: fly like the birds, dream of the Moon



1960's: to the Moon!

The space age: one small step for Armstrong...



Today: what next?

- What did we do on the Moon?
- What else have humans done in space?

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- Getting to the planets
- Getting **us** to the planets
- Getting to the stars

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The most important topic today, though, is your questions.

Spaceflight is inspiring; what would you like to talk about?

Apollo 11: the Moon, at last!

On 20 July, 1969, humanity walked on another world for the first time.

- Neil Armstrong and Buzz Aldrin descended to the lunar surface
- Michael Collins stayed in lunar orbit in the Command Module
- They stayed on the Moon for nearly a day, walking on the surface for two and a half hours
- They brought back around fifty pounds of moon-rocks
- Gallery of images:
http://www.hq.nasa.gov/alsj/a11/a11_eva_thumbs.html

The remainder of Apollo

- The USA launched seven more *Apollo* missions to the Moon.
- Six of them made it; one, *Apollo 13*, suffered from an explosion en route.
 - Its story was made into a wonderful film of the same name
- 800+ pounds of moon rocks returned to Earth
- Dozens of hours spent on the lunar surface



Apollo 13

- Oxygen is nasty stuff...
<https://youtu.be/C3J1A09z0tA?t=10>



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 - If you've not watched the film, you really should.
- The explosion happened while moving away from Earth
- They had to survive long enough to use the Moon's gravity to turn around
- Only cleverness and improvisation got the astronauts home
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- Humans aren't a successful species because we're good at what we're prepared for
- ... human intelligence lets us survive things we're *not* prepared for





Not just the Moon

Kennedy called for the USA to go to the Moon in 1961. The last Apollo mission to the Moon was in 1972.

Meanwhile...

- 1961: Soviets launch first Venera mission to Venus (it broke before arriving)
- 1962: TV satellite (USA); spy satellite (USSR)
- 1962: Americans launch Mariner 2, which flies by Venus (Mariner 1 failed)
- 1965: France launches a satellite
- 1965: Mariner 5 makes close pass by Mars

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- **Satellite constellations (like Starlink) new source of light pollution**
- "Anti-satellite" weapons could set off a chain reaction making orbit very dangerous

Robotic missions and the planets

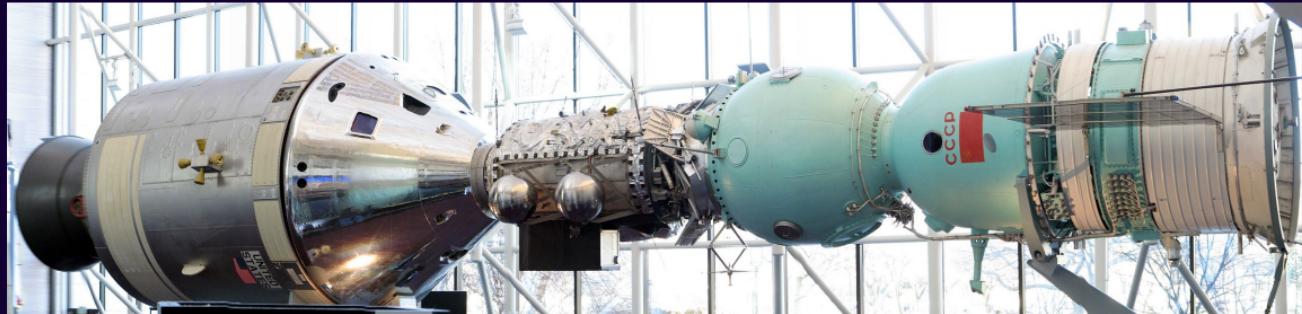
- 1971: Mariner 9 enters Martian orbit
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Robotic missions and the planets

- 1976: Viking 1 (USA) lands on Mars
- 1977: Voyagers 1 and 2 launched, passing by outer planets and leaving the Solar System
- 1981: Space Shuttle program begins
- 1986: USSR launches Space Station Mir (“Peace” or “World”); it crashes in 2001
- ... and more

Voyager 1: a history

- 1977: Launch (470 W power)
- 1979: Jupiter observations
- 1980: Saturn observations
- 1990: “Pale Blue Dot” portrait of Earth
- 1998: Passes *Pioneer 10* at 69 AU; furthest human object from Earth
- 2004: 94 AU; enters termination shock (edge of “heliosheath”)
- 2012: 121 AU; exits solar-wind bubble (“heliopause”)
- 2017: 141 AU; (19 light-hours) backup thrusters used for first time in 37 years; power down to 250 W
- 2022: 158 AU; 22 light-hours away
- 2025: 166 AU; power insufficient to run any instruments

The Space Shuttle

- Designed as a “truck” to low-earth orbit
- Great for human development (and spy satellites); not exciting for spaceflight
- Many, many flights – most but not all successful
- <https://www.youtube.com/watch?v=AfnvFnzs91s>

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- How can we go beyond LEO?

Why the Space Shuttle is not exciting



<https://upload.wikimedia.org/wikipedia/commons/8/82/Orbitalaltitudes.jpg>

Going beyond

- Good news: the hard part is just getting off of Earth; after that it's much easier
- <http://i.imgur.com/AAGJvD1.png>
- Can use planets' atmospheres as a brake to slow down once we get there (no need for another huge rocket burn)
- What about getting people to Mars?

Humans to Mars?

- We've got one-ton robots on Mars; why are humans so much harder?

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- We've got one-ton robots on Mars; why are humans so much harder?
- They're squishy
- They don't like radiation
- They want to come back (how much more Δv is that?)

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- They want to come back (how much more Δv is that?)
- Possible solution: “Mars Direct”-type plans
 - Send a robotic mission ahead of time
 - The robotic mission prepares living space and sets up a nuclear reactor
 - The energy from that reactor makes rocket fuel for the return trip out of Mars' atmosphere

The bigger obstacle: cost

- Cost of Apollo program: \$200B
- Cost of one Shuttle launch: \$450M (or \$1.4B)
- Cost of *Curiosity* rover mission: \$2.5B
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- US spending on healthcare (public and private) per year: \$4000B
- US spending on COVID response: \$4400B
- US gross domestic product per year: \$25,000B
- World GDP per year: \$96,000B

There is a very real debate here about priorities!

Is it important for humans to go to Mars?

- A: No; resources are limited and we have more important things to do on Earth
- B: No; we can explore just as well with robotic probes for a fraction of the cost
- C: Yes; science aside, sending humans to Mars advances the scope of human capability, in the same spirit as Kennedy's call for a moon mission
- D: Yes; there are things that only humans can do, and the extra cost is worth it in what we'll learn

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- E: Beam me up, Scotty; there's no intelligent life down here!

Tsiolkovsky: we just need better fuel!

Fuel exhaust speed	Fuel needed
1000 km/hr	300 million billion tons
2000 km/hr	5.5 million tons
3000 km/hr	680,000 tons
5000 km/hr	3100 tons
9000 km/hr (solid rockets)	87 tons
15400 km/hr (hydrogen/oxygen)	13 tons
104000 km/hr (ion thrusters)	470 kilograms

If we could just do better than hydrogen/oxygen rockets, we'd be in business...

Solutions to go beyond...

- Higher exhaust-velocity rockets: nuclear propulsion?
- Dealing with human lifespans

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