To the Moon!

Astronomy 101
Syracuse University, Fall 2022
Walter Freeman

December 6, 2022

Orbiting Earth in the spaceship
I saw how beautiful our planet is.
People, let us preserve and increase this beauty,
not destroy it!

–Yuri Gagarin, first human in space,
upon landing from his first flight in 1961

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This quote, and others pertaining to the voyage to the Moon and the quest for the stars, were set by Christopher Tin in his oratorio "To Shiver the Sky".

I discovered it just this morning, and listened to it while preparing for class today.

Give it a listen if you want:
`https://www.youtube.com/playlist?list=PLMfqyskB8JL8fNbX2h_4h1zUKNMAHOiv3`

Announcements: makeups/retakes

I am in the process of arranging the schedule for makeup labs. If you signed up to make up a lab, expect a note from me tonight or tomorrow morning.

I'll be in my office (215) or the Physics Clinic most of the day Friday. Come by if you want to chat about anything.

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- **At the final exam (Tuesday, December 13, 3pm-5pm)**

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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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curiosity.jpg

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 the TA's at Holden Observatory on Friday morning, December 10, from 9:30am-2pm
- To a box in front of my office, Physics Building 215, on December 10
- To your TA's mailbox (for papers and things that will fit)
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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, 10 December.

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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Since you can drop your lowest lab grade, this won't affect your grade too badly.

Preparing for the final exam

- The final exam is next Tuesday, 3PM - 5PM, 10 December
- Section 1 (12:30): Giffords Auditorium, in Huntington-Beard Crouse (not here)
- Section 2: (2:00): Stolkin Auditorium (here)
- Bring your final projects to the final to submit them

Preparing for the final exam: review sessions

- Office hours Wednesday/Friday as usual
- The best things to study and how to use them:
  - Previous exercises and homework

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  - Your labs

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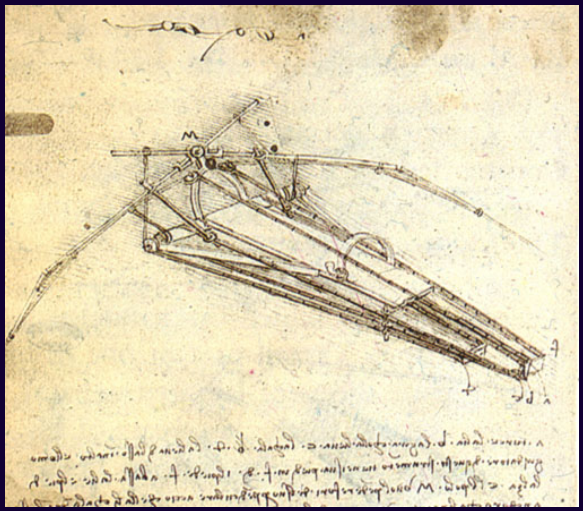
  - The study guides – as a narration of all the course content in one place
  - Your labs – the high points from them will also be on the final, but *there will not be detailed math*
- Next Monday: I'll be in the Physics Clinic as often as I can; so will Clinic TA's
  - I'll send out a note Monday morning/Sunday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

apollo-11-landing.jpg

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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- Getting to the stars

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

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

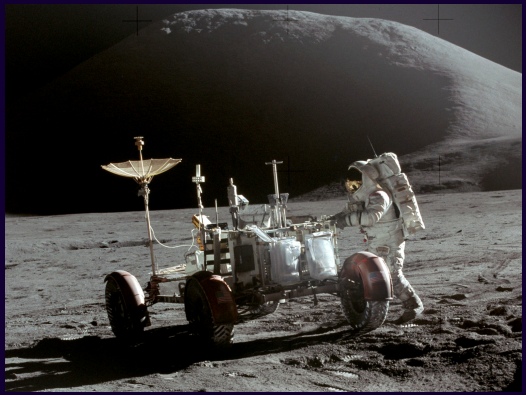
Apollo 11: the Moon, at last!

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/C3J1AO9z0tA?t=10

Apollo 13

apollo-13.png

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Apollo 13

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- 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
- https://www.youtube.com/watch?v=1cYzkyXp0jg

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apollo-13.png

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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


HERE MEN FROM THE PLANET EARTH
FIRST SET FOOT UPON THE MOON
JULY 1969, A. D.
WE CAME IN PEACE FOR ALL MANKIND
NEIL A. ARMSTRONG
ASTRONAUT
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EDWIN E. ALDRIN, JR.
ASTRONAUT
RICHARD NIXON
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HERE MAN COMPLETED HIS FIRST
EXPLORATIONS OF THE MOON
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MAY THE SPIRIT OF PEACE IN WHICH WE CAME
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ASTRONAUT
RONALD E EVANS
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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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- "Anti-satellite" weapons could set off a chain reaction making orbit very dangerous

Robotic missions and the planets

- 1971: Mariner 9 enters Martian orbit
- 1972: US launches Pioneer 10-11, which exited the Solar System
- 1973: USA launches Skylab, which didn't hit anyone on the way down (sorry, kangaroos)
- 1974: Mariner 10 waves to Mercury

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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"); it crashes in 2001
- ... and more

Return to the Moon?

The Soviets nearly made it to the Moon, but gave up their project after the Americans "got there first".

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The Chinese space program has developed rapidly in recent years.

- Robotic lander to the Moon: 2013
- People to the Moon for good: 2030?

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
- 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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- Management science: big enterprises are *hard* when you must catch all mistakes
- How can we go beyond LEO?

Why the Space Shuttle is not exciting

low-earth-orbit.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?

Humans to Mars?

- 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?)

Humans to Mars?

- 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?)
- 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
- Cost of crewed Mars mission: $500B+
- Cost of *Mars Insight*: $0.8B

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- Cost of US wars in Iraq: $2500B-$5000B
- Cost of Manhattan Project: $25B
- US military budget per year: $700B
- Revenue lost from 2017 tax changes: $1000-1500B (Senate Joint Committee on Taxation / Office of Management and Budget)

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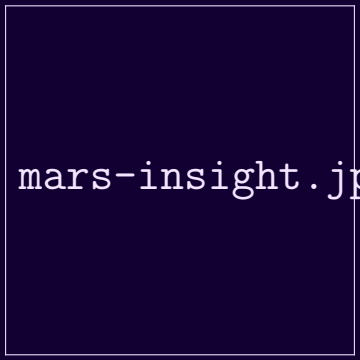
- US spending on healthcare (public and private) per year: $3200B
- US gross domestic product per year: $15,000B
- World GDP per year: $62,000B

There is a very real debate here about priorities!

Mars InSight

We landed another robot on Mars in 2018!



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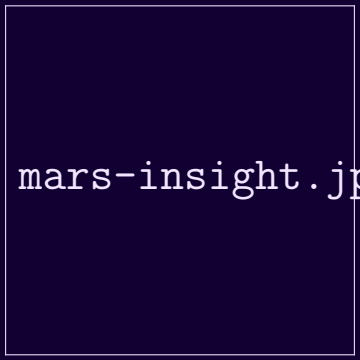

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- Seismometry: detecting marsquakes
- Thermometry: how does heat flow through Mars?
- Wobbleometry: how is Mars' mass arranged?
- Retroreflectors – surveying for the future!

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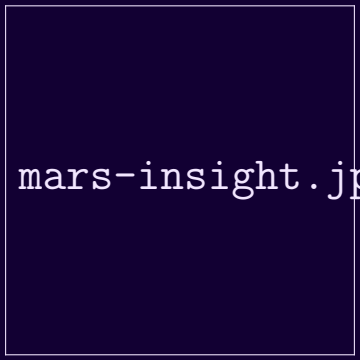

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- Retroreflectors – surveying for the future!
- Exploding meteor sonar – mad science at work!

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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