

# Ad astra per aspera

Astronomy 101  
Syracuse University, Fall 2021  
Walter Freeman

December 7, 2021



*Selfie by the Curiosity rover, on the Martian surface*

# Announcements: final projects

- 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](mailto: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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We want to accommodate your creativity. If you have something unusual in mind, let us know and we will work with you.

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:
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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

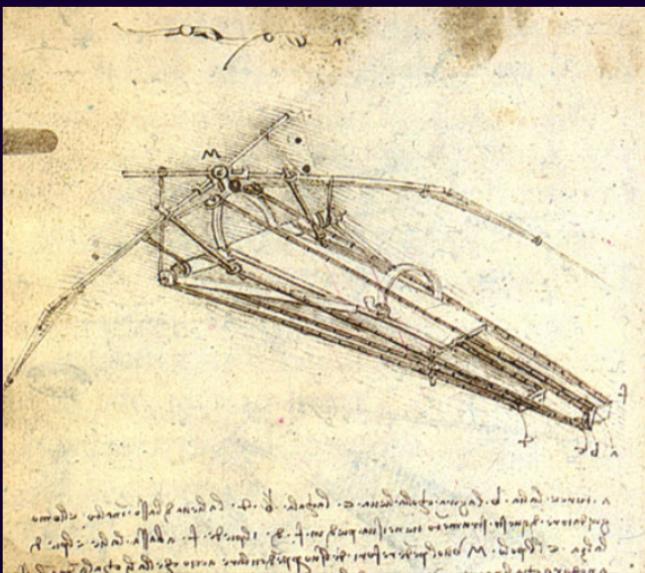
# 300 BCE: The dream of flight

The ancients; flight as hubris...



# 1450 CE: The dream of flight

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



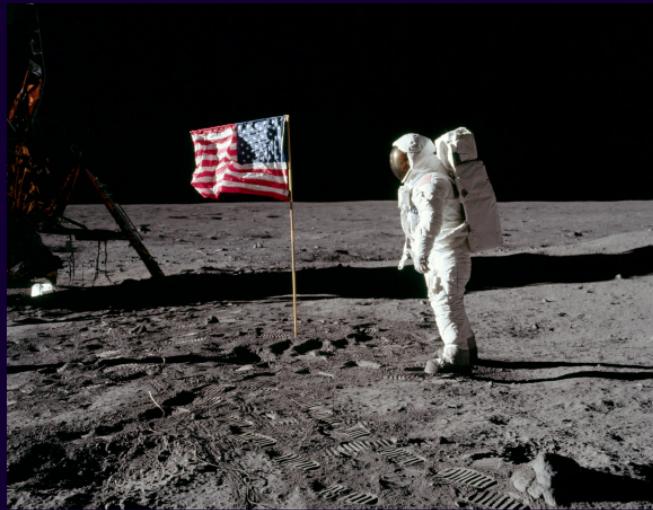
# 1850-1900: The reality of flight

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



# 1960's: to the Moon!

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



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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](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

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- 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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- “Anti-satellite” weapons could set off a chain reaction making orbit very dangerous

# Robotic missions and the planets

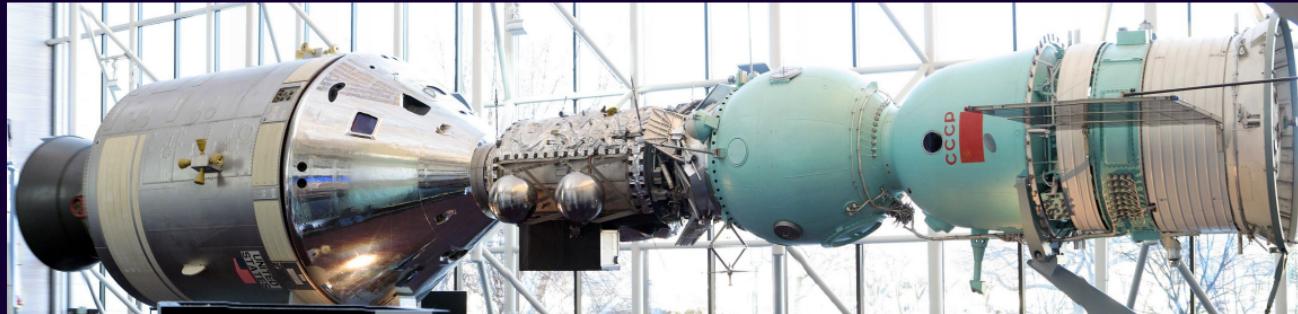
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# Robotic missions and the planets

- 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?

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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
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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?

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- They're squishy
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- 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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- 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)

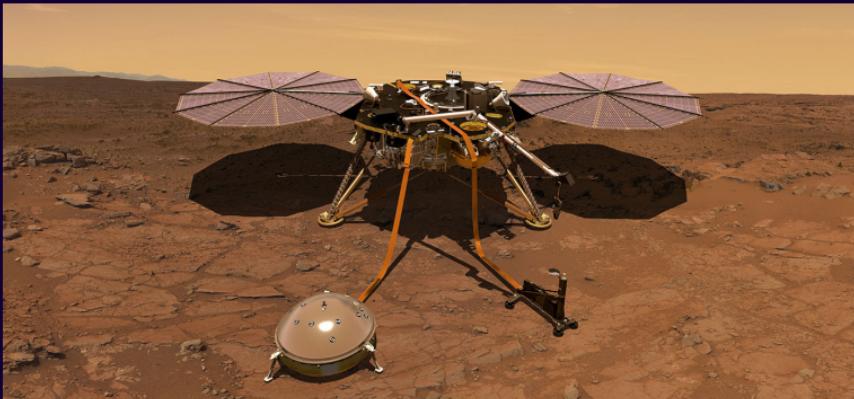
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- US spending on healthcare (public and private) per year: \$3200B
- US gross domestic product per year: \$15,000B
- World GDP per year: \$62,000B

There is a very real debate here about priorities!

# Mars InSight

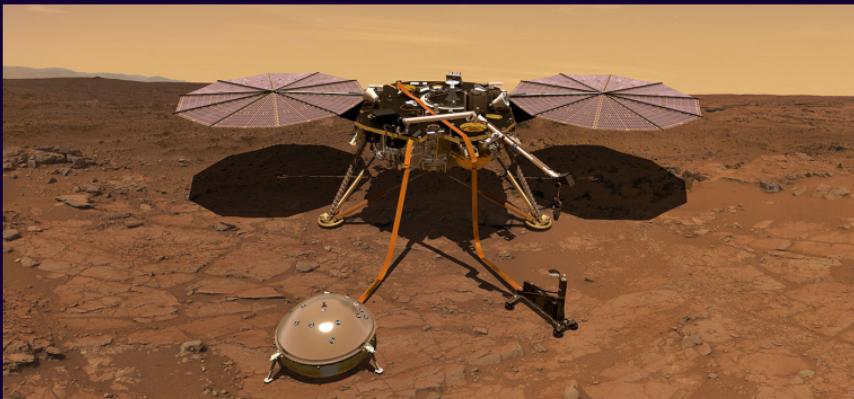
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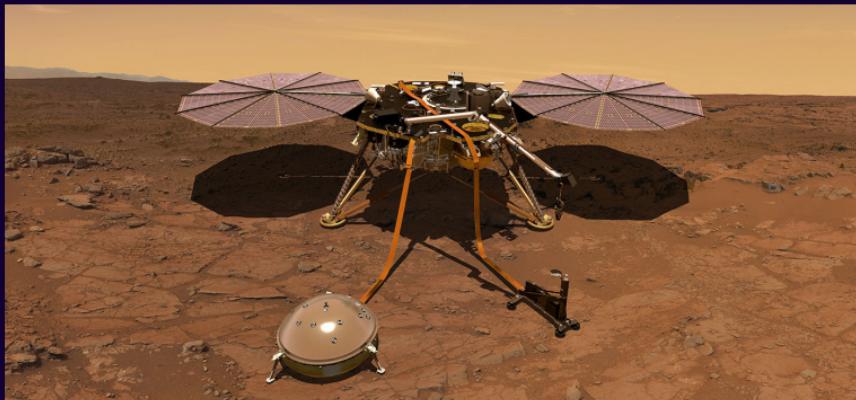


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- Thermometry: how does heat flow through Mars?
- Wobbleometry: how is Mars' mass arranged?
- Retroreflectors – surveying for the future!

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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?
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