

Ad astra per aspera

Astronomy 101
Syracuse University, Fall 2018
Walter Freeman

December 4, 2018



Selfie by the Curiosity rover, on the Martian surface



Sandra Tayler
@SandraTayler

Sometimes when I forget that humans are amazing, I think of curiosity singing Happy Birthday on Mars, and this response:

 thebaconsandwichofregret

No guys you don't understand.

The soil testing equipment on Curiosity makes a buzzing noise and the pitch of the noise changes depending on what part of an experiment Curiosity is performing, this is the way Curiosity sings to itself.

So some of the finest minds currently alive decided to take incredibly expensive important scientific equipment and mess with it until they worked out how to move in just the right way to sing Happy Birthday, then someone made a cake on Curiosity's birthday and took it into Mission control so that a room full of brilliant scientists and engineers could throw a birthday party for a non-autonomous robot 225 million kilometres away and listen to it sing the first ever song sung on Mars*, which was Happy Birthday.

This isn't a sad story, this a happy story about the ridiculousness of humans and the way we love things. We built a little robot and called it Curiosity and flung it into the star to go and explore places we can't get to because it's name is in our nature and then just because we could, we taught it how to sing.

That's not sad, that's awesome.

This meme popped up on my Facebook feed at this time last year...

Is this...

- A: Ridiculous
- B: Wasteful
- C: Heartwarming
- D: Awesome



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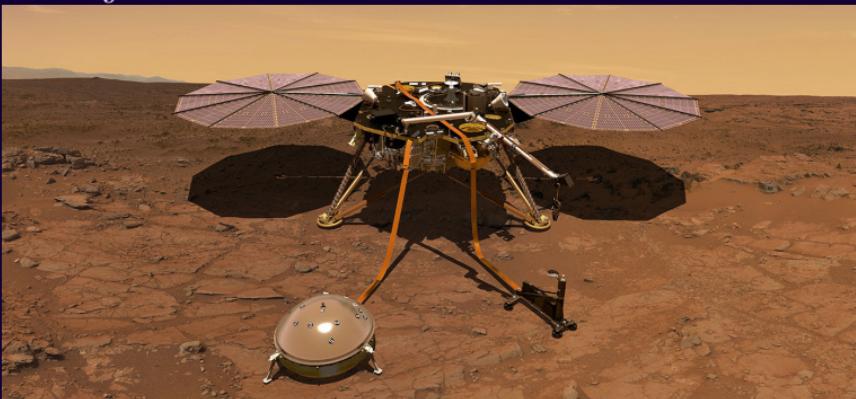
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Mars InSight

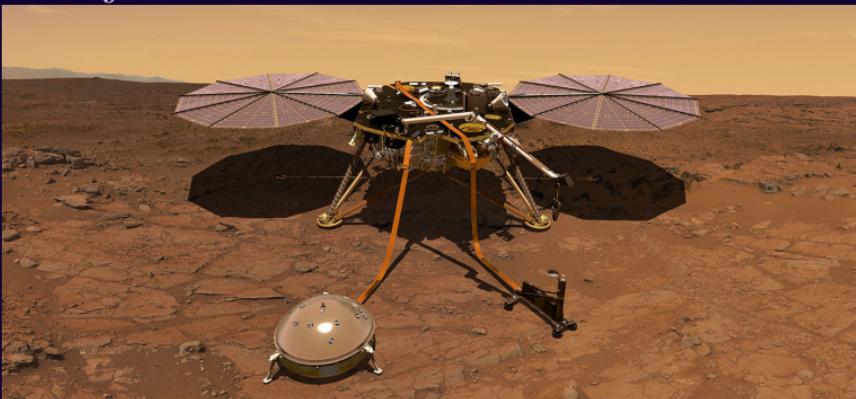
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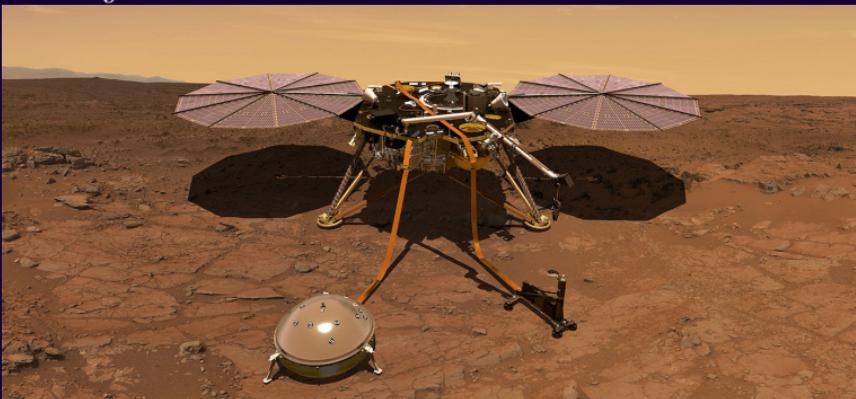


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- Seismometry: detecting marsquakes
- Thermometry: how does heat flow through Mars?
- Wobblemetry: how is Mars' mass arranged?
- Retroreflectors – surveying for the future!

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

Announcements

- 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 like papers
 - 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 ODS, get your project to me before/after (I'll be around)

Announcements

I am behind on answering mail.

I hope to be caught up with mail you all have sent me in the last few days by tomorrow at noon.

Preparing for the final exam

- The final exam is next Tuesday, 3PM - 5PM, 11 December
- Section 1 (12:30): Grant Auditorium (Falk)
- Section 2: (2:00): Stolkin Auditorium (here)
- Exam will be around 50 multiple choice questions
 - Roughly half will cover Unit IV
 - The other half will be comprehensive
 - This will focus on the big-picture ideas

Preparing for the final exam: review sessions

- Lab all this week (to review Unit 3)
- Wednesday: office hours 3-5
- Friday: office hours 9:30-11:30
- Sunday: 4-7 PM, Hall of Languages 102 (led by Anna)
- Next Monday: I'll be in the Physics Clinic much of the day
- Next Tuesday: will be in and out of the Physics Clinic from 10AM until your exam starts
- Study guides for the entire class are online

Grade checking

- I anticipate finishing all my backlog of grading tonight or tomorrow morning.
- I'll send out an email when this is done; at that point, your grades should be on Blackboard.
 - This doesn't include Exam 3 corrections or incidental extra credit
- When I do that, please **check** your Blackboard grades for accuracy. If anything is wrong:
 - If there is a problem with *lab grades*, contact your TA
 - If there is a problem with *paper grades*, contact your TA cc: me
 - If there is a problem with *exam grades*, contact me
- Friday is a good time to tell me about grade issues (bring your papers if you have them)

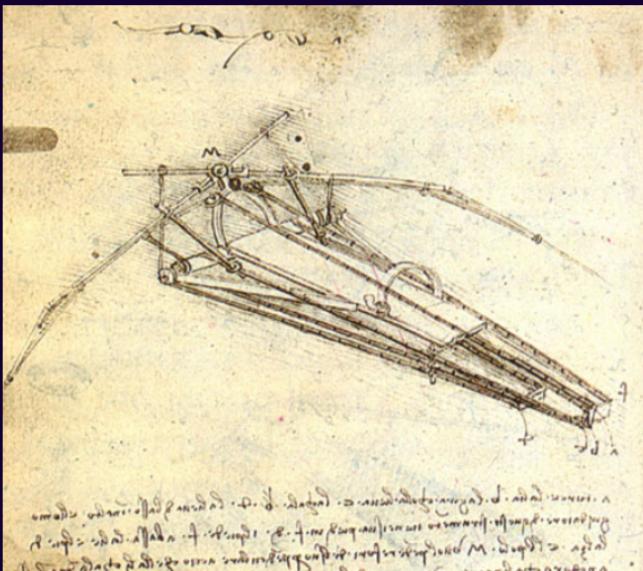
300 BCE: The dream of flight

The ancients; flight as hubris...



1450 CE: The dream of flight

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



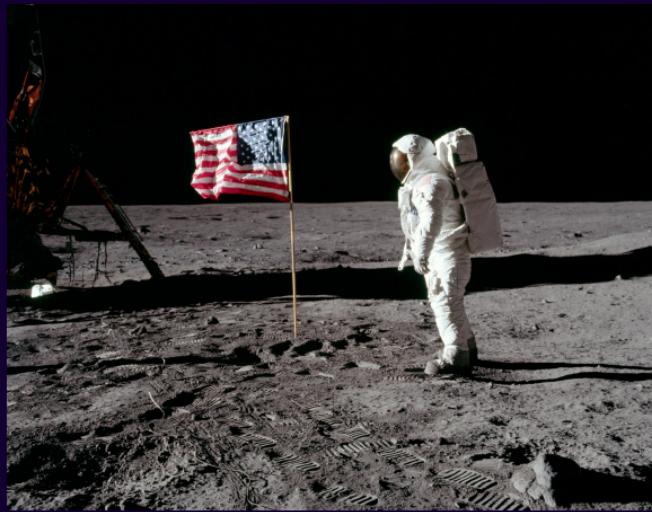
1850-1900: The reality of flight

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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- What did we do on the Moon?
- What else have humans done in space?
- Getting to the planets
- Getting **us** to the planets
- Getting to the stars

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

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<https://youtu.be/C3J1A09z0tA?t=10>



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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 Venera 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
- late 1960's: US launches Pioneer craft in solar orbit (some survived for 30+ years)
- 1970: Japan and China launch satellites

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)
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- 1975: Docking between Soyuz-19 and Apollo 18
- 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 ("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: 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?

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

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- They don't like radiation
- They want to come back
- 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

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!

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
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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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