

Ad astra per aspera

Astronomy 101
Syracuse University, Fall 2019
Walter Freeman

December 3, 2019



Selfie by the Curiosity rover, on the Martian surface

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, and will be in the Physics Clinic after the exam)

Announcements

I am behind on answering mail and messages because of an illness in the family.

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

Announcements

Take home lab due date extended until **Friday of this week** at 5PM; put in your TA's mailbox

Makeup labs: **this Friday, from 2 PM to 5:30 PM and again from 6:30 PM to 10 PM.**

- If you missed lab on Monday when class was canceled, you *may* attend the makeup lab
- If you missed lab on the week before Thanksgiving, you *must* attend the makeup lab (or drop that grade as your lowest)

If you are coming, join **#ast101makeuplabs** on Slack and say when you're coming and which lab you're making up.

Preparing for the final exam

- The final exam is next Tuesday, 3PM - 5PM, 10 December
- Section 1 (12:30): Stolkin Auditorium (here)
- Section 2: (2:00): Grant Auditorium (in Falk)
- Bring your final projects to the final

Two-part final:

- A standard exam on Unit IV (graded as a standard exam)
- Three mini-exams that will let you raise your grade on previous exams
- If you don't take any of those, they won't count against you

Preparing for the final exam: review sessions

- Possible weekend review depending on my workload – stay tuned
- Wednesday: office hours 3-5
- Friday: office hours 9:30-12, makeup lab in afternoon/evening
- 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 almost all of my backlog of grading 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 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)

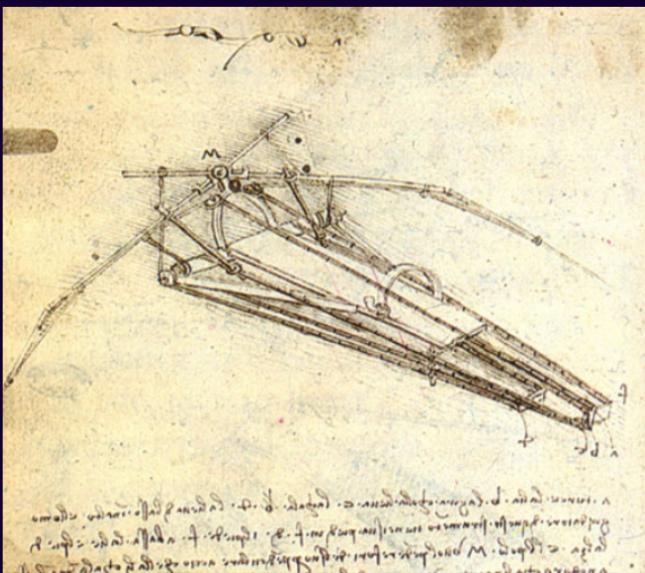
300 BCE: The dream of flight

The ancients; flight as hubris...



1450 CE: The dream of flight

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



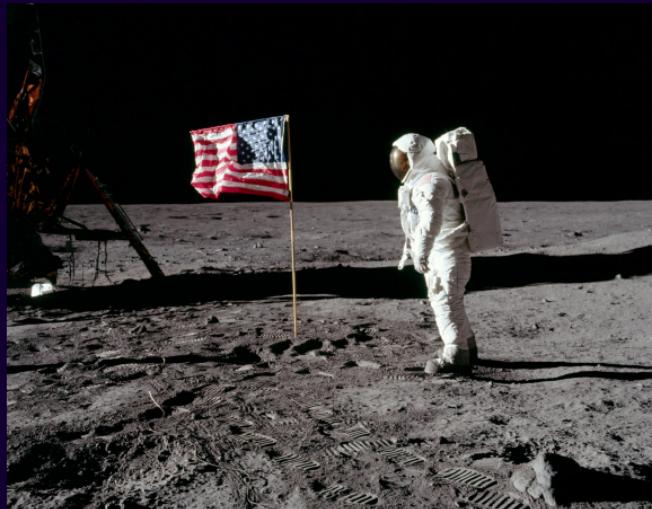
1850-1900: The reality of flight

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?

Today: what next?

- 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

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



Apollo 13

- Oxygen is nasty stuff...
<https://youtu.be/C3J1A09z0tA?t=10>
 - If you've not watched the film, you really should.



Apollo 13



- Oxygen is nasty stuff...
<https://youtu.be/C3J1A09z0tA?t=10>
 - 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
- <https://www.youtube.com/watch?v=1cYzkyXp0jg>

Apollo 13



- Oxygen is nasty stuff...
<https://youtu.be/C3J1A09z0tA?t=10>
 - 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
- <https://www.youtube.com/watch?v=1cYzkyXp0jg>
- 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
- late 1960's: US launches Pioneer craft in solar orbit (some survived for 30+ years)
- 1970: Japan and China launch satellites
- 2019: 9000 satellites launched, 5000 still up there, 2000 still working
- ... we've gotten so good at this that “space pollution” is now an issue!

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

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
- 1975: Docking between Soyuz-19 and Apollo 18

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
- 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 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”.

After the end of Apollo, the Americans never went back to the Moon.

Return to the Moon?

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

After the end of Apollo, the Americans never went back to the Moon.

Growing up in a NASA town, this was a sore point!

Return to the Moon?

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

After the end of Apollo, the Americans never went back to the Moon.

Growing up in a NASA town, this was a sore point!

Neither the Americans nor the Russians have designs on the Moon. However, another nation is interested...

Return to the Moon?

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

After the end of Apollo, the Americans never went back to the Moon.

Growing up in a NASA town, this was a sore point!

Neither the Americans nor the Russians have designs on the Moon. However, another nation is interested...

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
- <https://www.youtube.com/watch?v=AfnvFnzs91s>

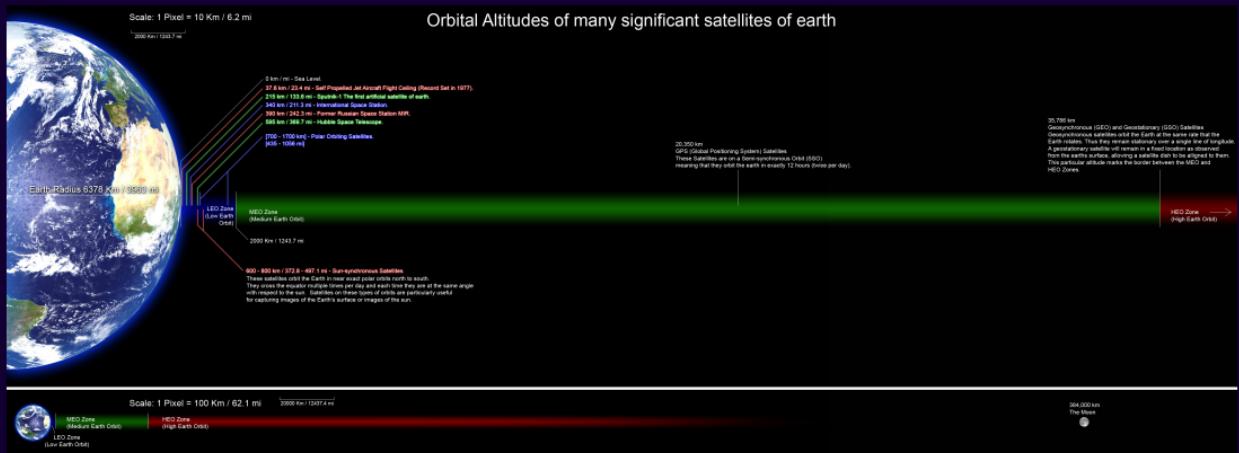
The Space Shuttle

- 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>
- <https://youtu.be/MWZs8l2AMps?t=8>
- Management science: big enterprises are *hard* when you must catch all mistakes

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>
- <https://youtu.be/MWZs8l2AMps?t=8>
- 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



<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?

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

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
- 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)

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
- 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)
- 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

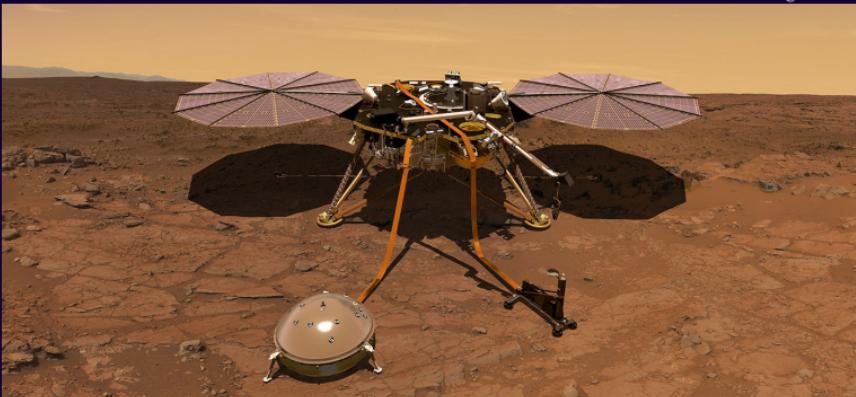
We landed another robot on Mars last year!



Mars InSight is a different sort of Mars robot. Instead of driving around, it will stay in one place and probe details about planetary geology.

Mars InSight

We landed another robot on Mars last year!

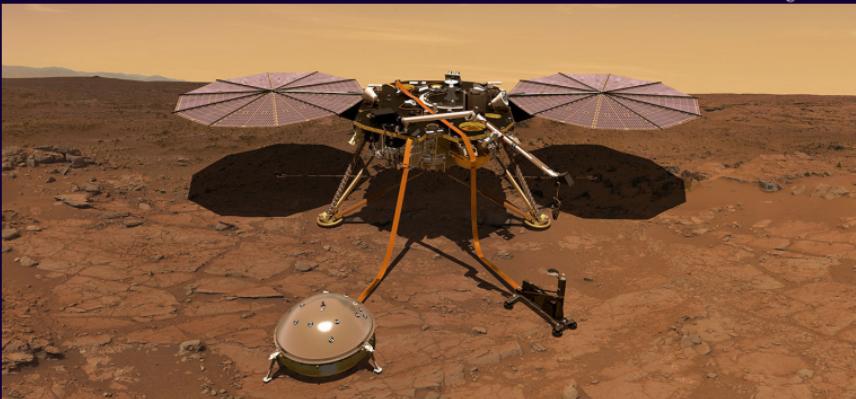


Mars InSight is a different sort of Mars robot. Instead of driving around, it will stay in one place and probe details about planetary geology.

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

Mars InSight

We landed another robot on Mars last year!



Mars InSight is a different sort of Mars robot. Instead of driving around, it will stay in one place and probe details about planetary geology.

- Seismometry: detecting marsquakes
- Thermometry: how does heat flow through Mars?
- Wobbleometry: how is Mars' mass arranged?
- 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

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
- 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

Solutions to go beyond...

- Higher exhaust-velocity rockets: nuclear propulsion?
- Dealing with human lifespans
- Sudden vs. gradual advancement – what's happened in a century?

Solutions to go beyond...

- Higher exhaust-velocity rockets: nuclear propulsion?
- Dealing with human lifespans
- Sudden vs. gradual advancement – what's happened in a century?
- More next time!

Solutions to go beyond...

- Higher exhaust-velocity rockets: nuclear propulsion?
- Dealing with human lifespans
- Sudden vs. gradual advancement – what's happened in a century?
- More next time!

<https://www.youtube.com/watch?v=S-WRKeSerUE>