Ad astra per aspera

Astronomy 101
Syracuse University, Fall 2019
Walter Freeman

November 19, 2020

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

Announcements

- I've heard a lot of fantastic ideas for final projects already
- We're replying to proposals as fast as we can, but if you don't hear back from us, go ahead and start!
- Remember, you can make up anything you're behind on in lab
- We will be having a "last-chance" makeup during the scheduled final exam period
  - There is no final exam in our class, but the University doesn't know that
- Sorry about the typo in the link for Project 5; it's up now
- Project 6 will be a brief reflection for you and your groups, posted next week, due December 5
- There will also be a final "group evaluation", where you will tell us how your group worked together
  - It will be an individual Blackboard "quiz" that should take you 5-10 minutes
  - Posted after Thanksgiving, due December 10

Grade “audit”

- During Thanksgiving week, we will get all of your grades from your graded work on Blackboard
- At that point you’ll have an opportunity to tell us if anything is amiss
- I’ve gotten mail from people about some issues like this, and am a few days behind
- I will try to catch up tomorrow

Discussion hours tomorrow

I think the boring-meeting people don't have any boring meetings I have to go to tomorrow!

This means I should be on Zoom all morning (9am-12:30pm).

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

- Oxygen is nasty stuff...
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- 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

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
PRESIDENT, UNITED STATES OF AMERICA

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ASTRONAUT
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ASTRONAUT
HARRISON H. SCHMITT
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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
- 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)
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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 Mir ("Peace"); it crashes in 2001
- ... and more

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The Chinese space program has developed rapidly in recent years.

- Robotic lander to the Moon: 2013
- Landing on the lunar south pole: 2019
- People to the Moon: 2030?

中国探月
CLEP

Voyager 1: a history

- Early 1970's: design and planning
- 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
- 2020: 152 AU; (21 light hours);
- 2025: 166 AU; power down to 218 W, insufficient to run any scientific instruments
- 2036: 196 AU; power down to 174 W; loss of radio contact with Earth

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https://money.cnn.com/2015/10/27/technology/voyager-nasa/

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- 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 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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- Total economic damage from COVID-19 in the USA: $16,121B (Cutler and Summers, 2020, published in JAMA)
- World GDP per year: $62,000B

There is a very real debate here about priorities!

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- 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; 2020 is awful!

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...

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