CS 161
Introduction to CS I
Lecture 28

C++ in Space

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Week 10 tips

- Proficiency demo!
- Check Canvas for any missing grades
  - Notify cs161-020-ta@engr.orst.edu by Wednesday (3/11)
  - Your Canvas grade may not be your final course grade
- Final exam: Monday, 3/16, 6-7:50 p.m., LINC 128
  - All T/F and multiple choice (no short answer)
  - Review Midterm 1 and 2 solutions
  - See additional practice questions for structs and recursion (website)
  - No Thursday review session: review in class instead on Friday
- Extra credit (for final exam): **survey of course materials**

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Assignment 5 creativity!

- Excellent diversity of items!
- airJordan, album, baby tooth, ball, barnacle, bean, bomb, book, bookshelf, brain, cake, car, cat, clothing, coin, computer, cookie, cuisine, dice, dog, door, dvd, egg, elect_device, employee, equipment, food, fruity, game, gem, goods, healing crystal, hot wheels, house, ice cream, instrument, jersey, jewelry, lego, lightsaber, lipstick, memory, monster, music, necklace, ore, pencil, people, phone, photo, pin, plant, pokemon, poster, prosthetic, record, rock, room, scrunchie, ship, shoe, song, spool, stock, surfboard, sword, tea, teddy, ticket, torus, transit_card, turtle, vinyl, water bottle, weapon, wine, woodchip, yoyo…

C++ in Space

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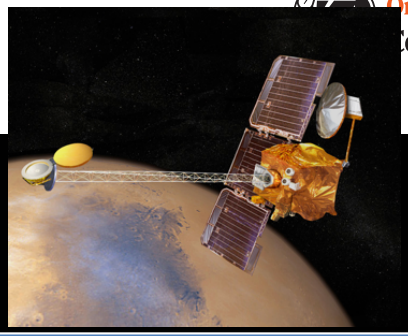
- What's the big difference?

vs.



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	Laptop on Earth	Mars Odyssey spacecraft
Configuration	CPU: 2 GHz RAM: 16 GB + virtual memory HD (SSD): 500 GB	CPU: 33 MHz RAM: 128 MB HD (SSD): 1 GB
Testing	Human user Crash: bug report, power cycle	(1) Simulator (2) Testbed Crash: break testbed?
Runtime	Hazards: spills, drops Crash: bug report, power cycle	Hazards: radiation, temperature Crash: attempt self-reset (“safe mode”)

Operational Constraints in Space

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- Processor limitations
  - Radiation-hardened: RAD6000 (33 MHz, 128 MB of RAM)
  - Can't run it at 100% (risk!)
- Memory limitations
  - No virtual memory
  - What happens if you run out?
- Storage limitations
  - Hundreds of MB to a few GB
  - Custom filesystem designs (e.g., to handle radiation)

Programming Constraints

- Strict programming guidelines
  - For predictability, clarity, and safety
- Examples (each mission differs):
  - No dynamic memory allocation
  - No recursion
  - No file input or output
  - No goto
  - Declare variables at smallest possible level of scope
  - No more than two levels of indirection (&&value)
  - No more than two levels of dereferencing (**ptr)
- What else would you add?

Programming Constraints (2)

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- Minimize library dependencies
- To enable "lights out" operations, fault protection and recovery is essential

- What happens if the code crashes?

Impact of Bugs for Spacecraft

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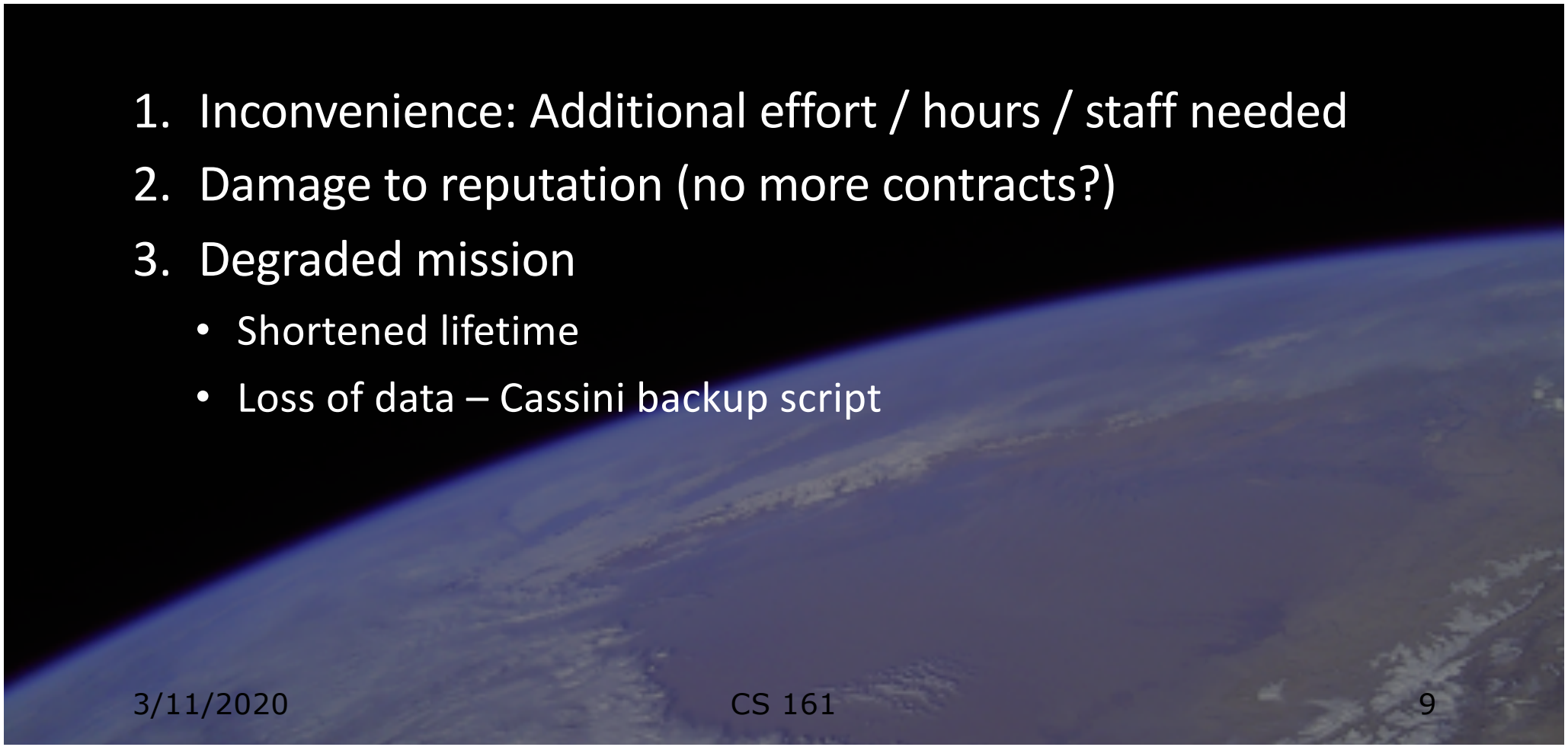
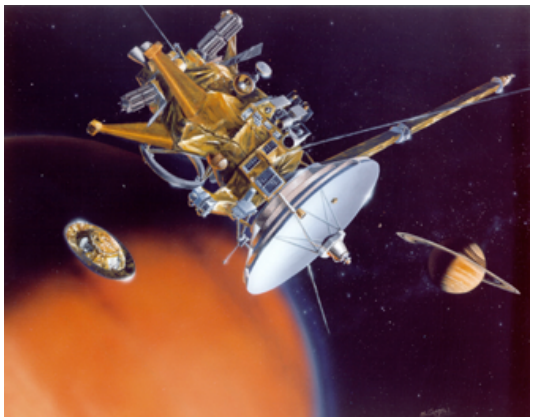


1. Inconvenience: Additional effort / hours / staff needed
2. Damage to reputation (no more contracts?)
3. Degraded mission
   - Shortened lifetime
   - Loss of data – Cassini backup script

NASA Lessons Learned



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- https://llis.nasa.gov/
- #1781: "Verify the Proper Performance of Critical Backups" (Cassini)
  - "When a 2004 backup tape for a Cassini instrument testbed was needed in late 2005 to restore important files, it was discovered that **a coding error in the backup script had been causing the backup files to be overwritten and the backup data to be lost.** Do not assume that critical data backups are being properly performed, but assure that a computer system administrator familiar with both the script and the backup hardware verifies the actual performance of the backups."

Impact of Bugs for Spacecraft (2)

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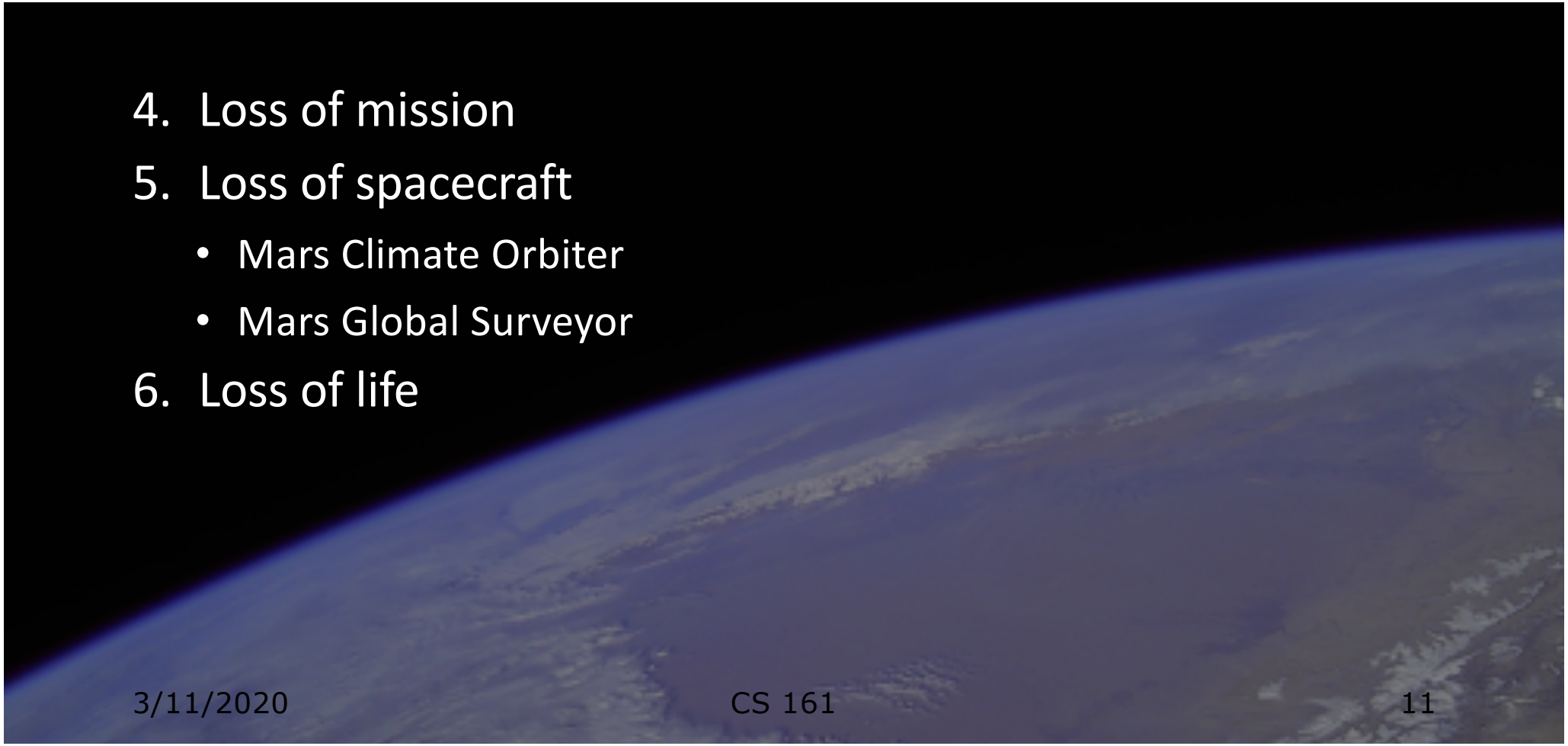

4. Loss of mission
5. Loss of spacecraft
   - Mars Climate Orbiter
   - Mars Global Surveyor
6. Loss of life

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NASA Lessons Learned

- #1805: "Mars Global Surveyor (MGS) Spacecraft Loss of Contact"
  - "Contact was lost with the Mars Global Surveyor (MGS) spacecraft in November 2006 during its 4th extended mission. A routine memory load command **sent to an incorrect address** **5 months earlier** corrupted positioning parameters, and their subsequent activation placed MGS in an attitude that **fatally overheated a battery and depleted spacecraft power**."

https://llis.nasa.gov/lesson/1805

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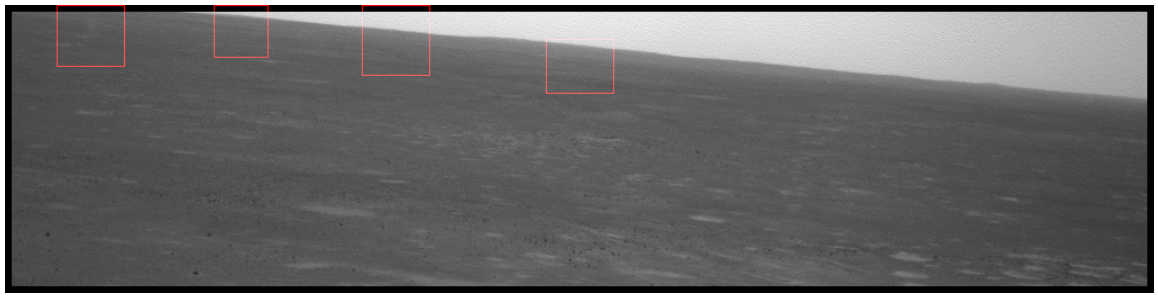
Dust Devils on Mars

- Seasonal activity. But when and where?
- Mars Exploration Rovers: Spirit and Opportunity
  - 128 MB RAM – dust devil detector given only 4 MB
  - 33 MHz processor (RAD6000)



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Autonomous Science on Mars

- Mars Exploration Rovers
- Which rocks are interesting?
- Given limited time, which ones to take close-up pictures of?

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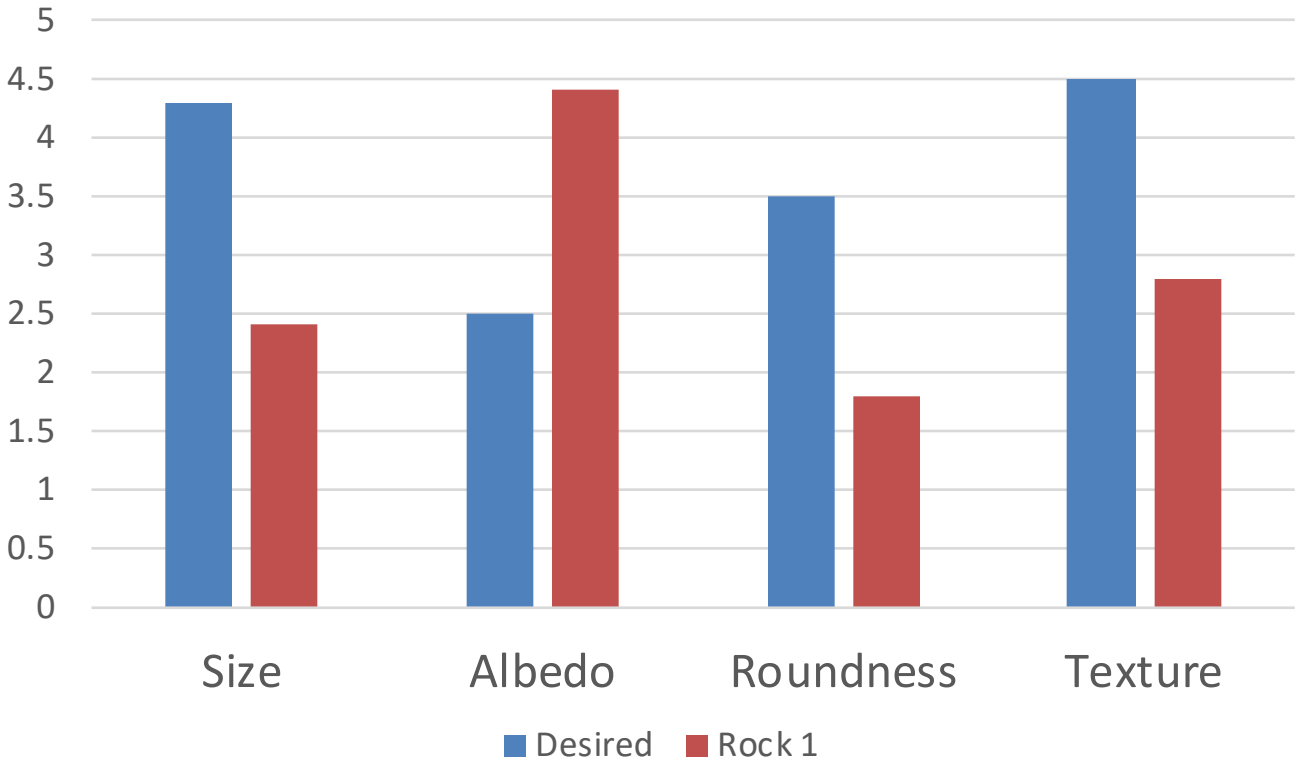
Rock "signature" matching



Rock 1

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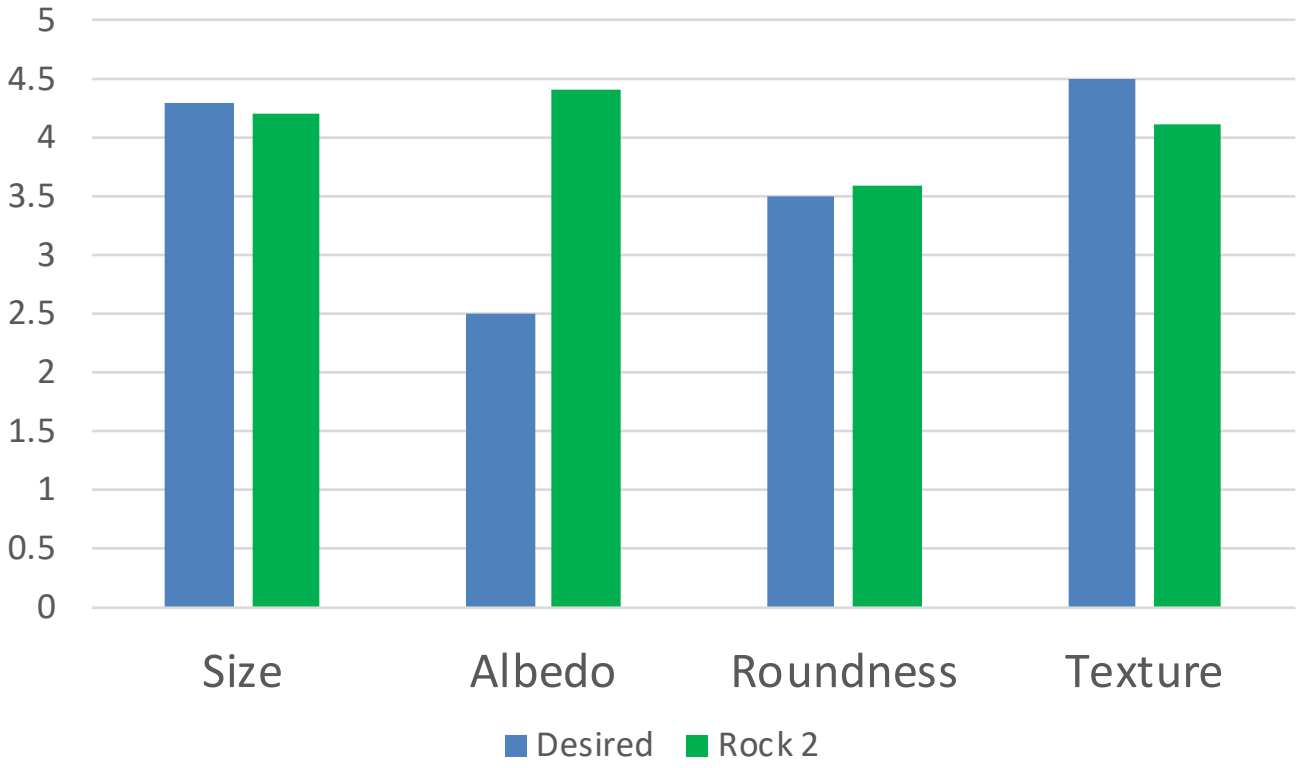
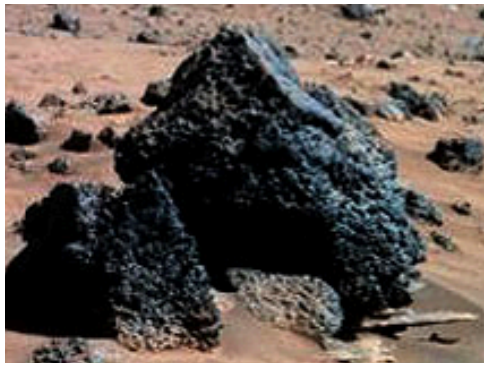
Rock "signature" matching



Rock 2



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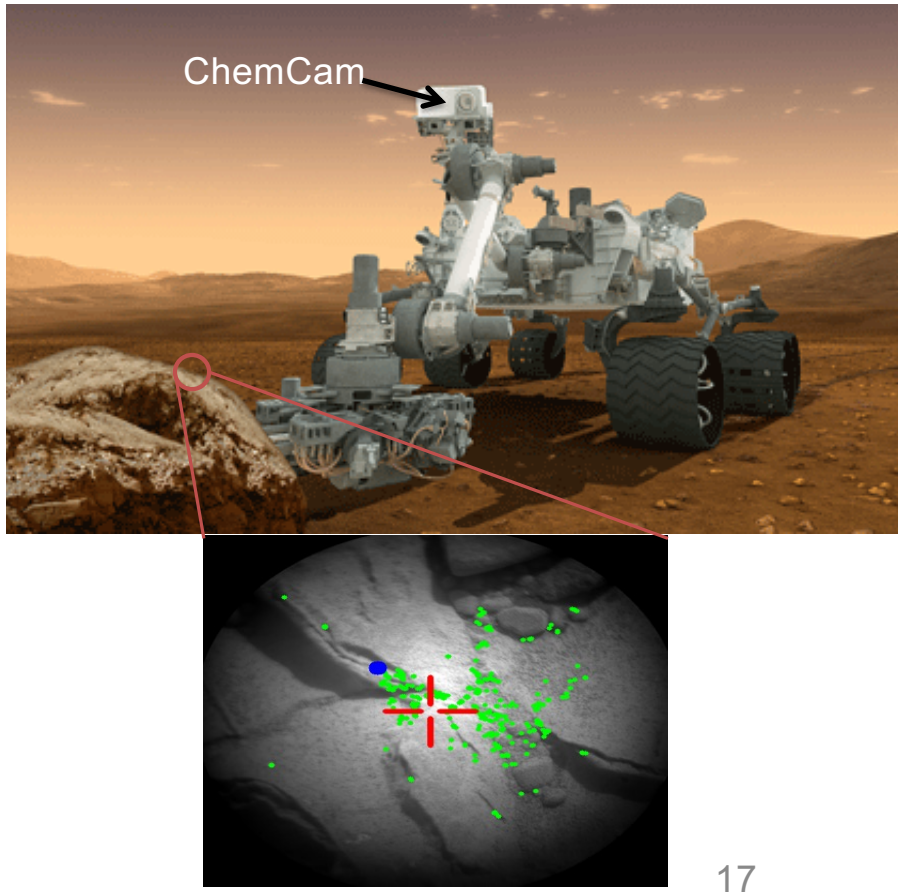
Autonomous Science on Mars

- MSL: Mars Science Laboratory
  - 128 MB RAM – AEGIS given only 16 MB
  - 133 MHz processor (RAD750)
- AEGIS: Autonomous Exploration for Gathering Increased Science
  - Find rocks in images
  - Prioritize rocks
  - Fire ChemCam laser and collect spectra
  - Send results to Earth



Programming for Spacecraft

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- Enables autonomous operations (too far away for human control)
  - Navigation
  - Exploration
  - Data collection
  - …
- Strict code quality, testing, verification requirements
  - Bugs can cause loss of time, data, money, careers, … lives

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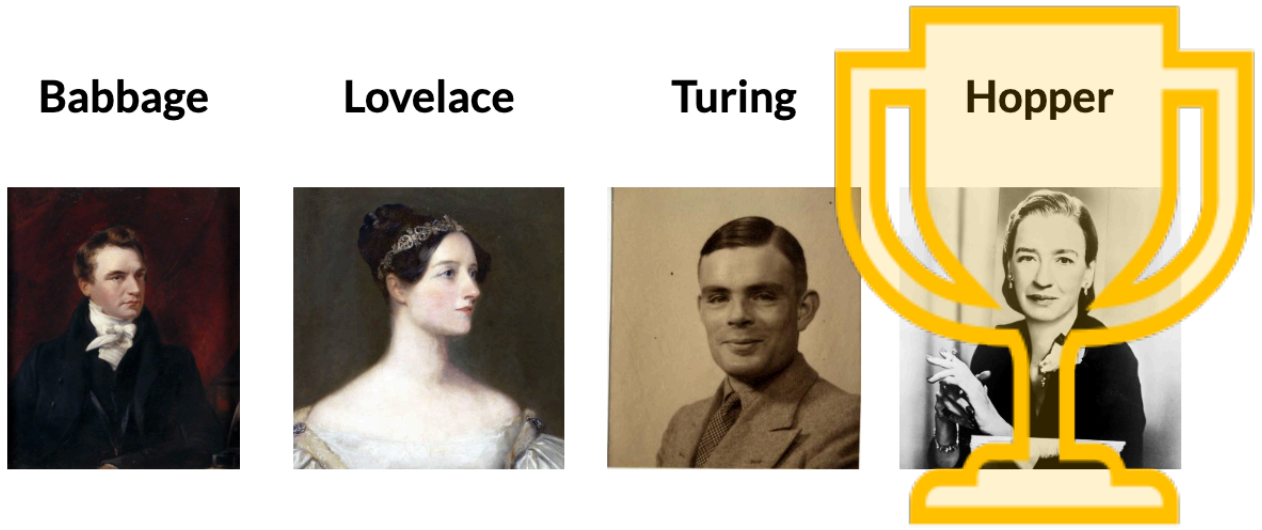
HOUSE CUP AWARDS



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Week 10 continues

- ❑ Demonstrate your proficiency in lab! Flex your muscles!
- ❑ Review and study for the **final exam (in-class review Friday)**
- ❑ **Assignment 6** (due **Saturday, March 14**)

Best wishes to you all.
It has been wonderful having you in class!