Astro-1 Honors 2020
Class 3: Getting to the Moon and Surviving

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ESA is working on a pair of twin rovers to search for life-supporting elements on the Moon

See:
https://www.esa.int/Science_Exploration/Space_Science/SMART-1/New_lunar_south_polar_maps_from_nobr_SMART-1_nobr
Problems we will address today:

1. Getting to the Moon
2. Hazards to overcome in order to survive on the Moon
3. Likely places to develop a human colony on the Moon

Earth Rise: An artist’s rendering shows Skidmore, Owings & Merrill’s vision for an expanding lunar colony.
1. Getting to the Moon

“NASA’s backbone for deep space exploration is the biggest rocket ever built, the Space Launch System (SLS), the Orion spacecraft and the Gateway lunar command module. “

https://www.nasa.gov/specials/apollo50th/back.html

NASA’s website detailing progress on the SLS: https://www.nasa.gov/exploration/systems/sls/factsheets.html
3 components in the NASA lunar launch scenario:

1. Space Launch System (SLS)
2. Orion Spacecraft
3. Gateway Lunar Orbiter

See an overview of the program:
https://www.youtube.com/watch?v=vl6jn-DdafM
NASA has designed the Space Launch System as the foundation for a generation of human exploration missions to deep space, including missions to the Moon and Mars. SLS will leave low-Earth orbit and send the Orion spacecraft, its astronaut crew and cargo to deep space. To do this, SLS has to have enough power to perform a maneuver known as trans-lunar injection, or TLI. This maneuver accelerates the spacecraft from its orbit around Earth onto a trajectory toward the Moon. The ability to send more mass to the Moon on a single mission makes exploration simpler and safer.
Test mission without people. See https://www.nasa.gov/experience-artemis-1
ARTEMIS I Mission Priorities

A flight test that will enable NASA to fly crew to the Moon and back on Artemis II:

1. **Demonstrate Orion heatshield at lunar entry velocities**
2. **Operate Systems in Flight Environment**
3. **Retrieve Spacecraft**
4. **Complete Remaining Objectives:**
   Perform residual mission in the absence of system failures and conduct all mission content as planned
The SLS core stage, the largest rocket stage ever built by NASA, 212 feet tall, 27.6 feet in diameter. Propellant tanks hold a total of 733,000 gallons of liquid oxygen and liquid hydrogen to fuel the four RS-25 engines during launch.

The core stage was designed by NASA and Boeing in Huntsville, Alabama, then manufactured at NASA’s Michoud Assembly Facility in New Orleans by lead contractor Boeing, with input and contributions from more than 1,100 large and small businesses in 44 states.
SLS core stage is currently (end of January, 2020) undergoing tests at Stennis Space Center in St. Louis, Mississippi. From there it will go to KSC in Florida.

Launch of Artemis 1 planned for end of 2020 or mid 2021.
Frist crewed mission with SLS and Orion, scheduled to launch and fly by the Moon in 2023.

Crewed Hybrid Free Return Trajectory, demonstrating crewed flight and spacecraft systems performance beyond Low Earth Orbit (LEO)
Launch
Get to Earth parking orbit
Perform Trans Lunar Injection to transfer orbit
Catch up with Moon, and transfer to a lunar orbit

https://en.wikipedia.org/wiki/Trans-lunar_injection
Lunar transfer, perspective view. TLI occurs at the red dot near Earth.

rotational velocity at Cape Canaveral launch site ~ 3.5 km/sec

Earth parking orbit ~ 7.8 km/s

Translunar orbit: spacecraft must get to ~ 10.4 km/sec
Examples of launching from Earth to LEO, performing Trans Lunar Injection to Keplerian orbit with the Earth and Moon at the two foci.

https://en.wikipedia.org/wiki/Trans-lunar_injection
GATEWAY A spaceport for human and robotic exploration to the Moon and beyond

- HUMAN ACCESS TO & FROM LUNAR SURFACE
  Astronaut support and teleoperations of surface assets.

- U.S. AND INTERNATIONAL CARGO RESUPPLY
  Expanding the space economy with supplies delivered aboard partner ships that also provide interim spacecraft volume for additional utilization.

- INTERNATIONAL CREW
  International crew expeditions for up to 30 days as early as 2024. Longer expeditions as new elements are delivered to the Gateway.

- SAMPLE RETURN
  Pristine Moon or Mars samples robotically delivered to the Gateway for safe processing and return to Earth.

- COMMUNICATIONS RELAY
  Data transfer for surface and orbital robotic missions and high-rate communications to and from Earth.

- SCIENCE AND TECH DEMOS
  Support payloads inside, affixed outside, free-flying nearby, or on the lunar surface. Experiments and investigations continue operating autonomously when crew is not present.

GATEWAY SPECS

- 4 Crew Members
- 30-90 Day Crew Missions
- 125 m³ Pressurized Volume
- Up to 75mt with Orion docked

ACCESS

- 384,000 km from Earth
  Accessible via NASA’s SLS as well as international and commercial ships.

SIX DAYS TO ORBIT THE MOON
The orbit keeps the crew in constant communication with Earth and out of the Moon’s shadow.

A HUB FOR FARTHER DESTINATIONS
From this orbit, vehicles can embark to multiple destinations: The Moon, Mars and beyond.
Gateway Enables Exploration of the Moon and Mars

- Initial Gateway focuses on the minimum systems required to support a 2024 human lunar landing while also supporting Phase 2
- Provides command center and aggregation point for 2024 human landing
- Establishes strategic presence around the Moon – US in the leadership role
- Creates resilience and robustness in the lunar architecture
- Open architecture and interoperability standards provides building blocks for partnerships and future expansion

https://www.youtube.com/watch?v=_T8cn2J13-4
Achieving 2024 – A Parallel Path to Success

Artemis will see government and commercial systems moving in parallel to complete the architecture and deliver crew.

**CREW**

NASA Programs SLS and Orion

**Artemis 1**
First flight test of SLS and Orion as an integrated system

**Artemis 2**
First flight of crew to the Moon aboard SLS and Orion

**Artemis 3**
First crew to the lunar surface; Logistics delivered for 2024 surface mission

Between now and 2024, U.S. industry delivers the launches and human landing system necessary for a faster return to the Moon and sustainability through Gateway.

**PPE**
Power and Propulsion Element arrives at NRHO via commercial rocket

**Pressurized Module**
Small area for crew to check out systems prior to lunar transfer and decent

**Human Landing System**

**Transfer**
Transfers lander from Gateway to low lunar orbit

**Descent**
Descends from Transfer Vehicle to lunar surface

**Ascent**
Ascends from lunar surface to Gateway

Up to three commercial rocket launches, depending on distribution of the Transfer, Descent, and Ascent functions.
2. Hazards to overcome in order to survive

- Space radiation
- Lunar regolith
- Low gravity
- Micrometeorites
NASA's Twin Study: Twin astronauts Mark and Scott Kelly. Scott spent one year on the ISS. No changes in his DNA were found, but there were changes in his gene expression.

No long lasting effects on Scott, the twin who spent a year on the ISS.

BUT – he was in LEO (Low Earth Orbit), still protected from space radiation by the Earth’s magnetic field.

For astronauts going into deep space, they are subject to dangerous radiation.

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Galactic cosmic rays (GCRs) are of most concern to NASA. It is challenging to shield against GCRs. They come from exploding stars called supernovae.
Predicted solar cycle between 2020 and 2024 – solar activity will be increasing, hence more solar wind particles and increased potential for CMEs and solar flare events between 2023 and 2026.

Toxicity of lunar regolith:

* Eye damage
* Lung damage
* Skin damage

In low g regolith particles are carried more easily by blood stream.

Sharp particles are abrasive to skin, lungs, eyes, and clothing.
Micrometeorite damage to a surface in LEO. Similar damage can occur on the Moon where micrometeorites land at upwards of 10 km/second.
“Moon Village” Habitat Concept with Inflatable Structure and Shield Protecting Astronauts and Equipment

The shield can be built with a 3D printer and lunar regolith and can incorporate water ice available in polar soils. This material can provide stopping power against solar particle events, galactic cosmic rays, and meteoritic impacts.

Image credit: ESA, Foster + Partners, and B.H.F
1.5 metric ton block at ESTEC in Noordwyk was 3D printed from lunar regolith simulant.
3. Likely places to develop a human colony on the Moon
ICE CONFIRMED AT THE MOON’S POLES

- Scientists have observed evidence of lots of ice in craters on the South Pole of the moon.
- The presence of ice means that moon water could potentially be used as a resource for future missions.
- Nasa is aiming to send astronauts here by 2024 with a reusable lunar landing system.
- Moon water could help astronauts explore the moon for longer or even stay there.
6,000 – 15,000 km² in south pole craters are in permanent shadow.

Aitken Basin is a giant impact crater, ~2500 km across and 12 km deep at its lowest point.

Likely contains numerous PSRs with water and other volatiles, and possibly mantle materials churned up by the impact.
Shakelton Crater at the Lunar South Pole – interior is completely in shadow. This crater has been named as a potential site for NASA’s lunar outpost.
Illuminating Shakleton Crater

The rover makes its way out of the landing module, transporting a compactly folded TF, and approaches the rim.

The TF unfolds to reflect sunlight into the crater—it is placed at a location that provides line-of-sight coverage of the planned ER path, and, under its own actuation, adjusts its position/posture for improved stability. A crosslet origami unfolding is depicted.

The ER starts its descent into the crater. The TF continuously tracks the ER, lighting its path with reflected sunlight. As the ER reaches areas with ambient temperatures below 100K, it is powered and warmed by the TF projected energy.

The TF continuously adapts its reflector shape, precisely tracking the moving ER, pointing the reflected energy onto its solar arrays, and controlling the beam as required for the ER to examine its surroundings and to take measurements.
Make solar panels out of very thin PV material which can be folded for transport.
ESA: Building a Moon Base

https://www.esa.int/ESA_Multimedia/Videos/2016/02/ESA_Euronews_Moon_Village