Deep Space Exploration: The Future Challenge in Engineering

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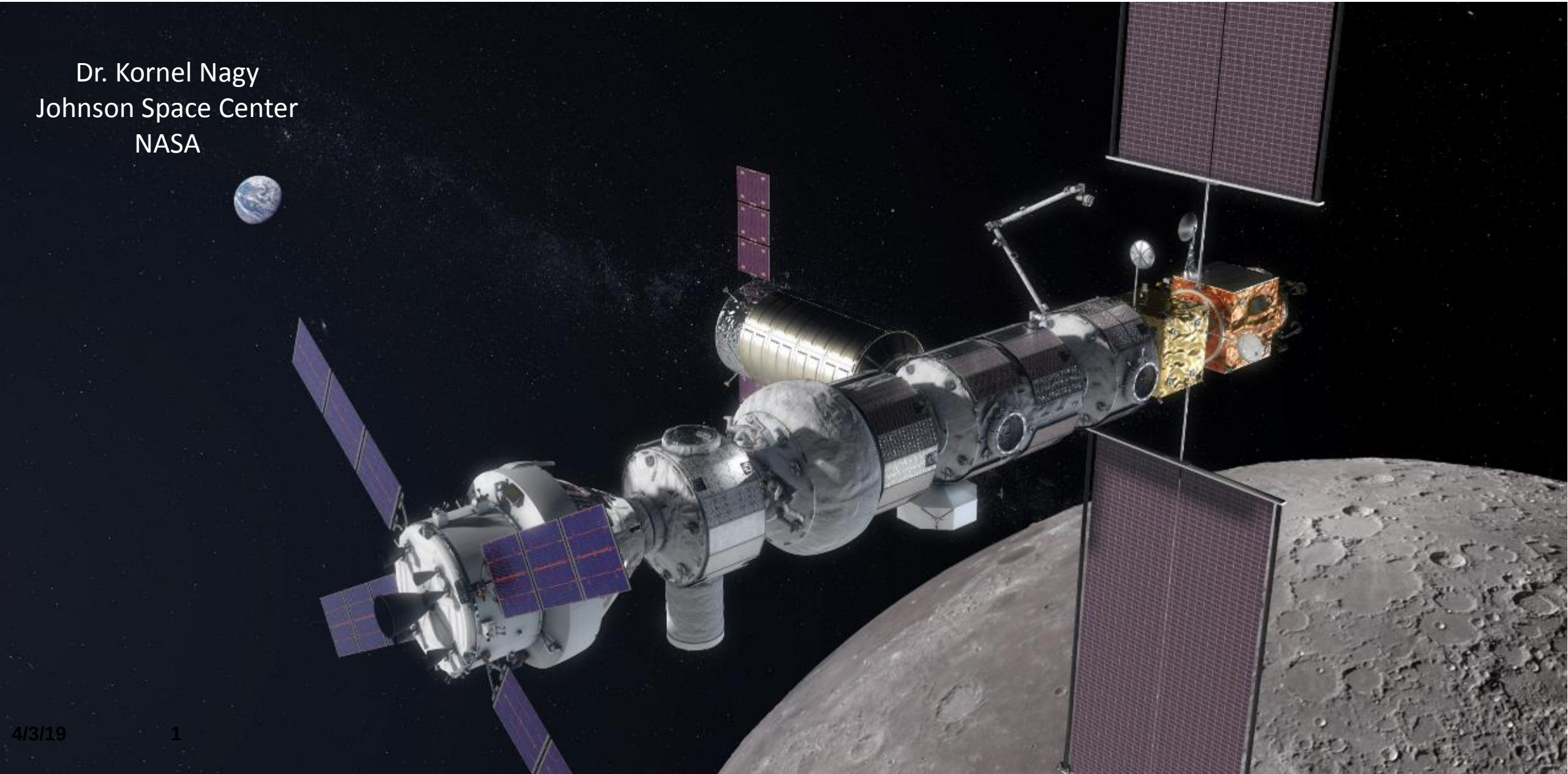

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Purpose: This presentation is focused on the future engineering challenges of human crewed spaceflight beyond Earth orbit, referred to as "deep space" by some

Topics:

- ***Missions to date are Apollo missions to Moon***
- ***Current proposal are missions to Moon and Mars***
  - ***Proposed phased implementation approach***
- ***Technical challenges for missions***
  - ***Transportation of large masses of cargo from Earth to Moon, Mars***
  - ***Deep space environment***
  - ***In situ lack of resources***
  - ***Crew environmental hazards***
  - ***Reliability of all hardware/software***
  - ***Communication time lag due to distance***
  - ***Limited logistics delivery***
- ***Funding challenges for missions***
  - ***Low Earth orbit spacecraft designs have to be modified for deep space environment***

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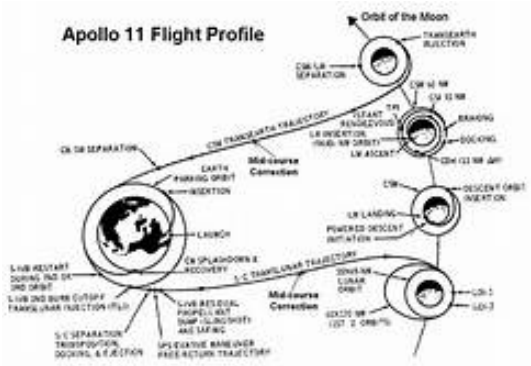
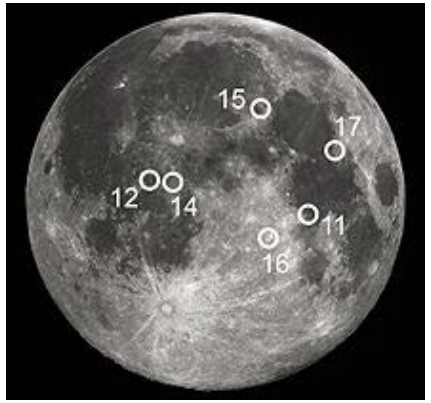


Apollo lunar trajectories

Apollo CM and SM

Apollo lunar lander (LM)



Apollo lunar landing sites

***Missions to date** are Apollo missions to Moon; six landings except Apollo 13*

***Apollo 11** was the first landing, in Tranquility Base, Sea of Tranquility. Surface EVA time: 2:31 hr. Samples returned: 47.51 pounds*

***Apollo 17** was the last landing, in Taurus–Littrow. First geologist on the Moon. Apollo's last, and the most recent, manned Moon landing. Surface EVA time: 22:02 hr. Samples returned: 243.40 pounds*

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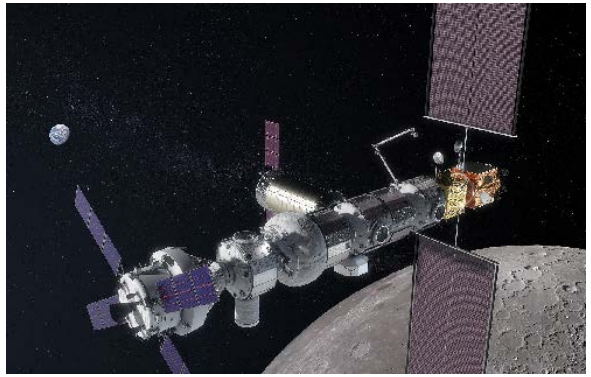
Space Launch System



Gateway

<u>Current proposal</u> are missions to Moon and Mars

Proposed phased implementation approach of a sustainable deep space exploration system

- ***Space Launch System (SLS) and commercial launch vehicles***
- ***Orion crewed spacecraft with Command Module (CM) and Service Module (SM)***
- ***Deep Space Gateway in Cislunar orbit***
  - ***Supports Lunar and Mars missions***
- ***Lunar and Mars transit spacecraft and surface systems***

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Technical challenges for missions

- ***Transportation of large masses of cargo from Earth to Moon, Mars***
  - ***Basically you require more propellant to Moon and Mars orbits than to Earth orbit***
    - ***The propulsion systems are staged to reduce the mass during ascent***
      - ***The rockets have stage 1, stage 2, etc…***
      - ***The rocket stages can be recoverable/reusable***

- ***Deep space environment***
  - ***More intense radiation and thermal environment than on surface of Earth***

- ***In situ availability of resources***
  - ***Research underway for water, minerals for propellant production, etc. on Moon and Mars***
  - ***Currently orbiting satellites and surface rovers obtaining data***
    - ***Powered by solar cells or RTGs (Radioisotope thermoelectric generator)***

Body	Mass (kg)	Radius (km)	Escape Velocity
Sun	1.99×10^{30}	696,000	6.177×10^{7} cm/second
Mercury	3.30×10^{23}	2,439	4.3 km/second
Venus	4.87×10^{24}	6,051	10.3 km/second
Earth	5.98×10^{24}	6,378	11.2 km/second
Moon	7.35×10^{22}	1,738	2.4 km/second
Mars	6.42×10^{23}	3,393	5.0km/second
Jupiter	1.90×10^{27}	71,492	59.5km/second

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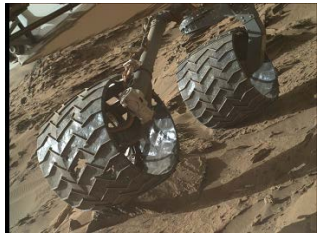

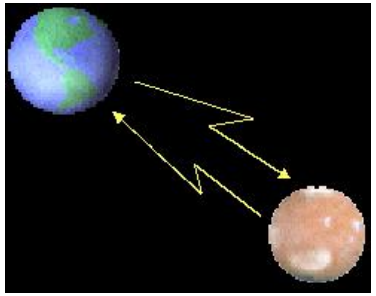

Technical challenges for missions (cont'd)

- ***Crew environmental hazards***
  - ***Reduced gravity effect on crew health; Earth's gravity is 9.807 m/s²***
    - ***Zero gravity in orbit,***
    - ***Mars is 3.711 m/s², 38 percent the gravity on Earth***
    - ***Moon is 1.62 m/s², 17 percent of gravity on Earth***
- ***Reliability of all hardware/software***
  - ***All equipment to perform it's required function for the duration of the mission***
    - ***Limited maintenance and spare parts available***
    - ***Redundancy required in the design of components***
- ***Communication time lag due to distance***
  - ***Earth-Moon 384,000 km 1.3 s***
  - ***Earth-Mars 55 - 378 million km 3 - 21 minutes***
  - ***Earth-Jupiter 590 - 970 million km 33 - 53 minutes***

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Conclusions

Deep space exploration by means of human crewed spaceflight beyond Earth orbit started with the Apollo program

Presently our country and other spacefaring nations are proposing missions to Moon and subsequently missions to Mars

The technical challenges for the missions will be met by the engineering community

The design and development of the spacecraft will be based on accumulated engineering knowledge during some 60 years of spaceflight to date

On a personal note: I started with NASA in May of 1968 as a contractor, fantastic work experience on Space Shuttle, International Space Station and now the Gateway program

All of the engineering students today have the great opportunity to do engineering in Deep Space Exploration

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