NASA and Future Human Exploration of the Solar System

Presentation to the Westinghouse Science Honors Institute Murraysville, PA

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Introduction

• Why space flight?
• The Space Act and Technology Development.
• Human exploration of space (in the past).
• Transitions.
• New Space Launch System.
• Robotic Mars Exploration.
• Pluto and New Horizons.
• Concluding remarks.
Why Space Flight?
The National Aeronautics and Space Act (1958)

- (1) The expansion of human knowledge of the Earth and of phenomena in the atmosphere and space;
- (2) The improvement of the usefulness, performance, speed, safety, and efficiency of aeronautical and space vehicles;
- (3) The development and operation of vehicles capable of carrying instruments, equipment, supplies, and living organisms through space;
- (4) The establishment of long-range studies of the potential benefits to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes;
- (5) The preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere;
Why Space Flight?
The National Aeronautics and Space Act (1958)

• (6) The making available to agencies directly concerned with national defense of discoveries that have military value or significance, and the furnishing by such agencies, to the civilian agency established to direct and control nonmilitary aeronautical and space activities, of information as to discoveries which have value or significance to that agency;

• (7) Cooperation by the United States with other nations and groups of nations in work done pursuant to this Act and in the peaceful application of the results thereof;

• (8) The most effective utilization of the scientific and engineering resources of the United States, with close cooperation among all interested agencies of the United States in order to avoid unnecessary duplication of effort, facilities, and equipment; and

• (9) The preservation of the United States preeminent position in aeronautics and space through research and technology development related to associated manufacturing processes.
Artemis Phase 1: To the Lunar Surface by 2024

- Artemis 1: First human spacecraft to the Moon in the 21st century
- Artemis 2: First humans to orbit the Moon in the 21st century
- Artemis Support Mission: First high power Solar Electric Propulsion (SEP) system
- Artemis Support Mission: First pressurized module delivered to Gateway
- Artemis Support Mission(s): Human Lander System delivered to Gateway
- Artemis 3: Crewed mission to Gateway and lunar surface

Commercial Lunar Payload Services
- CLPS delivered science and technology payloads

Early South Pole Mission(s)
- First robotic landing on eventual human lunar return and ISRU site
- First ground truth of polar crater volatiles

Large-Scale Cargo Lander
- Increased capabilities for science and technology payloads

Humans on the Moon - 21st Century
First crew leverages infrastructure left behind by previous missions

Lunar South Pole Target Site

2019

2024
Nuclear Thermal Rocket
For Piloted Mars- Asteroid Missions
Nuclear Electric Propulsion for Piloted Mars - Asteroid Missions
Without technology investments, the mass required to initiate a human Mars mission in LEO is approximately twelve times the mass of the International Space Station (ISS).

Technology investments of the type proposed in the FY2011 budget request are required to put such a mission within reach.
A New Rocket to Rival Saturn V

NASA plans to use the Space Launch System (SLS) to launch astronauts and heavy payloads into Earth orbit and beyond.

**CREW MODULE** (above) is larger than the Apollo Command Module developed in the 1960s.

**CORE STAGE** has the same diameter as the space shuttle's external fuel tank. It uses RS-25 engines—modified versions of the shuttle's main engines—which are fueled by liquid hydrogen and liquid oxygen.

**SERVICE MODULE** carries fuel, solar panels, and equipment.

**STRAP-ON BOOSTERS** are similar to the shuttle's boosters, but are longer because they have additional solid fuel aboard.

At liftoff, SLS fires its five liquid-fueled main engines and two solid-fueled boosters.

**ORION Multi-Purpose Crew Vehicle (MPCV)** holds four astronauts.

**ESCAPE TOWER** is to pull the capsule away from the booster in the event of an emergency during launch.

An advanced version of the SLS would include an additional **UPPER STAGE** with a simpler J-2X engine derived from engines used on the Saturn V rocket. This engine burns liquid hydrogen and liquid oxygen.
How SLS Stacks Up Against Other Rockets

The Space Launch System's initial configuration (below, left) can be enhanced later for better performance (second from left).

<table>
<thead>
<tr>
<th>Country</th>
<th>United States</th>
<th>United States</th>
<th>United States</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years of operation</td>
<td>First launch planned for 2017</td>
<td>to be determined</td>
<td>1967-1973</td>
<td>1981-2011</td>
</tr>
<tr>
<td>Destinations</td>
<td>Earth orbit, deep space</td>
<td>Earth orbit, deep space, asteroid, moon, Mars</td>
<td>Earth orbit, moon</td>
<td>Earth orbit</td>
</tr>
<tr>
<td>Height</td>
<td>320 ft (97.5 m)</td>
<td>400 ft (122 m)</td>
<td>363 ft (110 m)</td>
<td>194 ft (59.1 m)</td>
</tr>
<tr>
<td>Lift capability</td>
<td>70-77 metric tons</td>
<td>up to 130 metric tons</td>
<td>130 metric tons</td>
<td>24.4 metric tons</td>
</tr>
<tr>
<td>Thrust</td>
<td>8.4 million lbs (3.8 million kg)</td>
<td>9.2 million lbs (4.2 million kg)</td>
<td>7.5 million lbs (3.4 million kg)</td>
<td>7.8 million lbs (3.54 million kg)</td>
</tr>
</tbody>
</table>

LH2 = Liquid hydrogen fuel
LOX = Liquid oxygen oxidizer
Solid fuel = Solid Rocket Booster Composite mixture

SOURCES: NASA, LOCKHEED MARTIN

KARL TATE / © SPACE.com
Hayabusa Visiting Asteroid Itokawa
Hayabusa Visiting Asteroid Itokawa
Hayabusa Visiting Asteroid Itokawa
Hayabusa 2 Visiting Asteroid Ryugu
### Economic Analysis of 2-km M-Class Metal Rich Asteroid

<table>
<thead>
<tr>
<th>Component</th>
<th>Fraction of metal by mass</th>
<th>Mass</th>
<th>Estimated value ($/kg)</th>
<th>Estimated dollar value ($ trillions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>0.89</td>
<td>2.7x10^{13}</td>
<td>0.1</td>
<td>3</td>
</tr>
<tr>
<td>Nickel</td>
<td>0.10</td>
<td>3.0x10^{12}</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Cobalt</td>
<td>0.005</td>
<td>1.5x10^{11}</td>
<td>25</td>
<td>4</td>
</tr>
<tr>
<td>Platinum-group metals</td>
<td>15 ppm</td>
<td>4.5x10^{8}</td>
<td>20,000</td>
<td>9</td>
</tr>
<tr>
<td><strong>Total value</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>25</strong></td>
</tr>
</tbody>
</table>
Mars Science Laboratory
Mars Science Laboratory flight system, expanded view
Locations of landing sites for Curiosity and previous Mars rovers and landers
Proposed MSL Field Site In Gale Crater

Landing ellipse
- very low elevation (~4.5 km)
- shown here as 25 x 20 km
- alluvium from crater walls
- drive to mound

Inverted DN THEMIS IR from Christensen/ASU + Viking USGS MDIM 2.1

4th MSL Landing Site Workshop, 27–29 September 2010
MSL Landing Site Images

Gale Crater

Primary Site: 4.49°S, 137.42°E
Elevation: -4451 m  Target: Layered Sulfates, Phyllosilicates
Sky Crane Operations
Mission update from NASA-JPL via telecon
Mission update from NASA-JPL via telecon
Major gases released from the bedrock called “John Klein” and analyzed by the SAM instruments.
Making Humans a Multiplanetary Species

Elon Musk, SpaceX

at the

67th International Astronautical Congress (IAC)

09-27-2016
SYSTEM ARCHITECTURE

TARGETED REUSE PER VEHICLE
1,000 uses per booster
100 per tanker
12 uses per ship

1. SHIP PREPARES TO LAUNCH
2. BOOSTER RETURNS TO LAUNCH AGAIN
3. TANKER'S REFILL SHIP THEN RETURN TO EARTH
4. SHIP HEADS TO MARS
5. MARS ARRIVAL
6. IN SITU PROPELLANT PRODUCTION
7. SHIP RETURNS TO EARTH
BFR
118 m Tall
Over 100 t Payload to LEO with Full Reuse
“Our vision is millions of people living and working in space, and New Glenn is a very important step. It won’t be the last, of course.”

Jeff Bezos, Blue Origin
Where will we find life next?

If there’s some place in our solar system that’s secretly harboring life, you told us where you thought it might be hiding. That icy shell didn’t stop Europa from taking top honors, although you said you’re probably not ready to move there just yet. But once there’s a Starbucks, most of us would be game.

- **47.1% Europa**: Jupiter’s icy moon has an ocean — and we all know life likes oceans.
- **22.9% Mars**: There’s ice and water and maybe even microbes in those dunes!
- **16.2% Titan**: Saturn’s cloud-covered moon has its own atmosphere and methane lakes. Sounds like a haven for alien cephalopods.
- **9.2% Enceladus**: Saturn’s geyser moon seems like the perfect place for life to take root.
- **2.5% Jupiter**: The planet’s clouds could be the perfect home for hardy, blimp-like creatures.
- **2.1% Venus**: Sure it rains sulfuric acid and the days are super hot, but there could be life lurking under the Venusian clouds.

How willing would you be to live on a planet other than Earth?

- **32.2%**: I’ll wait until a colony has been established somewhere.
- **27.4%**: As soon as there’s a ship with a seat for me, I’m game.
- **26.9%**: I’d go, but only if I could return to Earth eventually.
- **13.5%**: Planet Earth is the only one for me.

*Source: ThinkGeek.com*
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  Jupiter's icy moon has an ocean — and we all know life likes oceans.

- **22.9% MARS**
  There's ice and water and maybe even microbes in those dunes!

- **16.2% TITAN**
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  Saturn's geyser moon seems like the perfect place for life to take root.

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SOURCE: THINKGEEK.COM

PHOTOS: NASA
New Horizons Team Finds Haze, Flowing Ice on Pluto

Press Conference, July 24, 2015

Flowing ice and a surprising extended haze are among the newest discoveries from NASA’s New Horizons mission, which reveal distant Pluto to be an icy world of wonders.
Alice Solar Occultation of Charon

![Graph showing normalized count rate vs. elapsed seconds during an occultation event.](image-url)
Ethylene ($C_2H_4$) and Acetylene ($C_2H_2$)
Pluto’s atmospheric pressure in micro bars (millionths of a bar; 1 bar = 14.5 psi)
Pluto’s atmospheric pressure in micro bars (millionths of a bar; 1 bar = 14.5 psi). New Horizons REX measured 10 microbars.
Rugged cratered terrain

Nitrogen ice flow

Nitrogen ice flow

Polygonal cells

Sputnik Planum

20 miles
With advanced propulsion, one must always look to the past and look to the future.