HUMAN LANDING SYSTEM

Intro to HLS Propulsion Team

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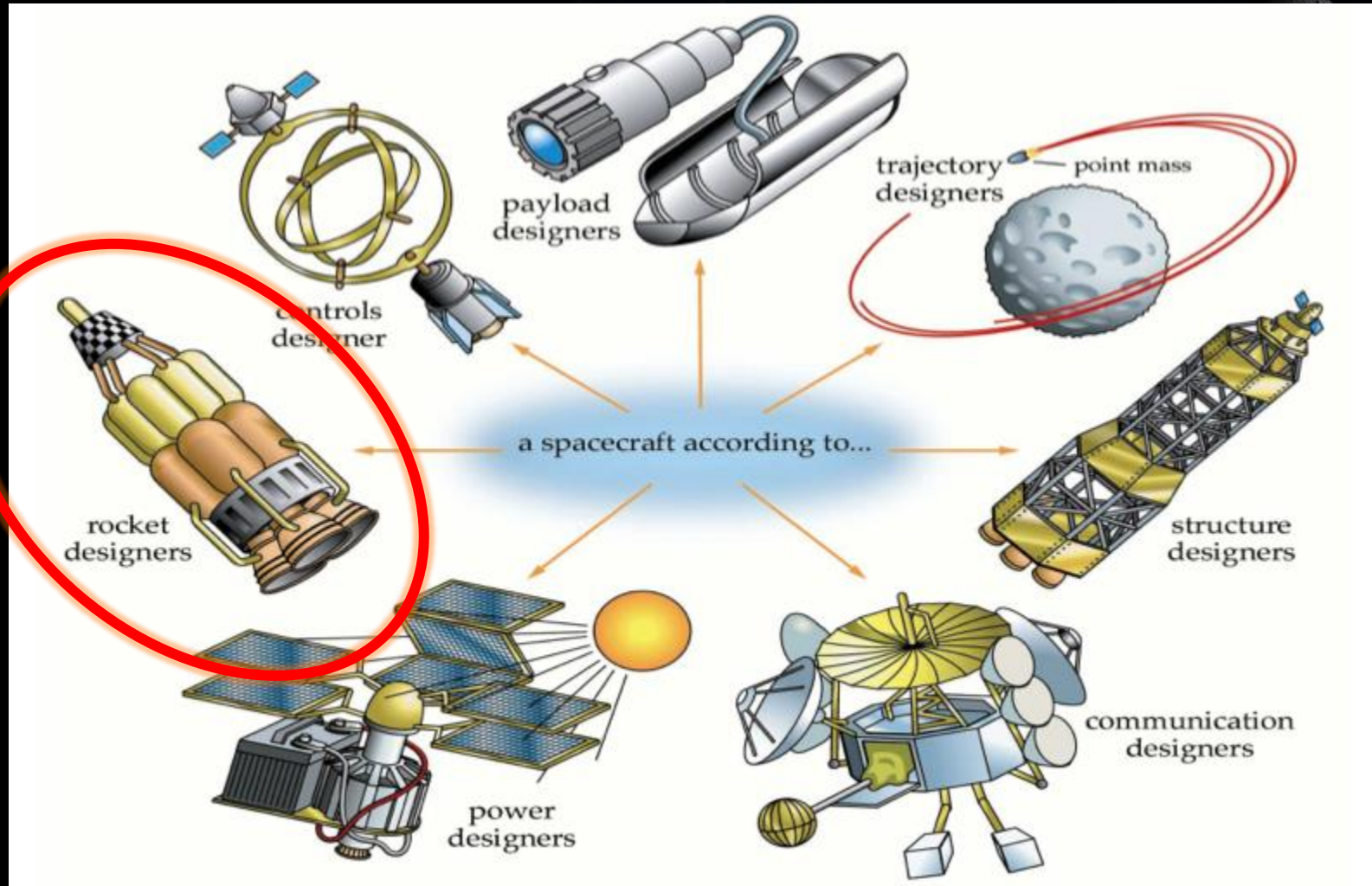[2]HLS CFM / MPS Lead, Marshall Space Flight Center

[3]HLS CFM SME, Glenn Research Center

WARNING: Propulsion Biased Presentation

NASA HLS Propulsion
Team Engineers

Image: Understanding Space Figure 11-25 (Sellers J. et al. 2005)

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Vacuum Raptor Cold Start Test – August 2023

BE-7 TCA Hotfire Test – March 2023

Video Credit: SpaceX

Video Credit: Blue Origin

Needless to say… we have the best job in the world

WARNING: Propulsion Biased Presentation

However, best ≠ easiest — Propulsion includes…

- Main engines (see previous slide)
    - And all the fun that goes with them (turbomachinery, combustion devices)
- Main Propulsion Systems / Cryogenic Fluid Management (CFM)
    - Including conditioning, storing, transferring, and gauging cryogenic propellants
- Reaction / Attitude Control Systems
- Gas Storage and Generation Systems
- +all the supporting lines, valves, tanks, small structures, analysis, etc.

If it's really hot, really cold, really high pressure, spins really fast, or shoots flames out the back… it's probably Propulsion ™

not actually trademarked

Human Landing System (HLS)

Objective – Return U.S. astronauts to the lunar surface for a sustained campaign of exploration and utilization

Goals (HLS-PLAN-001)

- Create a sustainable path to rapidly and safely get humans back to the moon

- U.S. Industry-led design, development, manufacture, and operation of lunar human landing systems

- Strengthen and utilize subject matter expertise of the NASA workforce critical to developing human-rated lander capabilities

Bottom Line: Get the moon and <u>stay there</u> with U.S. Industry

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S T A R S H I P

Human Landing System (HLS)

NASA is working with SpaceX to develop its Starship Human Landing System for use on:

- Artemis III - the mission that will put the next two Americans on the surface of the Moon

- Artemis IV - which meets an extended set of requirements such as docking with Gateway for crew transfer, more mass to the surface, and longer mission durations

SpaceX will perform an uncrewed demonstration mission prior to the crewed Artemis III mission.

Image Credit: SpaceX

BLUE MOON

Human Landing System (HLS)

NASA is working with Blue Origin to develop a human landing system for use on:

- <u>Artemis V</u> – meets NASA's extended set of requirements such as docking with Gateway for crew transfer, more mass to the surface, and longer mission durations

Blue Origin will perform an uncrewed demonstration mission prior to the crewed Artemis V mission.

The team's approach consists of: **Blue Origin's** Blue Moon lander and **Lockheed Martin's** Cislunar Transporter along with partners:

- **Draper**
- **Astrobotic**
- **Boeing**
- **Honeybee Robotics**

Image Credit: Blue Origin
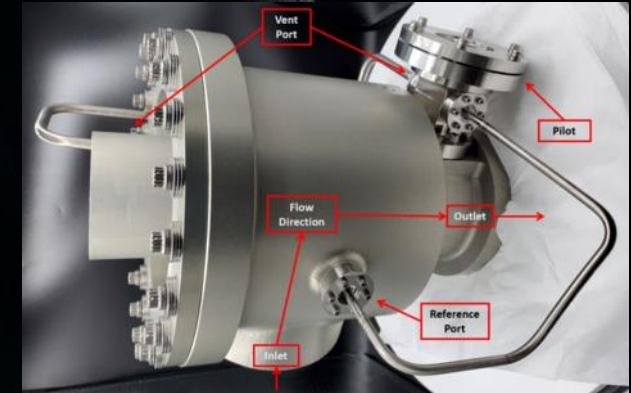
How do we get from today…

… to here?

Propulsion Industry Collaboration

Working together to develop key technologies and analyze difficult technical challenges to ensure successful lunar exploration missions

Engine Systems and RCS

- Turbomachinery and Combustion Devices expertise sharing
- Transient and steady state engine performance modeling
- Plume Surface Interaction (PSI) lessons learned and modeling assistance
- Thrust Vector Control (TVC) verification and certification lessons learned
- Reaction Control Systems (RCS) design, development, and test lessons learned

Cryogenic Fluid Management and Prop Transfer

- Cryogenic valve leakage analysis and testing, and low leakage valve design
- Thermal analysis of cryogenic propulsion systems
- Lessons learned from previous CFM projects at MSFC, GRC, and KSC
- CFM modeling leveraging extensive NASA experience and expertise
- Models of propellant transfer operations
- STMD CFM Portfolio Projects – Tipping Point flight tests & cryocooler development

NASA Internal Low Leakage Relief Valve (LLRV) Development Article
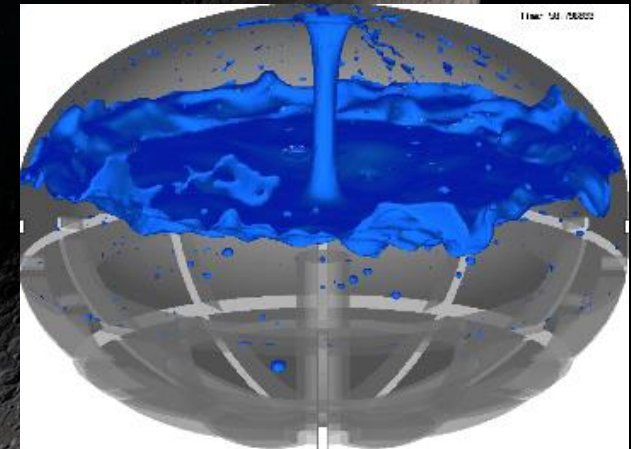
NASA MSFC ER42 CFD Simulation of Tank Slosh

HLS Propulsion Insight

Leveraging the <u>best</u> of NASA's propulsion and fluids technical community to <u>understand</u> Commercial Provider designs and processes and <u>inform</u> Program stakeholders

**Starts with a great team—led by MSFC with support across NASA centers**

- Deeply technical and disciplined team of engineers committed to the lunar mission

Focused insight justified by risk to <u>understand</u> provider designs

- Use risk-based analysis to justify deeper insight in targeted areas
- e.g., Engines, CFM

Use the understanding to <u>inform</u> the Program by:

- Providing expert propulsion insight and analysis to support Program Management (PM) and Technical Authority (TA) risk assessments and real-time mission support
- Providing expert propulsion design, certification, and flight hardware reviews to support Design Certification and Certification of Flight Readiness (COFR)
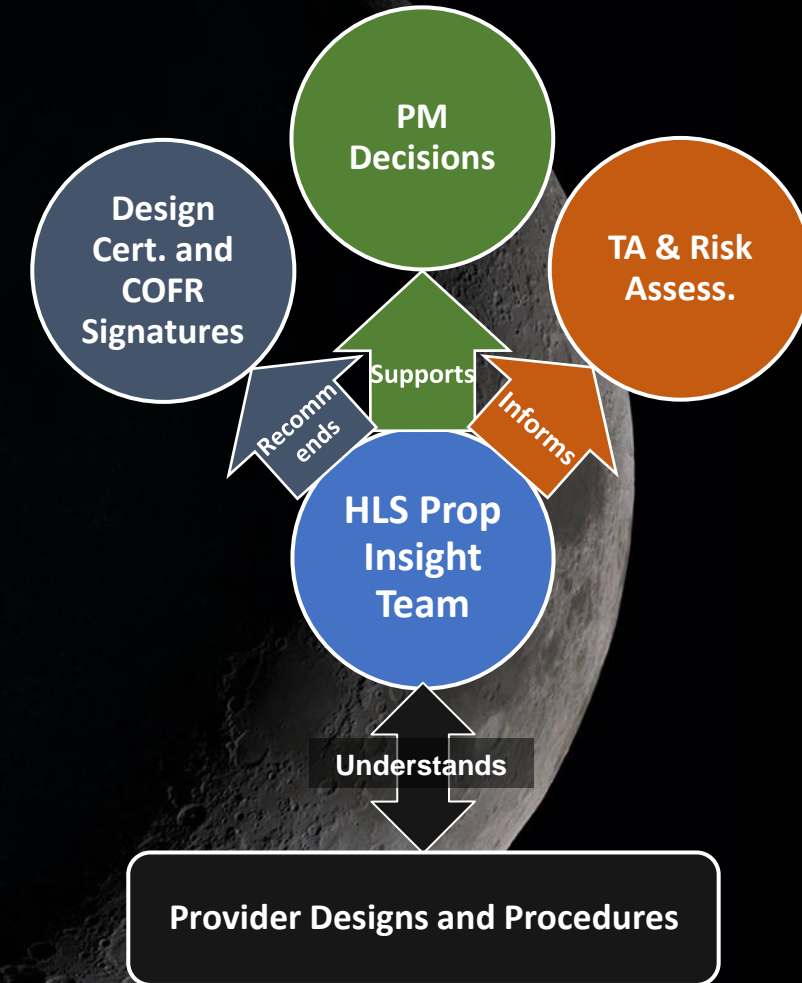
To summarize, NASA has:

- **Goals** – land on the Moon and stay

- **Partners** – U.S. industry designing and building vehicles

- **Methods** – insight and collaboration with partner operation

- **People** – deep technical bench committed to the lunar mission

- **Capabilities** – extensive manufacturing, test, and analysis
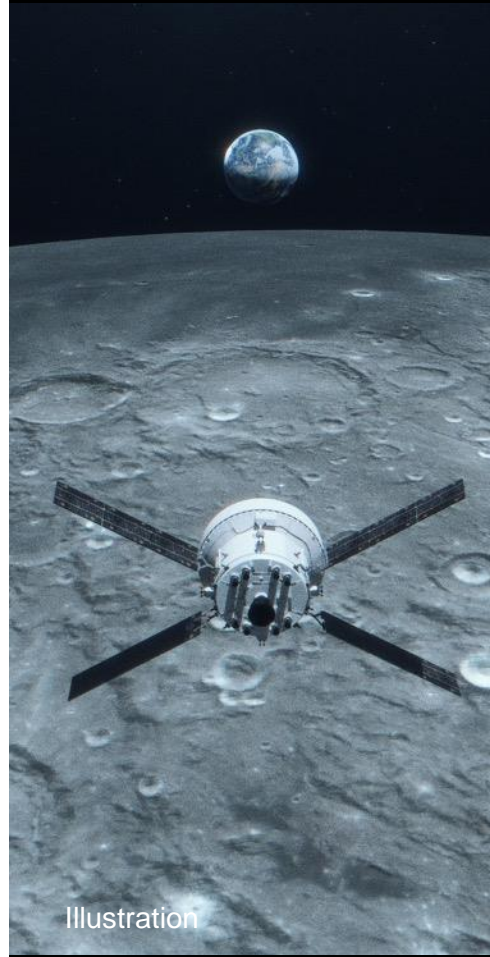
What's next?

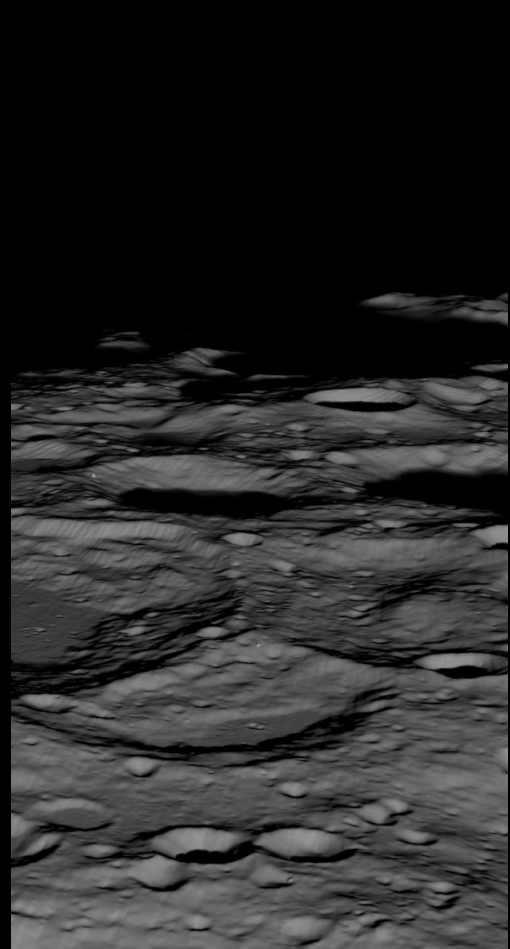| Artemis I	Artemis II	Artemis III	Artemis IV	Artemis V
Uncrewed flight test **COMPLETE**	*Crewed flight test*	*Crewed surface expedition*	*Gateway assembly, crewed sustaining lander expedition*	*Crewed mobile surface exploration, Gateway expansion*
SLS, Orion, EGS	SLS, Orion, EGS	SLS, Orion, EGS, HLS, EHP	SLS, Orion, EGS, HLS, EHP, Gateway *(PPE/HALO, I-HAB)*	SLS, Orion, EGS, HLS, EHP, LTV, Gateway *(ESPRIT, Canadarm3)*
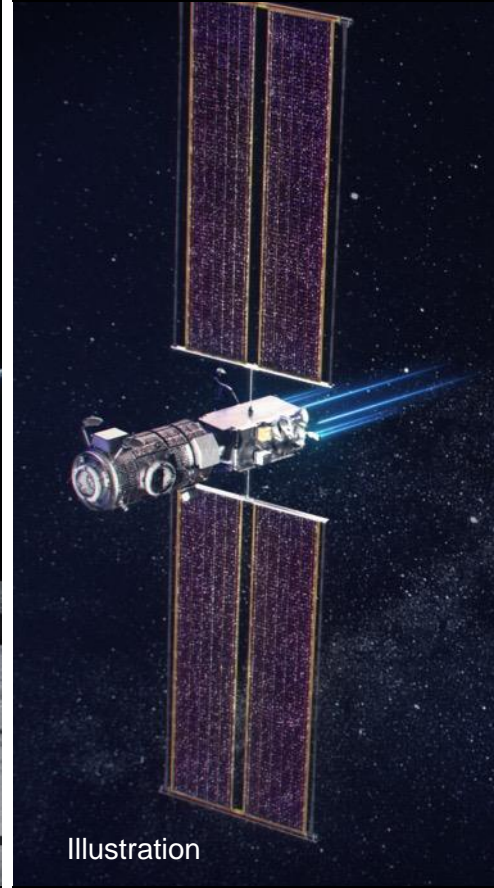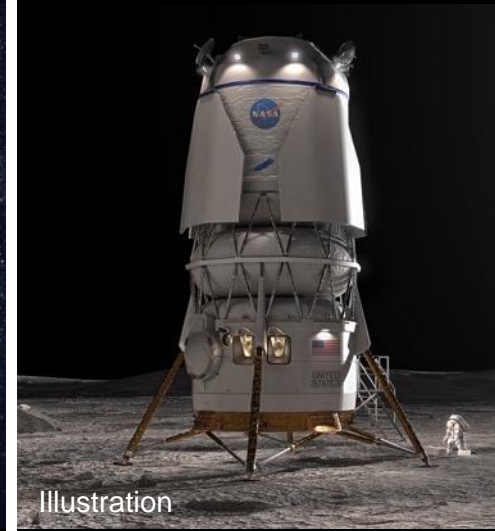
HLS Uncrewed Demo
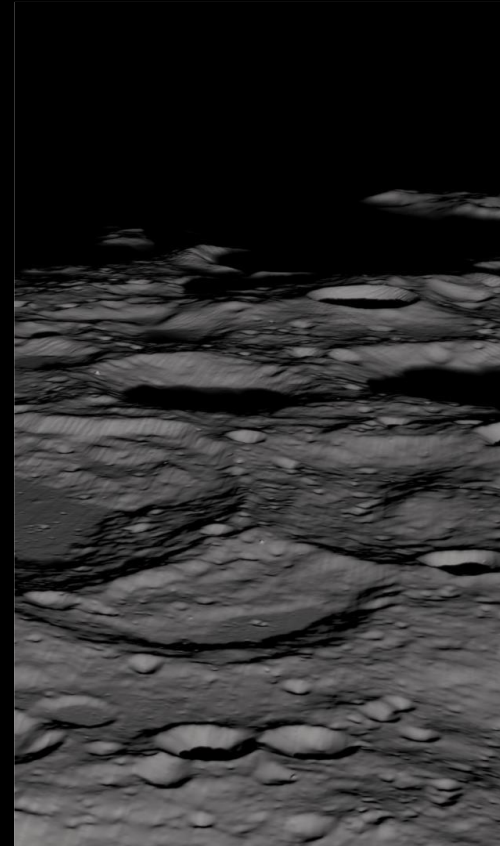*SpaceX Starship*

Artemis III
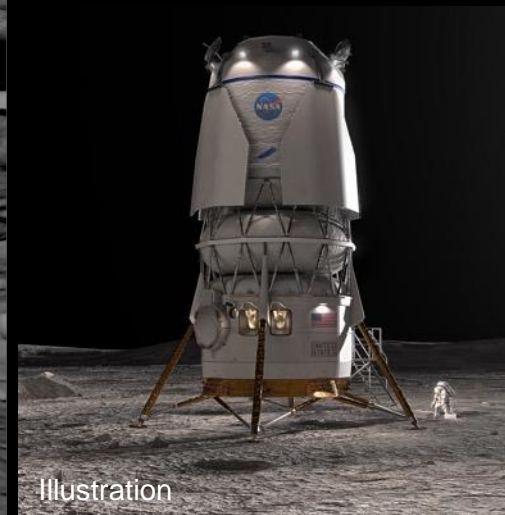*SpaceX Starship*

Artemis IV
SpaceX Starship

HLS Uncrewed Demo
Blue Origin Blue Moon

Artemis V
Blue Origin Blue Moon

Illustration

Illustration

Illustration

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Questions?

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