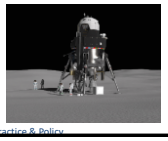
ASTR 4800 - Space Science: Practice & Policy

Today: Guest lecture by Tim Cichan & Dr. Christy Edwards on *New Exploration Missions with Orion , the Lunar Gateway & Artemis*

Next Class: Meet at Fiske Planetarium for student presentation on the ISS.

- Read about the ISS at the NASA website referenced on the class website for Oct. 6.



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NASA's New Exploration Missions

Tim Cichan
Lockheed Martin Space Exploration Architect

Dr. Christine Edwards
Cognitive Mission Manager Lead Systems Engineer

October 2022

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Commercial Civil Space

– Innovating in Space to Benefit Humanity

Communications Systems	Weather & Earth Science	Human Space Exploration	Lunar Exploration Campaign	Deep Space Exploration
Connecting People and Commerce: Netcentric, Secure, and Ubiquitous	Protecting People and the Planet by leveraging 21st century expertise and technology to secure our global future	Developing the core transport vehicle and infrastructure for Lunar & Mars missions	Exploring the frontier of human exploration and breaking boundaries to enable new commercial opportunities	Discover and Cultivate the Cosmos: Enable humanity's expansion into our solar system

Customers: NASA, NOAA, DARPA → COMMERCIAL → INTERNATIONAL

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Artemis Snapshot


SLS


Commercial Lunar Payload Services


The Gateway in Lunar Orbit


Orion


First Woman and First Person of Color to the Moon


Artemis Base Camp

Courtesy of NASA

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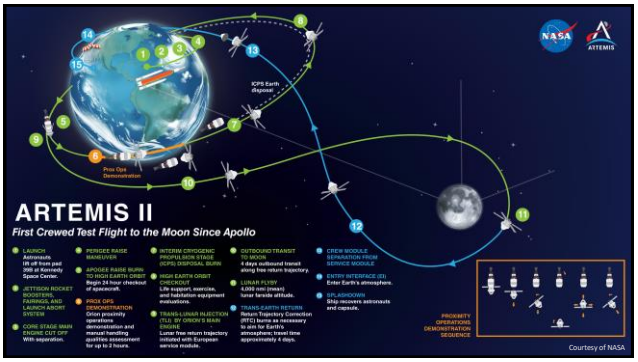

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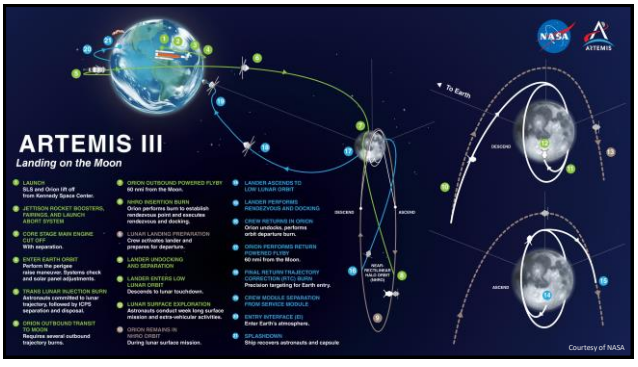
ARTEMIS III
Landing on the Moon
Courtesy of NASA

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Dynetics
A Leidos Company
SPACEX
NATIONAL TEAM
Courtesy of NASA

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ORION
TO THE MOON AND BEYOND

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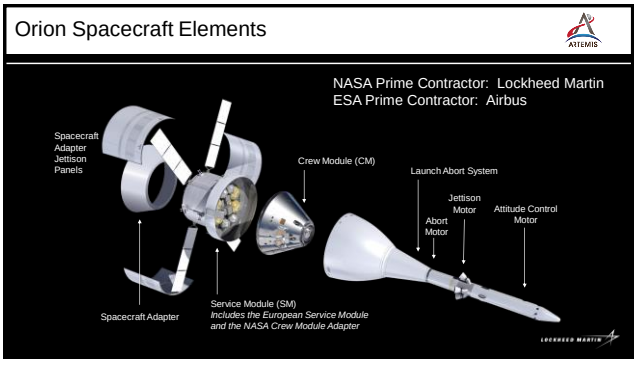
Orion Spacecraft Elements
NASA Prime Contractor: Lockheed Martin
ESA Prime Contractor: Airbus
Spacecraft Adapter Jettison Panels
Crew Module (CM)
Launch Abort System
Jettison Motor
Abort Motor
Attitude Control Motor
Spacecraft Adapter
Service Module (SM)
Includes the European Service Module and the NASA Crew Module Adapter

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Artemis I Crew Module
EXPLORE MOON to MARS

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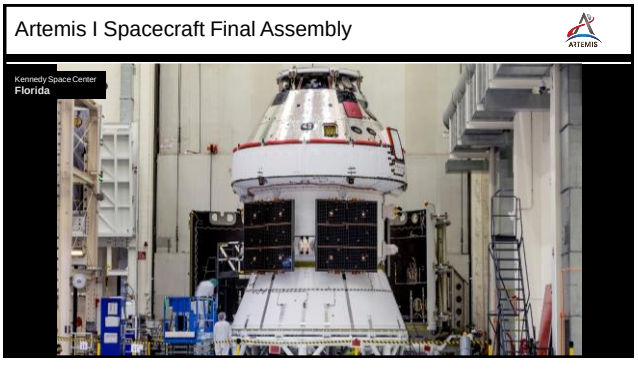
Artemis I Spacecraft Final Assembly
Kennedy Space Center
Florida

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Artemis I SLS Core Stage Prep for Lift/Mate

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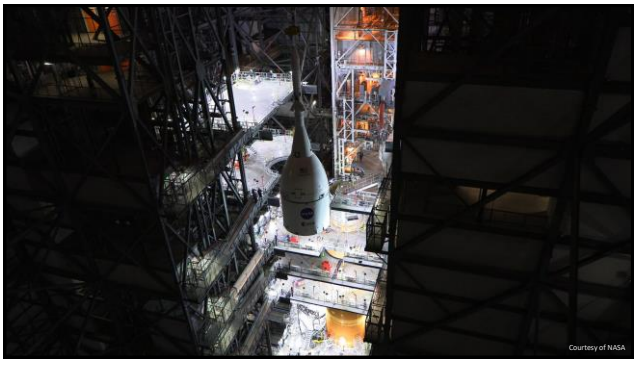

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Artemis 1 Stacking and Roll Out

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Artemis II Spacecraft Assembly

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Artemis III Spacecraft Assembly

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Artemis III Heat Shield

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The Artemis Accords

- Peaceful Purposes
- Transparency
- Interoperability
- Emergency Assistance
- Registration of Space Objects
- Release of Scientific Data
- Protecting Heritage
- Space Resources
- Deconfliction of Activities
- Orbital Debris and Spacecraft Disposal

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International Coordination

- Some missions will be conducted in close by locations (i.e. South Pole, orbit)
- Only Artemis Accords, signed by 21 countries, foresee coordination for lunar activities
- At UN level there is lack of Coordination Mechanisms, this could lead to harmful interference
- Need to create confidence and foster peaceful cooperation

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GLOBAL EXPERT GROUP on SUSTAINABLE LUNAR ACTIVITIES (GEGSLA)

- Multi stakeholders:
  - ❑ Space Agencies/Governments
  - ❑ Industries,
  - ❑ Academia,
  - ❑ Civil society
  - ❑ Public
- Composition, on a personal basis:
  - ❑ 37 Members from 20 countries
  - ❑ 195 Observers from 40 countries

GEGSLA document will be delivered to the UN Committee on the Peaceful Uses of Outer Space in 2023 as an input to their agenda item "Space Exploration and Innovation"

- Recommended Framework and Key Elements for Peaceful, and Sustainable Lunar Activities document, it includes:
  - ❑ Definition of key terms
  - ❑ International legal norms for lunar activities
  - ❑ Coordination and Management
  - ❑ Information sharing
  - ❑ Safe Operations and lunar environmental protection
  - ❑ Interoperability
  - ❑ Responsible governance
  - ❑ Benefits for Humanity
  - ❑ Sustained lunar economy
  - ❑ Human interactions

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WHAT DO WE MEAN BY SUSTAINABILITY?

Effective: The system must do what it is intended to do, and not do what it was intended to not do – including the minimization of unintended negative consequences

Efficient: The system must be designed to minimize use of input resources required to accomplish system requirements

Resilient: The system must be robust (continue to work well over a wide range of non-ideal circumstances), antifragile (system actively responds to stressors and is not degraded by low probability events), and adaptive (system has the capacity to learn with increased execution exposure to allow for continued operations)

"The long-term sustainability of outer space activities is defined as the ability to maintain the conduct of space activities indefinitely into the future in a manner that realizes the objectives of equitable access to the benefits of the exploration and use of outer space for peaceful purposes, in order to meet the needs of the present generations while preserving the outer space environment for future generations." **- UN Policy on Space Sustainability**

Sustainability **is not an endpoint – it is a multivariate goal framework in which a system's / system-of-system's *staying-power* can be optimized**

** Image Courtesy of NASA*

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FINANCIAL & POLITICAL CONSIDERATIONS

- **Financial sustainability references the ability to deploy a system within a realistic budget and with funding sources that are highly likely to continue to be available**
- We are at the beginning of the technology maturation and early systems design phase to enable sustained human presence on the moon. Largely, the cost of these systems is not yet supported by a commercial space economy, and economic engines to drive that effort forward do not yet exist
- While driving to low predicted recurring costs is important, system-of-systems architectures designed to transition to future ecosystems and infrastructure will drive the market size. This minimizes transition complexity, fosters competition, enables niche innovation, and ultimately drives down costs

Government Funded Program Executions
↓
State Subsidized Technology Development
↓
Public-Private Partnerships
↓
Establishment of Commercial Enterprises
↓
Reduction in Capital Barrier to Entry

Investment in economic engines to generate the cislunar / exploration economy represents the most effective way to drive down costs & reduce the capital barrier to entry

- **Policy sustainability references how a system supports the long-term interests of a governing body, broadly and consistently, over time, while enabling meaningful discourse and arbitration on the evolution of those policies as lessons are learned**
- Key Topics of Consideration:
  - Oversight & regulation of public, private, or public-private executions that limits the pace of human exploration campaign vs equitable distribution of finite non-terrestrial resources and their economic gains
  - Arbitration of near-term vs future needs - addressing the human tendency to disproportionately favor present needs at the expense of future needs
  - Consensus on missions that represent low-probability existential threats
  - Credible policy accountability to mitigate lone actors executing in their own short-term interests with limited risk adjudication that impacts long-term sustainable systems and infrastructure
  - **Tragedy of the Commons:** a situation in which individual actors, who have open access to a resource unconstrained by shared structures or formal rules that govern access and use, act independently according to their own self-interest, contrary to the common good of all users, cause depletion of the resource through their uncoordinated actions

If we are to succeed in creating and maintaining long-term sustaining systems, we must first ensure that we avoid events that set us on a path toward the tragedy of the commons

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ADOPTION OF OSA / MOSA PRINCIPLES

Open Systems Architecture (OSA)

1. Employing architectures that incorporate appropriate considerations for **reconfigurability, portability, maintainability, vendor independence, technology insertion, reusability, scalability, interoperability, upgradeability, and long-term supportability**
2. Modular designs based on standards, with **loose coupling and high cohesion**, to allow for independent component acquisition
3. Enterprise investment strategies that **maximize reuse** of proven hardware system designs
4. Transformation of the life cycle sustainment strategies for software intensive systems through **technology insertion** and **software product upgrade**
5. Lower development risk through **transparency of system designs**, continuous design disclosure, and [Governing bodies], academia, & industry reviews
6. **Strategic use of data rights** to ensure a level competitive playing field and access to alternative solutions and sources, across the life cycle

Modular Open Systems Approach (MOSA)

1. **Establish an Enabling Environment** - developing an understanding of technology development, produce market availability, business support strategies, etc
2. **Employ Modular Designs** - ensuring that subsystems/assemblies/components efficiently isolate their required functionality during the design process to facilitate modification, upgrades, replacement, and maintenance
3. **Design Key Interfaces** – prioritizing interfaces based on mission criticality, to better support execution and focused assessments on technology stability, module reliability, etc
4. **Use Open Standards** – increasing transparency to maximize competition, bounding the problem, and facilitating compatibility, communication efficiency, interconnection, and interchangeability
5. **Certify Conformances** – providing prepared validation and verification mechanisms to confirm plug-and-play interface accommodation compliance

Executing OSA/MOSA principles enhances competition, innovation, facilitates technology growth & refresh, enables cost avoidance, and improves both integration & interoperability across different vendors throughout the system lifecycle

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INDUSTRIAL ECOLOGY

- **Industrial Ecology:** A field of study focused on the stages of the production of goods and services from a point of view of nature, trying to mimic a natural system by conserving and reusing resources, as well as avoiding long-term depletion of available resources
- A core tenant of industrial ecology is an emphasis on utilizing the output waste of one system as a readily available input resource to a separate system
  - System architecture efficiencies can be increased by transitioning from open-loop processing to increasing closed loop resource utilization
- **Key Topics of Consideration:**
  - High cohesion vs self-sufficiency
  - Discussion of the execution risk posture with respect to resource availability
  - Time span and frequency of expected resource needs
  - Understanding amount of work a particular system deployment changes over time with respect to abundance / scarcity / production efficiency of a particular resource
  - Relative probabilities of unintended consequences
  - Planning for servicing, maintenance, and cannibalization

In-Situ Resource Utilization (ISRU)

- Increasing the ***staying-power*** of non-terrestrial systems is directly impacted by the degree of ***reliance*** on external terrestrial infrastructure
- Systems that deploy ISRU infrastructure and transition to the use of those local resources **increase the resilience of that system**

Adopting industrial ecology design principles can support sustainable systems architectures by enabling improvements to system efficiency and resiliency

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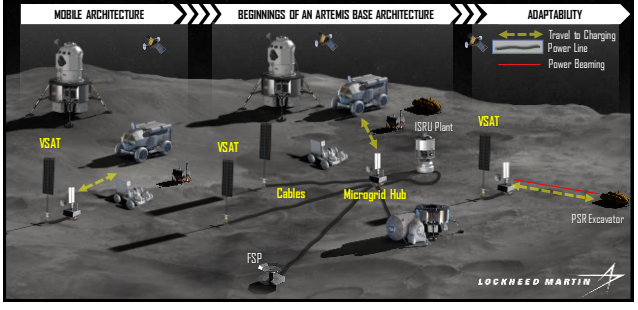
LUNAR SYSTEMS & INFRASTRUCTURE



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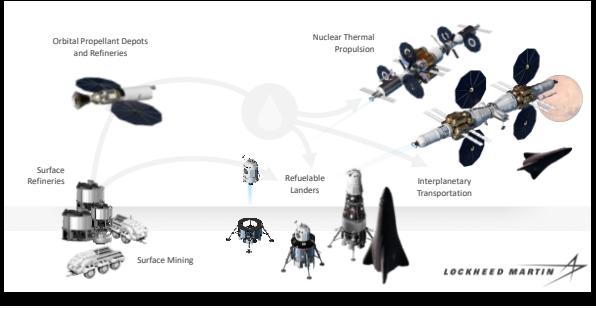
LUNAR SYSTEMS SUPPORTING MARTIAN EXPLORATION



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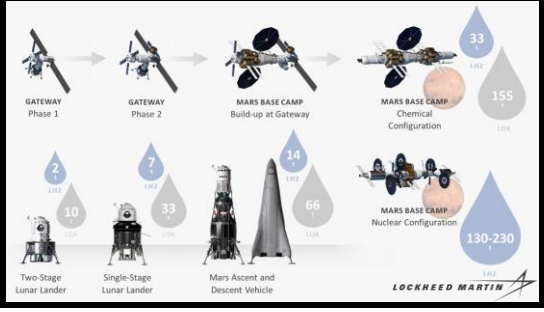
MARS SYSTEMS PROVIDING DEMAND FOR A LUNAR ECONOMY



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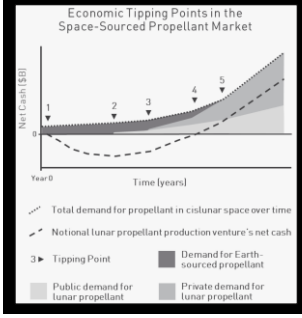
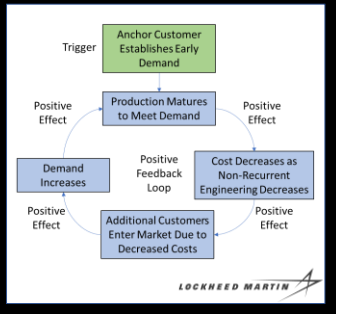
SUSTAINABILITY FOCUSED TIPPING POINTS





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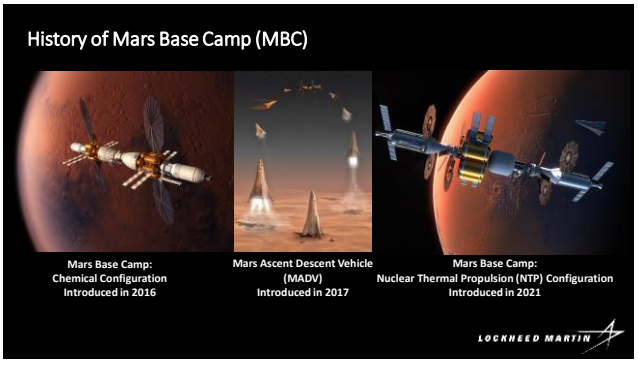

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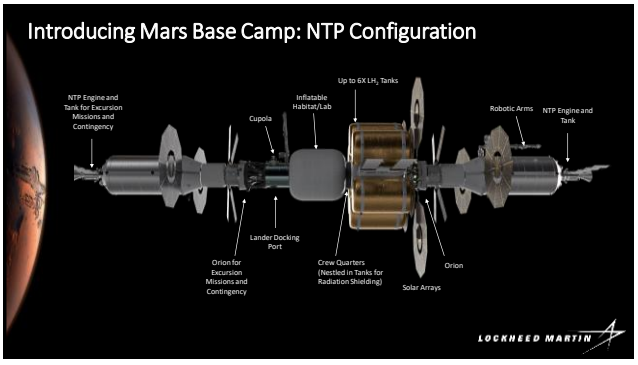

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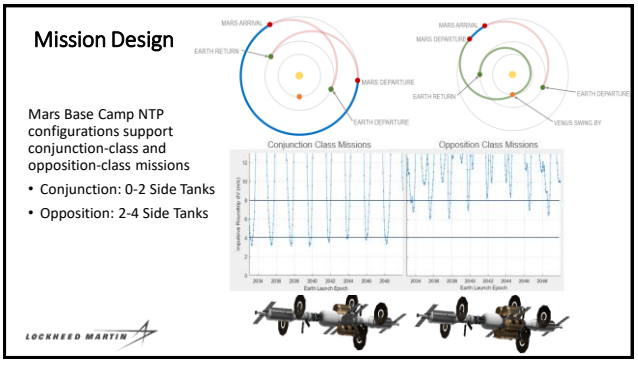

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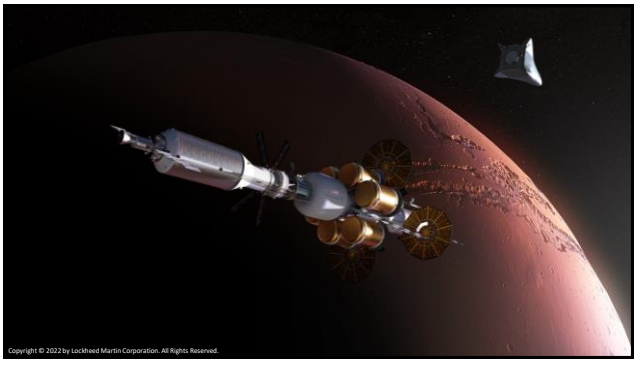

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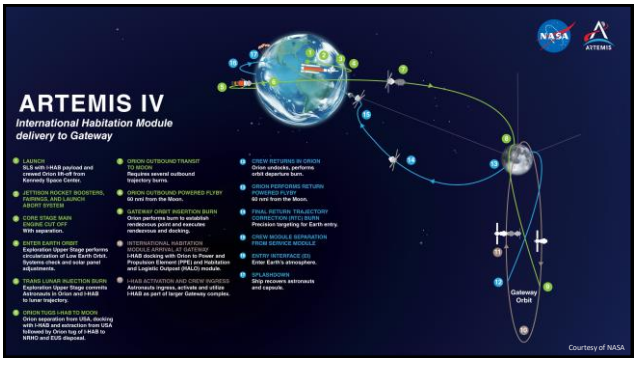

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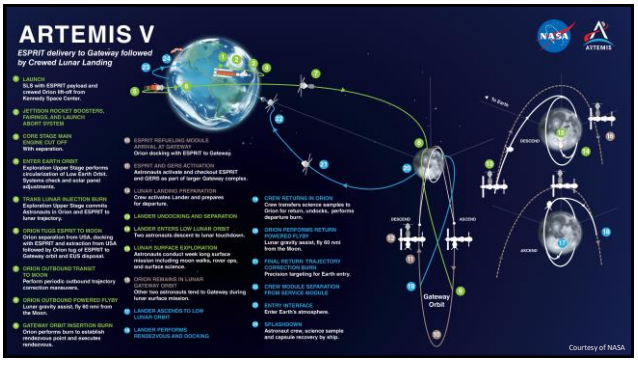

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