America's Ride to Space

The CisLunar Marketplace

Working as a Community Towards a Brighter Future for All

Dan Collins
Chief Operating Officer
United Launch Alliance

6 April 2017

Agenda

- Introduction – Dan Collins
- Roadmap – David Kornuta
- Resources – James Orsulak
- Transportation – Dr. Melissa Sampson
- Human Space – Dr. Steven Jolly
- Space Energy – Gary Barnhard
- Manufacturing – Justin Kugler

Introduction

- CisLunar 1000 is the vision of a sustainable economy that can support 1000 people living and working within the space between Earth and the Moon.
- United Launch Alliance has hosted several workshops with key players from the space community to identify opportunities and barriers to developing CisLunar space
- These workshops have led to the formation of the CisLunar Marketplace: a forum in which contributors to future space development can discuss strategies to overcome the obstacles of expanding the space economy and sphere of human influence
- The following data has been collected and compiled from the last workshop of the CisLunar Marketplace

The CisLunar Marketplace

- 100 Year Starship
- 490 Bio Tech Inc
- Accion Systems
- ACME Advanced Materials, Inc
- Aerospace Medical Association
- Agile Aero
- AIAA
- AIAA Rocky Mountain Sector
- Air Force College
- Alpha Space
- ALS (Adaptive Launch Solutions)
- Andrew Aldrin
- Angelus Funding
- Arconic
- Asia Pacific Aerospace Consultants
- Assn of Manufacturing Technology
- Astrobotics
- Axiom
- AxoSim Technologies
- Ball Aerospace
- Bank of America Merrill Lynch
- Barclays
- Bessemer Venture Partners
- Bigelow
- BioSpace Experiments, Inc.
- Black Sky
- Blue Origin
- Boeing
- Buzz Aldrin Space
- Caelus Partners
- CalTech
- CASI
- Chandah Space Technologies
- Coalition for Deep Space Exploration
- CO Office of Economic Dev't & Int'l Trade
- Colorado School of Mines
- Colorado University Boulder
- Commercial Space Flight Federation
- Deep Space Industries
- Deep Space Systems
- Deltion Innovations
- DexMat Inc
- Draper Laboratory
- Edge of Space Partner
- Effective Space
- Eli Lilly and Company
- Embry Riddle Aeronautical Univ.
- EOS of North America, Inc.
- EWI
- Excaliber Almaz
- FAA/AST
- Family Office Venture Capital
- FedEx
- Fiber Materials Inc
- Final Frontier Design
- Finance Technology Leverage
- Florida Institute of Technology
- FOMS Inc
- Fort Wayne Metals
- GE Oil & Gas
- GHO Ventures, LLC
- Google
- Greenfield Resources
- Heinlein Prize Trust
- Henry Ford Health System
- Houston Angel Network
- Humanity Innovation Labs
- ID Global Partners
- Immortal Data Incorporated
- Innovation Labs
- Intuitive Machines
- Iridium
- iSpace
- JACQ Technologies
- JesTech
- Jet Propulsion Laboratory
- Kelso Aerospace
- Little Prairie Services
- Lockheed Martin
- Lunar and Planetary Institute
- Made In Space
- Mankins Space Technology
- ManSat
- Mars Interstellar
- Masten Space Systems
- MD Anderson Cancer Center
- Merck Research Laboratories
- Metro Denver Econ. Dev't Corp.
- micro-gRx
- MOOG broad Reach
- Moon Express
- Nano Racks
- NASA Ames
- NASA HQ
- NASA Johnson Space Center
- NASA Marshall
- NASA STMD
- National Space Biomedical Research Institute
- National Space Society
- Naval Research Labs
- Near Earth LLC
- New Mexico State University
- NY Center for Space Entrepreneurship
- NewSpace NYC
- Northrop Grumman
- Oceaneering
- Oceanit
- Offworld Consortium
- Offworld Industries
- Orbital ATK
- OSD & Virginia Spaceflight Authority
- OSD/NA
- Perella Weinberg Partners
- Planet Labs
- Planetary Resources
- PoliSpace
- Poulos Air & Space
- Purdue University
- Quilty Analytics
- Rice Univ. Space Institute
- RRE Ventures
- Satellite Applications Catapult
- Schafer Corporation
- Secure World Foundation
- Shakelton Energy
- Shell Exploration and Production Company
- Sierra Nevada
- Silicon Valley Space Center
- SouthWest Analytic Network, Inc.
- Space Angels
- Space Florida
- Space Foundation
- Space Frontier Foundation
- Space Mining Coalition
- Space Policy
- Space Systems Loral
- Space Tourism Society
- SpaceCom
- Spacepharma
- Surrey Satellite Technology
- Tau Zero Foundation
- Tethers Unlimited/Spiderfab
- TransAstra
- TYVAK
- United Launch Alliance
- University of Houston
- Urthcast
- Virgin Galactic
- Vulcan Aerospace
- Xtraordinary Innovative Space Partnerships, Inc. - XISP-Inc.

America's Ride to Space

The CisLunar Marketplace

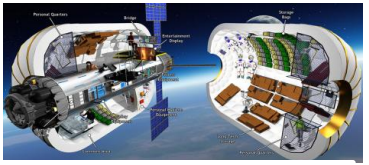
Roadmap

David Kornuta
CisLunar Project Lead Advanced Programs
United Launch Alliance

6 April 2017

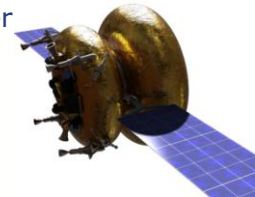
Today to 2022: Foundations

- Improved Access to Space
  - Decreasing launch costs
  - Commercial utilization of ISS
  - Human-rated commercial transportation
  - First commercial LEO habitat
  - Development of rapid recovery vehicle
- Prospecting in the Neighborhood
  - Near Earth Object (NEO) survey
  - Lunar polar region exploration
    - Sampling of lunar ice/resources
- Technology Demonstration/ Development
  - Space-to-Space/ground Power Beaming
  - Manufacturing ZBLAN & SiC
  - On-orbit additive manufacturing
  - Lunar polar resource extraction



Bigelow B330

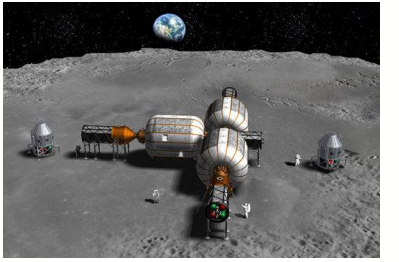
Sierra Nevada Dream Chaser



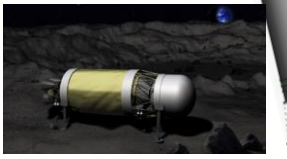
Planetary Resources Prospector

2022 to 2027: The Tipping Point

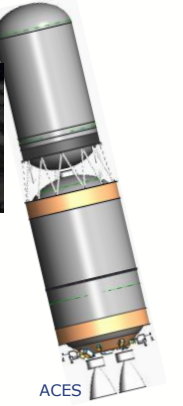
- Infrastructure Development
  - Commercial/government CisLunar outpost
  - Dedicated orbital manufacturing facilities
  - Orbital propellant refueling tech demo
  - Commercial lunar refueling infrastructure
  - GEO solar power satellite demo
  - ACES/XEUS vehicles deployed
- Enabled Capabilities
  - Deep space astronaut training and improved lunar studies
  - Recycling orbital debris and in-space hardware manufacturing
  - On orbit fuel and transfer capability
  - Lunar resource capture and processing demonstration
  - Initial space solar power beaming operation
  - Refuelable CisLunar transportation system established
  - Established L1 staging hub for Earth/Moon Transit



Bigelow Lunar Outpost



XEUS Lunar Lander



ACES

2027 to 2032: Space Industrial Revolution

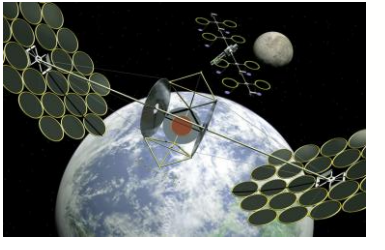
- Enabled Industries
  - Commercial crops on orbit
  - Space solar power for Earth grid, lunar base and space manufacturing
  - Lunar propellant production
  - NEO mining missions
  - In-space resource utilization
  - Lunar manufacturing facilities
  - Space tourism beyond LEO
  - Robotic servicing of satellites
- Sustained Expansion
  - Commercial lunar base becomes economically viable
  - Increasing space solar power terrestrial and space customers
  - Manufacturing and space resource utilization established
  - CisLunar trade routes established

https://spaceflight.nasa.gov/gallery/images/exploration/lunarexploration/html/s83_28324.html

2032 to 2037: Safeguarding Our World

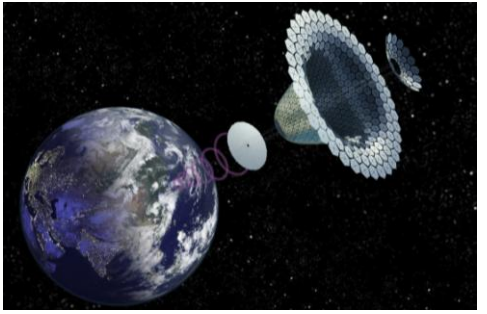
- Clean, Affordable Energy
  - Space solar power beyond 2 GW capability
  - Large scale in-space solar plant manufacturing
  - All terrestrial and space markets impacted by space solar power
- Access to Limitless Resources
  - Resource production at industrial scale
  - Large scale lunar propellant batch
  - Commercial asteroid mining
  - Lunar mining operations
  - Space supports substantial number of humans

https://er.jsc.nasa.gov/seh/sei52.GIF



https://science.ksc.nasa.gov/shuttle/nexgen/Nexgen_Images/solar_power_satellite_concept.jpg

2037 and Beyond: New Era of Exploration



Space Solar Power (Mankins)

https://www.nasa.gov/sites/default/files/thumbnails/image/nasa-mars-art-manned-mission.jpg

- CisLunar Stepping Stone
  - Propellant staging for Mars missions
  - Greater than 10 GW space solar powered infrastructure
  - Manufacturing capability established beyond CisLunar space
  - Mars mission staging node established in CisLunar pace

America's Ride to Space

Conclusion

- First time in history that this vision is within grasp
- Sustainability based on viable commerce
- No single entity can make this happen
- By working together today, we secure a better future for all

CISLUNAR MARKETPLACE

RESOURCE REPORT
33rd Annual Space Symposium

James Orsulak, Planetary Resources
james@planetaryresources.com

VOLATILES + ENERGY

Water

- Life Support
- Agriculture
- Shielding

Propellant

- Hydrogen
- Oxygen
- Methane

Sunlight + Energy Storage

Helium-3

STRUCTURES + METALS

Structures

- Regolith
- Metal
- Clay

Precious Metals

- Electronics
- Catalysts

VOLATILES + ENERGY

Water

Government Stations

Commercial Space Station

Propellant

Launch Providers

In-Space Services

Earth (SBSP) - Moon – Deep Space

Fusion Energy Providers

STRUCTURES + METALS

Structural

Moon Base

Orbital Megastructure

Government

Commercial

Precious Metal

Space Manufacturing

TIMELINE

Private Moon Missions | Resource Prospecting | Extraction Development | Scaled Delivery & Refining | Commercial Production

Resource Prospecting | Extraction Development | Scaled Delivery & Refining | Commercial Production

ISS Commercial Modules | Full Commercial: LEO-L1-Lunar Orbit | Lunar Surface / Orbital Hotel

Vulcan Development | ACES | Distributed Lift Capabilities

2016 2018 2020 2022 2024 2026 2028 2030 2032 2034 2036 2038 2040

CISLUNAR MARKETPLACE

RESOURCE REPORT
33rd Annual Space Symposium

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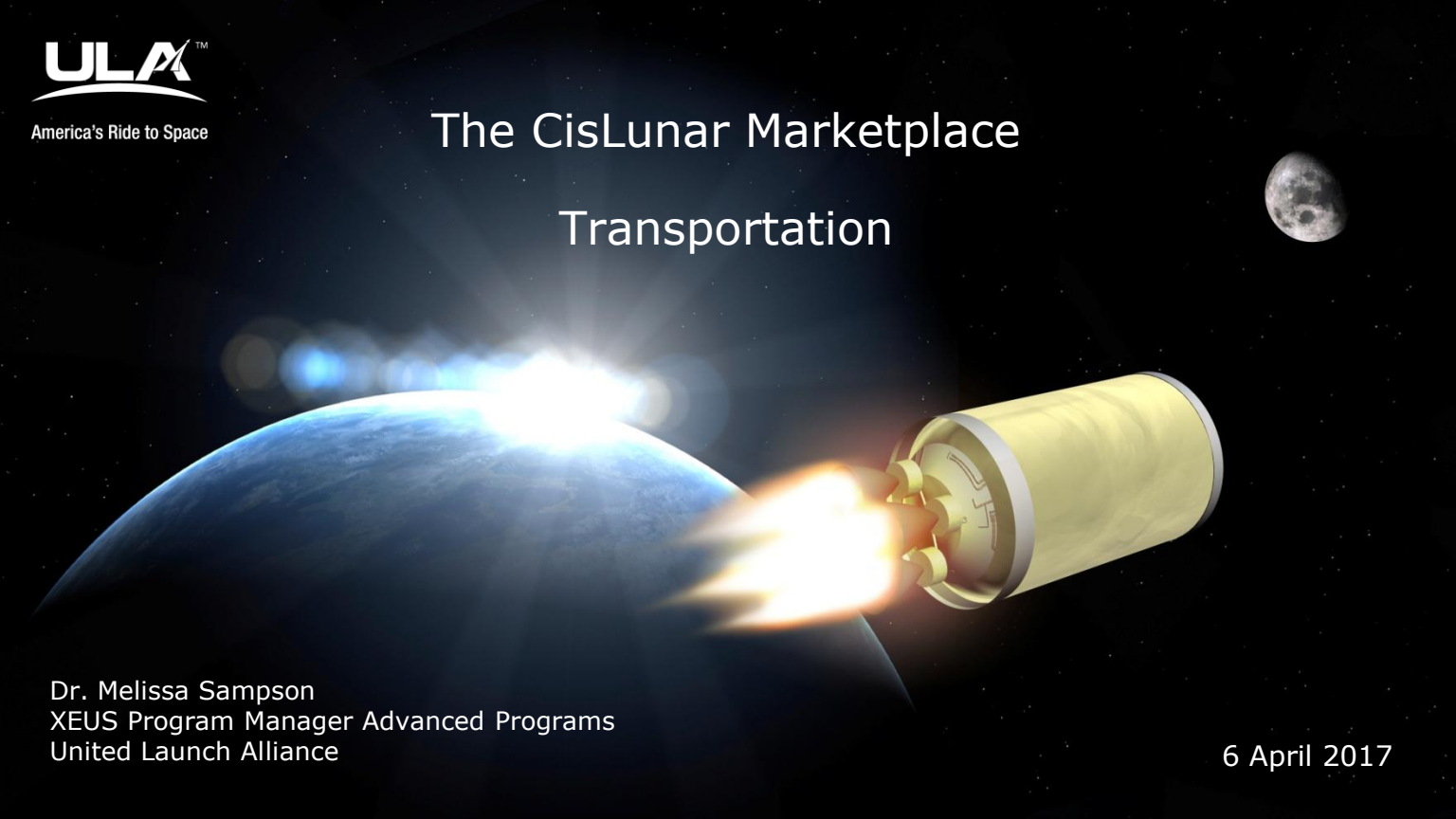
America's Ride to Space

The CisLunar Marketplace

Transportation



Dr. Melissa Sampson
XEUS Program Manager Advanced Programs
United Launch Alliance

6 April 2017

Session #1: Business Case

- Crucial connector for sustainable CisLunar marketplace
- Multiple products, customers and suppliers
  - Precious metals, payloads, people, manufacturing, in space rescue
  - Commercial, government, research, security, manufacturing
  - Propellant refueling, servicing, payload processing
- Investment arenas are cryo fuel management, landers, logistics and autonomy
- Infrastructure required for communication, travel corridors and standard interfaces
- Regulation may be needed for public safety, environmental, asset disposal, proximity, and insurance

Session #2: Roadmap

- 2019 Commercial human transportation
- 2021 Demonstrate LH2 & LO2 refinement on lunar surface
- 2021 Distributed Lift
- 2024 Standardize payload integration
- 2024 High launch rate
- 2025 Standardization of LH2/LO2 transfer
- 2027 LEO hub for water, oxygen, food, fuel, habitat
- 2029 Space Tourists beyond LEO
- 2031 Habitat at node 1 (lunar orbit)
- 2032 Operational space tug service
- 2035 Lunar hub for water, oxygen, food, fuel, habitat
- 2037 Habitat at node 2 (lunar surface)

Session #3: Intersections

- Miners and refiners
- Orbit debris salvage for manufacture
- $0.05-.1 solar power enabled by in space manufacturing and propellants
- Serve industry to support space tourism/living
- Infrastructure organizations pair with companies that use infrastructure
- Companies pair with resource groups
- Manufacturing companies strategically aligning core competencies to create holistic offerings
- Communications, remote sensing, and geology are a important enablers for this sector

America's Ride to Space

Discussion

THE CISLUNAR MARKETPLACE HUMAN SPACE

Dr. Steven Jolly
Director, Chief Engineer Civil Space
Lockheed Martin

6 April 2017

Session #1: Business Case

- Space habitats provide a wide variety of customers with services
  - US, foreign, and commercial astronaut training/medical research
  - Space manufacturers infrastructure and transportation node
  - Private citizens participation in space tourism
- Transportation opportunities to support human space
  - Ascent, decent, and lunar lander vehicles
  - Diversity of human rated launch vehicles supporting high launch rate
- Investment and R&D opportunities
  - Technology developed for in space survivability
  - In space resource utilization (in space repairs)
  - Propellant production/storage/transportation/extraction
- Major regulatory issues needing to be addressed
  - International standards of human space flight
  - Legislation on non-government humans in space
  - Questions of sovereignty in space

Session #2: Roadmap

- 2017 Space Station with commercial augmentation
- 2018 US man-rated transportation to LEO
- 2020 Commercially affordable human-rated transportation
- 2023 Lunar orbital outpost with crew of 4
- 2024 Commercial lunar depot
- 2026 Deployment of L1 outpost
- 2027 Commercial lunar base economically viable
- 2030 CisLunar entertainment and quality of life services
- 2031 In space resource utilization
- 2033 LEO settlement
- 2037 Lava tube habitation
- 2042 100's of people living in LEO and on the moon
- 2045 CisLunar healthcare
- 2047 Human mission to Mars

Session #3: Intersections

- Investment challenges because demand is currently potential
- Launch cost needs to decrease to close more business cases
- Need establishment of regulation to protect investments
- Increasing government/commercial business development
- Government may act as an anchor tenant
- Early government funding reduces risk to commercial investment
- Potential future customers and suppliers can share cost of technology development
- Create standard reference orbit for initial commercialization (28.1 vs 51.6 inclination)
- Identify the tipping point at which stable demand begins to enable the economy

DISCUSSION

Energy

Cislunar Market Place Workshop Report
Orchestrating the Technology Development, Demonstration, and Deployment (TD^3) Missions needed to foster electrical utilities for Cislunar space

Cislunar Workshop Presentation
33rd Annual Space Symposium
Colorado Springs, CO
April 6, 2017

Presenter:
Gary Pearce Barnhard, President & CEO
Xtraordinary Innovative Space Partnerships, Inc. (XISP-Inc)

gary.barnhard@xisp-inc.com
www.xisp-inc.com

Session 1 – Energy Key Considerations

Sectors ➔ There are no unilateral sector options

Products/Services ➔ Cislunar Electrical Utility that leverages the economies of scale

Customers ➔ Near term service degraded systems

➔ Mid term enhanced new systems

➔ Long term immortal systems infrastructure

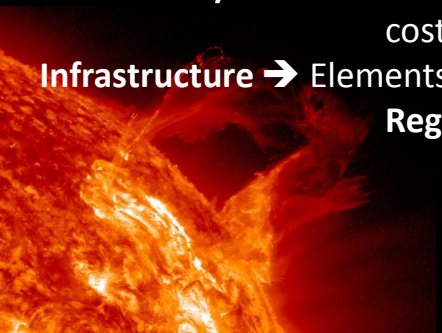
Supplier/Resources ➔ Trading the state-of-the-art vs. Satisfactory & Sufficient vs. optimal both a systems engineering and an economics challenge. Robotics and advanced automation are essential to meeting both challenges

Transportation ➔ Foster the market – government(s) role as NACA/IACA and first customers

Investment/R&D ➔ Matching investment tranches, staging, perceived & actual cost/schedule/technical risk, and returns

Infrastructure ➔ Elements, linkages, and operational procedures must be defined

Regulation ➔ Create a regulatory framework that is informed and driven by the confluence of interests necessary to grow the market



Session 2 – Energy TD^3 Milestones

Technology Development → Technology Demonstration → Technology Deployment

Space Solar Power

- **Space-to-Space**
- **Space-to-Luna**
- **Space-to-Earth**
- **Space-to-NEO**
- **Space In situ**
- **Luna-to-Luna**
- **Earth-to-Earth**

2018	**2020**	**2024**	**2029**	**2038**	**2047**
ISS TD^3	LEO TD^3	GEO TD^3	GEO TD^3	GEO TD^3	SSP's >
3-6 KW	~100 KW	~100 MW	~2 GW	10 GW	50 GW
SSP Testbed	SSP LEO Demo	SSP GEO Demo	Full SSP		
NASA/DOD	NASA/DOD/DOE	NASA/DOD/DOE	Electrical Utility		
Commercial	Commercial	Commercial	Commercial		
Co-orbiting Test	ComSats Recovery	ComSats Primary	→ $$$	→ $$$$	
Platform Model	Platform TD^3	Platform Ops	→ $$$	→ $$$$	
Spectrum Model	Spectrum Apply	Spectrum Allocation			
Orbit Slot Model	Orbit Slot Apply	Orbit Slot Allocation			
LP&L Seed/Angel	LP&L Series A/B/C	LP&L IPO	→ $$$	→ $$$$	
Co-orbiting Tests	Co-orbiting Labs	Co-orbiting Facilities	→ $$$	→ $$$$	
	Lunar Test(s)	Lunar Operations	→ $$$	→ $$$$	
	NEO Test(s)	Asteroidal Assay	→ $$$	→ $$$$	

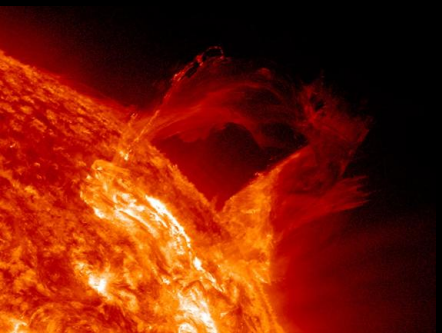
Session 3 – Energy Challenge Questions

Sectors ➔ Orchestration is essential in a cooperative+collaborative+competitive market.
Products/Services ➔ Cislunar Electrical Utility demand will scale with demonstrated supply.
Customers ➔ As soon as energy is available it will be used - Are customers really ready?
Supplier/Resources ➔ Establish standards, make economic sense and scale - reality check!?
➔ Robotics, advanced automation, and human involvement needed.
➔ System trades require iterative and recursive Technology Development, Demonstration, and Deployment (TD^3)
Transportation ➔ Match to mission requirements, be sustainable, and affordable to use.
Investment/R&D ➔ Each increment of investment needs to lead to actual customer use.
Infrastructure ➔ Elements, linkages, and operational procedures need definition & buy-in.
Regulation ➔ Consistent long term government commitment to foster the market and help mitigate perceived and actual cost, schedule, and technical risk.

What's Next?

Lunar Power & Light Company

an XISP-Inc Consortium



Don't wait for the future, help us build it!

www.xisp-inc.com

CisLunar Manufacturing

Justin Kugler, Made In Space

Key Themes & Discussions From the February 2017 CisLunar Workshop

Session #1
Table Discussions

- Two Dominant Sectors
  - 1) Build In Space For Space Applications
  - 2) Build In Space For Terrestrial Applications
- Potential Products
  - Biomedical Research in Microgravity
  - 3D Tissues In Space
  - New Alloys, Defect-Free Materials
  - Satellite Manufacturing In-Situ
  - Local Surface Infrastructure (Moon, Asteroids)
- Barriers
  - Raw Input Acquisition (Terrestrial Feedstock, Space Mining, Orbital Debris Recycling)
  - Resource Refining and Transportation
  - Need Ability to Buy Transportation “By the Drink”
  - Reliable, Affordable Earth Return
  - Limited Access to & Lifespan of ISS National Lab
  - Unclear Property Rights Regime in Space

Session #2
Evolution of CisLunar Manufacturing

Session #3
Collaboration Opportunities

- Key Intersections
  - Affordable Transportation & Energy Sources
  - Policy Framework Needed for Investor Confidence & Strategic Planning
- Big Gaps
  - NASA Transition Plan from LEO
  - Clear Picture of Quality & Quantity of Accessible Space Resources
  - Reliable Path for Quick Prototyping in LEO
- Supplier & Customer Collaborations
  - Standards, Regulatory Reform, Basic Research with Government Agencies
  - Co-Development on Infrastructure
  - Industry-Directed Application Development with National Labs
- B2B Opportunities
  - Specialization To Avoid Cannibalization
  - Teaming to Pitch Terrestrial Customers/Partners

Discussion