LEAG 2010
Fostering Commercial Partnerships: Transportation and Communications/Navigation

Peggy Slye

Futron Corporation

Futron Corporation • 7315 Wisconsin Avenue, Suite 900W • Bethesda, Maryland 20814
Phone 301-913-9372 • Fax 301-913-9475 • www.futron.com

Lunar Strategy

- NASA's cis-lunar activities will be most productive if they are developed in support of a specific program or portfolio based on analysis of broad market realities and potential outcomes

Market Understanding

- Scope of market
- Market segmentation schemes
- Broad market participants
- Financing / funding by segment
- Market drivers
- Market dynamics
- Key decision makers / influencers

Portfolio Options

Implications of Options

- Partnership opportunities / activities
- Innovative technology
- US space industry / industrial base
- Control of market (particularly relative to other countries)
- National security
- Budget / financial requirements

Other Issues / Considerations

- US and other Government Policies and Practices
- Corporate Structures and Practices (by segment)
- Technology and Innovation (best practices by segment)
- Technological Readiness (by segment)
- Investment and Spending Mechanisms / Timeframes
- Existing Agreements
- Current Partnering Programs

Lunar Strategy

- As NASA's priorities – as reflected in its budget – continue to shift, defining lunar policy becomes a moving target. To guide that effort, NASA needs to address four key questions:

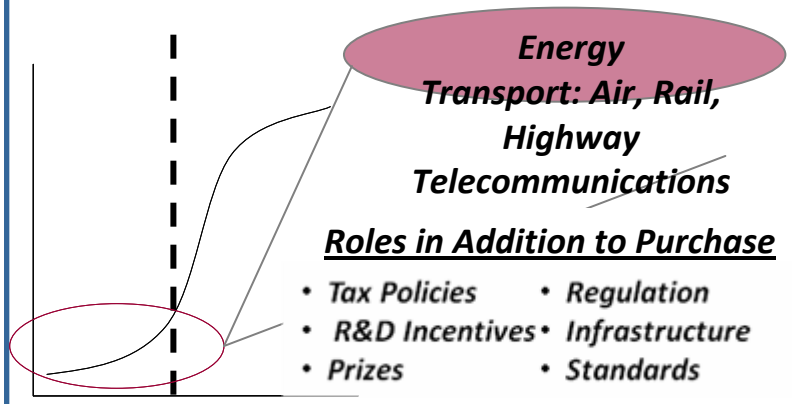
1 What is the role of the moon in NASA's big picture plan?	• Not a destination for its own sake?
	• Role in science, earth observation, exploration
	• Role as waypoint to deep space:
	  • Experimental conditions
	  • Logistical benefits
	  • Extraction / supply

2 What is the strategic value of the moon to US Government interests?	• Surveillance • Other countries / consortia • Military or national security interest in the moon
3 What lunar access does NASA need to protect for the long term?	• Property rights • Extractive resources • Security / back-up for other missions
4 What would be the impact of relinquishing a leadership role?	• Loss of intelligence • Influence over industry development • US dominance of space economy / market access for US companies

Lunar Strategy

Government's Role in Technology-Based Industry Development

Iterative Role in Technology Development: Example Sectors

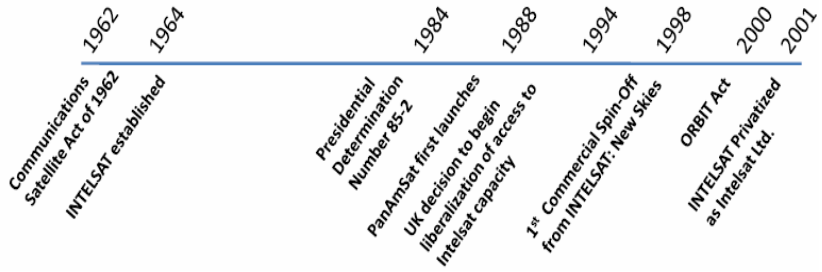


Roles in Addition to Purchase

- Tax Policies
- R&D Incentives
- Prizes
- Regulation
- Infrastructure
- Standards

Government Role	Air Transport	Highway Transport	Railways	Telecommunications	Energy
	Sector				
Funding Commitment		x	x	x	x
Quality/Safety Standards	x		x	x	x
Regulation	x	x	x	x	x
USG Intent to Purchase	x			x	x
Investment Incentives	x	x	x	x	x
Tax Policy			x	x	x
R&D Credits	x			x	x

Intelsat's Development



"In my judgment, a new Communications Satellite Act is required to provide an appropriate mechanism for dealing effectively with this subject--a subject which, by nature, is essentially private enterprise in character but of vital importance to both our national and international interests and policies." – John F. Kennedy

Role In Telecommunications Development

- *Early infrastructure support: purchase of land & installation of telephone wires*
- *Research and development funding: fiber optics*
- *Regulation and standards: FCC, oversight of Mergers and Acquisitions, Universal Access Mandate*
- *Government Commitment: National Rural Telecommunications Cooperative (NRTC), rural broad band initiative*
- *Tax Policy: Universal Service Fund*

Lunar Communications

Futron/ASRC Analysis for NASA 2008-2009

Results You Can Trust

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Objectives/Approach/Methodology

- Futron, working with ASRC, was asked to conduct a market assessment of the demand for lunar communications following two different approaches:
  - NASA conducts business as normal in the sense that it acquires or procures whatever capability it needs without pursuing any national or international strategy to promote commercial development
  - NASA collaborates with industry, other U.S. government agencies, and international parties to promote commercial development
- The assessment was based on use of several analytical tools, including a structured interview guide, market mapping, and competitive analysis techniques, to combine quantitative and qualitative feedback regarding commercial development of the lunar communications market

Lunar Communications – Key Markets

- Significant level of interest in commercialization of the lunar market is found among all industry segments
  - Public/private partnerships are widely seen as the most effective way to develop this market
  - Markets with highest potential are: scientific stations, base for energy generation and a post for preparation of missions to Mars
  - Middle range applications include: manufacturing, space tourism, mining, military outpost and a base for deep space exploration
  - Markets with lowest level of interest include: dumping site for hazardous waste and nuclear test site
- Projected revenues range from less than $1B to over $5B in the period 2013 – 2020, depending on the structure and funding of the initial market approaches, parallel commercial developments, and partnership synergies, and assumes cost-effective access to space
  - After 2020, the market may take off

Summary of Demand Issues

- Longer term, (2020-2025): high probability of manned missions means that a higher bandwidth network would be established, capable of supporting a link between lunar outposts and Earth with diverse broadband applications
- Short term, (2012-2020): any lunar communications network would likely be limited to low-bandwidth transfer capabilities supporting unmanned scientific and survey missions
  - Most likely uses for a lunar outpost would be as a research station or a waypost/refueling depot for a manned mission to Mars
  - Least likely uses for a lunar outpost were seen as a nuclear weapons testing site or hazardous waste dump
  - Respondents favored long-term contracts which create market stability
  - Pay-as-you-go, piecemeal pricing approaches to multiple partners or vendors were seen as the worst option for developing and funding such a network, potentially creating volatility, and viewed as suitable only for very mature markets

Lunar Communications: Alternate Market Models

NASA-Centered

- NASA acquires or procures whatever it needs without national or international partnerships
- Potential market for lunar communications and navigation capabilities
- Time horizon of 2011 through 2025

Collaborative Model

- NASA collaborates with industry, other US agencies, and/or international partners
- Potential market for lunar communications and navigation capabilities
- Time horizon of 2011 through 2025

Key Market Determinants

- Assumptions
- Industry segments
- Quantitative estimation
- Forecasting methodology
- Trend analysis and outlook
- Obstacles and risks
- Issues and recommendations

Recommendations for Action to Promote Activities for Lunar Communications

- For the “new space” companies: sustain already high level of interest with more industry days, offer prize mechanisms or other financial incentives, continue ongoing interactions
- For the satellite operators: initiate individual discussions, follow structured phased approach to preliminary projects to drive early revenues
- For the large integrators: build a solid business case using conservative assumptions and tailor some early projects for internal R&D investments
- For the international agencies: continue reaching out with joint missions
  - Build relationship starting with cooperation in scientific areas and later, leverage commercial developments

Lunar Transportation

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Lunar Transportation Business Model

- Futron, working with ASRC, built a business model for NASA to demonstrate how a hypothetical new company entering the lunar transportation market as a supplier might evolve. The model was built to address several objectives:
  - To determine, based on selected assumptions, what level of market demand would be necessary to support a commercial lunar transportation industry, and how much of that demand would have to come from NASA, assuming NASA's only role is as a customer
  - To initiate a dialog about appropriate cost and pricing / revenue assumptions within the space and financial communities by proposing starting values for those assumptions based on whatever data points are publicly available
  - To educate the entrepreneurial and financial communities about commercial lunar transportation business by offering a sample, highly generic financial model

Approach/Methodology

- The analysis was undertaken in two phases:
  - To explore the demand for commercial lunar transportation and
  - To build a business case for a hypothetical commercial company providing lunar transportation services.
- The model assumptions include:
  - The Moon is the final destination and that the commercial and international government sector are already working on competing technologies, funding plans, and customers to support transportation ventures
  - The model addresses demand for cargo transport only, and does not address the question of human lunar return. Moreover, it is hypothesized that the business model could be enriched through the offer of ancillary services, such as warehousing, or scheduling / clearinghouse, but the revenue potential of such activities is not incorporated into the current view.

Key Findings

- Based on the assumptions used in the model, the key model findings are:
  - As suggested in the Augustine Committee report, NASA's assurances regarding its demand will have a strong impact on the way the market develops, particularly with regard to pricing
  - NASA's commitment to market development through entering the market as a customer can represent a 44% swing in long-term pricing. A strong, market maker position on NASA's part could result in pricing 10% lower than baseline, whereas if NASA opts not to take a lead role, prices could be as much as 34% higher than baseline
    - For the purposes of this analysis, the bankable return is defined to mean a minimum 40% IRR within 7 years. This definition was developed from interviews conducted with the investor community in which they described a 40-50% return in a 5-7 year period as the target return.

Key Findings

- Lunar transportation is an economically feasible market, in which the private sector is prepared to participate
  - Capability and capital are both available, but not easy
  - The business model is feasible and offers attractive returns, subject to strict assumptions, including timing
  - Commercial players are already preparing to enter this market
  - International space agencies are ready to start working with commercial providers
- The private sector is waiting for NASA to signal its interest in commercial lunar transport
  - NASA's leadership is critical to market development
  - The business case works at either high or low levels of NASA demand, but companies need guidance
  - A multi-year, phased approach is required for funding and deployment

Key Findings

- Commercial lunar transportation is a low-cost way for NASA to accomplish multiple objectives
  - Supports positive image for NASA for proactively considering multiple options for key markets
  - Expands NASA's credibility relative to international collaboration and public-private partnerships
  - Early participation gives NASA the ability to influence how the market develops
  - A strong, market maker position on NASA's part could result in pricing 10% lower than baseline, whereas if NASA opts not to take a lead role, prices could be as much as 34% higher than baseline

Key Business Assumptions

Parameter	Range	Rationale / Sources
Total Missions, 2011-2021	18-24	Benchmarked against multiple sources
Target Cargo Capacity	40kg	Assumption based on shape of NASA demand
Years to achieve target cargo size	3-10	Scenario definitions
Capacity Utilization	100%	Ramp up of capacity accounts for demand conditions; all missions are now presumed to be fully subscribed
Price per kg (at target capacity)	$4.5-7 million/kg	Based on Astrobotic statement of price; adjusted to reflect competition and decline with volume
Direct Cost per Mission (at target capacity)	$100 million	Dr. Butler Hine, NASA Ames Research Center, "Small Spacecraft Systems Engineering & Integration", validated with Futron engineering analysis; assume cost per kg declines as capacity increases
SG&A Costs	$10-330 million	Includes Indirect Labor, Insurance, R&D, and Other; based on interviews
R&D	15% of Capex 60% capitalized	In line with commercial R&D cost structure
Capex (Yrs 1-5)	$300-500 million	Calculated based on cost per mission and number of missions
Market Share	100%	Assumption for future sensitivity testing

Summary of Alternate Scenario Results

	Baseline	Optimistic	Pessimistic
- Market Development -	• Attain 40 kg capacity in 5 yrs; 5% growth thereafter	• Attain 40 kg capacity in 3 yrs; 5% growth thereafter	• Attain 40 kg capacity in 10 yrs
- NASA Role -	Dominant player	Market maker	Periodic buyer
- Funding -	Private equity	Private equity Capital markets	Wealthy individuals / corporate coalitions
- Likely Players -	• SpaceX • GLXP companies • Established industry	• Established industry • Emerging space players	• ESA • Arianespace • Wealthy entrepreneurs
- Returns -	41% in 7 yrs	43% in 7 yrs	47% in *10 yrs*
- Pricing -	$6.0-5.0 m/kg	**$6.0-$4.5 m/kg**	**$6.0-7 m/kg**

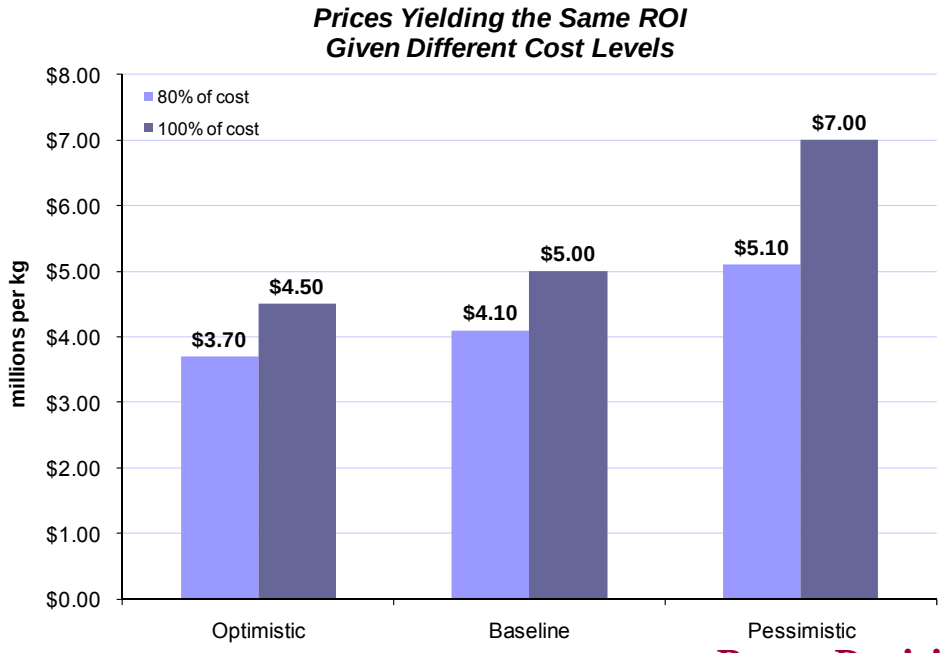
- All scenarios start out at 15 kg capacity with a starting price of $6.0 m/kg

Sensitivity Analysis

- Three different sensitivities were assessed:
  - Catastrophic loss
  - Cost efficiencies
  - Pricing
- *Catastrophic loss:* The possibility of a catastrophic loss at some point during the 10-year program is non-trivial
  - The model tests the impact of such a loss by assuming full costs and 0 revenue for the mission on which the loss occurs, and assumes that the catastrophic loss occurs in the first year of the enterprise
  - This loss reduces the 7-yr IRR from 41% to 14%
  - In order to reach the 40% IRR threshold in 7 years, prices for the years following the loss would need to be increased by approximately 22%.

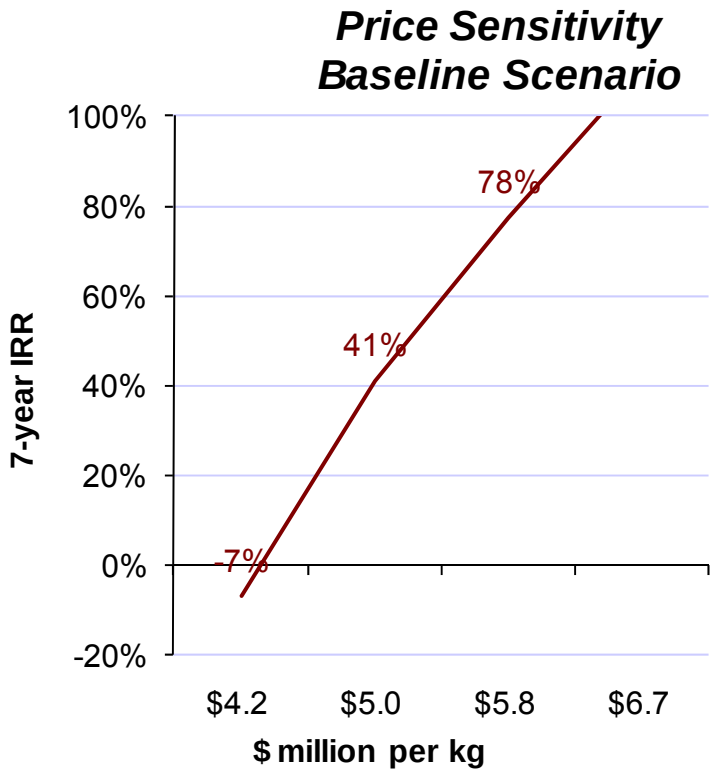
Sensitivity Analysis: Cost efficiencies

- If the commercial sector is able to achieve scale economies, then costs could be somewhat less than the assumptions made in the baseline model.
  - The model's sensitivity to a 20% cost reduction was tested, with the impact of lower costs on the price necessary to reach the 40% IRR shown below:



Sensitivity Analysis: Prices

- The baseline assumption sets target pricing at $5.0 m per kg, which would be the price once the commercial operator comes off of the 5 year start-up ramp, which is the period assumed to get up to a 40 kg capacity per mission, 2 missions/year, and $100m per mission cost
  - The IRRs associated with different target pricing within the $4.2-6.7 million per kg are shown here



Demand Analysis

- An independent market analysis was developed of the potential business opportunity from commercially provided lunar transportation and landing capability for the decade 2012-2021
  - Analysis focused on commercially-provided lunar data and lunar payload delivery for NASA and commercial, international, or other government agencies that may be conducting activities at the Moon.
- This analysis evaluated projected demand, in dollars, for lunar transportation services, specifically including:
  - Demand drivers and requirements of key stakeholder group
    - Frequency, certainty and length of the demand, identifiable risks to each of the listed demand characteristics
    - Assessment of the initial supply, organizational structure of the supply, and supply sources
    - Level of investment, return on investment, preferred investment timeframe and any key barriers to entry of the market from the perspective of a potential commercial supplier

Demand Framework: Market Segments

Demand Analysis: Supply-side Impact

- Many potential users are also potential suppliers of lunar transportation, including Google Lunar X-Prize (GLXP) participants which are also likely to demand related services, such as launch or communications

Indicative Supply Framework

Demand Summary

Buyer Type	Existing Space Program	Budget Size	Strategic Need	Purchase Criteria	Preferred Market Role	Customer?
NASA	✓	High	▪ Defined Programs ▪ Increased flexibility	▪ Meets defined standards / program requirements ▪ Cost efficiency ▪ Meets additional agency goals	▪ Market leader ▪ Independent ▪ Partner ▪ Potential customer	✓
Other Nations: Spacefaring	✓	Medium to High	▪ Identified lunar goals ▪ Specific program support	▪ Integration with existing programs ▪ Cost efficiency ▪ Extends technical capabilities	▪ Independent ▪ Partner	varies
Other Nations: Emerging Space	✓	Low to Medium	▪ Need to achieve position in next tier space race	▪ Cost/time efficiency ▪ Transfer new technical skills ▪ Integration with national and regional programs	▪ Strategic / economic buyer ▪ Commercial customer ▪ Consortia member ▪ Independent	✓
Other Nations: Aspiring Space		TBD	varies	▪ Meeting strategic goals ▪ No specific economic sensitivity	▪ Commercial customer	ad hoc
Other USG	✓	Varies	▪ Reliable, cost effective access to space	▪ Satisfy program requirements ▪ Meet standards ▪ Increased efficiency	▪ Independent ▪ Partner ▪ Potential commercial customer	✓
Commercial	✓	High	▪ Ongoing access to space	▪ Meet program needs ▪ Cost and time efficiency	▪ Commercial customer ▪ Bulk buyer ▪ Potential partner	✓
Academic	✓	Low to Medium	varies	▪ Meet program and financial requirements ▪ Maximum flexibility	▪ Commercial customer ▪ Limited partner	✓

Requirements to Engage Private Investment

- Venture capital markets will accept 30-40% internal rates of return for communications ventures but seek 40-50% for space-related ventures
  - Private equity has realized 20-25% for communications projects and seeks 30%+ for the higher risk space-related investmetns
  - Traditional time period for return on investment is 3-4 years, but for lunar transportation, a slightly longer time frame would be acceptable – 4-7 years; institutional investors will be the last to engage
- Investors' stated requirements for space investments short-term are:
  - A largely NASA-funded program, such as a lunar version of a COTS program, with strong NASA commitment over the start-up timeframe
  - Several "beta-successful" companies during the initial years of the program
  - Substantial revenue guarantees offered by NASA during the early years
  - Improve on successful government / industry programs
  - Multiple revenue streams