Google Lunar XPRIZE Market Study 2013

A Report to the XPRIZE Foundation

MEDIA SUMMARY

Prepared by

London Economics

October 2013

About London Economics

London Economics (LE) is a leading independent economic consultancy, headquartered in London, United Kingdom, with a dedicated team of professional economists specialised in the application of best practice economic and financial analysis to the space sector. As a firm, our reputation for independent analysis and client-driven, world-class and academically robust economic research has been built up over 25 years with more than 400 projects completed in the last 7 years.

We advise clients in both the public and private sectors on economic and financial analysis, policy development and evaluation, business strategy, and regulatory and competition policy. Our consultants are highly-qualified economists with experience in applying a wide variety of analytical techniques to assist our work, including cost-benefit analysis, multi-criteria analysis, policy simulation, scenario building, statistical analysis and mathematical modelling. We are also experienced in using a wide range of data collection techniques including literature reviews, survey questionnaires, interviews and focus groups.

Drawing on our solid understanding of the economics of space, expertise in economic analysis and best practice industry knowledge, our Aerospace team has extensive experience of providing independent analysis and innovative solutions to advise clients (both public and private) on the economic fundamentals, commercial potential of existing, developing and speculative market opportunities to reduce uncertainty and guide decision-makers in this most challenging of operating environments.

All consultants of our Aerospace team are highly-qualified economists with extensive experience in applying a wide variety of analytical techniques to the space sector, including:

- Insightful and accurate market analysis and demand forecasting;
- Analysis of industrial structure, strategy and competitive forces;
- New technology adoption modelling;
- Estimation of public utility benefits;
- Opportunity prioritisation and targeting to maximise exploitation of investment;
- Sophisticated statistical analysis (econometrics, regression);
- Economic and financial modelling, including: Cost-Benefit Analysis (CBA), cost effectiveness analysis, Value for Money (VfM), impact assessment, policy evaluation, business case development, cash flow and sustainability modelling.

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Acknowledgements

We would like to acknowledge the useful guidance and feedback provided by Andrew Barton (Director, Technical Operations, Google Lunar XPRIZE) and the XPRIZE Foundation throughout this research. We would like to thank the GLXP teams that we consulted with for their time and the valuable information that they provided. Responsibility for the contents of this report remains with London Economics.

Google Lunar XPRIZE Market Study 2013: Media Summary

This short note summarises the findings of the Google Lunar XPRIZE Market Study 2013, conducted by London Economics' Aerospace team[1] for the XPRIZE Foundation.

Context

Since the inception of the Google Lunar XPRIZE (GLXP)[2] in 2007 the global financial support for lunar exploration has varied, particularly with the cancellation of the Constellation Program and the global economic crisis. Despite these events the GLXP has remained active in its support for lunar exploration.

The global space economy is lucrative and growing ($304 billion in 2012, a 7% increase on 2011), with just under three-quarters of this revenue, and the vast majority of the growth, accounted for by the commercial sector.[3] A 2009 study by Futron[4] established a baseline study for the commercial lunar market.

Objective

The objective of the Google Lunar XPRIZE Market Study 2013 was to identity, define and independently quantitatively evaluate, using the most up-to-date publicly available information and expert knowledge, the value of commercial market opportunities that could be served by teams competing in the GLXP.

Scope

The scope of the study covered established, emergent and future market opportunities available to GLXP teams, with extensions to non-space sector industries. Sponsorship, entertainment and media markets were excluded. The geographic scope of the study was global, focusing on international markets, recent and developing opportunities related to the strategic plans of major established space agencies, emerging space agencies and the growing and increasingly numerous commercial operators. The time horizon for the analysis is the 10 and 25 years following closure of the GLXP in 2015, marked by increasing uncertainty and estimation error out over time.

Methodology

A multi-stage research and analysis methodology was employed. Firstly, the capabilities being developed by the GLXP teams were profiled based on desk-based review of publicly available information and consultation with team leads. Next, the market opportunities that could be served by these capabilities were then identified (allowing for further development over time).

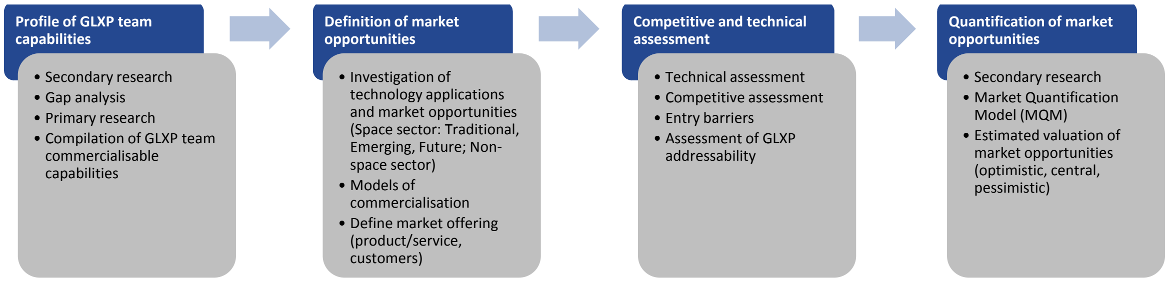
[1] For further information on London Economics, please see inside front cover.

[2] X PRIZE Foundation. 2013. "Google Lunar X PRIZE." Retrieved 8/30/2013 from: http://www.googlelunarxprize.org

[3] Space Foundation. "The Space Report 2013" Colorado Springs, Colorado. 2013.

[4] Futron Corporation. "Lunar Markets Analysis." Bethesda, Maryland. 2009.

Entry barriers and technical and competitive constraints were also explored to assess the addressability of the market by GLXP teams.



The quantification and valuation of market opportunities was achieved by developing an Excel assumption-based Market Quantification Model (MQM). To inform the quantitative modelling, the most important and reputable publicly available sources of market data were reviewed, including purchased industry/market reports and databases, in addition to expert opinion. The study quantified the estimated global market, focusing on international markets, recent and developing opportunities related to the strategic plans of major established space agencies (NASA, ESA, ROSCOMOS, JAXA) in addition to smaller (Canada-CSA) and emerging (India-ISRO, China-CNSA, Brazil-AEB) space agencies. For example, NASA has already signed deals to purchase $30.1 million worth of data over a period of up to five years from six GLXP teams under its Innovative Lunar Demonstrations Data (ILDD) programme.[5]

The Market Study was a modest study with ambitious objectives. The estimates of the valued market opportunities are high-level estimates based on research-based assumptions and expert judgement, but remain subject to potentially large estimation bias. Given the degree of uncertainty surrounding many of the estimates a scenario-based sensitivity analysis was used to indicate Optimistic and Pessimistic bounds for our Central estimate. That said, a persistent issue in quantifying future/emergent markets is that quantification is (necessarily) limited to foreseeable future applications; i.e. it may exclude opportunities that have not yet been (at least publicly) acknowledged, imposing a natural conservatism.

Assumptions

Team Capabilities

To ensure coverage of a comprehensive range of the potential commercial opportunities open to GLXP teams, an aggregate profile of GLXP team proprietary capabilities (knowledge, experience, space infrastructure and facilities, innovative technologies, manufactured assets, systems, sub-systems and mission services) was established.

With the competition ongoing at time of writing, the status of almost all capabilities considered in the study may be described as 'in development' or expected. Nonetheless, in forward-looking market forecasting exercises it is necessary to make certain assumptions regarding the future. Accordingly, it was assumed that the expected set of capabilities will be successfully developed,

[5] NASA Lunar Science Institute. 2013. "NASA Awards Contracts for Innovative Lunar Demonstrations Data." Retrieved 8/30/2013 from: http://lunarscience.nasa.gov/articles/nasa-awards-contracts-for-innovative-lunar-demonstrations-data/

thus opening up access to the identified range of market opportunities. Notably, many of the opportunities could be served without achieving success in the GLXP, or even achieving orbit. This is not an unreasonable assumption. In fact, given that the GLXP teams are, by their very nature, characterised by strong innovation and enterprise, it is possible (if not probable) that additional capabilities will be developed, creating even further market opportunities.

A successful GLXP mission requires a team to develop certain core capabilities[6], but many teams are developing a range of supplementary capabilities to generate additional revenue streams to support the GLXP mission and/or achieve other team objectives. Any further capabilities planned for development after the GLXP (e.g. return module for sample return), were excluded from the scope of the study. The aggregate core and supplementary capabilities are listed below.

Core	Supplementary

• Spacecraft design and assembly, integration and test (AIT)
• Spacecraft subsystem design and assembly, integration and test (AIT), including:
  • In-space propulsion technology
  • Space power and energy storage
  • Thermal management system
  • Spacecraft navigation subsystem
• Descent and landing system
• Independent surface exploration craft*
• Robotic, tele-robotic & autonomous systems
• Technical/scientific data capture subsystem
• HD imagery capture subsystem
• Communication and data/imagery transmission subsystem
	• Launch propulsion system
	• Auxiliary payload capacity
	• Lunar night operation and survival
	• In-space technology demonstrations
	• Sample extraction system (e.g. scooper)
	• Conduct scientific experiments
	• Permanent lunar installation (e.g. observatory, communications relay)
	• Public/STEM education outreach
	• Patents
	• Other (varies by team)

Commercial opportunities

A range of specific commercial market opportunities were identified that could be addressed by the GLXP teams over the next 3, 5, 10, 20 and 25 years, classified according to the delivery timeframe and degree of certainty in the estimates (inversely related): established market opportunities (1+years), emergent market opportunities (5+years) and future market opportunities (10+years). Timeframes quoted are from the completion of the GLXP (year 0: 2015).

Potential customers

The customer types considered were: public sector; commercial sector (companies may play the role of competitor, customer, partner or acquirer); non-space sector; third sector; high net-worth individuals; and the general public. Prominent examples of each type of customer are listed overleaf.

[6] * Note that a small number of teams are developing a lander that is capable of hopping to explore the lunar surface rather than an independent surface exploration craft.

Public sector

- **Major established space agencies**
  NASA, ESA, ROSCOMOS, JAXA
- **Smaller established space agencies**
  CSA, European Member States
- **Emerging space agencies**
  ISRO, CNSA, AEB
- **Other governmental organisations**
  US Department of Defence, UK Ministry of Defence, EU Member State Defence Ministries, NOAA (National Oceanic and Atmospheric Administration, National Agricultural Ministries etc.

Commercial sector

- **Launcher manufacturers and launch service providers**
  United Launch Alliance (Lockheed Martin and Boeing), EADS Astrium, Arianespace, Boeing Launch Services, Mitsubishi Heavy Industries, SpaceX, International Launch Services, Sea Launch (Land Launch), SpaceDev (Sierra Nevada Corporation), Orbital Sciences Corporation, Antrix Corporation (India), China Aerospace Science and Technology Corporation, SpaceQuest, ISC Kosmotras, Starsem, Alcantara Cyclone Space, SUPARCO, Yuzhmash, etc.
- **Lander, rover and probes**
  Lavochkin, Teledyne Brown Engineering, China Aerospace Science and Technology Corporation, Deep Space Industries, SpaceX, Planetary Resources, etc.
- **Space tourism**
  Virgin Galactic, EADS Astrium, SpaceX, XCOR Aerospace, Armadillo Aerospace, Bigelow Aerospace, Blue Origin, Golden Spike Company, Masten Space Systems, Mojave Aerospace Ventures, Orbital Sciences Corporation, RocketShip Tours, Scaled Composites, Sierra Nevada Corporation, Space Adventures, MarsOne, etc.
- **Satellite communications**
  SES, Intelsat, Eutelsat, Inmarsat, etc.
- **Earth observation/imagery** (e.g. Planet Labs)

Other

- **Third sector**
  Universities, research institutes (Carnegie Mellon University Robotics Institute etc.), not-for-profit organisations
- **Non-space sector companies**
- **High net-worth individuals**
  Lunar burial
- **General public**
  Imagery (e.g. ARKYD telescope)

Market opportunities

The full range of considered commercial market opportunities is listed below, and each classification of opportunities discussed in turn subsequently.

Established *(1+ years)*

- Scientific and technical data
- Payload hosting
- Spacecraft and hardware
- Subsystems and proprietary technologies
- Space infrastructure and facilities
- STEM education outreach

Emergent *(5+ years)*

- Lander systems
- Lunar rovers
- Lunar/asteroid/planetary orbiters
- Lunar samples
- Mars rovers
- Asteroid exploration systems
- Orbital servicing

Future *(10+ years)*

- Support extended duration crew missions
- Lunar mining
- Lunar In-Situ Resource Utilisation
- Asteroid mining
- Mars mission support

Technology transfer *(2+ years)*

- Patents, spin-offs, acquisitions and partnerships

Established market opportunities

The most readily accessible commercial opportunities for GLXP teams to address with the capabilities developed in a successful GLXP mission are the supply of 'traditional' products and services. Some of these established markets could be addressable immediately (e.g. sales of scientific and technical data) whereas others will entail some lead time (e.g. spacecraft sales).

Emergent market opportunities

Allowing more time for procurement negotiation and technology development, there is a range of markets that are set to develop over the coming years as defined by the medium-term planned missions of the major established and emerging space agencies. To address these commercial opportunities, the GLXP teams will have to adapt their developing technology to become competitive over a timeframe of five to ten years onwards, and are therefore subject to a degree of greater uncertainty.

Future market opportunities

Looking further into the future, the analysis considered markets for products and services that are currently only at the conceptual stage, but that are likely to become very important over the timeframe of 10 to 20 years onwards. GLXP teams are likely to require considerable expansion of their capabilities to compete in these markets, although the technologies they have developed may give them a competitive edge.

Given the long-term nature of these opportunities and the considerable uncertainty involved, the study did not attempt to quantify and value these markets since any such estimates would be highly speculative and lack credibility. Nonetheless, the considerable commercial potential of the future market opportunities is clear.

Technology Transfer

Additional revenue for GLXP teams may result from new, or adapted, products and/or services based on the technology developed for the GLXP mission, sold to enterprises within and outside the space sector.

Examples of non-space applications might include spin-offs to leverage the potential that the already developed technologies (e.g. robotic rover) provide to the open market, especially for sectors which deal with harsh environments, such as fire rescue, deep sea, defence, dangerous production plants (nuclear, chemical, etc.), natural disasters, and tele-operation (e.g. terrestrial mining applications).

London Economics estimated the value of the above technology transfer market opportunities by adopting a ‘ripple effect’ multiplier. Previous research and analysis by London Economics showed that a factor of 2.0 times the initial technology investments could be used to estimate technology transfer sales to non-space sectors. To quantify the total investment by GLXP teams, a long-tail distribution was assumed for all registered teams with the maximum investment per team set at US$75 million (with launch costs removed). This resulted in a total investment across all teams of $146.3 million to which the factor of 2.0 was applied for estimating the technology transfer sales.

Market trade restrictions

There are a range of market entry and trade barriers that limit the potential customers and markets that are accessible to specific GLXP teams. Briefly these are summarised as follows:

- **International trade restrictions** - many national governments impose strict restrictions on international trade of aerospace products and technologies to protect national strategic assets. The best-known example of such restrictions is the US' International Traffic in Arms Regulations (ITAR). Depending on whether a license is granted, ITAR can cause either a significant delay, or an absolute barrier to trade in spacecraft technologies.

- **Domestic industrial bias** - for example, NASA predominantly contracts with US-based companies, and Space companies must be located in an ESA-participating member state in order to win ESA contracts. Purchase of established spacecraft may not be an option for emerging space agencies seeking to establish prestige based upon their space-faring capabilities.
- **Legacy systems** - given the long and costly development, testing and technology demonstration cycle for high-reliability space hardware and software, there exists strong inertia towards existing technical standards and legacy technologies and systems. This inertia will be a constraint in the short- and medium-term for GLXP team technologies that are disruptive to the existing standardised frameworks, despite possibly being technologically superior and/or lower cost.

Results and conclusions

The estimated market values for the commercial opportunities open to Google Lunar XPRIZE teams out over 10 years (2016-2025) and 25 years (2016-40) are presented overleaf.

With an overall estimated market value in the 10 years directly following the competition of US$1.9 billion, and $6.4 billion over the 25 year longer term, it is clear that the Google Lunar XPRIZE presents a very significant incentive for teams to organize themselves to pursue and capture the various commercial opportunities that they can access.

Whilst the market will initially be driven by public sector customers (56% of the US$1.9 billion market at 10 years), the private and third sector will increase in significance (68% of the US$6.4 billion at 25 years) to outstrip public sector demand over the longer time period.

It is hoped that the study outputs might serve to secure the continued commitment of the 21 registered GLXP teams (correct at the time of writing), financiers, partners, sponsors and anchor customers, as well as assist them in attracting additional funding from angel investors, venture capitalists and other private sources (e.g. advance service deals and orders, sponsors).

It is clear that the GLXP awards serve as significant monetary incentives to attract teams of individuals and companies from around the world to embark on the challenge of achieving a commercial lunar mission, but the real payoff will come from the commercial opportunities that follow in the short, medium and long-term after the GLXP mission has been completed, in a newly created commercial cislunar/lunar mission market.

Table 1: Valuation of market opportunities, 0-10 years and 0-25 years (US$m)

Market opportunities	10 years			25 years		
	Pessimistic	Central	Optimistic	Pessimistic	Central	Optimistic
Established market opportunities						
Scientific and technical data	38	53	77	38	53	77
Payload hosting	233	396	504	978	2,592	4,058
Spacecraft and hardware	202	336	488	202	336	488
Subsystems and proprietary technologies	6	15	23	10	25	38
Sub-total	**478**	**800**	**1,091**	**1,227**	**3,005**	**4,660**
Emergent market opportunities						
Lander systems	144	240	336	504	840	1,176
Lunar rovers	70	140	263	372	740	1,388
Lunar/asteroid/planetary orbiters	112	168	224	440	660	880
Lunar samples	46	93	123	206	413	551
Mars rovers	90	180	252	213	425	595
Sub-total	**463**	**820**	**1,198**	**1,735**	**3,078**	**4,589**
Future market opportunities						
Support extended duration crew missions	n/q	n/q	n/q	n/q	n/q	n/q
Lunar mining	n/q	n/q	n/q	n/q	n/q	n/q
Lunar In-Situ Resource Utilisation	n/q	n/q	n/q	n/q	n/q	n/q
Asteroid mining	n/q	n/q	n/q	n/q	n/q	n/q
Sub-total	n/q	n/q	n/q	n/q	n/q	n/q
Technology transfer opportunities						
Sub-total	**146**	**293**	**439**	**146**	**293**	**439**
OVERALL ESTIMATE OF MARKET VALUE	**1,087**	**1,913**	**2,728**	**3,108**	**6,376**	**9,688**

Note: Market valuations are nominal (no Present Value adjustment has been applied); n/q: Not quantified.
Source: London Economics analysis

Notes for editors

About XPRIZE Foundation

XPRIZE is the leading organization solving the world's Grand Challenges by creating and managing large-scale, high-profile, incentivized prize competitions in five Prize Groups: Learning; Exploration; Energy & Environment; Global Development; and Life Sciences. Active prizes include the $40 million Google Lunar XPRIZE, the $10 million Qualcomm Tricorder XPRIZE, the $2.25 million Nokia Sensing XCHALLENGE and the $2 million Wendy Schmidt Ocean Health XPRIZE. For more information, go to www.xprize.org.

About the Google Lunar XPRIZE

The Google Lunar XPRIZE is the largest international incentive based prize of all time with $40 Million in incentive based prizes sponsored by Google and operated by the XPRIZE Foundation. It aims to do something that humanity hasn't done since 1972: to safely land on the surface of the Moon. More than half of the world's population has never had the opportunity to view a live transmission from the lunar surface. The Google Lunar XPRIZE aims to create a new 'Apollo moment' for this generation and to spur continuous lunar exploration by challenging and inspiring engineers and entrepreneurs from around the world to develop low-cost methods of robotic space exploration.

In order to win this money, a private company must land safely on the surface of the Moon, travel 500 metres above, below, or on the lunar surface, and send back two 'Mooncasts' to Earth.

Fig. 1 LAUNCH

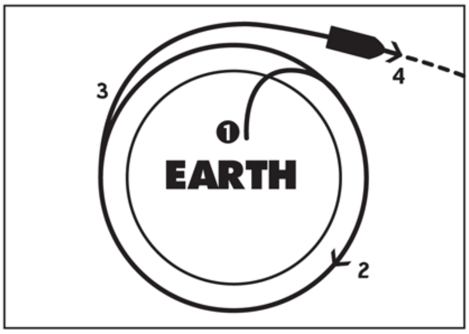


Fig. 2 LUNAR LANDING

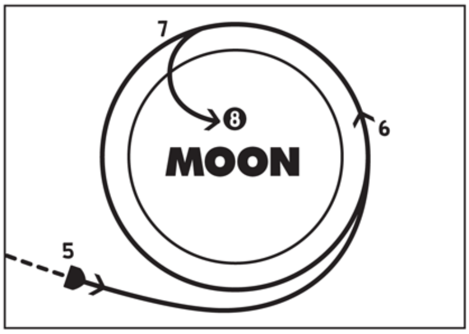


Fig. 3 LOCOMOTION

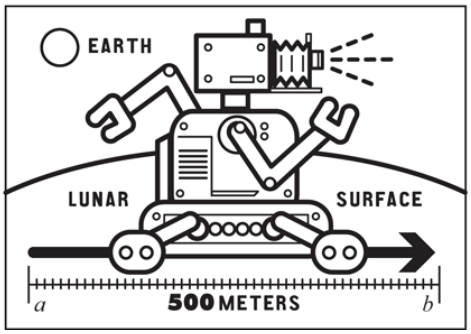
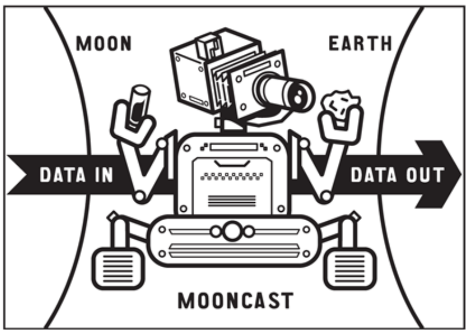


Fig. 4 DATA COLLECTION AND TRANSMISSION



The first team to do so will claim a $20 million Grand Prize, while the second team will earn a $5 million Second Prize. Teams may also compete for $5 million in Bonus Prizes (image Apollo site/artefact; image heritage site/artefact; find water; survive the lunar night; travel the furthest distance; promote diversity in education and outreach), $6 million in 'Terrestrial' Milestone Prizes (imaging; mobility; landing), and $4 million in 'In-Space' Milestone Prizes. All of this must be completed by December 31, 2015. At time of writing, 21 teams active in more than a dozen countries are participating in the Google Lunar XPRIZE.

For more information, go to www.googlelunarxprize.org.

About London Economics

See inside front cover.

Paper presented at International Astronautical Congress (IAC) 2013, Beijing

Barton, A., Wong, N., Sadlier, G. and Innes, D. (2013) "Quantifying the Market Addressable by Google Lunar XPRIZE Teams", IAC-13,B4,8,4,x17642. Paper co-authored by XPRIZE Foundation and London Economics, submitted and presented orally (Symposium: B4. 20th Symposium on Small Satellite Missions; Session: Hitchhiking to the Moon and Beyond) to the International Astronautical Congress (IAC) 2013, 27th September, Beijing, China.

Glossary

AEB	Agência Espacial Brasileira
CNSA	China National Space Administration
CSA	Canadian Space Agency
EAR	Export Administration Regulations
EREP	European Robotic Exploration Programme
ESA	European Space Agency
GEO	Geostationary Earth Orbit
GER	Global Exploration Roadmap
GES	Global Exploration Strategy
GLXP	Google Lunar XPRIZE
ILDD	Innovation Lunar Demonstrations Data
IP	Intellectual Property
ISRO	Indian Space Research Organization
ISRU	In-situ Resource Utilization
ITAR	International Traffic in Arms Regulations
JAXA	Japanese Aerospace Exploration Agency
LEO	Low Earth Orbit
LLO	Low Lunar Orbit
MQM	Market Quantification Model
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
REE	Rare Earth Elements
ROSCOSMOS	Russian Federal Space Agency
SELENA	Sustainable Experiment on Lunar Exploitation
STEM	Science, Technology, Engineering and Mathematics

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