COMMERCIAL IN CONFIDENCE

Report prepared for the Ministry of Business, Innovation & Employment

Economic Impact Analysis of the Development of a Rocket Industry in New Zealand

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Note: commercially sensitive information has been removed from this report to make it suitable for publication. This means that some information supporting our assumptions, and information related to any risks or challenges for the project is not contained within this version.

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Executive summary

Rocket Lab is a start-up company establishing a rocket launch venture in New Zealand. The company is seeking to disrupt the orbital launch service industry by providing frequent, dedicated and low cost launch services to the growing small satellite industry. New Zealand's location is important to the company's proposition in that it requires access to particular launch angles (azimuths) for dedicated launches, and clear skies and clear seas to enable frequent launches. Locating its operations in New Zealand also poses a range of challenges the largest of which is that, unlike the US, New Zealand does not have an established space industry which Rocket Lab can draw on for easy access to experienced personnel, rocket components and launch infrastructure. This inability to use US products means Rocket Lab have had to design a new rocket system including a new guidance and navigation system.

The company is in prime position to claim a first mover advantage with key competitors being approximately 3 years behind. Like any new business there are risks that could mean that the launch venture fails. However, the confidence of very experienced US based space industry investors and Rocket Lab's success to date (in flying a prototype for example) are strong indicators that the project has a relatively good chance of success.

Specifically, there is a good chance Rocket Lab can offer a reliable, scheduled service to deliver small satellites to low Earth orbit (LEO) at a launch price starting from $50,000 for a 1U Cube Sat satellite. This contrasts with alternative launch services for small satellites which are generally ride-share solutions on larger rockets (offering satellite owners little to no control over where their satellite is placed or when it is launched) and are materially more expensive.

Identifying the benefits

We were asked to conduct an economic impact assessment on the potential development of a rocket launch industry in New Zealand. Through interviews with a wide range of stakeholders and a review of the literature on the economics of space industries we have identified the following types of economic benefits:

- Additional employment by Rocket Lab to scale up to launch capacity.
- Additional activity and employment in supplying industries (industries that supply Rocket Lab with intermediate inputs (components) and other linked industries in the supply chain).
- Space tourism – international visitors or New Zealanders watching rocket launches, and members of the satellite industry or their clients attending the launch of their satellites.
- Construction and launch activities – Rocket Lab building or upgrading facilities for rocket launches including satellite dishes, launch pads.
- Cluster effects - development of related clusters for example in the areas of satellite manufacture/technology, carbon composites or 3D printing.
- Aspiration effects - achievements in aerospace have been shown to have a significant impact in motivating prospective students and researchers into the field.
- Knowledge and technology spillovers - the benefits from technology, information and knowledge that is generated by Rocket Lab (or its key suppliers) being applied in other companies or sectors of the economy.
- Prestige effects – enhancements to national prestige resulting from having a space industry.

- Human capital effects - benefits to New Zealand from an increased proportion of highly skilled personnel in the population.

At a high level, we observe that the profile of the economic benefits likely to flow to New Zealand from Rocket Lab's launch venture is as follows:

- The majority of benefits are likely to accrue to a small number of closely related companies. Unlike the dairy industry, where an increase in demand or output affects nearly the whole economy, a rocket launch industry will have the most direct benefit for a small number of niche manufacturing companies. The immediate benefits are likely to accrue firstly to the company owners and investors (most of whom are overseas-based), secondly in employment opportunities for New Zealand based Rocket Lab personnel and then largely to the three or four key New Zealand component suppliers.
- Indirect benefits (activity in industries which supply products and services to Rocket Lab and its key suppliers) are likely to be in sectors with high import ratios such as the import of titanium powder for 3D printing, which could limit the extent of the benefits to New Zealand.
- Spill-over benefits are likely to be limited given the high reliance on trade secrets in this industry, research and development is likely to be closely held. We expect the 'ecosystem' of niche manufacturing companies to remain small to control information flows and technical secrets.

Quantifying the benefits

In assessing the economic benefits we see three different scenarios:

- **Base case scenario** – the situation where the range of possible launches per year is between 52 (i.e. one a week) to 120 per year; 120 represents the number of launches the Wairoa District Council has consented. In reflecting on our interviews this feels like the most probable scenario.[1]
- **Upside opportunity** – there are situations, with non-trivial probabilities, where the benefits of Rocket Lab's activity are orders of magnitude larger than we have assumed. Advances in aerospace technology have a long history of leading to advances in a wide variety of industries.[2] Additionally, Rocket Lab's success could attract other, similar companies, to New Zealand. Further, employees benefit from the experience of working in a start-up and go on to found other companies.
- **Downside risk** – the risk that launch issues/problems could mean that Rocket Lab is not able to launch frequently enough to remain financially viable and exits, likely in a trade sale of its technology.

The focus of our modelling is the base case scenario. We report a range for our estimates, with the low point and the high point scenarios representing the range of possible outcomes around our base case. The worst case is no benefit.

1 We assume it takes five years to reach this level of output.

2 Comstock, Lockney, D., Glass, C., *A Sustainable Method for Quantifying the Benefits of NASA Technology Transfer*. In *AIAA SPACE 2011 Conference & Exposition* (p. 7329).

In order to prepare our economic impact assessment, we have had to make a number of assumptions and extrapolate potential impacts based on information from interviews, the literature (where relevant), or in the absence of either, informed judgement. Our assumptions are appropriately conservative to mitigate the risk of overstating potential benefits. Further we focus on quantifying a minimum set of benefits - it is probable that the scope and magnitude of benefits will be greater than reported.

We focus on additional value-added output owing to Rocket Lab activities rather than additional gross output – the key difference being that value-added nets out the use of immediate goods from other sectors in the production of the final "good". On a conceptual basis this is the same approach used in calculating GDP. Intuitively it is a concept closer to operating surplus rather than revenue.

The second conceptual distinction we make is to focus on "trade creation" rather than "trade diversion" – that is we focus on quantifying the benefits to New Zealand of new production as a result of Rocket Lab's activities, rather than quantifying money or resource flows that are reallocated in the New Zealand economy owing to Rocket Lab's activities.

Base case results

Our findings on the potential economic benefits of the establishment of a rocket launch industry in New Zealand are described in a table in the following section.

The figures provided are for a 20 year period, generally with an 8 per cent discount rate applied. However, we recognise that there is a set of benefits grouped under "catalyst"– aspiration effects, spill-overs and the benefit to New Zealand industry of having more convenient access to satellite technology - that are more speculative. To account for the uncertain nature of this benefit stream we discount it by 50 per cent.

In summary we estimate that in this base case scenario:

- Establishing a rocket launch industry will contribute between $400-$1,150 million of value add to the New Zealand economy in the form of direct, indirect and induced impacts. We are as **confident as one can be** in our estimation of direct effects as this is based on company information we directly sourced. We are **reasonably confident** in our estimation of indirect and induced effects. While no specific New Zealand space industry multipliers exist, we used the closest available multipliers for similar activities in New Zealand.[3]
- We further estimate this industry could add between $30-$110 million of value added in catalyst effects, and between $160-$340 million of value add as a result of New Zealand industries having easier access to satellite technologies.[4] As noted earlier this benefit stream is **highly speculative**, hence we discount this benefit stream by 50 per cent.

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3 For example we use the multiplier for the rubber, plastic and polymer manufacturing industry to estimate the indirect and induced effects of the activity carbon composite supplier. We use the construction multiplier to estimate the flow on effects of the construction of the launch pad.

4 We proxy this by a 1-2 percent shock to GDP in the agricultural and information, media and telecommunications sector. To put this assumption in context McKinsey (2011) believe firms that use big data to its full potential could have a 60 per cent increase in operating surplus.

- In total then, we estimate that the industry could contribute between $600 and $1,550 million of value add to New Zealand over the relevant period.

The numbers in context

The numbers seem large. However put in context on a comparable per year basis Rocket Lab and its key suppliers will contribute directly around $30 to $80 million per year in value-add terms to the New Zealand economy under this base case scenario. This is about 5 to 10 per cent of the direct contribution of the "printing" industry ($557million in 2009/10 dollars), the "Textile, leather, clothing, and footwear manufacturing" industry ($683 million) or the wine industry (Nominal GDP: $436 million; NZIER 2014).[5] To put the additional tourism spending in context, the value of tourism in the Gisborne region will be approximately 2 to 8 per cent higher per year under this base case.[6]

Shelley *et al.* (2015) estimates the annual economic gain from beyond line of sight UAVs is between $151 million and $189 million. Summing this annual gain over 20 years and discounting by 8 per cent gives a present value of benefits between $1,600 and 2,000 million. This is slightly higher than the number we estimate as the top of our base case range. We caveat this comparison with the fact we discount a number of our more speculative benefits by a discount rate by 50 per cent, whereas we apply a blanket 8 per cent discount rate to the Shelly *et al.* (2015) estimated benefits; some of these benefits may be just as speculative as ours.

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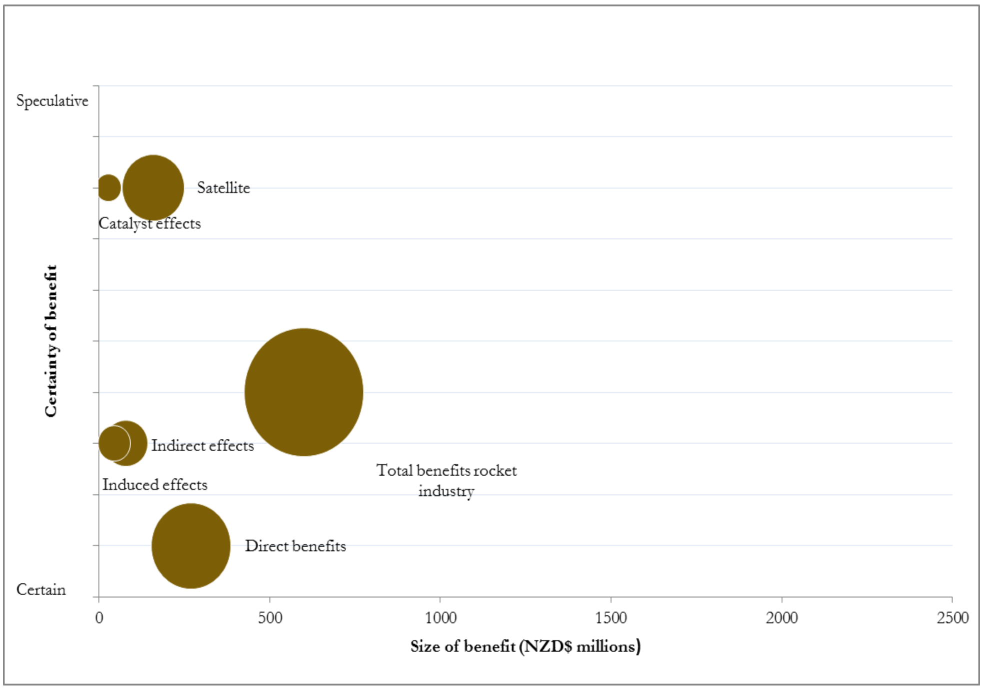
5 NZIER (2014), The economic contribution of the New Zealand wine sector: The impact of growth since 2008, Report to New Zealand Winegrowers, March 2014. The two cited manufacturing subsectors are the two smallest of all the manufacturing subsectors.

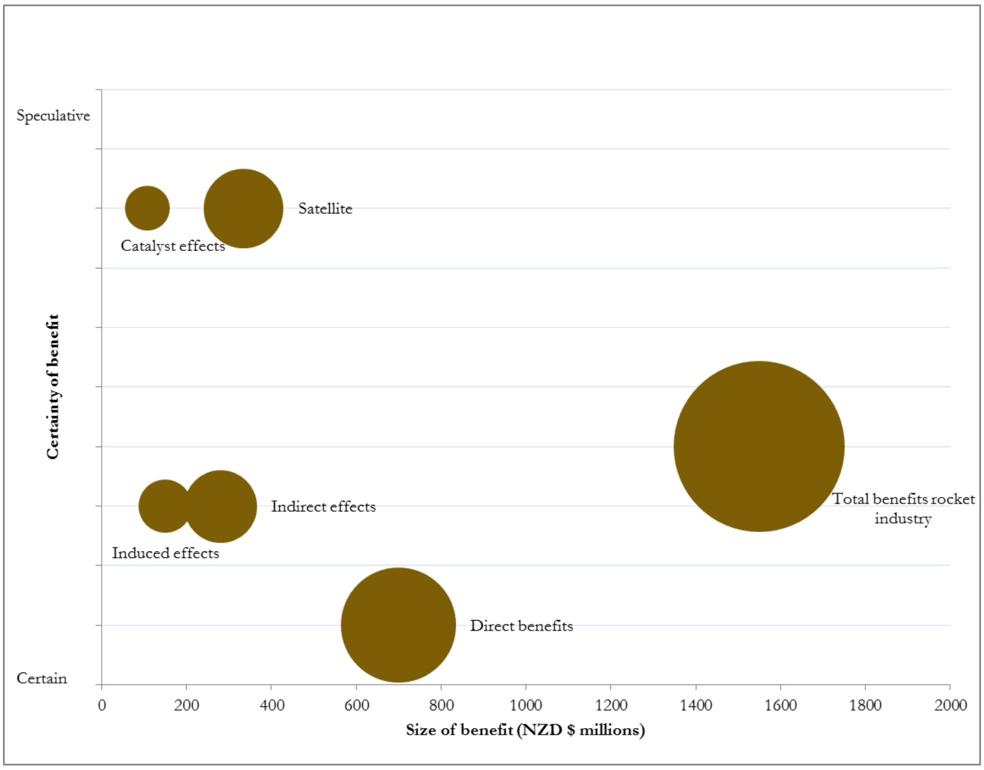
6 Gisborne's GDP is assumed to $71 million (see https://www.tianz.org.nz/main/news-detail/index.cfm/2014/08/new-statistics-highlight-tourism-value-to-gisborne-region)

Figure 1 Present value of benefits over 20 year period – one launch a week



Source: Sapere estimates

Figure 2 Present value of benefits over 20 year period - two launches a week



Source: Sapere estimates

Table 1 Benefits to New Zealand from the development of a rocket launch industry

Effect	Definition	Included benefits	Magnitude (millions)
Direct effects	Activity and employment by Rocket Lab and its key suppliers. Key suppliers are those who directly supply parts of the rocket.	Salaries of the additional employees Rocket Lab and its key suppliers take on to meet Rocket Lab demand as launch frequency increases.[7] The profits of Rocket Lab's key suppliers (where the profits accrue to New Zealanders). Rocket Lab's profits are omitted as Rocket Lab is predominately overseas owned.	$270 - $700 over 20 years, discounted at 8 per cent.
Indirect effects	Activity and employment by industries "upstream" and "downstream" of Rocket Lab and its key suppliers.	**Indirect benefits modelled**: construction of launch facilities, space tourism, and other activity by those with supply chain links to Rocket Lab and its key suppliers e.g. electricity distribution services. **Indirect benefits not modelled**: Clustering effects around key suppliers e.g. carbon composites or 3D printing capability. Road upgrade to Mahia.	$80- $280 over 20 years, discounted at 8 per cent.
Induced effects	Activity and employment that is the result of spending by those employed directly or indirectly owing to Rocket Lab's activities.	Induced impacts are the successive rounds of increased household spending resulting from the direct and indirect impacts.	$45 – $150 over 20 years, discounted at 8 per cent.
Catalyst effects	Other benefits not counted above where Rocket Lab's activities have acted as a catalyst to benefits being realized.	**Catalyst effects modelled**: Aspiration effects and knowledge/technology spill-overs. Easier access of New Zealand firms to satellite technology. **Catalyst effects not modelled**: Prestige effects and human capital effects.	Catalyst effects (excl. satellite access): $30 - $110 Satellite access: $160 - $340 over 20 years, discounted at 50 per cent.

7 The specialised nature of the industries mean we assume very little displacement of other employment in the economy.

1. Introduction and background

1.1 Purpose and approach

Rocket Lab New Zealand has developed world leading rocket technology and is looking to establish a launch base in New Zealand. Rocket Lab already has considerable activities underway in New Zealand to support the launch at present.

> *Rocketlab's [sic] solution, the Electron, is novel. The combination of a carbon-fibre, recoverable rocket, a dual electric/dry fuel engine, secret-sauce electronics and an end-to-end launch facility in New Zealand means Beck reckons he can slash the price of launch from about $US130 million to $US4.9 million.*[8]

In order to go ahead with this project, Rocket Lab needs to bring technology and expertise into the country from the United States of America (USA). A bilateral treaty – the Technology Safeguard Agreement (TSA) is being negotiated between the governments of New Zealand and the USA in order to facilitate this.

As part of the work being undertaken to bring New Zealand to a position where the TSA agreement can be signed, the Ministry of Business, Innovation and Employment is undertaking an analysis of the regulatory impacts of the agreement. To inform this work Sapere was commissioned to undertake an economic impact analysis to understand the nature and size of the opportunity presented by Rocket Lab's proposition in an economic sense. This work is not intended to be an investment analysis however it necessarily touches on the competitive nature of the rocket industry.

We were commissioned to undertake an economic analysis covering the following topics:

- Identification of the benefits associated with the development of a rocket industry in New Zealand.
- Quantification of the proposed benefits of this opportunity.
- Identification of what might need to be done to capture or capitalize benefits including in regional development and the science and innovation system.

Our analysis is limited to economic aspects only because of the sensitive nature of this industry and its links to military technologies. Where relevant and appropriate, we have provided brief comment on wider benefits but the nature of these wider benefits is necessarily speculative. We have not been asked to comment on political and security benefits.

1.1.1 Our approach to the economic impact assessment

As agreed upon at the inception of this project, the approach that we have undertaken in this economic impact assessment is as follows:

[8] http://idealog.co.nz/venture/2015/08/mission-possible-inside-rocketlabs-big-commercial-space-venture

1. Initiation meeting. We had an initial meeting with Rocket Lab CEO Peter Beck on site at his facility in Auckland to get a sense of his plans and any existing information about the expected economic benefits or costs of his planned operations.
2. A desk-based scan was conducted on the nature of competition in the rocket industry and how this is likely to evolve.
3. We conducted a series of interviews with a range of key stakeholders to identify, size, and verify the benefits associated with the development of a rocket industry in New Zealand. This included discussions with investors, suppliers including manufacturers, rocket scientists and other academics, and others as identified and deemed relevant. A list of interviewees is attached at appendix 2.
4. Preparation of a pragmatic economic impact assessment setting out the nature of the likely benefit, the magnitude of benefit, measurement of that benefit where applicable, and level of supporting evidence.
5. Analysis of related opportunities.

In the following sections we provide a brief overview of the rocket industry and the various implications that this might have for New Zealand.

2. The current market environment for rockets

2.1 The globalisation of the space sector

The OECD (2014) characterises the global space sector as a high-technology niche with a complex ecosystem comprised of: public administrations (space agencies, space departments in civil and defence-related organisations), the space manufacturing industry (building rockets, satellites, ground systems); direct suppliers to this industry (components), and the wider space services sector (mainly commercial satellite telecommunications) and also universities and research institutions.

The OECD estimates the global space economy represented around USD 256.2 billion in revenues in 2013, comprised of revenues in the space manufacturing supply chain (33 per cent), satellite operators (8.4 per cent) and consumer services (58 per cent). This estimate also included actors who relied on satellite capacity to generate their own revenues, such as direct-to-home satellite television services providers.

The OECD further notes a strong trend toward the globalisation of the space sector. In contrast to the 1980s where only a handful of states were engaged in the space industry, now many more countries and corporates across a wide range of industrial sectors are engaged in space related activities. Despite the fact that the space sector remains heavily influenced and shaped by strategic and security considerations, and this can at times constrain trade, nonetheless OECD research suggests product and service supply chains for space systems are rapidly internationalising.

There has been significant interest in the economic impacts of space projects event though they typically represent a small proportion of directly measureable/attributable economic activity (for example NASA's budget represented less than 1 per cent of GNP during peak activity years in the late 1960s). The reason for this interest, Schnee hypothesises in relation to NASA, is these projects involve a high rate of technological change which in turn exerts a particularly important influence on economic growth. Similarly, Brookings notes in relation to the Colorado space economy, advanced industries like the space industry are the high-value engineering and R&D intensive industrial concerns that are the prime movers of regional and national prosperity in the US.

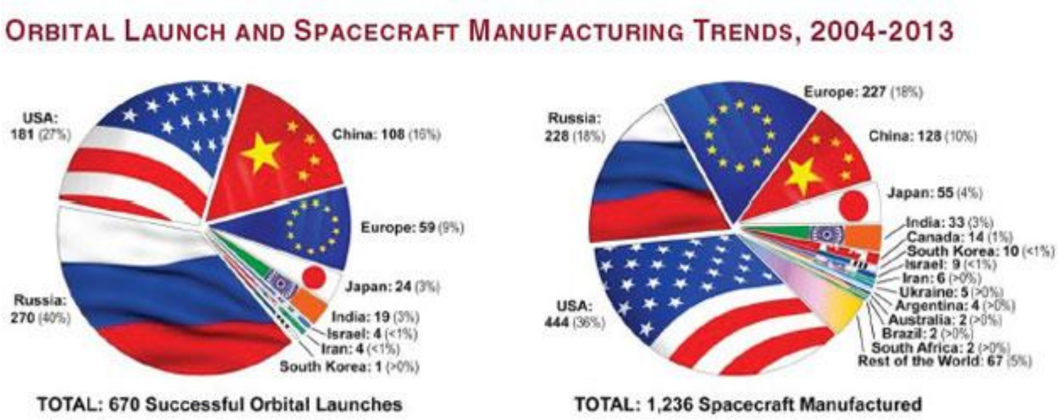
2.2 Global market trends

Bloomberg analysis puts the value of the commercial launch industry at approximately US $6 billion dollars.[9] The image below illustrates share by country of orbital launch activity and

9 Boolmberg.com, Julie Johnsson (13 April 2015) 'Forget Musk's Mars: Billionaires Branson, Allen Seek Earth Orbit' http://www.bloomberg.com/news/articles/2015-04-13/forget-musk-s-mars-billionaires-branson-allen-seek-earth-orbit

spacecraft manufacturing for the period 2004-2013. During that period there were a total of 670 successful orbital launches.

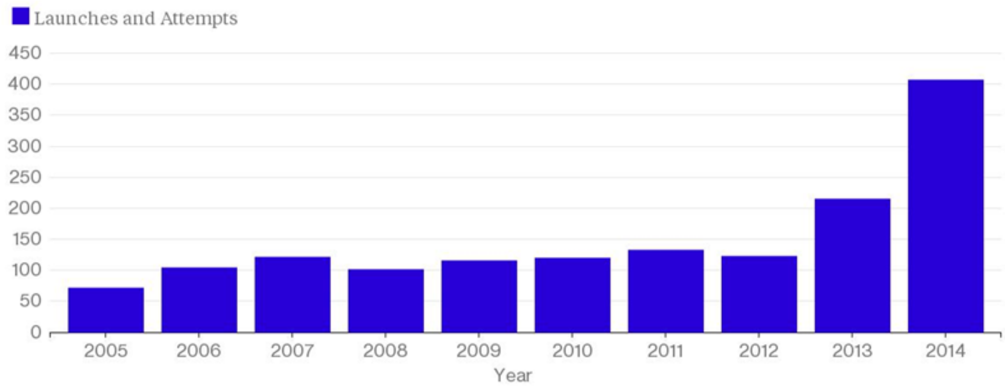
Figure 3: Orbital launch and spacecraft manufacturing trends (2004-2013)[10]



Source: Spaceref (8 May 2014) 'Futron Releases 2014 Space Competitiveness Index'

In the last year the number of launches and attempts has nearly doubled on the previous year driven by the demand from the satellite industry. Space Works forecasts between 2,000 and 2,750 nano/microsatellites will require a launch from 2014 through 2020 (based on announced and future plans of developers and programs). Over half of future nano/microsatellites will be used for Earth observation and remote sensing purposes (compared to 12 per cent from 2009 to 2013).[11]

Figure 4: Launches and launch attempts (2005-14)[12]



Source: Bloomberg, 2015

10 Spaceref Business (8 May 2014) 'Futron Releases 2014 Space Competitiveness Index', Accessed online, URL: http://spaceref.biz/commercial-space/futron-releases-2014-space-competitiveness-index.html

11 Space Works (2014) *Nano/Microsatellite Market Assessment.*

12 Boolmberg.com, Julie Johnsson (13 April 2015) 'Forget Musk's Mars: Billionaires Branson, Allen Seek Earth Orbit' http://www.bloomberg.com/news/articles/2015-04-13/forget-musk-s-mars-billionaires-branson-allen-seek-earth-orbit

Historically, annual satellite deployments have ranged from about 70 to 150 per annum as seen in Figure 4 above. More recently however, especially with satellites now able to be constructed on a much smaller scale, the pace at which deployments occur has accelerated.

In 2014 the tally included 303 satellites from 1 kilogram (2.2 pounds) to 1,000 kilograms with a market value of $1.9 billion, according to Teal Group data.[13]

2.2.1 The growing small satellite market

Although widely used, satellites have traditionally been very expensive to build and to launch. That has, however, began to change in recent times. Taking advantage of smartphones and other consumer technologies, the prevalence of tiny satellites, which are generally much less costly, are beginning to change the space business.[14] With a single chip you can now create most of the capabilities that you would have found in *Sputnik*, but a lot faster.[15]

In 2014, around 107 commercial nano/microsatellites (1-50 kg) launched and thousands of commercial small satellites (101-500 kg) are planned for launch over the next fifteen years. Recent multi-million and multi-billion dollar investments in various ventures confirm the commercial sector's continued interest in the nano/microsatellite and small satellite industries.

With 92 launches, 2014 experienced the second highest annual launch rate since 1994:

- Planet Labs has launched 97 CubeSats to date (93 in 2014), the largest quantity ever contributed by a commercial company.
- Antares CRS-2 launched on July 13th with 32 CubeSats on board. While deploying the satellites, the NanoRacks CubeSat dispenser experienced two failures (one non-deployment event and one unplanned deployment), forcing 14 satellites to remain onboard the International Space Station.
- Since most nano/microsatellites (1 - 50 kg) launch in large clusters as secondary payloads, a single failure can result in significant loss; 30 nano/microsatellites were lost when Antares failed shortly after launch on October 28th.
- In just nine days, Planet Labs built and delivered two satellites to include on the SpaceX CRS-5; these satellites replicated the specifications of the 26 satellites lost on Antares.

Multiple companies were also rumoured to be developing large communication satellite constellations in 2014. In early 2015, SpaceX and OneWeb (formerly WorldVu, Ltd.) confirmed their plans to pursue sizeable constellations of 4,025 and 648 satellites, respectively. Both companies have secured significant funding as well as launch arrangements.

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13 http://www.bloomberg.com/news/articles/2015-04-13/forget-musk-s-mars-billionaires-branson-allen-seek-earth-orbit

14 The Economist (7 June 2014) *Nanosats are go!*

15 See for example, "*Moore's law*", which suggests that the number of transistors in a dense integrated circuit doubles approximately every two years.

There is, therefore, expected to be significant growth in the small satellite market. Most recent projections conducted by SpaceWorks estimates an average annual growth rate of nearly 24 per cent over the next six years from 2014-20.[16]

2.2.2 Downstream applications of satellite technology

The general consensus is satellite technology will have a significant impact on the technological progress of other industry sectors.[17]

Small satellites, in particular, have various current and projected future applications. Over half of future nano/microsatellites will be used for Earth observation and remote sensing purposes (compared to 12 per cent from 2009 to 2013).[18] One particular example of this observation purpose is Envisat. As of 2012 Envisat, which was launched in 2002, was the world's largest earth observation satellite. This satellite has now provided over ten years of invaluable environmental data on air quality, the size of the ozone hole, the extent of sea ice, and the risks from earthquakes, volcanos and floods.[19]

Other applications also include enhanced meteorological uses (e.g., better weather forecasting etc.), spatial crop management for the agricultural sector, communications, and a number of other applications that rely on GPS satellite technologies.

2.2.3 Upstream applications of satellite technology

Upstream applications of satellite or space technology can be generally described as "manufacturers of space hardware and providers of services that enable the launch of systems into space."[20] The material and hardware used in satellite/space technology have many uses outside of the space industry.

This concept of knowledge spillovers to other industry sectors has been discussed extensively in existing literature. In a paper prepared by Michel Dumont and Wim Meeusen for the OECD-NIS (National Innovation Systems) Focus Group on Innovative Firms and Networks, the authors assess potential knowledge spillover effects for other industry sectors as a result of greater R&D investment.

The authors adapt a method from existing approaches to quantify its impact on Belgian firms operating in a number of different industry sectors. To define this effect, the authors use the following definition of "spillover effects" from academic literature.

> *"By technological spillovers, we mean that (1) firms can acquire information created by others without paying for that information in a market transaction, and (2) the creators (or current*

16 Spaceworks (2015) Small Satellite Market Observations, summary accessed online: http://www.spaceworksforecast.com/docs/SpaceWorks_Small_Satellite_Market_Observations_2015.pdf

17 https://spinoff.nasa.gov/pdf/AIAA%202011%20Quantifyin%20Spinoff%20Benefits.pdf

18 Space Works (2014) Nano/Microsatellite Market Assessment.

19 Research Councils UK (2013) *Satellites and commercial applications of space*, accessed online 1 October 2015, URL: http://www.rcuk.ac.uk/RCUK-prod/assets/documents/documents/RCUK_Space_Timeline_WEB.pdf.

20 http://www.qi3.co.uk/wp-content/uploads/2012/07/Qi3-Insights-White-Paper-Space-Market-Opportunities-of-Non-space-Companies-12060704.pdf

owners) of the information have no effective recourse, under prevailing laws, if other firms utilise information so acquired." (Grossman and Helpman, 1992: p.16)[21]

Or more simply, in a broader context:

"R&D spillover refers to the involuntary leakage, as well as, the voluntary exchange of useful technological information." (Steurs, 1994: p. 2)[22]

Using the number of cooperative links between firms as a proxy measure for the underlying knowledge flows, the authors find that these externalities are more likely to occur between industry sectors (inter-sectoral knowledge flows), rather than within industry sectors (intra-sectoral knowledge flows).[23]

We find that there are many examples of space technology being used in other industry sectors. One such example is carbon composite technologies. Many of the advances in the carbon composite technology, a material that is typically used in satellites and rockets has been found to have a number of different applications in other industries such as in marine, automotive, aerospace, energy, and other engineering-related disciplines.[24]

2.3 Opportunities for New Zealand

As discussed above, there is expected to be significant growth in the 'rocket industry' in the near to longer term, particularly for smaller-sized satellite launches. There is an emerging comparative advantage for New Zealand, as outlined below, which has the potential to be seized and turned into a sustained competitive advantage.

2.3.1 Geographical advantages

Access to key azimuths

Despite being headquartered in the United States, Rocket Lab has selected a New Zealand launch location as it offers technical, logistical and economic advantages. The location, which has been used for suborbital flights by NASA in the past, can reach a wide range of inclinations from sun-synchronous through to 45 degrees. [25]

Rocket Lab plans to launch from New Zealand primarily because its planned site there supports a wide range of launch azimuths[26] for satellites that need to go into polar or more equatorial

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21 Grossman, G.M. and E. Helpman (1992), Innovation and growth in the global economy, MIT Press, Cambridge (MA) / London (UK).

22 Steurs, G. (1994), Spillovers and Cooperation in Research and Development, doctoral dissertation KU Leuven.

23 http://www.oecd.org/sti/inno/2093436.pdf

24 http://www.infosys.com/engineering-services/white-papers/Documents/carbon-composites-cost-effective.pdf

25 http://www.rocketlabusa.com/worlds-first-commercial-launch-site

26 The launch azimuth is the angle between north direction and the projection of the initial orbit plane onto the launch location. It is the compass heading you head for when you launch. - http://www.orbiterwiki.org/wiki/Launch_Azimuth

orbits. "It's like a combination of Cape Canaveral and Vandenberg Air Force Base," Peter Beck said of the site."[27]

Isolated with clear skies and seas

New Zealand is remote, surrounded by water and has comparatively much lower levels of shipping and air-traffic. This creates scope for a high frequency of launches which is a critical part of the Rocket Lab offering.

2.3.2 Socioeconomic advantages

Skilled and cost-competitive workforce

New Zealand Trade and Enterprises (NZTE) marketing material aimed at overseas investors in the high value manufacturing sector notes that New Zealand has a small and well-educated population, with one of the highest tertiary qualification rates in the world. Its manufacturing operations are well staffed, and have established a solid history of high-quality production and innovation. Currently, 40 percent of the adult workforce holds tertiary qualifications, compared with the OECD average of 32 percent.[28]

NZTE further notes that New Zealand's skilled labour force is cost competitive by developed country standards. Engineering employee costs are also lower in New Zealand, making it an attractive place to set up a high-value manufacturing business.

Space for a new industry

Although Rocket Lab needs to re-create an entire industry's worth of infrastructure (albeit on a smaller scale) in New Zealand for its enterprise, there are benefits to being the first to do so in New Zealand. For example there is scope for cheaper launch sites: "In the US all of the launch sites are government owned – and you have to pay their console officers to launch your rocket. The best price for a launch there is $1million a shot, and then if the weather is bad that's another million."[29]

Trusted and supportive government

New Zealand is also English-speaking, is non-corrupt, and has a trusted Government from a US perspective. New Zealand is consistently ranked as one of the easiest places in the world to do business.[30]

27 http://spacenews.com/silicon-valley-fund-invests-in-new-zealands-rocket-lab

28 NZTE, https://www.nzte.govt.nz/en/invest/sectors-of-opportunity/high-value-manufacturing

29 Peter Beck, Meeting at MBIE, 14 September 2015.

30 World Bank Group 'Doing Business Index' - http://www.doingbusiness.org/data/exploreeconomies/new-zealand

2.3.3 Identified challenges and risks

There is no 'rocket industry' in New Zealand

Rocket Lab is having to build a rocket industry in New Zealand from scratch. In the US there are launch stations already set up and a whole support industry. Whereas in New Zealand, setting up will require huge investment and change. For example it will require regulatory change and significant investments in infrastructure such as launch sites and a monitoring station.

Cannot use American rocket componentry

Due to technology controls it is not possible for Rocket Lab to access the US supply of rocket componentry.

3. Description of Rocket Lab

3.1 Business overview

Rocket Lab is an aerospace company founded in 2007 by New Zealander, Peter Beck. The company is focused on delivering innovative, high quality technologies to the space industry. Rocket Lab is a US corporation with a New Zealand subsidiary, and has complete vertical integration over the launch process, from rocket manufacturing through to its own commercial launch range.

Rocket Lab was created to cater to the growing requirement within the international market for fast, low cost methods of delivering payloads to space. Since inception, the company has successfully developed a number of leading rocket-based systems, from sounding rockets through to new advanced propulsion technologies.

Rocket Lab was the first private company to reach space in the southern hemisphere in 2009 with its Atea 1 suborbital sounding rocket. Following this success the company won contracts with aerospace giants Lockheed Martin, DARPA and Aeroject Rocket-dyne.[31]

The company's aim is as follows:[32]

> *Rocket Lab's mission is to remove the barriers to commerce in space. It was founded on the belief that in order to make space a place where commerce can thrive, two fundamental aspects must be addressed: a dedicated service for small satellites at an affordable cost, and a launch frequency that enables regular access to space. Since its foundation in 2007, Rocket Lab has delivered a range of complete rocket systems and technologies for fast and low-cost payload deployment.*

The company has a headquarters in Los Angeles but has most of its technical staff at its base of operations in Mangere, Auckland.[33]

3.1.1 Company structure

Rocket Lab currently employs 68 staff (as at 19 September), most of whom are based in Auckland, with the rest located in Los Angeles. Approximately 25 per cent of staff have a PhD. 60 per cent are New Zealanders and 40 per cent are foreign experts. The company currently has open vacancies for 28 staff.

Rocket Lab is seeking to grow rapidly. The company is currently hiring staff at a rate of around 1-2 per week and expects to have a total workforce of somewhere between 200-400 personnel. In addition to its current engineering and development staff Rocket Lab is seeking to hire people in launch operations support roles for example: mission managers, range safety officers, launch control operators, and assembly technicians.

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31 http://www.rocketlabusa.com/rocket-lab-usa-poised-to-change-the-space-industry

32 http://www.khoslaventures.com/portfolio/rocket-lab

33 http://spacenews.com/silicon-valley-fund-invests-in-new-zealands-rocket-lab

3.1.2 Governance and management

Rocket Lab Board:

In addition to Peter Beck himself, the Rocket Lab board is made up of Silicon Valley based investors with backgrounds in space and satellite technology investments.

- **David Cowan, Partner, Bessemer Venture Partners**
  David is a partner at Silicon Valley-based venture capital firm, Bessemer Venture Partners. He launched the firm's practices in cloud infrastructure, consumer technology, cyber security and space technology. David's other space related investments include Skybox imaging, a satellite company which specialises in Earth imagery.
- **Sven Strohband, CTO, Khosla Ventures**
  Sven is the chief technology officer (CTO) of Khosla Ventures, a Silicon Valley-based venture capital firm. He has worked on numerous technologies ranging from autonomous robots, automotive LED front lighting, user interface and display technologies to RFID systems for production verification. During his tenure at KV, Sven has led the technical diligence for numerous investment opportunities in both IT and sustainability.

  Khosla Ventures was also previously an investor in Skybox Imaging.
- **Scott Smith, COO, Iridium**
  Scott joined Iridium in April 2010 and serves as Chief Operating Officer, leading technology development and all ground and satellite operations including the Iridium NEXT initiative, the company's program to develop, build and launch its next-generation satellite constellation. He has over 33 years of experience managing large, complex commercial satellite programmes.

Executive team:[34]

- **Peter Beck, CEO and Founder** – Peter founded Rocket Lab in 2007, following almost a decade and a half of propulsion research and market development in the international space community. Peter has since established Rocket Lab both in New Zealand and the United States as a premier institute for innovative space systems.

  Peter is an acclaimed scientist and engineer, having been awarded a Meritorious Medal from the Royal Aeronautical Society for service of an exceptional nature in New Zealand aviation, and the Cooper Medal, presented by the Royal Society bi-annually to those deemed to have published the best single account of research in physics and engineering.
- **Shaun O'Donnell, Guidance Navigation and Control Lead** – As head of the Guidance Navigation and Control (GNC) division, Shaun O'Donnell has broad responsibility over all electronic and software systems on board Electron.

  Shaun has been involved with Rocket Lab since 2007, where he was solely responsible for all electronics and software systems, including the Atea, Instant Eyes and VLM projects. Prior to Rocket Lab, Shaun worked with a small start-up designing electronics for GPS-based systems, following which he started the specialist electronics company Novitas Technology Development, which creates turn-key electronics solutions using the latest

34 http://www.rocketlabusa.com/about-us

technology available. Shaun holds an Electrical Engineering degree from the University of Auckland in New Zealand.

- **Lachlan Matchett, Propulsion Lead** – Lachlan holds a Bachelor's degree in Mechanical Engineering and Master's degree in Electrical Engineering from the University of Canterbury in New Zealand. During these studies he developed a comprehensive knowledge of sounding rockets and advanced capabilities in trajectory modelling.

  Lachlan joined Rocket Lab in 2012 and worked on the initial propulsion and stage configurations for the Electron launch vehicle, translating the business model into a definitive path forward.

- **Sandy Tirtey, Vehicle Lead** – In 2013 Dr Sandy Tirtey became the vehicle team lead for Electron, responsible for the design of all structural elements, aerodynamics, and deployment systems in the launch vehicle.

  Sandy joined Rocket Lab from the University of Queensland (UQ, Brisbane) where he was the Technical Lead and Project Manager of the Scramspace I Scramjet propulsion free-flight experiment. Sandy managed the project's flight-team who, in cooperation with DSTO and 12 others international partners, successfully built and flew the Scramspace I vehicle in September 2013. Sandy holds a PhD in Hypersonics from The von Karman Institute for Fluid Dynamics (VKI, Belgium) for his work on the ESA EXPERT hypersonic re-entry vehicle.

3.2 Corporate strategy

3.2.1 Nature of the technology

Rocket Lab is targeting a market for high frequency and low cost launches to deliver small satellites into orbit. This has necessitated the development of a low cost launch vehicle. Rocket Lab has developed the Electron rocket which represents a potentially world leading approach to the challenge of affordably launching small commercial satellites.

The technology Rocket Lab has developed has attracted significant investor interest from major participants in the aerospace sector. For example, Lockheed Martin made a strategic investment in the company. Lockheed's chief scientist noted that Rocket Lab's work could have applications for Lockheed's research and development efforts in the area of small lift capabilities and hypersonic [Mach 5 and above] flight technologies.[35]

The Electron

Electron is 16m long, with a 1.2m diameter and has a lift-off mass of 10.5 tonnes. It is capable of delivering payloads of up to 150kg to a 500km sun-synchronous orbit, which is the target range for the high-growth constellation-satellite market.[36]

35 http://www.stuff.co.nz/business/industries/66863431/rocket-lab-teams-with-us-giant-lockheed

36 http://www.nzherald.co.nz/business/news/article.cfm?c_id=3&objectid=11490157

Electron is built completely out of composite carbon. It is designed to reduce the total time it takes to launch a satellite into orbit from years to just weeks. The rocket is expected to cost less than US$5 million (US $4.9 million) (NZ$7.2 million) per launch.

A further description is provided in an infographic in Appendix 1.

The Rutherford Engine

Rocket Lab's flagship engine, the 4,600lbf Rutherford, is a turbo-pumped LOX/RP-1 engine specifically designed for the Electron Launch Vehicle. Rutherford adopts an entirely new electric propulsion cycle, using electric motors to drive its turbo pumps, and is the first oxygen/hydrocarbon engine to use 3D printing for all primary components.[37]

According to Peter Beck, the Rutherford engine is the world's first battery-powered rocket engine and the first new rocket propulsion system created in 50 years. Unlike traditional propulsion cycles based on complicated and expensive gas generators, the Rutherford uses an entirely new electric propulsion cycle, using electric motors, batteries and software to drive its turbo pumps.[38]

3D printed primary components

Rutherford is the first oxygen/hydrocarbon engine to use 3D printing for all primary components including its engine chamber, injector, pumps and main propellant valves. Using this process, Rocket Lab's engineers have created complex, yet lightweight, structures previously unattainable through traditional techniques, reducing the build time from months to days and increasing affordability.[39]

Electronic systems[40]

Rocket Lab develops complex electronic systems with applications in avionics, guidance and control, optics, and communications. The avionics, guidance and navigation systems are the brains of any rocket system.

Avionics[41] – Rocket Lab's Electron launch vehicle uses highly modular electronics nodes, with near-identical modules used in both stages. This modularity provides a high level of reliability and requires minimal reconfiguration, a key enabler for Rocket Lab's high-frequency launch schedule.

Guidance and navigation[42] – Deploying a payload to orbit requires precise guidance and control of the launch vehicle from lift-off until payload separation. Rocket Lab is developing advanced guidance algorithms to achieve precise orbit insertion with minimal reconfiguration

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37 http://www.rocketlabusa.com

38 http://www.stuff.co.nz/business/small-business/67717283/rocket-lab-unveils-electric-rocket-engine

39 http://www.rocketlabusa.com/rocket-lab-reveals-first-battery-powered-rocket-for-commercial-launches-to-space

40 http://www.rocketlabusa.com/about-us/electronic-systems

41 http://www.rocketlabusa.com/about-us/electronic-systems/avionics

42 http://www.rocketlabusa.com/about-us/electronic-systems/guidance-and-control

between missions. Again this guidance and navigation system is the first to be developed in the last two decades.

Electron makes use of thrust vector and reaction-mass altitude control to guide the vehicle along its trajectory. Each of the 9 Rutherford engines on Electron's first stage incorporates a two-axis thrust vector control system, allowing Electron to launch even in the strongest wind conditions. This range of control enables >99 per cent launch availability due to upper atmosphere winds at the New Zealand launch facility.

Carbon composite technologies[43]

Over the past five years, Rocket Lab has invested heavily in the development of carbon composite flight structures, especially propellant tanks. A low structural mass fraction is a crucial performance indicator for orbital launch vehicles. Traditionally, a low mass fraction is hard to achieve for smaller rockets in Electron's class. Designing Electron as a fully carbon-fibre vehicle allow Rocket Lab to meet its mass fraction targets without compromising structural integrity. The key enabler for this design is the use of advanced materials to make carbon composite tanks compatible with liquid oxygen, the powerful cryogenic oxidizer used in Electron.

Thermal Protection[44]

During flight, Electron will experience extreme thermal conditions with its cryogenic tanks operating at temperatures of -200 degrees Celsius and its thermal protection system pushed to thousands of degrees. Thermal protection systems are required in order to ensure the safe delivery to orbit of the rocket's payload. Rocket Lab has previously developed and commercialized a range of thermal protection products.

Payload integration[45]

Electron's upper stage is designed with the capability to disconnect the payload integration from the main booster assembly. Sealed integrated payloads can then be transported back to Rocket Lab where integration with the main booster can occur in a matter of hours. This approach eliminates the risk of cascading delays and allows customers to regain control of the integration process, using their own preferred facilities and personnel.

3.2.2 Business model

Rocket Lab's business is centred on the challenge of providing dedicated, frequent and affordable launches for the small satellite market. Over the last couple of years, there has been a massive growth in commercialisation of space as well as the technology behind it. In particular satellite technology has come down substantially in both size and price. The company's aim is to tap the growing market for commercial applications using increasingly capable small-satellite technology.

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43 http://www.rocketlabusa.com/about-us/carbon-composite-technologies

44 http://www.rocketlabusa.com/about-us/thermal-protection

45 http://www.rocketlabusa.com/rocket-lab-reveals-first-battery-powered-rocket-for-commercial-launches-to-space

Rocket Lab's launch services are designed to take satellites to low Earth orbit (LEO). Satellites in these orbits currently have a lifespan of between 5-7 years after which they need to be replaced.[46] This means that there are opportunities not only to be part of the growth phase of the commercial satellite constellation market, but also in the replacement of these satellites.

Frequent launch

As described above, Rocket Lab has designed its launch vehicle to minimise the time taken to get into space. Its business proposition and reason for locating its business in New Zealand is centred on the goal of providing a high frequency launch service of approximately 2 rockets per week.

Rocket Lab seeks to make the process of launching satellites streamlined and accessible. For example it is already taking online bookings for launches starting in the third quarter of 2016. A number of these launches are already fully booked.

Dedicated launch

There are dozens of satellite launches every year but Rocket Lab and the Electron represents a new approach to an old problem. So far most of the commercial effort has gone into satellite technology, with only a handful of companies reinventing launch. The current industry approach was described by Peter Beck in a recent Idealog profile of Rocket Lab:[47]

> *"What's normally done in this industry is that you take a heritage Russian rocket motor from here, and a heritage tank from over there, and you put them all together. But to start from scratch and assume there are no constraints is a new approach."*

There is a significant advantage to dedicated missions as opposed to ride share than just the time line to reach orbit. Small satellites rely on numbers ranging from 3 to 2,000 to form constellations. A dedicated launch vehicle is able to place a satellite to exactly the orbit the customer requires and the spacing required to create a commercial constellation. This accuracy allows a whole host of new and improves satellite services such as building much higher resolution images of earth and image feeds that are closer to real-time. Ride share flights just go where the main payload is heading and no adjustment for orbital insertion is made for ride share satellites.

Cost of launch

Electron's total launch cost is US$4.9 million. This launch cost is estimated to be a minimum of 50 per cent cheaper than anything else in the market.[48]

Rocket Lab is currently taking online bookings for upcoming launches for:[49]

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46 http://www.stuff.co.nz/business/industries/69859442/Rocket-Lab-eyes-Birdlings-Flat-Canterbury-as-launch-site

47 Vincent Heeringa (12 August 2015) 'Mission possible: inside Rocket Lab's big commercial space venture', *idealog*, accessed online, URL: http://idealog.co.nz/venture/2015/08/mission-possible-inside-rocketlabs-big-commercial-space-venture

48 Figure taken from MBIE paper.

49 http://www.rocketlabusa.com

- USD$50,000 – $90,000 for a 1u cube satellite launch.
- USD$180,000 – $250,000 for a 3u cube satellite launch (3 x 1u).

Launch prices reduce or increase based on available space and proximity to the launch date.[50]

The importance of a dedicated launch over a ride share is that the customer has control over when the launch will occur. This is critical to the rapid cycle and "new space" business as large numbers of satellites are required in constellations to realise their business models.

3.2.3 Key competitors

The key competitive strengths of Rocket Lab's launch venture are as follows:

- Target the small satellite market which is likely to grow very quickly.
- Likely to be first to market with a launch vehicle and service offering that meets the needs of this market, being:
  - Price.
  - Dedicated launches.
  - Frequent launches.
  - Access to specific orbits.

Currently operational launch services are not well positioned to serve the growing small satellite industry. Existing launch offerings are all large rockets or air launch systems. These include:[51]

- The SpaceX Falcon 9, starting from $61.2 million USD for a Falcon 9 launch.[52]
- The Arianespace Ariane 5 ECA, estimated launch price of around $210-220 million USD.
- International Launch Services which sell launch services of the Russian Proton rocket.

Arianespace's launch price is at the more expensive end of the spectrum but the company has a strong track record of reliability. Even in spite of a recent mission failure, SpaceX remains the most competitive company in this field as commercially focussed and agile company in comparison to the other companies which are large, lumbering and often reliant on military or other government funding.[53]

For small satellite customers the most cost effective way of getting to orbit in the current market is to 'ride-share' as a secondary payload. However, as noted earlier this means that these customers have little control over the timing of the launch and the destination in terms of the specific orbit. Secondary payloads are also at greater risk of being destroyed if something goes wrong with the mission.

50 http://www.rocketlabusa.com/space-is-open-for-business-online

51 There are approximately 15 international launch service providers that provide commercial services. World Launcher Review 2015-16.

52 http://www.spacex.com/about/capabilities

53 Jeff Foust (25 August 2014) The unsettled launch industry', *The Space Review* accessed online http://www.thespacereview.com/article/2585/1, and World Launcher Review 2015-16.

Rocket Lab is aiming at quite a different offering and market than the established launch industry described above. It is not the only company aiming to claim this market niche, there are other start-up companies aiming to develop similar launch vehicles and to provide similar services. However, Peter Beck and experienced US-based space industry investors consider that Rocket Lab is around 3 years ahead of its competition. In particular, Rocket Lab has conducted successful prototype launch and has its engine already built. It appears that Rocket Lab is in a good position to claim a significant first mover advantage.

3.3 Key parties

3.3.1 Investors

Rocket Lab is a privately funded company. Its major investors include Khosla Ventures, Sir Stephen Tindall's K1W1 investment fund, Bessemer Venture Partners and Lockheed Martin.[54]

Table 2: Rocket Lab Investors and Partners

Investors		
Party	**Date**	**Nature**
Defense Advanced Research Agency (DARPA) (US)	2011	Phase one research contract focussed on propellants.
DARPA and the U.S. Office of Naval Research (ONR) (US)	2011	Phase two contract of the propellant development programme.
Khosla Ventures (US)	2013 2015	A-Round venture capital funding. B-Round venture capital funding
K1W1 (NZ)	2015	B-Round venture capital funding
Bessemer Venture Partners (US)	2015	B-Round venture capital funding

54 http://www.stuff.co.nz/business/small-business/67717283/rocket-lab-unveils-electric-rocket-engine

Investors		
NASA (US)	2015	Commercial Space Launch Act Agreement with the National Aeronautics and Space Administration (NASA). The agreement enables Rocket Lab to use NASA resources – including personnel, facilities and equipment – for launch efforts.
Lockheed Martin (US)	2015	Strategic investment to support exploration of future aerospace technologies.

3.3.2 Customers

Rocket Lab is unusual in that it already has customers pre-signed with commitments for over 30 launches. These contracts are a vote of confidence in the company and to a certain extent demonstrate its credibility. At the same time a number are also likely to be an 'insurance policy' for some of the bigger players who cannot risk not having a space in Rocket Lab's launch manifest in the event that they are successful.

3 levels of customer:[55]

1. CubeSat – box and shoot.
2. Blue chip clients.
3. NASA-type clients - For someone like NASA a $100million satellite is nothing.

Recently there has been growth in customers from Europe.

Rocket lab's forward orders have come from the following industries:

- Communications – 80 per cent.
- Earth observation – 10 per cent.
- Technology – 5 per cent.
- Scientific – 5 per cent.

Customers include companies like Moon Express (US), a Google Lunar XPRIZE competition entrant. Moon Express has recently signed a three launch contract with Rocket Lab to take three robotic craft to the Moon. Electron will take the Moon Express craft to Lower Earth Orbit (LEO) where the craft will make their own way to the moon.[56]

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55 Peter Beck, Meeting with MBIE, 14 September 2015.

56 http://www.nbr.co.nz/opinion/nzs-rocket-lab-signs-contract-company-planning-moonshots-2017

3.3.3 Key suppliers

Rocket Lab has established a small group of trusted suppliers including a carbon composites company a number of engineering firms and a 3D printing company.

3.3.4 Government involvement

Rocket Lab has received significant support from a variety of government agencies in New Zealand. The most significant involvement by government has been a grant from Callaghan Innovation towards funding for research and development. In 2013 Rocket Lab received a Growth Grant which provides 20 per cent public co-funding for qualifying firms' eligible R&D expenditure. Beyond the dollar value of the grant this funding also provides the project with a certain level of credibility which has helped Rocket Lab to secure further funding from private investors.

3.3.5 Other partners

University of Canterbury Rocketry and PhD programme

The University of Canterbury Rocketry Group (UC Rocketry) was founded in 2009 by Dr Chris Hann and one of his students. Rocket Lab participates as an industry supporter of this group. The collaboration between UC Rocketry and Rocket Lab has led to the development of an advanced engineering course specialising in aerospace engineering.

Currently around 6 alumni of this engineering programme are employed full-time at Rocket Lab. A number of these students are applying the research from their PhDs directly to Rocket Lab's operations.

3.4 Key assumptions and risks

Table 3: Key assumptions and risks

Key assumptions and risks		Likelihood that risk will occur and potential impact
Technological		
Ability to scale up	For the purpose of this report, we assume that any up-scaling risks are temporary risks than can be over-come given enough time to find and implement a solution.	High likelihood of occurring in the short term. Medium impact. Rocket Lab may need to look offshore to get parts supplied if domestic production can't meet demand. If Rocket Lab import parts this will lower the economic benefit to New Zealand.
Ability to streamline rocket production	A high launch frequency is at the heart of Rocket Lab's proposition.	Medium likelihood of occurring. It is likely in the short-to-medium term that Rocket Lab will experience some teething issues in its production. As above, we assume that these issues can be remedied given enough time to find and apply a solution. Medium impact. Production that is not streamlined would result in waste of time or effort that may not be sustainable over a longer period of time.
Newness of the technology	While many innovative approaches have been taken in developing Electron the key technological risk is likely to be in the area of guidance and navigation. The failure rate for maiden flights of brand new rocket designs since 1990 is approximately 50 per cent.[57]	Low likelihood of occurring. Rocket Lab has tested this system through the launch of proto-types. There appears to be a high level of confidence in the technology from key industry participants. Low impact. The impact of this risk depends on the nature of any technology failure, some initial issues and subsequent refinements would be expected; a big technology-related failure is assumed to be unlikely.

57 World Launcher Review 2015- 2016, p 35.

Key assumptions and risks		Likelihood that risk will occur and potential impact
Economic		
Demand for the technology	Achieve/maintain competitive advantage in key aspects of rocket production including propulsion, and guidance and navigation technologies. Risk of emergence of competing technologies or methods for deploying satellites.	Low likelihood of occurring. Rocket Lab's proposition represents a significant disruption to the launch industry, and one that has significant credibility with potential customers and investors. Any new technology and company would have a significant challenge to demonstrate reliability and credibility. Medium impact. Even if a competing technology were to come along, Rocket Lab's offering involves a number of points of advantage (e.g. location), and there is significant demand for launch services that is currently not being met, and is likely to increase as launch services become available and cheaper. As such the introduction of a competitive technology may not have a significant impact particularly in the short-medium term.
Demand for the service	The key parts of the proposition are: high frequency launch, dedicated launch, ability to reach particular azimuths. Achieve/maintain competitive advantage in key areas of the proposition. Assumes sufficient market demand for specific for specific orbits.	Low likelihood of occurring. The number of pre-signed launch contracts and the involvement of experienced investors from the space industry are indicative of strong demand assuming that Rocket Lab is first to market. Impact as above for 'demand for the technology'.
Availability of staff	Risk of failure to attract/retain necessary capability and capacity for Rocket Lab and key suppliers.	Medium-low likelihood of occurring. For the most part these skills are likely to be able to be imported from overseas. Additionally local tertiary providers and research institutions are moving to respond to demand. High impact. Rocket Lab and its suppliers run highly knowledge-intensive operations; an insufficient supply of skilled personnel could limit growth.

Key assumptions and risks		Likelihood that risk will occur and potential impact
Intellectual property		
First mover advantage	Risk that competing launch companies will get to scale faster.	Low likelihood of occurring. Rocket Lab is estimated to be 3 years ahead of its competition. Medium impact. The impact of losing a first mover advantage may not be severe if for example, locational advantage is maintained.
Regulatory risk		
Technology controls	Risk that technology controls will prevent the use of a piece of technology on the critical path for Rocket Lab or suppliers. This problem appears to have been largely overcome to date through the reinvention of many components that could otherwise have been imported, which has been strength out of necessity for Rocket Lab. However, as they move closer to launch things become more time critical.	Low likelihood of occurring. Medium impact. This assumes that any restriction would either be temporary until the TSA is signed, or that Rocket Lab or its suppliers could innovate around the barrier as they have done before. In both cases the impact would be a delay to reaching optimum launch frequency.

4. Stakeholder feedback

We interviewed a wide range of stakeholders including Rocket Lab and its suppliers, government agencies, scientists, and other commentators. A list of interviews is attached at appendix 2. We asked these stakeholders about the potential opportunities and economic benefits of the development of a rocket launch industry in New Zealand. While a range of views were expressed, there was broad agreement around a general set of themes.

4.1.1 Direct benefits, opportunities and challenges

Immediate benefits to New Zealand companies/suppliers

Rocket Lab's key suppliers are a small group of high-tech niche manufacturers. In our conversations with them, each of these suppliers noted:

- The work they do for Rocket Lab, even just in the production phase, is very significant (in revenue terms) to their businesses.
- They have been required to innovate in response to Rocket Lab's demands for novel, highly technical and high quality products and services.
- They are either in the process of, or have already, made significant investments to expand their operations.

Opportunities relating to scale

Stakeholders noted significant benefits from an increase in scale of operations in some key areas of manufacturing as a result of Rocket Lab's activities.

Opportunities

Provides scale in areas where we have an emerging competitive advantage (high tech manufacturing and advanced materials).

The work generated by Rocket Lab has increased the capacity of New Zealand business and continues to challenge them and raise their ambition. Most suppliers we talked to had made significant investments in capital to increase their capacity.

In relation to Rocket Lab's 3D printing manufacturer, plans have already been made to scale the business to a size where it can manufacture components for a schedule of one launch per week.

The CEO told us he considers that this scale creates big opportunities for other New Zealand companies as it gives them greater access to the capabilities and technology that they would either not have access to or would otherwise need to go overseas for. Additionally growing scale in New Zealand in this industry has flow on benefits for other businesses when it anchors projects here.

Opportunities related to skills

All stakeholders we spoke to considered that the highly skilled nature of Rocket Lab's launch venture was likely to have significant economic benefits to New Zealand.

Opportunities

Dr Hann at the University of Canterbury views one of the key benefits of Rocket Lab's activities as generating high skilled employment for engineering graduates in New Zealand. He commented that the Rocket Lab project was a 'nice coming together of what everyone is looking for' – jobs in maths, chemistry and physics. A number of graduates from his advanced engineering program have been employed by Rocket Lab. Some of them have had the opportunity to apply their PhD research directly to the development of Rocket Lab's Electron rocket. Dr Hann noted that a key benefit of this type of project is that it keeps skilled people in the country and attracts skills from overseas.

Additionally, the high profile and exciting nature of the Rocket Lab project inspires students to study engineering and other related disciplines (referred to elsewhere in this report as 'aspiration effects'). Dr Hann has observed an increase in interest both from current tertiary students (he received 50 applications for the advanced engineering programme but could only take 8), but also from students at the high school level.

4.1.2 Indirect effects

Potential 'platform play'

Echoing some more general comments we heard from a variety of stakeholders about wider benefits, one stakeholder we spoke to considered that the Rocket Lab project offered an opportunity for New Zealand to make a 'platform play'[58]. In this particular stakeholder's opinion, New Zealand needs to identify proven disruptive high value opportunities in emerging markets with great management teams that have the ability to become new billion dollar platforms. And then concentrate the innovation system (research institutions) linked to industry on supporting the growth of these platform plays into scale export opportunities.

This particular stakeholder considers that Rocket Lab is a perfect example of a potential platform play for New Zealand and as such, there is a need to build industry clusters around Rocket Lab. An example of a cluster provided was a nano satellite industry in New Zealand linking Universities or research organisations with companies like Google, Rakon, Tait, and Trimble and directed towards applications like agriculture etc.

Potential for a spin-off satellite industry

Most people that we spoke to spoke of the potential for a spin-off satellite industry and generally agreed that satellites would probably easier for New Zealand to make than rockets in terms of the nature of the technology and level of skill involved.

One stakeholder we spoke to noted that while Rocket Lab's launch business would still have economic benefits for New Zealand even if it was nothing more than a "service business" to

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58 This is a reference to the following concept: In construction, a platform is something that lifts you up and on which others can stand. The same is true in business. By building a digital platform, other businesses can easily connect their business with yours, build products and services on top of it, and co-create value. This ability to "plug-and-play" is a defining characteristic of Platform Thinking. Source: https://hbr.org/2013/01/three-elements-of-a-successful-platform.

the international satellite industry, but that the benefit to New Zealand could be increased by establishing a New Zealand based satellite industry.

A further stakeholder noted however that there is already an existing satellite industry base in a number of other countries such as the US and the UK among others. New Zealand satellites would be up against large vested interests and embedded investment which means that even if the technology is very good, market entry will be difficult. He argued that in order to get around this New Zealand's satellite industry would need to be differentiated in some way.

We heard from a couple of stakeholders about a potential New Zealand-based satellite venture. Additionally, Dr Hann noted there was potential to expand the rocket PhD course into engineering for satellites through an existing partnership with a German University. He further noted the potential to partner with companies like Trimble (navigation) and Tait Limited (communications), innovative companies which both have offices in Christchurch.

Composites

Another potential cluster area identified by a number of stakeholders is in advanced materials such as carbon composites. For example, there are potentially significant opportunities in the area of advanced composites with applications across a wide range of industries including Formula 1 race cars. "The composites industry is set for revolution, everything needs to lighter, stronger and faster." Other applications mentioned in various interviews include satellite manufacturing, lightweight vehicles for improved fuel economy, lighter and more efficient wind turbines, and lighter more efficient industrial equipment.

A conversation with some of Callaghan Innovation's leaders of the Advanced Materials Network confirmed that there are significant opportunities in the area of advanced composites.

4.1.3 Catalyst effects

Rocket Lab is a charismatic venture which has attracted a lot of attention and excitement from those in the space industry as well as lay people. In our interviews it was clear that this excitement arose not just from the activities and innovations of Rocket Lab itself, but also from the potential opportunities that this type of project might catalyse in New Zealand. This section of our report provides an overview of the broader and more speculative benefits that stakeholders identified could come out of a launch industry being established in New Zealand.

Generating research and development activity

Rocket Lab has located all of its research and development activity in New Zealand. The company has developed innovative products before the Electron, such as Instant Eyes, a joint venture with L2 Aerospace which developed a rapidly deployable hand launched rocket UAV system. Indications from Peter Beck are that the company will continue to undertake research and development in New Zealand beyond the setup of a launch business.

As noted above, the ambitious nature of Rocket Lab's project and the fact that it is novel in New Zealand has pushed its suppliers to innovate. For example, we heard from the company that supplies its propellant fuel that it had been required to find novel solutions to the temporary storage and transfer of fuels at locations and under conditions that they have not previously been required to work in.

The carbon composites manufacturers have had interactions with top designers and upgraded their quality management processes right throughout the business as a result of its work with Rocket Lab.

Knowledge and technological spillovers

Professor John Raine, Vice Chancellor of Research and Innovation at Auckland University of Technology, emphasised the wider benefits to the innovation system of having people working on diverse areas of very advanced technology. His view was that where you have teams of engineers and scientists working on advanced technology like this there is huge potential for ideas to feed into other industries. Developments in the areas of avionics, software and communications are likely to have benefits that flow into other industries. Professor Raine noted that these benefits can be very difficult to predict.

An example of where spillovers have already occurred was provided by Professor Hann at the University of Canterbury who explained that advances in medical technology have contributed to Rocket Lab's guidance and navigation system. It is possible that advances made in the algorithm through its application to aerospace engineering may then flow back through to the medical industry or find new applications entirely.

Stakeholders we spoke with from Callaghan Innovation noted that the Un-manned Aerial Vehicle (UAV) sector in New Zealand is an area where technology spill overs may occur. Currently New Zealand's UAV sector largely specialises in hardware manufacture and we have some companies that are very successful in this area. We also have locational advantages for testing UAVs. However, these activities sit at the lower-value end of the UAV value chain with activities in aeronautics and navigation for example, at the high value end. If the advances that Rocket Lab have made in the area of guidance and navigation for example, were to flow through to the UAV industry it could substantially increase the value of the industry here.

Reputation benefits

The high profile and high-tech nature of Rocket Lab's project provides opportunities to showcase New Zealand's capabilities in some key areas which stakeholders consider creates the potential for significant reputational benefits both to the individual businesses/suppliers involved but also to New Zealand in general. Almost all stakeholders we spoke to mentioned this as a potential economic benefit.

For example, one engineering firm told us that the work they have done with Rocket Lab has already begun to create more business opportunities as it is increasingly recognised for being capable of making complex and 'space-worthy' products. Stakeholders generally considered that the project will have wider reputational effects giving New Zealand a name for being able to undertake innovative and complex technical projects.

4.1.4 Regional economic benefits

Regional economic benefits were explored in discussion with Fergus Power the CEO and Roger Mathews the Transformation Manager for the Wairoa District Council (WDC). Rocket Lab has chosen to establish a launch site at Mahia. The WDC granted Rocket Lab a consent which allows for 120 launches per year from that site. Rocket Lab is leasing land for its launch sites from a local Iwi. While the Fergus was unaware of the exact commercial arrangements he noted that the Iwi was extremely happy with the arrangement. The primary benefits identified by Fergus and Roger concern increased tourism and road upgrades.

Tourism

Fergus and Roger consider rocket tourism, visitors coming to view rocket launches, is likely to attract visitors to Wairoa. They considered that interest in rocket launches could add to a number of existing offerings in the wider area. For example, they noted there is significant cruise tourism in adjacent districts, particularly Napier. Fergus noted tourism infrastructure in the district is not currently well developed but that the council planned to invest in upgrading it, initially focussing on making the district camper-van friendly.

They also see significant potential to increase tourism in the district in relation to the Great Walk at Lake Waikaremoana noting that the Department of Conservation is looking to take pressure off of the Tongariro Crossing which may redistribute visitor numbers within the central North Island. Additionally, Tuhoe is making significant investments in building a conference centre and accommodation at Aniwaniwa. Fergus and Roger noted both plans would be hindered somewhat by the state of SH38, the access route to Waikaremoana, which is unsealed.[59]

Road upgrades

In respect of roading, the WDC notes Rocket Lab's activity may increase the business case for upgrading roads in the area. In particular State Highway 2 (SH2) which to the north links Gisborne with Opotiki, the rest of the Bay of Plenty including Tauranga and the upper North Island in general, and to the southwest links Gisborne and Wairoa to Napier, Hastings and the rest of the lower North Island. The WDC notes parts of this highway are vulnerable, for example heavy rainfall closed the road just a couple of weeks before our interview with them.

Heavy vehicle traffic in this area is significant and increasing due to the expansion of the forestry industry. If Rocket Lab conduct the full 120 launches per year from its site at Mahia, it will likely need to use SH2 to bring tankers of liquid oxygen down to the launch site approximately once a week. The findings of the 2014 East Coast Regional economic potential study indicate that heavy commercial vehicles (HCVs) account for about 10-20 per cent of total traffic on SH2. The study noted that an upgrade to the road was being investigated to make it more suitable for modern heavy vehicles but that the viability of the upgrade was constrained by the number of structures that would require upgrade and costs associated with managing deterioration.[60] Fergus and Roger consider that the increase in traffic (both heavy vehicle and tourist) and the need for road security associated with Rocket Lab's operations in the area will likely strengthen the business case for investment in the road.

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59 SH38 north of Wairoa provides a route between Wairoa and the Te Urewera National Park and Rotorua but much of this is unsealed and its use, particularly for freight, is very limited.

60 MBIE (2014) East Coast Regional Economic Potential Study, http://www.mbie.govt.nz/info-services/sectors-industries/regions-cities/regional-growth-programme/pdf-image-library/East%20Coast%20Study%20Stage%201.pdf.

Other potential benefits

Additional potential economic benefits identified by Fergus and Roger include the potential for job creation, and reputational benefits. They see potential for Rocket Lab to locate its assembly activity, and ideally some of its manufacture in Wairoa. They noted the area has some significant locational advantages over Auckland including the availability and affordability of land. If such activity were to be located in Wairoa it could have significant economic benefits through job creation in the area. Roger is also investigating the possibility of attracting further investment in the area from companies that might benefit from proximity to Rocket Lab's launch site such as satellite manufacturers.

Rocket Lab's presence in the District also has significant potential to positively affect its reputation. The East Coast Regional Economic study found that the wider region is perceived as offering high quality natural amenity and lifestyle factors however, the study also found the area to be perceived as "socio-economically deprived", with lower than average levels of education, lower levels of income, higher than average crime rates and a higher health burden.[61] Fergus and Roger also noted existing negative perceptions of the area and consider that Rocket Lab's activities offer the opportunity to rebrand Wairoa as a high-tech area which could have economic benefits in attracting further investment and also in raising aspirations.

4.1.5 Summary observations

A wide range of potential benefits were discussed with stakeholders. Our observation is that some of these are likely more achievable than others. For example, the direct effects of Rocket Lab's current activity and investment will be directly observable. Furthermore, benefits to the supplier ecosystem are highly likely to occur and to be reasonably significant to those businesses. Other benefits are more speculative, in particular some of the regional benefits such as increased employment resulting from the location of satellite manufacturing in the district.

61 MBIE (2014) East Coast Regional Economic Potential Study, http://www.mbie.govt.nz/info-services/sectors-industries/regions-cities/regional-growth-programme/pdf-image-library/East%20Coast%20Study%20Stage%201.pdf.

5. Economic impact assessment

5.1 Summary of results

This section assesses the economic benefit to New Zealand from Rocket Lab successfully establishing a launch industry here. The scenario modelled is a base case with an upper and lower bound. The lower and upper bounds are one launch per week (52 launches per year) to close to two launches per week (120 launches per year). 120 launches per year represents the number of launches the Wairoa District Council has consented and therefore represents a natural upper limit in the base case scenario. 52 launches, or a launch a week, reflects current forward orders. We have assumed that reaching this steady-state number of launches takes five years. In years one to five we assume the number of launches slowly "ramps up" to this steady-state.

We assume not all launches are supplied by domestic firms reflecting capacity constraints and some product is sourced offshore. The assumed proportions which are domestic vs foreign sourced is based on commercial sensitive information and hence not reported here.

Using a timeframe of 20 years, the table below shows the results of our modelled base case scenario.

We are reasonably confident in three "sets" of benefits – direct, indirect and induced and hence we discount them conservatively at 8 per cent. The final set of benefits, namely "catalyst effects", are more speculative. To account for the uncertain nature of this final benefit stream we discount it by 50 per cent.

We estimate that Rocket Lab could contribute between $600 and $1,550 million of value add to New Zealand over 20 years; of which direct, indirect and induced effects could be between $400 - $1,150 million.

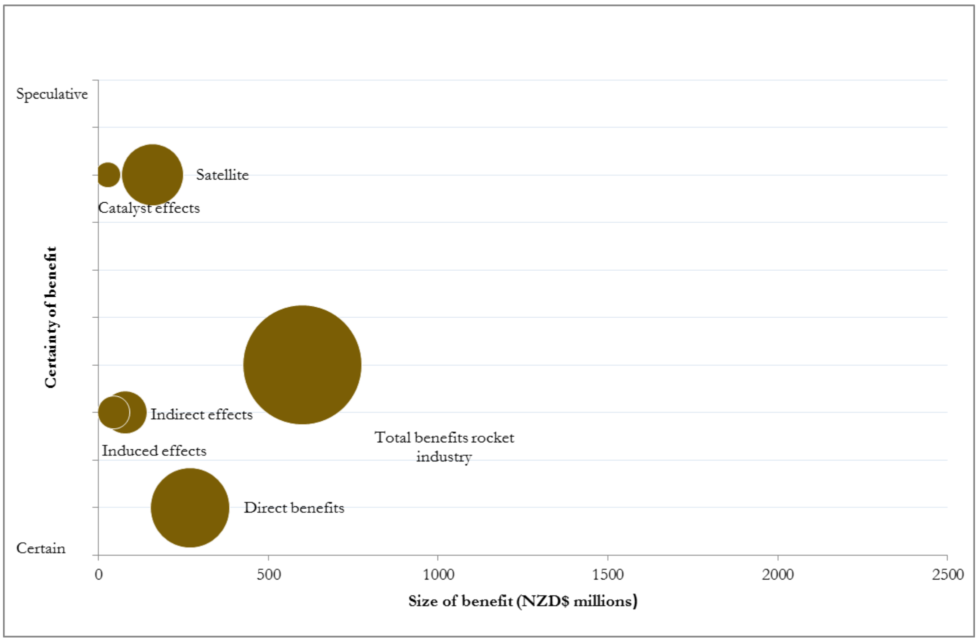
Table 4 Benefits to New Zealand from the development of a rocket launch industry

Effect	Definition	Magnitude (millions)
Direct effects	Activity and employment by Rocket Lab and its key suppliers. Key suppliers are those who directly supply parts of the rocket.	$270- $700 over 20 years, discounted at 8 per cent.
Indirect effects	Activity and employment by industries who supply intermediate goods[62] and services to Rocket Lab and its key suppliers. We also include space	$80- $280 over 20 years, discounted at 8 per cent.

62 Intermediate goods are goods produced by one firm/industry that are used in the production process of another.

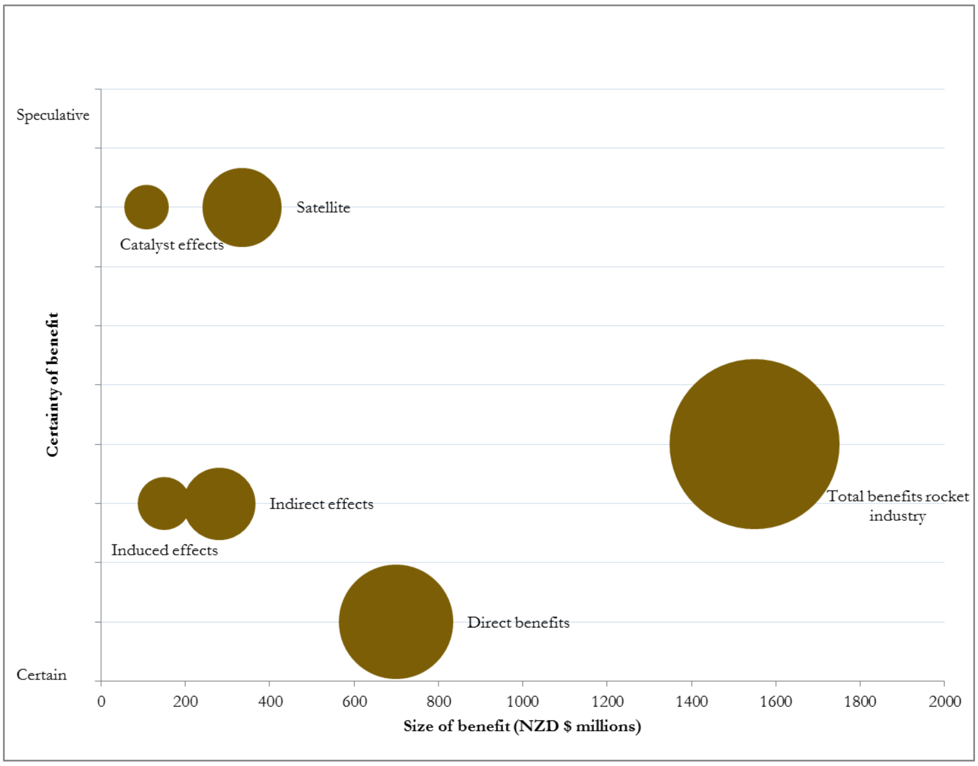
Effect	Definition	Magnitude (millions)
	tourism and launch infrastructure build in this class of benefits.	
Induced effects	Activity and employment that is the result of spending by those employed directly or indirectly owing to Rocket Lab's activities.	$45 – $150 over 20 years, discounted at 8 per cent.
Catalyst effects	Other benefits not counted above where Rocket Lab's activities have acted as a catalyst to benefits being realized. The benefits we specifically count are: - Aspirational effects - R&D spill-overs - Easier access to satellites for NZ industry	Catalyst effects (excl. satellite access): $30 - $110 Satellite access: $160 - $340 over 20 years, discounted at 50 per cent.

Figure 5 Present value of benefits over 20 year period – one launch a week



Source: Sapere estimates

Figure 6 Present value of benefits over 20 year period - two launches a week



Source: Sapere estimates

5.2 Analytical approach and process

Our economic impact assessment assesses the likely overall economic impact of the proposal/project, i.e. the impact on the economy of a proposal proceeding. An economic impact assessment differs from a cost benefit analysis as it ignores the costs of proposal and therefore does not allow ready comparison with other competing projects. This type of analysis differs from traditional financial analyses as it assesses only those costs and benefits or economic impacts overall on New Zealand Inc. rather than on an individual investor/firm.

An economic impact assessment can focus on two metrics:

- Expenditure/revenue/ gross output – gross output is principally a measure of an industry's sales or receipts, which can include sales to final users in the economy (value-added) or sales to other industries (intermediate inputs).
- Value-added – value-added nets out the use of immediate goods from other sectors in the production of the final "good". On a conceptual basis this is the same approach used in calculating GDP. Claus and Li (2003) note value-added includes compensation

of employees, gross operating surplus, consumption of fixed capital and "other taxes on production"[63].

We focus on the value-added metric for a number of reasons:

- As the Bureau of Economic Analysis (US)[64] notes: "gross output by industry is an essential statistical tool needed to study and understand the interrelationships of the industries that underlie the overall economy. However, because of its duplicative nature, it may not be a good stand-alone indicator of the overall health of an industry or sector". Therefore gross output is probably the metric of the two that policy makers are least interested in; and
- GDP is also calculated on a valued-added basis therefore it allows the magnitude of benefits we calculate to be directly compared with other industries.

The "typical" approach to economic impact assessment involves calculating the level of final output of the company/industry under investigation relative to the counterfactual (hereafter the change in output) and estimating how this change in output flows through to other industries and household spending. Typically two types of multipliers are used to estimate the flow on effects:

- Type I multiplier: The multiplier used to estimate the additional output in industries which supply intermediate goods and services to the industry whose output (or more correctly "final demand") is changing.
- Type II multiplier: The multiplier used to estimate the additional output in supplying industries, as well as the value-added from additional household expenditure from employees of affected industries. Therefore the difference between the value-added as calculated by type II multiplier and the type I multiplier represents the induced benefits.

In our analysis, except in a couple of instances we note below, we generally use multipliers to estimate the flow on effects of Rocket Lab's activities. Whilst multipliers are a useful tool they have a number of implicit assumptions that need to be considered:

- multipliers assume the industry being studied has spare capacity. If an industry is supply constrained (or its supply curve is generally inelastic) an increase in demand for its product may see a rapid increase in the product's price but not necessarily much increase in the industry's output.
- multipliers assume there is no change in relative prices in the economy that would lead to substitution effects.[65]

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63 Statistics New Zealand (2014) defines other taxes on production as "all other taxes that enterprises incur from engaging in production. They are payable irrespective of profitability and may be payable on the land, fixed assets, or labour employed in the production process, or on certain activities or transactions".

64 http://www.bea.gov/faq/index.cfm?faq_id=1034#sthash.Z8EalpUW.dpuf

65 The proper way to analyse the substitution effects from relative price effects is through CGE modelling. However for tractability CGE models normally aggregate industries, this means it would be difficult to model such a specific event such as the expansion of Rocket Lab in such as aggregate framework.

There are also issues of applicability:

- applicability across time – multipliers are based on information contained in Supply and use/ Input-output tables which are produced periodically by statistical agencies. Statistics New Zealand's last release of these tables was for the March 2007 year. This data is prior to global financial crisis and there may have been some changes to the relationships in the New Zealand economy since then (particularly how industries interact with the finance sector).
- applicability within an industry - a multiplier for an industry may not be applicable for a certain firm within an industry if that firm's production function differs significantly from the industry average (i.e. the firm produces its output using the different proportions of imports, labour and capital than the industry average). For this reason we do not use multipliers to estimate the effects of a change in Rocket Lab's output on its key suppliers as it is a very specific relationship. Instead we use what we term "an accounting approach", which we will outline below.
- applicability across countries - A multiplier from one country may not be applicable in another if the countries have different industrial structures (see Claus and Li, 2003 for a comparison of New Zealand's industrial structure with other economies). For this reason we are reluctant to use multipliers for the space industry from other countries - especially given the nascent state of New Zealand's space industry will mean materials are more likely to be sourced from overseas than in countries with an established space industry. This reliance on imports will mean a similar expansion in output will stimulate less domestic production in New Zealand than overseas.

We use what we term an accounting approach to calculate the increase in output (in value-added terms) of Rocket Lab and its key suppliers owing to the increase in Rocket Lab's launches. The accounting approach uses company specific information to calculate the gross operating surplus and compensation of employees.[66] This is a proxy for the value-added of a company. The advantage of this approach is it is company, industry and country specific.

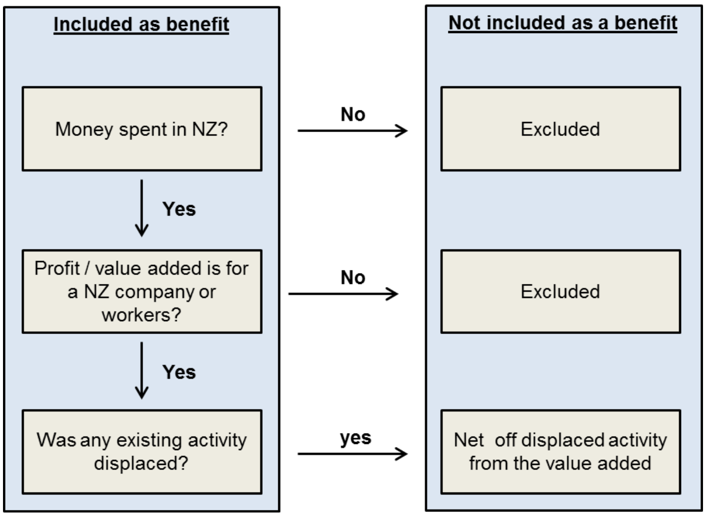
Creation versus diversion

The second conceptual distinction we make is to focus on "trade creation" rather than "trade diversion" – that is we focus on quantifying the benefits to New Zealand of new production as a result of Rocket Lab's activities, rather than quantifying money or resource flows that are reallocated in the New Zealand economy owing to Rocket Lab's activities.

The figure below highlights the high level decisions made in order to determine the benefits (in terms of newly created value-added) to New Zealand of the proposal

[66] We focus on pre-tax values of these aggregates, because as we noted earlier taxes on production are included in value-added. For this reason we count business tax as it is a newly created flow in the economy.

Figure 7: Decision tree



Catalyst effects

We also model a class of benefits we term catalyst effects. This class of benefits captures the extent to which the Rocket Lab's activity boosts New Zealand's welfare, outside the benefits to firms (and their employees) that have direct supply chain links to Rocket Lab (as outlined under indirect and induced effects). We focus on three types of benefits under this banner:

- R&D spillovers refers to the benefits from technology, information and knowledge that is generated by Rocket Lab's (or its key suppliers) activities being applied in other companies or sectors of the economy.
- Aspiration effects - Achievements in aerospace have been shown to have a significant impact in motivating prospective students and researchers into the field.
- Increased use of satellite technology by New Zealand firms and/or government owing to ease of access and/or "priming" effects.

On the last point priming refers an implicit memory effect in which exposure to a stimulus influences behaviour later. We hypothesise that hearing about Rocket Lab's activities may act as stimulus for some New Zealand firms using satellite technology who otherwise would not have. A higher quantum of more accurate and timelier data result in large productivity increases to New Zealand industry and government. For example, Jeyaseelan (2003) discusses the possibilities of using satellite technology to mitigate the effects of droughts and floods on agricultural output.

These types of benefits are relatively amorphous, so we use general representative values to quantify the benefits (outlined below). The fact that these values lack specificity does not mean the benefit type is unimportant, rather there is a lack of more specific information on which to base the analysis. Further, these types of benefits are more speculative – they could result in huge economic gains to the New Zealand economy or conversely they may result in few economic benefits. To account for the uncertain nature of this benefit stream we discount it by 50 per cent.

Our base case scenario in context

We have identified there are three broad scenarios that could occur:

- **Base case scenario** – as described earlier this describes a situation where the range of possible launches per year is between 52 (i.e. one a week) to 120 a week. Based on our interview with Rocket Lab we assume that staff numbers increase to 200 to 400 relative to the counterfactual.
- **Upside opportunity** - there are situations, with non-trivial probabilities, where the benefits of Rocket Lab's activity are orders of magnitude larger than we have assumed. Advances in aerospace technology have a long history of leading to advances in a wide variety of industries.[67] Additionally, Rocket Lab's success could attract other, similar companies, to New Zealand. Further, employees benefit from the experience of working in a start-up and go on to found other companies.
- **Downside risk** - the risk that launch issues/problems could mean that Rocket Lab is not able to launch frequently enough to remain financially viable and exits, likely in a trade sale of its technology.

The focus of our modelling is the base case scenario. Given we are dealing with large amounts of uncertainty we report a range for our estimates. The reported range represents the range of possible outcomes around our base case, rather than range of all possible outcomes (i.e. what could happen under the downside risk scenario and the upside opportunity scenario).

5.3 Detailed results

In this section we provide an overview of the information and assumptions which have informed our results.

The figure below provides a diagram of some of the key relationships in the Rocket Lab supply chain. The table provides some information of how the interrelationship is modelled. The letters in the ( ) in the figure, corresponds the letters in [ ] in the table.

67 Douglas A. Comstock, Daniel P. Lockney and Coleman Glass (2011) 'A Sustainable Method for Quantifying the Benefits of NASA Technology Transfer', *AIAA SPACE 20011 Conference & Exposition*. (p. 7329).

Figure 8 Diagram outlining the relationships we are modelling

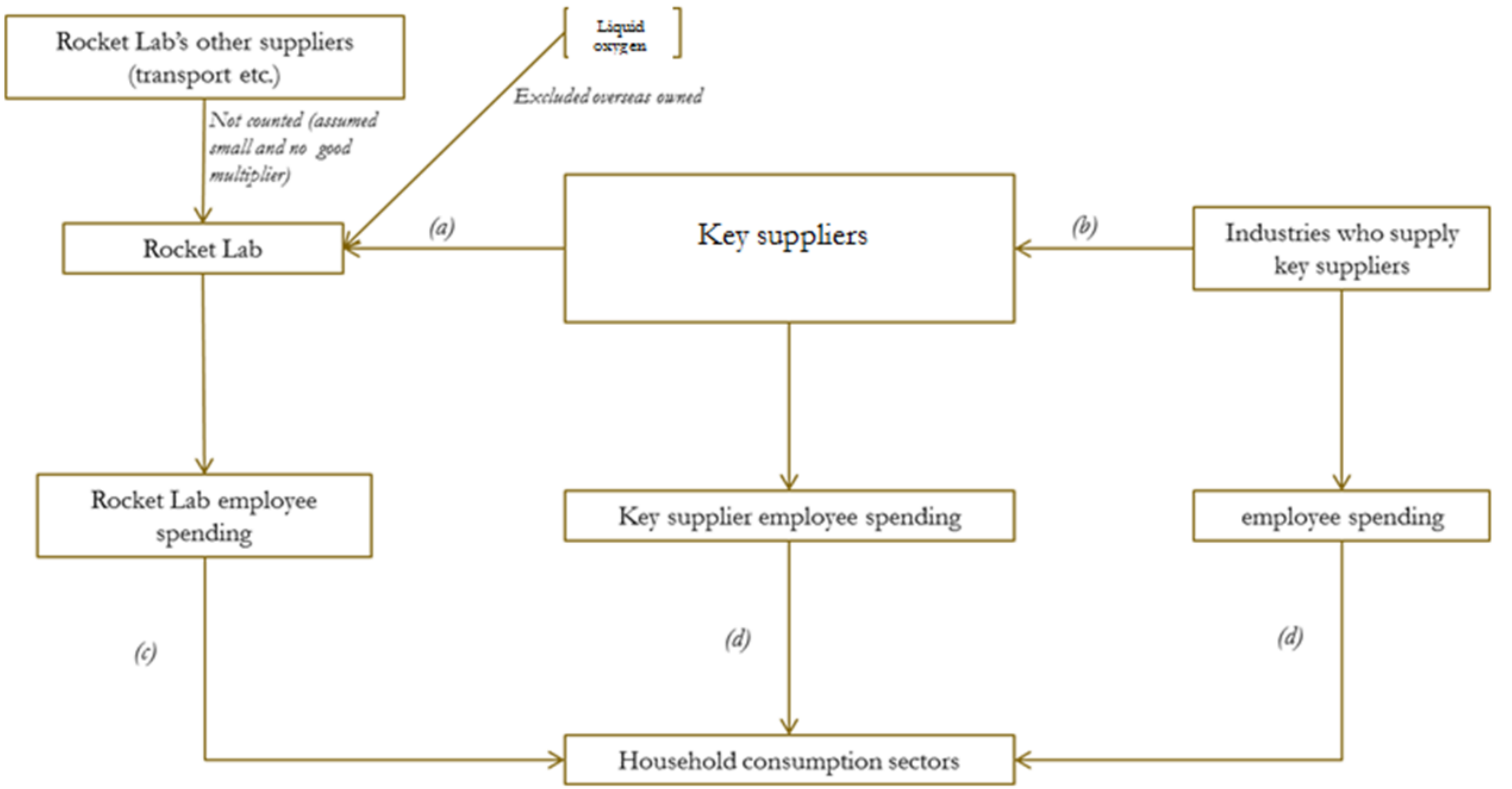


Table 5 Estimation of direct, indirect and induced effects

	Estimation technique
Rocket Lab	*Accounting approach using information from the interviews* Rocket Lab has 68 employees and has open vacancies for 28 more staff. They believe a workforce of between 200-400 personnel will be needed to support one or two launches a week. The value added of Rocket Lab's workforce is measured by the salaries of its employees, and the number of Rocket Lab employees increases as launch frequency increases. The specialised nature of the industries mean we assume very little displacement of other employment in the economy – that is most of the additional employment by Rocket Lab are new jobs to the New Zealand economy. The average salary of these new workers is assumed to be higher than the current average salary in the firm reflecting more recruiting is occurring from offshore. Rocket Lab's profits are not counted as Rocket Lab is predominately overseas owned.
Key suppliers **[a]**	*Accounting technique using information from interviews* We use company information to estimate additional operating surplus and compensation of employees owing to Rocket Lab's activities for the three suppliers. Excludes liquid oxygen supplier as it is foreign owned and requires little labour input.
Flow on effects to other industries from increase in activity in Rocket Lab's key suppliers **[b]**	*Type I multipliers* We apply a type I multiplier to the direct value-added we estimated above for Rocket Lab's key suppliers. We use the type I multiplier for NZ rubber, plastic and polymer manufacturing as estimated by BERL (2012) of 1.93. We use the valued added multiplier for rubber, plastic and polymer manufacturing sector as it seems analogous to what the key suppliers are doing

	Estimation technique
	(taking a raw material and transforming for use in another industry), further the sector has a relatively high import component.[68] For reasons outlined above we do not use the multipliers for the space industries from other countries but as a point of reference these can range from 0.6 to 2.6 (see FAA, 2010 and London Economics, 2014). Note that these overseas multipliers include all indirect effects, we have separated out some effects – such as tourism – into different categories. We apply this multiplier to the change in output Rocket Lab's key suppliers rather than the Rocket Lab's output to avoid double counting. However this means we do not capture any flow on effects from Rocket Lab's activity that does not go through these key suppliers. Although our assessment is these flow on effects are likely to be small.
Space tourism industry	The Brownsville Economic Development Council estimates that 10,000 to 15,000 visitors might attend each of SpaceX's launches.[69] If we were to scale this finding by the ratio of the New Zealand population to the United States population (318.9 million as of 2014), we find that around 140 to 150 additional visitors might visit Mahia to attend each launch. We also assume that some representatives from the companies launching the satellites as payload on the Rocket will come to New Zealand to watch the launch – we assume that represents about an additional 50 people per launch. To translate this into a tangible economic benefit, we assume: • International visitors spend an average of $129 per day, and domestic visitors an average $79 per day[70]. • 40 per cent of visitors are international, with the remaining from other domestic locations.[71] • The proportion of gross expenditure that is value-added is assumed to be 35 per cent[72]

68 Other potentially analogous sectors display similar multipliers.

69 http://skift.com/2013/10/14/the-bucolic-gulf-coast-island-that-may-launch-space-tourism

70 MBIE International Visitor Survey.

71 Based on the average split of international to domestic visitor spend per annum in the aforementioned survey.

72 Statistics New Zealand (2014), *Tourism Satellite Survey*. Calculated based on the ratio of direct tourism value added to direct tourism expenditure.

	Estimation technique
	• The type I multiplier is assumed to 1.71[73] • Average visitor stays between an additional three to four days per each launch. The extended length of stay reflects the rurality of launch location and the fact that the launch might be delayed while weather conditions become more optimal.
Infrastructure build	We assume that the value of this work is [commercially sensitive]. We assume that value added is 17 per cent of gross output in the non-residential building sector.[74] We assume there is little displacement of other work to achieve this work. We assume a type I multiplier of 2.3 based on PWC (2011) who estimate multipliers for the construction industry in New Zealand.
Induced effects	
Rocket Lab and key suppliers **[c]**	We assume a multiplier of 2.47 based on type II multiplier for the New Zealand rubber, plastic and polymer manufacturing as estimated by BERL (2012) and apply it to the direct effects for key suppliers estimated above. Induced effects are the difference between values calculated by the type II multiplier and the type I multiplier. In practice this means the *induced effects only* multiplier is about 0.5. This compares to values of 0.8 and 1.4 overseas (FAA, 2010 and London Economics, 2014).
Infrastructure build	We assume a type II multiplier of 3 based on PWC (2011) who estimate multipliers for the construction industry in New Zealand. Again induced effects are the marginal difference between values calculated by the type II and I multipliers.

73 *Ibid.* based on the ratio of direct tourism vale added to indirect value added as calculated.

74 Based on Table 4.33 of the "level four" tables of the Annual Enterprise Survey see the downloads section at: http://www.stats.govt.nz/browse_for_stats/businesses/business_finance/AnnualEnterpriseSurvey_HOTP14.aspx

5.4 Catalyst effects

This section describes the methodology we use to estimate what we have termed catalyst effects.

Table 6 Catalyst effects

R&D spill overs	We model the societal rate of return on certain aspects of Rocket Lab's R&D to date. Rocket Lab's R&D expenditure is commercially sensitive, however we have inferred a value for it based on some information made available to us but the confidence intervals around our estimates are very large. To indicate this uncertainty we use a range of possible R&D expenditures for Rocket Lab. We apply the societal rate of return between 20 per cent and 40 per cent to this range. In a paper prepared by Chase Econometric Associates, the authors estimated that the society's rate of return on NASA R&D expenditures was 43 per cent.[75] However given that much of NASA's research is publically funded, this research is likely to be more readily shared and hence the rate of return larger, hence we also model a 20 per cent rate of return. In our interviews it was noted advances in medical technology have contributed to Rocket Lab's guidance and navigation system, and developments in this area may flow back through to the medical technology industry and/or into the UAV industry.
Aspiration effect	In a survey conducted by Nature around 18 per cent of respondents claimed that the Apollo missions inspired them to become scientists.[76] Currently there are around 80 engineering graduates in New Zealand in the field of Aerospace Engineering and Technology.[77] An 18 per cent increase would constitute 11 extra graduates a year. This number feels a little low given the profile Rocket Lab could

75 Cited in http://er.jsc.nasa.gov/seh/economics.html

76 http://www.nature.com/nature/newspdf/apollo_results.pdf

77 Based on total number of international students enrolled in the 'Aerospace Engineering and Technology' field of study in 2013 (i.e., 90 students): Source: http://www.educationcounts.govt.nz/publications/80898/41801/3

	have. Therefore we model another scenario where the number of Aerospace Engineering and Technology graduates increases by 40 a year. The question then is how to best model the benefits from this increased number of graduates. The option that immediately springs to mind is to model the benefit of this aspiration as the wage premium the additional graduates get over and above what they would have otherwise earnt. This is less than ideal as it misses out the non-monetary benefits of working in an industry you find rewarding/ exciting. We assume that the new graduates in Aerospace Engineering and Technology receive a salary similar to the average Rocket Lab salary of [commercially sensitive] compared to an average New Zealand salary for person with a degree of 67,000[78]. As an analytic short cut to estimate the life time present value of these wage premiums we model the discounted future benefits as a perpetuity.[79] Dr Hann at the University of Canterbury has already begun to observe aspiration effects from Rocket Lab's activities in increased interest in his advanced engineering programme, and interest in the area from high school students.

78 Median salary from: http://www.stats.govt.nz/browse_for_stats/income-and-work/Income/NZIncomeSurvey_HOTPJun15qtr.aspx, multiplied by 1.5 to reflect "median earnings for young bachelor's graduates were 53 per cent higher than the national median wage" (source: http://www.stuff.co.nz/national/education/8205505/Degrees-ranked-by-earning-potential).

79 The alternative is model it as a 40 year annuity (40 years is the length of a typical career). Given the heavy future discounting of income 40 years and onwards when discounted back, a perpetuity will represent a good approximation.

Effects on NZ industry of having more convenient access to rockets to launch satellites	We model this potential benefit as a permanent productivity shock – that is New Zealand is able to provide more output with its current resources given faster, more and improved data as monitoring is enhanced etc. It is hard to know who and in what sequence New Zealand industries/companies will take up the opportunities provided by this platform. Clearly some industries will benefit more than other. Two industries where it seems obvious they will benefit are agriculture, and information and media and telecommunications. How much they will benefit is highly uncertain. To capture the uncertainty we model the impacts of a 1 per cent and 2 per cent permanent productivity shock in these two sectors of the economy. We believe this effect is on the light side; to put our assumed productivity shock in context consider these innovations which result in faster and better data to firms (analogous to what Satellite technology can provide): • An Australian trial using a harvester with an onboard computer system to select highest value trees in radiata pine plantations demonstrated a 9.3 per cent increase in harvester productivity and a 3.2 per cent increase in log value.[80] • Grimes et al (2012)[81] estimates that results indicate broadband adoption boosts individual firm productivity by 7–10 per cent. • McKinsey (2011) believe firms that use big data to its full potential could have a 60 per cent increase in operating surplus. We assume the full impact of the productivity shock takes 10 years to come into full effect. In the March quarter 2015, New Zealand's annual GDP in agriculture and the information, media and telecommunications sectors was $12.2 and 6.8 billion[82] Examples of latent demand relating to satellites in New Zealand include for example SkyTV may consider launching its own satellite to avoid having to lease space on Optus' satellite.

80 Walsh, Damian (2012) "Quantifying the value recovery improvement using a harvester optimiser", Bulletin 26, CRC for Forestry, May.

81 Grimes, A., Ren, C., & Stevens, P. (2012). The need for speed: impacts of internet connectivity on firm productivity. *Journal of Productivity Analysis*, 37(2), 187-201.

82 Statistics New Zealand, March 2015 GDP release.

5.5 Material benefits not modelled

There are a range of benefits we have not modelled:

- Road impacts - [commercially sensitive] spent on upgrading Mahia Peninsula road. Typically the economic benefits of upgrading a road relate to reduced transport costs to business for freight and to households in the reduction in the disutility associated with congestion and waiting. However given the current road is not prone to much congestion and that there is not much business on the peninsula the current costs are unlikely to be significant. Further the locals may not enjoy the increased traffic, which may take away from the charm of Mahia.
- Clustering effects - Potential clustering effects around key suppliers e.g. carbon composites or 3D printing capability. This potential benefit stream is not modelled due to its uncertain and speculative nature. Conversations with stakeholders indicate that there may be opportunities to build or further develop industry clusters around Rocket Lab building on our existing capability in areas such as composites or 3D printing manufacturing, or building on opportunities from proximity in the case of a potential satellite industry (or parts thereof).
- Prestige effects - of having a space industry was mentioned as a potential benefit in almost all stakeholder interviews. This benefit is not modelled as it was not possible to find representative values. In a survey conducted by Nature, an international journal of science, over 52 per cent of respondents agreed that human spaceflight benefited society by enhancing national prestige. A further 35 per cent somewhat agreed with this statement, while only 13 per cent disagreed.[83]
- Human capital effects - Benefits to New Zealand from increased proportion of highly skilled personnel in the population. This benefit is not modelled as it is difficult to find representative values, and also overlaps to some extent with R&D spillovers. However, we consider the potential benefit is worth noting as Rocket Lab creates a small but significant population of specialist skills in New Zealand. 25 per cent of Rocket Lab employees have PhDs. It has employed around 6 students from the advanced aerospace engineering course at the University of Canterbury. Rocket Lab has attracted talent from other high profile aerospace projects such as SpaceX. The experience these employees have with Rocket Lab may lead them to go on and start their own businesses as was evidenced in our report on the human therapeutics industry.

83 http://www.nature.com/nature/newspdf/apollo_results.pdf

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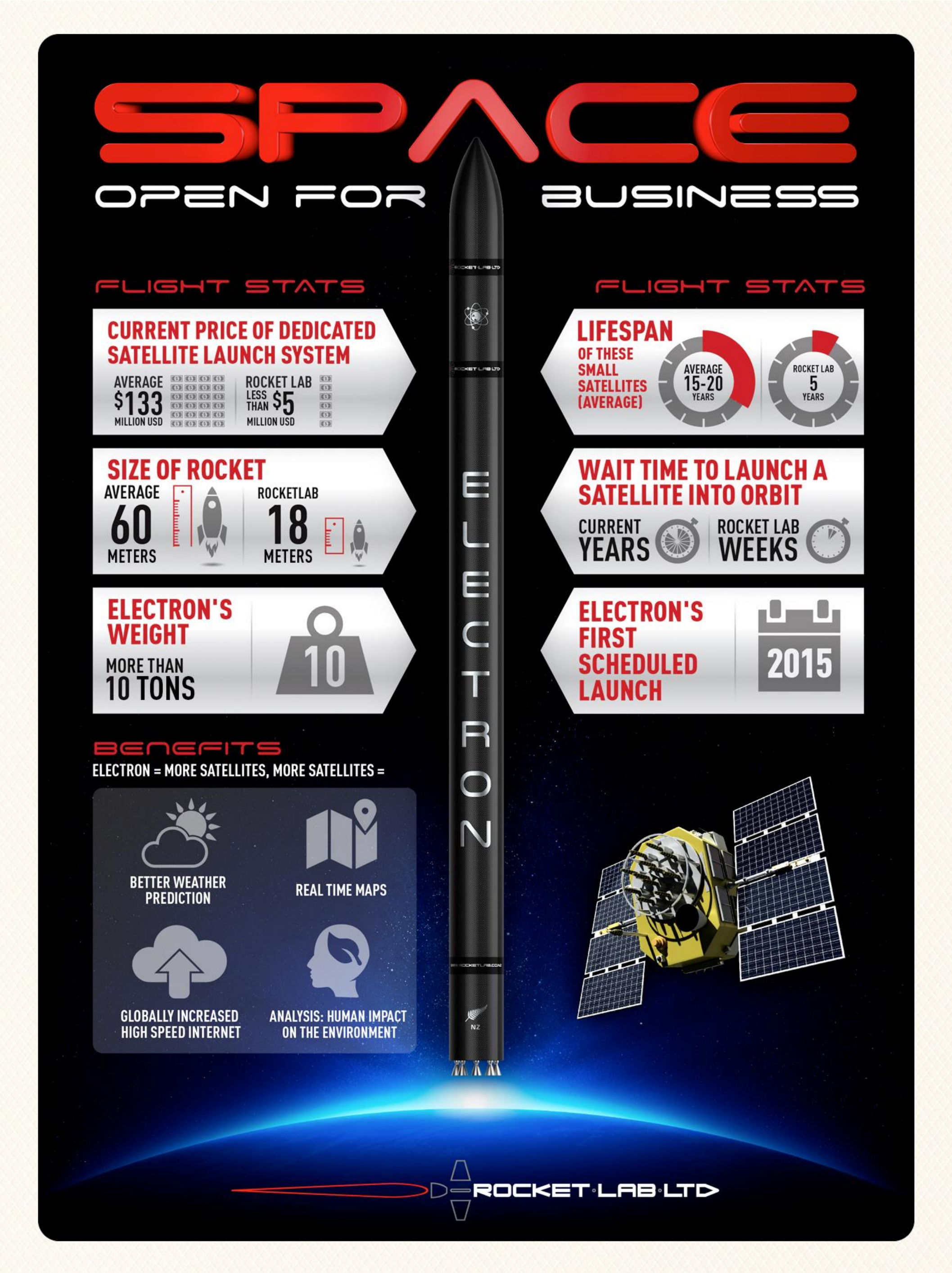
Appendix 1 Electron infographic



Source: http://www.kiwispace.org.nz/display/PORTAL/Rocket+Lab?preview=/5472469/47841281/Electron_infographic.jpg

Appendix 2 List of interviews

Peter Beck, CEO, Rocket Lab

Kathryn Jones, Customer Manager, New Zealand Trade and Enterprise

Nick Brewer, Business Innovation Advisor, Callaghan Innovation

Dr Chris Hann, Senior Lecturer, University of Canterbury

Tom McLeod, Industry Development Manager, ATEED

John Raine, Pro Vice Chancellor – Innovation and Enterprise, Auckland University of Technology

Greg Bodeker, Owner and Director, Bodeker Scientific

Scott Smith, CEO, Iridium

Fergus Power, CEO, Wairoa District Council, and Roger Matthews, Transformation Manager, Wairoa District Council

Dr Kirsten Edgar, National Technology Network Manager – Advanced Materials, Callaghan Innovation, and Dr Conrad Lendrum, Group Manager Advanced Materials, Callaghan Innovation

[Key suppliers – names are commercially sensitive]