

ACPA7005

Introduction to Innovation Management

Assignment B

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1. Introduction

Innovation is a term that most business leaders include in their conversations but with different definitions in mind. Innovation can refer to something new or a change made to an existing product, idea or field of activity (Merriam-Webster, 2016). Alternatively, innovation could be the management of all the activities involved in the process of idea generation, technologies, manufacturing and marketing of a new product or process (Trott, 2017).

The purpose of this assignment is to select one innovation from an organisation and analyse the innovation history with an evaluation of the innovation process.

2. Background

2.1 Organisation

Boston Dynamics (founded under Marc Raibert) is an American engineering and robotics design company, founded in 1992. It was a spin-off company from the Massachusetts Institute of Technology. Boston Dynamics' mission is to create robots to enrich people's lives and building machinery with advanced mobility, dexterity and intelligence (Boston Dynamics, 2022c). They wanted to build robots with 'legs' that could go where people go to perform hazardous and dangerous tasks, reducing the risk of humans performing industrial or military operations. Currently, the company holds a portfolio of robots, mainly aimed at solving challenges in the manufacturing, logistics and construction sectors.

2.2 Product/Process/Marketing Innovation

The innovation selected for this assignment, chosen from the company's robot portfolio is a four-legged robot called **Spot**, introduced in 2015.

Spot is an advanced, agile mobile robot with sensing capabilities that is able to navigate through unsteady terrain to carry out remote inspection and data gathering tasks. The features of Spot are shown in Figure 1.

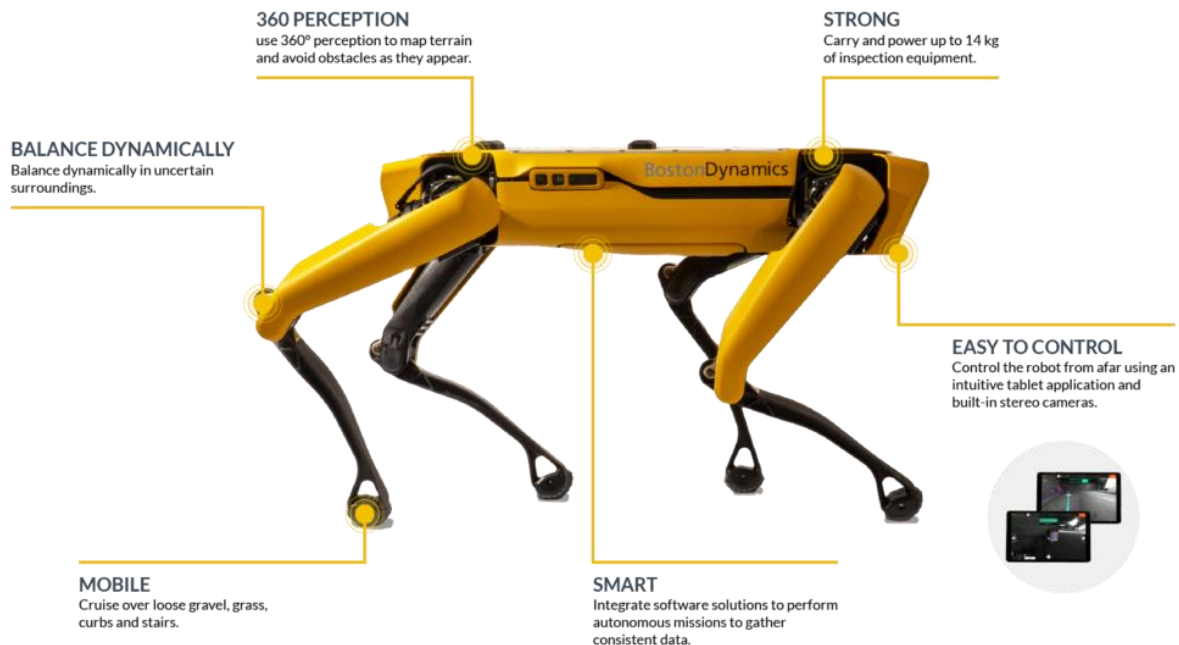


Figure 1: Boston Dynamics 'Spot' Robot

Spot has been typically used for various activities i.e. creating digital twins in a construction environment, inspecting leakage in gas pipes in power stations and monitoring asset conditions in a factory.

This innovative product was chosen because it was the company's first commercial robot available in the market costing \$75,000 from 2019 onwards (Mariane, 2019). Spot's USP is that it can go to places where other wheeled robots cannot, especially with its' 14kg payload and 1.6m/s speed (Biswas, 2021). Marc Raibert was the first person tackling the problem of building dynamically stable, legged machines before anyone else in the research field. The company reached a point where the techniques developed cannot be found anywhere else in the world (Boston Dynamics, 2022c). Finally, the journey to reach this innovation was not easy as Boston Dynamics had to work through several iterations of this product and was acquired by several organisations to see this product through to commercialisation (Petrova, 2021).

3. Analysis of Innovation

3.1 Principal Driver(s)

There are two principal drivers for legged robots such as Spot. In early development stages, Spot was used as part of a military project (DARPA) to address military needs such as holding soldiers' gear over challenging terrains to prevent soldiers fatigue when in combat and for reconnaissance ahead of a room-clearing exercise (Moses and Ford, 2021).

Interestingly, Boston Dynamics decided to repurpose Spot's capabilities in recent years to solve humanitarian and industrial problems instead, due to the negative sentiment it received from the general public, labelling Spot as a 'killer' robot (Moses and Ford, 2021).

Secondly, emerging opportunities in technology has enabled Spot to reach its current state of innovation. For example, a drive in LiDAR technology enabled Spot to be able to sense its surroundings. Additionally, a push in open-source software has enabled developers to integrate new add-on technology and create bespoke applications (Boston Dynamics, 2021b). These developments had to take advantage of research in SLAM (a navigation method) to provide simultaneous localization to allow Spot to perform autonomously (Guizzo, 2019).

3.2 Barriers and Risks

The main barrier faced in developing Spot for commercialisation was developing the computer vision well enough that it can recognise what is 'human' and 'non-human' (Niquille, 2019). Boston Dynamics had to work on Spot's vision system to recognise objects of various shapes and sizes to avoid interacting with the wrong objects, as there is a risk that Spot could recognise an object as a human, thus avoiding it when in fact it needs inspecting in a critical environment. Missing a particular inspection could be catastrophe if an asset failed in industry. To overcome this barrier, Boston Dynamics created a test house to collect and train Spot to see different objects. They also created synthetic data using Blender to build a dataset of objects which Spot could potentially run into.

The biggest challenge for developing Spot was turning it into a viable business. The capability of robotics is well known in research and Spot had previously been a laboratory experiment. However, transitioning this innovation to generate revenue required the company to identify the purpose of Spot in a commercial environment (Bora, 2018). There was an element of risk where

the company could have found themselves where Spot could not be used for anything, which would have limited the company investment and development of the innovation. The company decided to tackle this barrier/risk by scaling the size of the robot from initial prototype called BigDog (Boston Dynamics, 2022b) to work in commercial applications (Vincent, 2019). Additionally, the company hired business experts to bridge the gap between industry and technology, to understand how Spot can be used to solve business problems, rather than throwing the technology into the field. Forecasting how well Spot will do is difficult and it's almost comparable with the uncertainty of how the future of hydrogen fuel cell technologies will play out in industry.

3.3 Key Determinants of Innovation Development

The key determinant for the company to develop the innovation was funding. Without funding, there wouldn't be an opportunity for Boston's engineers to commercialise Spot. Interestingly the only way Boston received funding was to be acquired by organisations which had an interest in robotics. The company went through a series of acquisitions from DARPA, Google, Softbank Group and Hyundai Motor Group (Bora, 2018). The key acquisition was from Softbank group which provided funding for Boston Dynamics to scale the robot down in size for industrial applications. Once the company developed Spot to be used in a commercial environment, Boston Dynamics needed to be creative in their marketing techniques in order to make sales to continue development. For example, Boston recently released a video of Spot interacting and dancing to music in social media (Boston Dynamics, 2021a). This enabled the audience to understand what Spot is capable of and to generate ideas from customers on potential applications.

Another key determinant was the knowledge the CEO (Marc Raibert) held throughout his time in Boston Dynamics. Since the innovation is so unique in terms of how it operates, it requires bespoke algorithms and methods which only the CEO has knowledge about. Hence this bespoke piece of knowledge had to be shared with the rest of the organisation for other robotic engineers to develop the innovation as time went along. This required a lot of trust from the workers as it was essentially the company's IP that was being shared internally.

Finally, a key determinant for Boston Dynamics to develop Spot was the infrastructure to house the robotics i.e. the test lab facilities (Bergmeyer, 2021). The test facility is large enough in space and has appropriate guarding and cranes to provide sufficient safety to test Spot for new applications. The benefit of having a new space means that the company is able to push the

innovation forward by testing the limits of Spots' agility and mobility compared to a typical, small university lab.

3.4 Innovation Development

The development of Spot to reach the commercial version required the company to tap into various technologies and processes along the journey. In fact, each prototype developed had incorporated new technology which was only possible through R&D. Before discussing the technologies used for Spot, an overview of the development history is shown in Figure 2 below.

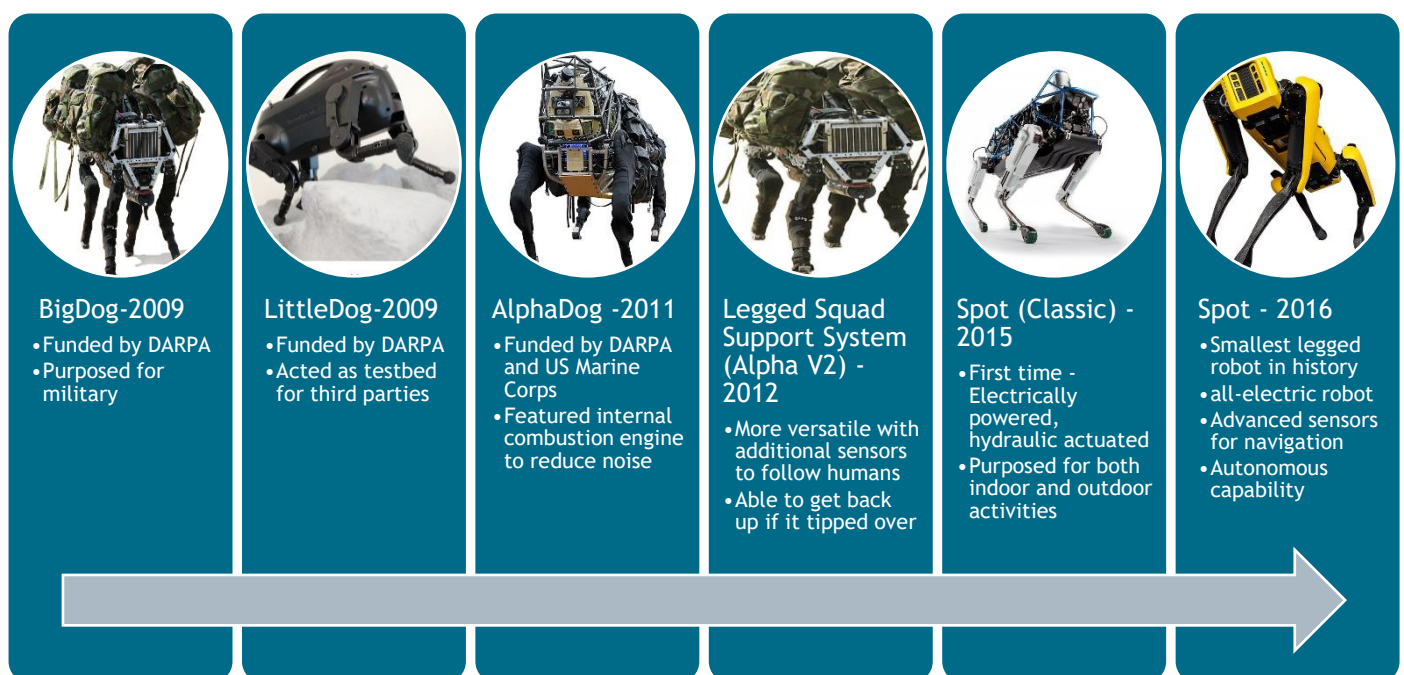


Figure 2: Boston Dynamics Legged Robot History – Evolution of Spot (Furness, 2018)

As shown in Figure 2, the development for Spot was dependant on various technologies, but also the techniques required for Spot to operate dynamically, which stemmed from early research.

The evolution of Spot started from BigDog and one of advancements the company took advantage of was electric batteries. From the evolution of BigDog to Alpha V2, a combustion engine was used along with custom hydraulic actuator which made the robot significantly heavier and louder (Buehler, Playter and Raibert, 2005). The military thought this was ineffective as it would be easily heard by enemies (Furness, 2018). Thus, Boston Dynamics started to look at electric power from Spot Classic onwards and saw the potential to make the robot lighter yet durable for operations.

Another technology the company used is sensors. The company started off with stereo and depth cameras to help the robot see where it was going and identify objects to avoid (Frank, 2021). However, stereo cameras were limited in resolution and frames per second, meaning the robot acted slowly to navigate through obstacles. In recent years, the company used LiDAR (Light Detection and Ranging) which involved using lasers to measure the time for reflected light to return to the receiver (Boston Dynamics, 2022c). This technology, which was first introduced in Alpha V2, enabling the legged robot to see more of its surroundings rather than stereo cameras which limited the robot field of vision.

Boston Dynamics used sophisticated navigation techniques such as SLAM (enables the robot to build 3D maps and localise itself within the generated map (Ramezani *et al.*, 2020)) and obstacle avoidance algorithms (Boston Dynamics, 2022c). This enabled the company to extract the best out of the LiDAR and GPS technology and to ensure Spot was capable of autonomous operation.

The company used advancements in legged locomotion systems, which primarily started off as a research area, involving the dynamics of robotic legs. This system was inspired by animal locomotion and was the most involved technological development the company went through. Without this technology, Spot would never be as mobile as it should be. Legged locomotion systems originated with the CEO's academic studies into active legged systems that can balance actively (Raibert *et al.*, 1989) and move dynamically in 1995 (Raibert *et al.*, 1989).

The company then moved onto development programs such as the 'Learning Locomotion Program'. This involved research groups developing locomotion algorithms by using LittleDog as a test bed, funded by DARPA (Murphy *et al.*, 2011). In order to promote innovation, the company had built several LittleDog robots to minimise the upfront development effort from research groups (Murphy *et al.*, 2011). As a result, the technological advancements seen in LittleDog directly transferred over in developing the Spot robot.

In order to control the legged locomotion system, the company had to build control software to provide omni-directional control during walking and climbing operation and to react under physical disturbances (O'Connor, 2022).

3.5 Innovation Reliance

The development of Spot relied on several external factors to the company, which was cleverly managed to ensure Spot remained at the forefront of legged robotics.

Boston Dynamics relied on acquisitions to develop Spot throughout the innovation history. They relied on funding from DARPA to create several prototypes and accelerate research, enabling Spot's predecessors to become more agile and sustainable over time (Bora, 2018). Then, the company was acquired by Google Alphabet in 2013 to enhance Google's robotics division and for Boston Dynamics to continue with their research. This allowed Boston Dynamics to tap into people resource at Google to utilise some of their engineers to help with developing the innovation. Unfortunately, due to an uncertainty in what Google wanted to do with robotics, along with uncertainty that Boston Dynamics could create a marketable product and the conflicting vision seen between the two organisations (Google wanted commercial robots and Boston Dynamics did not want this), Boston Dynamics parted ways with Google in 2016 (Crouse, 2016).

In 2017, Softbank bought the company from Google (Bora, 2018). This acquisition enabled the company to use Softbank's experiences in telecommunications and robotics to commercialise Spot. Recently, in 2021, Hyundai Motor Group acquired a controlling interest (80%) with Softbank (20%) in Boston Dynamics which will look at accelerating development of cutting-edge robotics (Hyundai Motor Group, 2021). It is expected that this deal will allow the company to leverage Hyundai's strengths in manufacturing, construction, logistics and automation, such that the company can purpose Spot as a solution in various industries (Hyundai Motor Group, 2021). It can be deduced that Hyundai will provide Boston Dynamics access to their networks to gain market knowledge.

The development of the product in terms of making Spot 'smarter' in an autonomous way required heavily reliance from third-party companies. This allowed Spot to be offered not just as a 'base' robot but a robot with enhanced capabilities to be seen as a useful product for industry. For example, the company collaborated with HoloBuilder to provide 360 degree reality capture solutions for construction projects by bolting add-on technology to Spot (Lauter, 2019). The company also acquired other firms i.e. Kinema Systems to leverage their industrial robotic arm technology (called Pick) to start selling variants of Spot with robotic arms (Vincent, 2019). The intelligence of Spot relied on artificial intelligence, which was only possible through Boston Dynamics partnership with Vinsa. This partnership enabled Vinsa to provide deep learning models

for Spot to conduct high quality inspection tasks i.e. read a gauge in the energy, oil and gas industry (Carroll, 2020).

3.6 Innovation Management Overview

Spot was managed differently throughout its' development stages. In the early stages, the senior management team in Boston Dynamics saw legged robots purely as a research area (from BigDog to Alpha V2). There was never any intention to commercialise the innovation and to only use it as a test bed for researchers to work on - this was the initial strategy of the company (Allan *et al.*, 2022). The company managed the development of the innovation by securing funding from organisations that were interested in advanced robotics. Due to this fact, Boston Dynamics reached a sufficient point in the development process, especially during the acquisition under Softbank, where the innovation had become advanced enough to bring value to commercial applications. (Bora, 2018). Again, this was only possible through advancements in computer vision and control systems for locomotion. To fully realise the value of Spot and where it can be applied in industry, Boston Dynamics have hired key staff i.e. Brain Ringley, a construction technology manager to oversee the business development activities to ensure Spot delivers value to their customers (Jones, 2021). Fascinatingly, Brain spoke about how Boston Dynamics manages the introduction to Spot when pitching to customers. The company prefers to work backwards by understanding the business problem and derive Spot as a solution, rather than shove the technology in a field to see if it works (Cheeseman, 2020).

Spot had knock-on effects with other developments in the company. For example, the development of Atlas, a humanoid robot which acts as a research platform to push whole-body mobility (Boston Dynamics, 2022a). A lot of the research derived from Spot and its' predecessors regarding the algorithms developed for legged locomotion was transferred to create Atlas. This enabled the company to continue advancing the capabilities of mobile robots whilst creating sales from Spot.

3.7 Best Practice of the Innovation Process

The innovation process for Spot can be mapped against Greg Satell's innovation matrix (Figure 3). However, it cannot be mapped against one quadrant as the company innovation strategy transitioned from basic research to sustaining innovation over the past decade.

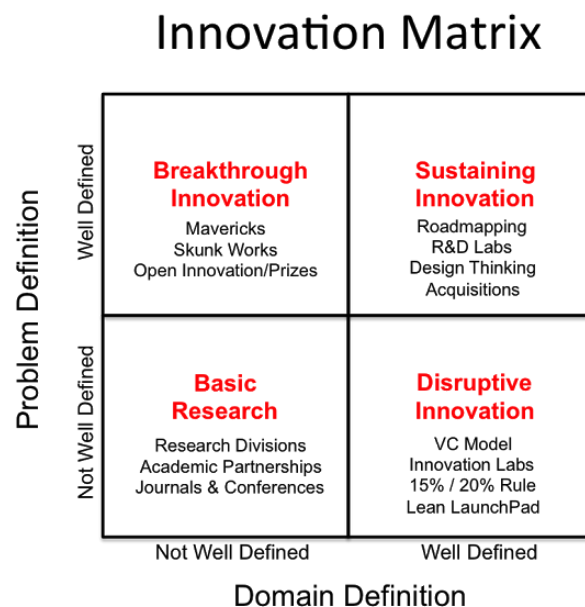


Figure 3: Greg Satell's Innovation Matrix

Satell saw basic research as a means of companies conducting research to discover something new and unexplored to build cutting edge solutions (Satell, 2017). In Boston Dynamic's context, the domain was not well defined and neither was the problem, thus making the company fall under basic research. Legged robotics was simply an area of interest for Boston Dynamics is see if it was possible to replicate the locomotion in animals through actuators. There was no problem to address at that time. The CEO worked in robotic divisions at Massachusetts Institute of Technology and published research papers, which helped create the building blocks to develop the first Spot prototype (BigDog). Boston Dynamics fell under sustaining innovation once Spot became commercialised in 2015. This is because the problem had become well defined i.e. how can we reduce worker's risk in inspecting hazardous environments? Additionally, the company had went through several acquisitions, allowing the company to leverage other expertise to improve their knowledge on robotic systems (thus the domain is well defined). Additionally, the company acquired other firms to gain specialised knowledge i.e Vinsa for artificial intelligence to ensure the

company continues to innovate the product further. The company has invested in R&D labs which enabled them to continually keep up-to-date with their domain knowledge and in solving new industrial problems.

From the paragraph above, the approach the company had taken this fits well with Joseph Tidd and John Bessant discovery in that 'innovation is not a solo act but a multi-player game' (Tidd and Bessant, 2009a). Thus, it can be understood that this innovation process involved some element of best practice in terms of innovation networks (Tidd and Bessant, 2009b). Boston Dynamics network type falls under 'community of practice' because the network involves players inside (Boston, Hyundai, Softbank) and across different organisations (those looking to purchase Spot to develop own applications using the open-source development kit) to share knowledge on how Spot can be used in industry. This promotes innovation because the company is allowing industry and other researchers to develop novel applications which could be pitched as a potential future product. Furthermore, it could enable the company to diverge into other markets (diversification) to generate additional revenue and thus cement the company's future survival.

4. Evaluation

Boston Dynamics' Spot is a remarkable piece of innovation that stemmed from research in academia and developments under military contracts. The main risk in developing the innovation was the availability of funding. In my opinion, this was a single point of failure as Boston Dynamics did not seem to have any other methods to secure funding, apart from being bought by other organisations that had a specific agenda to develop their own advanced robotics capability. It's surprising to see that the company had not decided to apply for grants or collaborate with research institutions to continue development. Perhaps, the cost and time for development was so large that the company required to find an organisation which held sufficient R&D budget.

It is interesting to learn about how the company continued to focus one area for such a long time, despite struggling for initial funding and in solving technical barriers in locomotion control. The company was dropped twice, DARPA and Google for no longer seeing a need in legged robots. Yet, the company managed to find a way to attract investment. Personally, this emphasises the culture of innovation by the company, such that they opted for a 'high risk, high reward' approach and didn't change their core focus because they believed the work will pay off in the long run.

Spot is a clear success in the fact that it's the first dynamic legged robot in the market able to perform reconnaissance and inspection activities to reduce human workload. However, it is not clear how Boston Dynamics will measure success as sales are currently ongoing. It has sold over 400 Spot robots from 2015 to 2020, but it's not enough to cover the costs of running the company (Amadeo, 2020). Personally, in order for the company to be sustainable in the long run, the company will need to depend on the robotics community to pitch in with further applications where Spot can be used in new markets to drive business revenue. Luckily, Boston Dynamic's open innovation approach with open-source software and partnership with technology organisations is a key enabler to ensure Spot's future development will be continued. A major critique of this approach is that Boston competitor's will be able to 'copy' Spot i.e. Unitree Robotics (Unitree, 2022). Thus, it is possible that the company could potentially lose interest by customers because their competitor products may offer better benefits with the same technology. The future of Boston Dynamics is bright but requires skilled business development resource to ensure the company can start building key relationships with industry to gain recognition and to push the innovation through commercial markets ahead of their competitors.

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