Characterizing the Augmented & Virtual Reality Industry

by

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ABSTRACT

The information age has included several computing platforms and interfaces to enable humanity. Each computing platform has had its capabilities and limitations. From mainframe computers to personal computers, and now to smartphones, we have seen a revolution in computing that has had several advantages for society, in spaces from education to healthcare. However, these devices have their limitations and their innovation is becoming incremental. The growth of data and content, along with the insatiable demand to view and analyze it and content – calls for a new platform that can enable such experiences.

There have been several candidates for such interfaces, but none of them have the promise of Augmented Reality (AR) or Virtual Reality (VR) today. These technology candidates, although in the spotlight now, have had several waves before, unfortunately with very limited success. This time, however, the outcome seems poised to be different. Smartphone technology, particularly displays, processors, and other microchips, along with wireless technology have increased capabilities and driven costs down dramatically, enabling some of the core components of Augmented and Virtual Reality (AR/VR).

Industry players, including venture capitalists, engineers, sales and marketing, consultants, and others have begun gathering data on this emerging industry. However, there has been little synthesis thus far, nor a comprehensive view that seeks to harmonize these data points to clearly describe the state of the industry as a whole and its likely future. Furthermore, little analysis has been done to analyze the industry with management related academic studies of the past.

Using several different types of data, analysis, and projections, the paper shows that although Augmented Reality and Virtual Reality have begun to show genuine benefits over traditional computing platforms, the behavioral change required for its evolution in to a mainstream general purpose computing platform is still significant. This makes AR/VR great for enterprise use cases, such as construction, field work and training, but limited in day to day consumer computing.

With this analysis we can also identify high and low value market segments and use cases within the industries, prognosticate the evolution of different platform architectures or types of AR/VR, and begin to outline the implications for various stakeholders within the industry, such as Venture Capitalists.
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My journey to MIT was not typical or straightforward. I can remember the first day I saw the famous dome five years ago; it was impressive, intimidating, and inspiring. The opportunity to attend MIT came through a great deal of sacrifice, hope, and eventually execution. However, the only reason I am here today is because of the people around me who have inspired me to dream big and make my dreams a reality.

I would like to first thank my advisor Michael A.M. Davies. He saw something in me before there was much to see, and he gave me the opportunity to work beside him. Michael showed me the MIT-way and cared about my education from the moment he got to know me. He has been a great example of making work, ‘life’s art.’

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I would also like to thank Peter Kurzina, who mentored me before and during my time at MIT. Peter was instrumental in building my professional character, which has grown tremendously through his wisdom.

My friends Tony Yaghjian, Aret Zartarian, Shahan Khoshafian, Nareg Khoshafian, Nishan Khoshafian, and Spencer Tuohy, have all listened and advised me on my journey to a new world and life at MIT. Their wisdom, patience, and giving hearts have pushed me along in tough times.

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My last thanks goes to those who are no longer with us. During the last 10 years of my life I’ve lost all my grandparents, who are survivors of genocide, two uncles, an aunt, and a close friend. Although they are no longer here, their thoughts, characters, love, and experiences have influenced me deeply. They have taught me the value of life and what it means to persevere.
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# Nomenclature

## Industry Acronyms

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<th>Acronym</th>
<th>Description</th>
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<tr>
<td>AR</td>
<td>Augmented Reality</td>
</tr>
<tr>
<td>VR</td>
<td>Virtual Reality</td>
</tr>
<tr>
<td>MR</td>
<td>Mixed Reality or Merged Reality</td>
</tr>
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<td>VC</td>
<td>Venture Capital</td>
</tr>
<tr>
<td>LP</td>
<td>Limited Partner</td>
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<tr>
<td>HMD</td>
<td>Head Mounted Display</td>
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<tr>
<td>MDM</td>
<td>Mobile Device Manufacturer</td>
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<tr>
<td>IMU</td>
<td>Internal Motion Unit</td>
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<tr>
<td>PMT</td>
<td>Positional Motion Tracking</td>
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<tr>
<td>CGI</td>
<td>Computer Generated Images</td>
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<tr>
<td>IP</td>
<td>Intellectual Property</td>
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## Other Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tr>
<td>MDM</td>
<td>Mobile Device Manufacturer</td>
</tr>
<tr>
<td>UI</td>
<td>User Interface</td>
</tr>
<tr>
<td>UX</td>
<td>User Experience</td>
</tr>
<tr>
<td>B2B</td>
<td>Business to Business</td>
</tr>
<tr>
<td>B2C</td>
<td>Business to Consumer</td>
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I. Introduction

The current dominant computing platforms, such as desktops, laptops, tablets, and smartphones have begun to mature as their product innovations become more incremental. Data creation and capture is on the rise and there is an inherent need for new computing interfaces that are even more advanced, immersive, and disruptive as prior platforms. The lack of the right information displayed in the right context is a challenge that limits several business and consumer use cases. Several different alternative human-computer interface platforms have emerged in the past, but none have succeeded in displacing the current dominant platforms.

The recent rise of Augmented and Virtual Reality (AR/VR) make them considerable candidates to become the next general purpose computing platform. It remains very unclear, however, how these platforms will develop, and how they will impact enterprises and consumers.

The industry is still very early in its evolution and little academic research has been done to understand the implications of these technologies for involved stakeholders. Much of the existing research is either very technical in nature, in specific topics such as optics, or very high level data providing simple market projections. Furthermore, there is relatively little unbiased research synthesizing industry data to uncover insights, implications, and opportunities for the industry.

This thesis seeks to bridge academic and professional frameworks and approaches in fields such as business strategy, system architecture, innovation dynamics, product management, venture capital, and platforms to uncover such insights.

Problem Statement

The purpose and goal of this thesis to address the following:

Characterize the state and future of the Augmented Reality & Virtual Reality industry, and describe the relevant implications and opportunities for industry stakeholders, and in particular potential investors, that is Venture Capitalists.

Although there may be other data and analyses that would be relevant to reaching the goal of this thesis, the hope is to make significant progress towards the following objectives:

1. Define AR/VR and characterize the current state of the emerging industry and its dynamics.

2. Prognosticate how the industry and key platforms will evolve
3. Identify the implications and opportunities for key stakeholders, such as Venture Capitalists

**Summary of Approach**

The starting point for the approach of this thesis is to gather and review as much high quality industry data as possible. This will be done through primary and secondary research. This includes reviewing industry reports, articles and blogs, conducting extensive interviews with technical and business experts, attending relevant conferences, experimenting with cutting edge products, prototyping products, and reviewing relevant academic research.

After data collection and review, frameworks and approaches from aforementioned disciplines in innovation dynamics, business strategy, product management, etc. are then used to synthesize and interpret the data, to achieve the aforementioned goals.

**II. Background & Literature Review**

To execute the approach of this thesis, there will be some implied knowledge originating from several different relevant disciplines. This thesis will be drawing mostly from knowledge, frameworks, and approaches generated from several fields, the most important ones of which are listed below.

1. Innovation dynamics
2. Product Management
3. Business strategy
4. Venture Capital
5. Platform strategy

This list is not necessarily exhaustive, as there may be other concepts from business, product development, enterprise architecting, software and hardware technology, investing, startups, that may be referred to as well.

It is important to note that these topics have tremendous breadth and depth in their respective disciplines. The distinctive contribution of this thesis to the state of the art is its attempt to synthesize these approaches to come up with a unique analysis.

As mentioned, the fields presented below each have significant depth and literature. This purpose of this literature review is to not provide a comprehensive description of each field, but rather to provide the reader of this thesis with a clear overview that will explain the context and approach of the broader analysis.
Innovation Dynamics

There have been several studies to capture the meaning and nature of innovation, along with the factors that enable it. As a result of these studies, there has been significant progress to understand how different innovations create industries and transform those that are impacted.

Understanding some of these dynamics helps to discover the current state of an industry and its likely evolution. This inherently helps enterprises participating in that ecosystem to understand how to navigate the dynamics of the industry. In particular, research done by James M. Utterback, provides simple and powerful frameworks.

One of these frameworks is shown in the figure above. Utterback introduces three phases to describe the state of an industry. The Fluid Phase is when most of the product innovation takes place with the entrance of several companies, both large and small. In this early phase, firms are experimenting with their own new designs. It is not until a dominant design (described later) emerges, that the industry moves into a transitional phase, where Process Innovation takes over. Lastly, as economies of scale take over, the Specific Phase arises. This phase is for enterprises looking to optimize for cost and create incremental innovations. (Utterback, 1996)

Central to these phases is the concept of Dominant Design.

Dominant Design
Dominant design is a concept that describes the 'de facto' or standard architecture of products within a particular industry. In the early days of an industry, enterprises tend to invest, design, engineer, and build products with their own distinctive designs. This is inherently resource intensive and causes fragmentation of products and experiences for users in the industry. Examples of this can be seen in many industries, particularly those where technology products are central. (Utterback, 1996)

Prior to the emergence of a dominant design, products within the industry have a wide variety of architectures both internally and externally. The fragmented external architectures of the products inherently create fragmented user inputs, interfaces, and experiences. As a result, users are unable to build tacit knowledge that translates from one product variant to another. This implicitly limits the growth and adoption of the products within the industry as well.

The dominant design of an industry is not necessarily the best design, but rather one that is well received in the market and dependent on technology roadmaps. (Utterback, 2013)

Utterback, and his colleague William Abernathy, demonstrate that the emergence of a dominant design has major implications for an industry: (Utterback, 1996)

1) Maturity within the industry
2) Shift in competition
3) Imminent growth

As mentioned, dominant design enables enterprises within the ecosystem and new entrants to focus on different aspects of the product rather than core design. This results in economies of scale and shifts in competition as different competencies become more valuable than others.

A relatively recent example of dominant design can be observed in the mobile phone industry. The original Apple iPhone is often considered the dominant design of the industry. (Battaglia, no date) Prior devices were mostly known as 'fixed function' or 'feature' phones. These devices each had different forms to serve particular functions. Enterprises created several models for different consumer segments that demanded different functionality. Additionally, tacit knowledge learned from one type of feature phone was not necessarily transferable to another. These devices had different mechanism for user input as well. (Utterback, 1996)

The iPhone popularized a new design with precise responsive multi-touch screen display. As a result, many MDMs began manufacturing devices with a similar design orientation to the iPhone. The emergence of the dominant design in the industry spurred growth and adoption, enabling the industry to move towards the transitional and specific phase of the industry.
Anticipating Dominant Design

One popular approach to prognosticating the emergence of a dominant design is to measure the number of enterprises created in an industry over time. In many industries a dominant design has emerged 1-3 years within the peak year of companies formed. (Utterback, 1996)

These frameworks will be helpful to characterize the AR/VR industry in subsequent sections.

Product Management

Product Management is an emerging role and discipline within technology companies over the last decade. There is a significant range of definitions of this term, but most would agree that Product Management refers to the discipline of determining the scope of the product through to working with engineers to build said product. In short, Product Managers are responsible for the success of their products without the authority to do. (Norton, 2005)

The figure below describes Product Management as a field at the intersection of business, technology, and the customer. In today’s open and shared information age, technology businesses are increasingly reliant on the value that their products provide to its users.

![Figure 2 - Product Management Disciplines](image_url)

Figure 2 – Product Management Disciplines

The figure above describes Product Management as a field at the intersection of business, technology, and the customer. In today’s open and shared information age, technology businesses are increasingly reliant on the value that their products provide to its users. In short, the attributes, features, and capabilities of products are increasingly influencing the success or failure of technology companies. (Norton, 2005)
Particularly in the context of startups, where product-market fit is one of the most common reasons for failure, excellent product management can mitigate these risks and make sure that engineers are building products that are actually demanded by the market.

Part of product management includes product design, which is critical to determining the user experience. As described in the subsequent section, the behavioral change required for use of a product is one of the most critical factors that determines the success or failure of a product. The figure below, are some important design concepts defined by Donald Norman, a leading cognitive scientist and usability engineer. (Norman, 2013)

| Visibility | UX allows users to always see what state the product is in and all actions that are possible |
| Feedback  | Products responds well to actions, allowing users to know what has happened (i.e. waiting symbol, visuals or sounds can help) |
| Affordance | Properties of device or UI give clues as to what it can do (i.e. easy to see you put hands to use scissor) |
| Mapping   | There is a strong relation between controls and their effect |
| Constraints | Restricting interactions to valuable ones, reduce chance of error, focusing attention |
| Consistency | Similar elements are used for similar operations, helping users build tacit knowledge (aesthetic, functional, internal and external consistencies) |

**Figure 3 – Norman’s Design Factors** (Norman, 2013)

These design concepts above will be referenced in subsequent sections to describe AR/VR products and the resultant strategies for stakeholders.

It is also important to introduce how product managers can go about brainstorming features that are aligned with business goals and thereby maximize the success of the product in the market. Given the infancy of this discipline, and the variance of the nature of roles across enterprise, there is little standardization in how this is done.

A noted author in the product management space, Lewis Lin, has contributed considerable content relating to this field. Building on this, together with interviews with several practitioners, below is a framework that synthesizes some of the approaches of leading product management practitioners. (Lin, 2013)
### Goals & Constraints

**Goals:** What are we trying to accomplish with this product?
- More revenue?
- More conversion?
- More retention?
- More users?
- Market share?
- Beat competitors?
- Customer satisfaction?
- Awareness?
- Visitors?
- Engagement (sessions, session length, daily active users, weekly actives, bounce rates)

Goals will depend on product (ex: popular product won't be more users)

**Constraints:**
- Budget?
- Schedule?
- Quality?
- Team capabilities?

### Users (Primary, Secondary, Negative)

**Pick a segment that are primary users:**
- By age?
- Geography?
- B2B (size/industry)?
- Income
- Occupation?
- Hobbies?
- Stage of life?

(select a group that matches the goal, new users = new user group, more retention = primary group)

**Describe their persona:**
And understand them:
- What do they need?
- What are their problems?
- What are the jobs they are trying to do?
- What do they do now?
- How is this coming up short?
- How does this make them feel?

### Requirements (User stories)

**User stories**
Come up with top use cases/stories that alleviate these needs:
- 10x solutions
- Don't describe solution
- As a __ I want ___ so I can __
- When __ I want to ___ so I can ___

3 of them

**Prioritize** these user stories/cases:
- Do they meet the goals (rev/engage)
- Are they value add for customer?
- Is it intuitive?
- Is it innovative?
- Meet defined constraints?

**Select one user story to focus on**

### Solutions

**Come up with three solutions** for this user story that will enable the experience
- Describe at a high level
- Don't describe pros and cons
- One should be 10x
- One should be metric mover
- Fixing existing problems

**Select and recommend one of these solutions**
- Re-iterate how they meet desired goals
- High value to user
- 10x/Innovative
- Intuitive

Describe technical implementation
- Mention new and trending technologies
- AR/VR/Wearables/IOT/AI/NLP/etc

### Figure 4 Product Management Framework (Lin, 2013)

This figure above is mostly self-explanatory. Ultimately, at its core, Product Management is the process of aligning the strategies and goals of a business to technological solutions that can maximize impact to achieve those goals. The framework works from left to right, and several items are bolded as they have become increasingly more important aspects of building great products.

Many of these are related to maximizing performance or utility, while maximizing engagement. This aligns well with business strategy concepts introduced in the next section and will help explain the implications for stakeholders in the AR/VR industry.

### Business Strategy

There is abundant literature and study in the field of business strategy. This thesis will focus on strategies related to companies that succeed because of their technology-based products. More specifically, it will focus on strategy related to introducing new products and maximizing their adoption in to the market.

A seminal study done by John T. Gourville, a Harvard Business School professor, will be a core framework and insight that will be used to analyze the AR/VR industry and its implications for key stakeholders within the industry.
Gourville, among many topics, discusses the 'Endowment Effect' and 'Loss Aversion'. These concepts describe consumers and their perception of the products they own, and the resulting perspective that they bring to consideration of new products. The Endowment Effect is a term in behavioral economics, coined by Richard Thaler and Kahneman, that describes consumers' tendency to overvalue the products they own and the features or attributes of those products. In these studies, it has been shown that these effects become stronger as the consumer owns the product over longer periods of time.(Kahneman et al., 1991)

There have been several studies to buttress this effect in new product adoptions. As a result, this 'Endowment Effect' helps to explain the importance of the existence of the status quo and the bias that it creates. Because consumers overvalue what they already own, they irrationally stick with that product even if a new product has better performance and or value.

This effect inherently has consequences for and effects on the success and failure of new products designed, engineered, manufactured, and sold to consumers. Every new product has tradeoffs that consumers will always consider while determining which product to adopt.

![Figure 5 - The Endowment Effect](image)

It takes both significant perceived value and minimal behavioral change for a consumer to adopt a new product. To understand the implications of the 'Endowment Effect' and 'Loss Aversion', Gourville created a simple framework, seen in the figure below, to help producers of innovative products to consider.
It is important to note that this framework does not consider or speak to other functions and factors of the business that can affect the success of the product.

**Easy sells** are those products that require minimal behavioral change for users, but simultaneously do not benefit the user significantly either. An example of this might be a new pen with better ink. The way the user interacts with the new pen is similar to every pen he or she has used before, but the benefits from better ink are trivial.

**Sure failures** are those products that require significant behavioral change in exchange for limited benefit to the user. An example of this would be the Segway, a transportation device meant for personal transportation. This product required users to learn a whole new mode of transport unlike any others they had experienced before. The benefit to the user was incremental, and the product failed as result.

**Long hauls** are those products that do provide significant benefit to users, but will require them to change their behavior significantly as well. These products take considerable time to mature and be accepted by consumers. An example of these products are early Personal Computers (PCs). These products took significant time to be adopted by users, as much behavioral change was required to experience the benefits they provided.
Smash hits are those products that require little behavioral change for users and simultaneously provide immediate and immense benefit. These products decrease the endowment effect on users, and enable them to enjoy the beneficial features and attributes of the product. An example of a smash hit would be the iPhone. The user experience was intuitive while the performance was perceived as higher than competition as well. (Battaglia, 2013)

With these factors in mind, there are some strategies, seen in the figure below, that technology companies can employ to navigate the adoption challenges of their products. In short, companies can accept and or minimize this resistance from consumers.

**Minimizing Resistance**
- Make behaviorally compatible products
- Seek out unendowed
- Find believers

**Accepting Resistance**
- Be patient
- Make 10x products
- Eliminate the old

*Figure 7 - Gourville Business Strategies* (J. T. Gourville, 2006)

To help minimize the resistance of consumers, companies can make sure that their products require very little behavioral change for users. These products need to be highly intuitive and leverage the design attributes described in the in the Product Management section.

Alternatively, companies can minimize the resistance of consumers by marketing their products to user segments that do not own any existing products or alternatives. These consumers are less likely to compare and contrast new products since, they do not have any tacit knowledge to conduct the comparison.

Lastly, Gourville suggests that companies can find select consumers who prize particularly highly the new features of the company’s products. These consumers, unlike their counterparts, have external pressures that make them undervalue the forgone benefits of abandoning their existing products and overvalue those benefits that are gained from the new products.
On the other hand, companies can accept the resistance that consumers have around their new products, particularly for those that require considerable behavioral change. The simplest of these strategies is to stay patient. Without doing so, companies can easily overspend their resources prematurely before enough consumers are willing to adopt their product.

An alternative strategy for companies launching products with significant behavioral change is to make sure these products perform ten times better than the current solution. The approach here is to rely upon the fact that vastly superior value will almost always override the outweighed losses that consumers might perceive.

Lastly, companies or regulatory agencies in the industry, can simply eliminate incumbent products. This naturally allows for new products to be adopted by consumers as they are forced to break away from existing alternatives. (J. Gourville, 2006)

Gourville argues that there is not a single path, but rather a careful understanding of the industry and its consumers that will lead to one or a combination of approaches that maximize success.

Another important aspect to determining the success of a new technology product is to analyze the factors that influence its rates of diffusion throughout a user base. A well-established framework by Everett Rogers, who is a professor of communication studies, is known as Rogers’ Five Factors. These five factors, listed and described as the traits of a product in the figure below, are the top factors that influence the rate of diffusion of a new technology. (Rogers, 2003)

<table>
<thead>
<tr>
<th>Trait</th>
<th>Definition</th>
<th>Implication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative Advantage</td>
<td>Being better than the ideas it supersedes</td>
<td>Seek 10x improvement in economic and aspiration value</td>
</tr>
<tr>
<td>Compatibility</td>
<td>Consistent with values &amp; experiences of potential adopters</td>
<td>Brand mirrors aspiration, UI doesn't change engrained behavior</td>
</tr>
<tr>
<td>Complexity</td>
<td>Relatively difficult to understand and use</td>
<td>Ease of use, Ease to put into use, no conflicts with existing structures</td>
</tr>
<tr>
<td>Trialability</td>
<td>Can experiment on a limited basis</td>
<td>Minimize barriers to trial, limit initial investment</td>
</tr>
<tr>
<td>Observability</td>
<td>Results are visible to others</td>
<td>Credible references</td>
</tr>
</tbody>
</table>

*Figure 8 - Everett Rogers ‘Five Forces’* (Rogers, 2003)

Building on Rogers’ work, a management expert, Geoffrey Moore, created a framework to segment the potential users of new technology. Moore identified that the diffusion of technology
products happens in a bell curve distribution. Furthermore, he identified a large gap between the adopters of a product that are ‘innovators’ or ‘early adopters’ of a technology, and the ‘early majority’ that are much more pragmatic.

The existence and size of this gap is often correlated with the behavioral change required for the ‘early majority’ to adopt the innovation. The majority of users, that is the ‘early majority’ and ‘late majority’ tend to adopt products of established companies with well-known brands. This is what inherently causes the ‘the chasm’. (Moore, 2014)

![Figure 9 - Geoffrey Moore’s Crossing the Chasm](Moore, 2014)

Moore argues that the best way for technologies to cross this chasm is to first identify a ‘specific niche’ inside of the ‘early majority’. He also warns against expanding prematurely in to this majority as it will compromise the ability of the technology or product to achieve product-market fit. Lastly, Moore suggests that companies position and market themselves as leaders in that specific niche prior to gaining the approval of the ‘early and late majority’. (Moore, 2014)

These frameworks will be helpful to understand how the AR/VR industry will evolve and consider the options for impacted and or interested select stakeholders.

**Venture Capital**

The core purpose of Venture Capitalists (VCs) is to invest capital in innovation driven enterprises, typically enabled by technology, to make a return on that capital. There are many different types of VCs. As shown in the figure below, they differ mostly in the way that they invest. These investments can differ by stage, whether they invest in businesses that sell to businesses (B2B) or those that sell to consumers directly (B2C), hardware or software businesses, or whether they invest in specific domains, the geography of said investments, and the variety of value added services that they provide their portfolio companies.
The primary attributes that differentiate VCs are stage and B2B v B2C. This is mostly because the capabilities, knowledge, and resource required to successfully invest in such companies are drastically different.

<table>
<thead>
<tr>
<th>Attributes/Types</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage</td>
<td>There are several rounds or stages of venture capital, from pre-seed, seed, series A, B, C, D and beyond. Different stages require different levels of capital and expertise.</td>
</tr>
<tr>
<td>B2B v B2C</td>
<td>Some VCs focus on only B2C companies and many others focus on B2B businesses. The ability to source, conduct diligence, and build such companies has different skill sets.</td>
</tr>
<tr>
<td>Hardware v Software</td>
<td>Hardware and software businesses have very different economics, product architectures, and levels of capital required. This often splits Venture Capitalists accordingly.</td>
</tr>
<tr>
<td>Generalist vs Domain Expert</td>
<td>Some Venture Capitalists choose to specialize in a particular domain and differentiate themselves with deep industry knowledge or insights, while others remain opportunistic and invest in all different industries.</td>
</tr>
<tr>
<td>Fund life cycle</td>
<td>The age of a fund can impact how a VC chooses to invest. A young fund might be willing to take on more risk than one that is near its end.</td>
</tr>
<tr>
<td>Geography</td>
<td>VCs are also very territorial. Some specialize in a particular geography because of their expertise or network. Different geographies have different funding cultures which leads to different types of deals and VCs.</td>
</tr>
<tr>
<td>Portfolio company services</td>
<td>VCs also differentiate themselves by the types of services that they offer their portfolio companies. These services have a range: sales, recruiting, technology development, partnerships, follow-on-investing, etc.</td>
</tr>
</tbody>
</table>

Figure 10 – Types of Venture Capitalists (Feld, 2016)

As seen in the subsequent figure, Venture Capitalists are typically made up of General Partners, often erstwhile senior technology executives, who raise money from Limited Partners, usually wealthy institutions of all kinds (education, insurance, family offices, endowments, private equity). VCs then use the networks they have created over their careers as inbound opportunities for potential investments. They use their experiences, insights, and strong networks of other VCs, both upstream and downstream, to help their portfolio companies with value added services that maximize their chances of success.

The operations of VCs in the United States are typically regulated by the SEC, and constrained by their Limited Partners and by the reputation that they build and maintain within their business ecosystem.

Finally, VCs help their portfolio companies exit through acquisition or initial public offering (IPO), and they split the resulting capital gains between themselves and their Limited Partners.
Startup and entrepreneurial activity is the cornerstone of the industry, enabling much of the innovation required to make AR/VR a mature industry. At the moment, however, most AR/VR startups remain in the seed stage. (Tom, 2017) Series A Venture Capitalists will play a critical role in the further development of the industry, and hence this project will focus on Series A investors as the key group of stakeholders.

At the highest level, VCs engage in five activities that enable their business model and purpose. This is shown in the figure below. First and foremost, they raise funds from Limited Partners (LPs) that they can invest in promising opportunities. VCs spend considerable time convincing LPs that they can have a higher return on investment with their particular investment approach than their counterparts. Second, VCs spend considerable time educating themselves on various emerging technologies and business models to inform their investments. They do this primarily by engaging with experts in such technologies, reviewing third party research (such as this thesis), and learning from the experiences of their portfolio companies.

As an investment hypothesis is being built, VCs source opportunities, conduct diligence on them, and then select and invest in those opportunities that align with their investment hypothesis, thesis, or approach, and they believe will yield worthwhile returns.

The conclusion of this thesis focuses primarily on the second activity described in this figure, although some suggestions around the third activity will be offered as well. Once a VC makes an investment, they usually spend considerable time supporting their portfolio companies by offering value added services such as: recruiting, sales, and business related recommendations. They also help their portfolio raise follow on funding from investors downstream, namely Series B, C, and D VCs. Finally, VCs spend considerable time helping their successful portfolio companies liquidate, usually through acquisition. This enables the VC to capture value and return capital gains to themselves and their LPs.
Key activities of Series A Investors

1. Raise funds from LPs
   - Who are the right LPs to approach for AR/VR?
   - How can a VC differentiate from competitors, including other investment classes?

2. Learn about emerging technologies and innovations to inform investments
   - Who can VCs partner with to create the right network of experts?
   - Where is the best place for a VC to invest in AR/VR given their competencies? What type of company?

3. Source and conduct diligence on startup opportunities
   - Who are the right stakeholders to partner with to see the right deals?
   - How to engage the AR/VR ecosystem?
   - What is the investment criteria to vet an AR/VR startup?

4. Provide support and value to portfolio companies
   - What are the best services that VCs can provide to maximize the success of their AR/VR companies?
   - Who are the best series B investors for invested AR/VR companies?

5. Find exits and capture value
   - What is the best type of exit for an AR/VR company?
   - Who are the best companies to target for an acquisition?

Figure 12 – VCs Key Activities & Questions

III. Introduction to AR/VR

Brief Introduction

The AR/VR industry has had several epochs in its past, but has re-emerged more recently largely because of the technology that has been enabled by the smartphone, wireless, and gaming industries, such as low-cost high-performance complex hardware components (display and GPUs), and recent advancements in gaming engines for traditional video game consoles. (Goldman Sachs, 2016)

Furthermore, favorable macro-economic trends and the availability of venture capital has also been a boon to the industry. Perhaps the one company most responsible for starting this latest epoch of AR/VR is a small company started in Irvine known as Oculus, founded by a young entrepreneur, Palmer Luckey. In 2012, Facebook acquired Oculus for over $2B, causing the technology industry to pay attention and gain interest in AR/VR. (Constine, 2014)

Since this acquisition, several other startups have followed suit, making several products required to create an entire ecosystem. As a result, unlike previous eras, several major technology companies have stepped in to the industry with serious investments, products, strategies, and initiatives. (Constine, 2014)
Definitions

There is significant debate in the industry over the precise definitions of Augmented Reality and Virtual Reality. The range of definitions often depends on the capabilities and features of the technology. In this thesis we will use definitions that many experts in the industry would agree upon.

1) Augmented Reality: overlaying digital information in over the physical world

Subsequent sections will add more dimensions to these definitions.

Augmented Reality

The history of Augmented Reality (AR) really depends on how AR is defined. Given the proposed definition, AR is a relatively new technology to be introduced to the market. The earliest AR systems were primarily used in the military, providing contextual information for military applications. More recently, consumers have used less sophisticated AR systems, such as heads-up displays in vehicles.

However, like VR, the more recent emergence of AR began with a company that was able to raise significant attention and capital for its efforts, Magic Leap, who will be discussed further in subsequent sections. (Sachs, 2016; Charara, 2017)

Types of AR/VR Platforms

In this recent epoch of AR/VR, there are several types of devices, each with different capabilities, designs, and resulting use cases. Below is a figure defining and describing the different types.
Augmented Reality

Real-time relevant information that is integrated onto the real world.

Virtual Reality

Fully enclosed synthetic digital experience. Users must not lose the feeling of presence.

Development Difficulty

Mobile AR

Spatial

Wearable AR

Vision

Figure 13 - Types of AR/VR Platforms

Less immersive = on the go use cases

More immersive = stationary use cases

360° video

This type of VR is most similar to how traditional two-dimensional (2D) video content is consumed, particularly because it does not necessarily require a headset to view content. '360° video' content is created with rigs of cameras to simultaneously capture all angles and perspectives of a particular point in space. After capture, complex software is used to 'stitch' these frames together to create a '360°' view of that environment. Viewers experience '360° videos' by clicking and dragging the content or viewing the content through a head mounted display. (Graham, 2016)

Facebook is leading the way with '360° video' content distribution, encouraging and enabling users to post their 360° content on social media. '360° video' is the simplest version of VR and is likely the best type of content for mass audiences to enjoy presently, as it is compatible with current computing platforms and requires little behavioral change to experience.

More recently, '360° video' is becoming more interesting as it is becoming easier for users to capture and create their own content. Low cost peripherals that are dual-lens cameras can now be used to capture 360 degrees of an environment and simple mobile apps can stitch the frames together. As has been seen with other platforms, such as smartphones, user generated content is essential for growth. (Graham, 2016)
'Mobile VR'

Smartphones have become ubiquitous in developed countries and in many use cases have become the primary computing device for users. Much of the innovations in display technology has been in smartphones over the past decade. Display technology is critical to VR, particularly as users’ eyes are significantly closer to the interface. (Oculus, 2016)

Given the ubiquity and technical capabilities of smartphones, it is natural for them to be leveraged to deliver VR experiences to a majority of the market. Users place smartphones in to hardware that can be placed around the head and face to view content. Most recently, these products include simple Bluetooth controllers with accelerometers and IMUs to allow for basic controls within the digital environment. This effectively turns the smartphone in to a Head Mounted Display (HMD).

There are several players who are fighting for share in the ‘Mobile VR’ space. Currently, Samsung and Google are leading in this market. This is unsurprising given their current leading positions within the smartphone market. (Superdata & Unity, 2016)

Although ‘Mobile VR’ could theoretically be used for all uses of VR, it is important to note that there are still several technical limitations involved in using a smartphone to power VR. As a result, most use cases today are short form, less critical and mostly entertainment focused. These technical limitations are mostly related to the power of the graphics processing unit (GPU) or related to battery life. These limitations are expected to be resolved as Mobile Device Manufacturers (MDMs) continue designing and manufacturing more advanced components. (Goldman Sachs, 2016)

'Tethered VR'

This type of VR has head-mounted displays (HMDs) that are ‘tethered’ with a cable to powerful personal computers (PCs) that can create and deliver the most premium and sophisticated VR experiences. The components available to PCs, particularly the computational power available from their graphical processing units (GPUs) and central processing units (CPUs), increase critical performance metrics for VR such as frames per second (FPS) and decrease latency, to create more vivid graphics and deliver superior experiences for users. (Sachs, 2016)

Additionally, these tethered systems include external trackers that are usually enabled by optical sensors to track the position of the user in the digital environment. This is a critical product attribute known in the industry as Positional Motion Tracking (PMT). This is currently a key point of differentiation between these premium “Tethered VR” systems and less sophisticated variants of VR such as ‘360° Video’ or ‘Mobile VR’. Additionally, these systems typically include two
sophisticated wireless controllers that enable users to fully interact with most content assets within
the virtual environment. These controllers, along with PMT, contribute to the critical design goals
of VR, described later in this thesis.

‘Tethered VR’ systems encompass the largest range of potential use cases given their
performance advantages. However, unlike the ‘Mobile VR’, tethered systems require ‘VR-Ready’
PCs that currently have prices that are mostly over $1500, and which only comprises about 10% of PC owners. These users are predominantly young male gamers, which limits the type of content that is developed and consumed for these VR systems to being predominantly entertainment or gaming content. (DigiCaptial, 2016)

‘Tethered VR’ systems will, however, given their complexity and price continued to be used in
several enterprise use cases, which will be described in further detail in subsequent sections. (Goldman Sachs, 2016)

‘Mobile AR’

Smartphones can also be used to deliver AR experiences. In this type of AR, the camera, along
with a combination of other components (GPS, IMUs, etc), collectively help the device triangulate
the exact environment of the user and detect objects within that environment. Through advanced
computer vision, object recognition, and image processing (among others), the device overlays
relevant information or content for the user to view on a smartphone’s display. (Perey, 2014)

The most popular embodiments of ‘Mobile AR’ that have been developed thus far are Snapchat’s
filters and Niantic’s ‘Pokemon Go’. From a hardware perspective, Google and its hardware
partners, such as Lenovo, are leading the way in this space, developing smartphones that are
dedicated to AR. (Merel, 2016a)

‘Mobile AR’ is arguably the largest opportunity for AR as its potential addressable market is all
smartphone users, particularly as MDMs plan to roll out hardware capabilities and architectures
that specifically target support for ‘Mobile AR’. In addition, the behavioral change required for
‘Mobile AR’ is arguably the lowest of all types of AR/VR. Many smartphone users are already
accustomed to using smartphone operating systems and cameras. As a result, much of the tacit
knowledge required to adopt and extract value from ‘augmented’ information is already
developed.

The use cases of ‘Mobile AR’ are more likely ‘on the go’ since users are not fully immersed but
able to continue interacting with the rest of their natural environment. (DigiCapital, 2016)
‘Wearable AR’

Head-mounted displays (HMDs) that are meant for AR are known as ‘Wearable AR’. These systems take on different physical forms than ‘Mobile AR’ systems, while the software forms are more similar. These products are worn on users’ heads, similar to ‘Mobile VR’ and ‘Tethered VR’, but are open enough for users to still observe their natural environment. Cameras, along with small optics and transparent displays are used for users to view relevant digital content. Given the demand for smaller form factors, some of these products often are wirelessly tethered to PCs or smartphones for more compute resources. (Merel, 2016a; Sachs, 2016)

‘Wearable AR’ gained popular awareness with Google’s Glass product, launched for consumers. The product was not received well for several reasons. However, ‘Wearable AR’ has made a resurgence in enterprise use cases, which will be discussed in subsequent sections. Microsoft and ODG’s products are some of the companies leading the way for ‘Wearable AR’. (Goldman Sachs, 2016)

‘Wearable AR’ is potentially a powerful tool because of its potential to be an incredibly natural interface for users. The vision of ‘Wearable AR’ is to provide the right information at the right time for any task a user might be performing. The opportunity for ‘Wearable AR’ is large because of the potential that the use of such products could be continuous, or ‘always on’, unlike current intermittent computer interfaces. The key challenge, however, for ‘Wearable AR’ will be the demand for form factors that can accommodate users’ requirement to be able to wear the devices in public environments. Additionally, to a greater extent than ‘Mobile AR’, ‘Wearable AR’ involves higher behavioral change for users since it is a new platform with little tacit knowledge.

Vision AR

‘Wearable AR’, ‘Mobile AR/VR’, and ‘Tethered VR’ are the dominant forms of the technology today in the industry. ‘Vision AR’, refers to AR devices that project light in to the retina of users. There are few companies using this approach and the only notable one is Magic Leap. (Stein, 2015)

Magic Leap is notoriously secret about their product and operations. It is by a large margin, the best funded AR startup in the entire industry. However, those who have been fortunate enough to demo the product have given high marks. This product is very unique in its architecture and capabilities and can be disruptive if it is well received by consumers. (Goldman Sachs, 2016)
Attributes & Design Goals

It is important to understand how AR/VR can be superior in performance in key computing functions than traditional platforms, i.e. smartphones or computers, so these are outlined briefly here.

At the highest level, the design goals of AR/VR are described below:

1. AR – close the information access gap between the digital and physical world; this provides more awareness for users within their environment, 'augmenting' their day to day experience as they interact with their natural environment. (CB Insights, 2016)

2. VR - experience a new world, enabling users to have presence in artificial worlds experiences they couldn’t otherwise without significant limited resources, so that for example users can simulate different worlds, connect with others at a human level, have endless screen real estate, and different interaction modes; VR has the promise to input content and information in to users' minds, creating memories they could not have with traditional 2D interfaces. (CB Insights, 2016)

AR is intended to overlay relevant digital information over a user’s real world: the user remains primarily engaged with their natural external environment. Alternatively, VR is on the other end of the spectrum and is intended to bring users out of their natural external environment and in to an immersive environment that is fully digital. The VR industry terms this alternative experience as ‘presence’. It is a critical design goal for all VR experiences. (Oculus, 2016)

Each of the aforementioned variants of AR/VR attempt, with varying degrees, to adhere to these goals. For example, ‘Tethered VR’ is much more immersive than viewing ‘360° Videos’ on the web or even ‘Mobile VR’. This level of immersion, among other attributes, is critical in understanding how different types of AR/VR map to particular use cases.

Below is a figure describing some of the important attributes that demonstrate the differences between some of the forms of AR/VR. These are not absolute parameters but rather relative values. For example, ‘Tethered VR’ has little available content in absolute terms, but nevertheless has relatively more content than that of ‘Mobile VR’.
Although there are many attributes of these products to consider, these seven attributes represent the most important factors considered by industry experts today.

There are some noticeable differences between these types. For example, 'Mobile AR' leads in user experience, form factor, and fit, requiring very little behavior change for users to enjoy AR applications. However, it is not relatively immersive, which is not necessarily a negative attribute but something to consider depending on the use case. These values were determined by experimenting with all architectures and synthesizing other relevant third party market data. The other architectures to follow after 'Mobile AR' are 'Mobile VR', 'Tethered VR', then 'Wearable AR'.

**Use cases**

These different types of AR/VR, depending on their different attributions, make them stronger or weaker tools for various use cases in several industries.

Below is a figure summarizing industries adopting AR/VR, some of their key challenges, and the type of AR/VR that is well suited to solve those challenges better than traditional platforms because of their attributes.
Table 1 - AR/VR Use Cases & Market Potential (Merel, 2016a; Sachs, 2016)

<table>
<thead>
<tr>
<th>Industry</th>
<th>Challenges</th>
<th>Example use case</th>
<th>Dominant AR/VR type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaming</td>
<td>• 2D interface lacks immersion</td>
<td>• Gamers use VR to play first person shooter games, so that the action feels more real</td>
<td>• 'Tethered VR'</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• 'Mobile VR'</td>
</tr>
<tr>
<td>Education</td>
<td>• In class engagement</td>
<td>• Immersive VR experiences to teach students history and complex scientific concepts</td>
<td>• 'Mobile VR'</td>
</tr>
<tr>
<td>Healthcare</td>
<td>• Quality of care</td>
<td>• Surgeons use 'Wearable AR' to help conduct surgery, so they can observe contextual and relevant data</td>
<td>• 'Tethered VR'</td>
</tr>
<tr>
<td></td>
<td>• Preventive care/rising costs</td>
<td></td>
<td>• 'Wearable AR'</td>
</tr>
<tr>
<td></td>
<td>• Training care providers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Military</td>
<td>• Resource intensive and dangerous training</td>
<td>• Soldiers use VR to train for extreme battle conditions</td>
<td>• 'Tethered VR'</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Special operations group use AR in the battlefield to better inform of their environment</td>
<td>• 'Wearable AR'</td>
</tr>
<tr>
<td>Engineering</td>
<td>• Visualization and collaboration in complex systems development</td>
<td>• Architects collaborate and review designs in a virtual environment</td>
<td>• 'Wearable AR'</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• 'Tethered VR'</td>
</tr>
<tr>
<td>Video</td>
<td>• 2D interfaces lack data, an immersive and social experience</td>
<td>• Virtual environment for friends to view favorite 2D content together and observe content meta data in new ways</td>
<td>• 'Mobile VR'</td>
</tr>
<tr>
<td>Retail</td>
<td>• Product discovery and experience before purchase</td>
<td>• Shoppers can experience products and brands, and how they fit in to their lives before purchase and remotely</td>
<td>• 'Mobile VR'</td>
</tr>
<tr>
<td>Live events</td>
<td>• Low attendance and high cost for fans</td>
<td>• Fans can 'be at' concerts regardless of where they are and how much it costs</td>
<td>• 'Mobile VR'</td>
</tr>
<tr>
<td>Real estate</td>
<td>• Observability</td>
<td>• Home shoppers or developers can step in and experience a home regardless of where they are in the world</td>
<td>• 'Mobile VR'</td>
</tr>
<tr>
<td></td>
<td>• Discovery</td>
<td></td>
<td>• 'Tethered VR'</td>
</tr>
<tr>
<td></td>
<td>• Visualization</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Each industry described above has its respective challenges and willingness to pay and adopt new technologies. As a result, some types of AR/VR are better suited for some industries rather than others. For example, the healthcare industry is much more heavily regulated, with stakeholders that have a high willingness to pay, and demanding performance requirements. In this industry, performance rather than price or form factor is more important, making 'Wearable AR' or 'Tethered VR' more viable options. (Medical Futurist, 2016)

It is noteworthy that AR systems, particularly 'Mobile AR' today, are more likely to be used as a new interface for general information discovery. This represents a large opportunity that is not captured in these estimates or industries, and will be discussed in later sections.
**Value chain, stakeholders, and ecosystem**

This section describes the structures of the AR/VR industry. Although they will be mentioned in brief, this section does not intend to detail specific companies, technologies, nor dynamics. These topics will be described in subsequent sections.

The AR/VR industry is made up of several types of stakeholders. At the highest level, some of these types, and in some cases companies, are shared across AR and VR. This section will describe the function of each key type of stakeholder and the value that flows amongst them. The analysis is mostly focused on VR, although is largely representative of the ecosystem structure in the AR industry, which is less developed in comparison.

![VR Ecosystem Structure](Chennavasin, 2017)

Above is a figure that captures the key stakeholders that are core to enabling VR. This map is not exhaustive, as there are some stakeholders who serve these core stakeholders, such as semiconductor equipment vendors.

**HMDs**

Starting from the bottom left, ‘HMD’ companies provide the hardware core of the VR experience, including the hardware needed to enable ‘Tethered VR’ or ‘Mobile VR’. Although not shown in the figure, given the complexity of different types of hardware within an ‘HMD’, these players participate in various levels of the design, manufacturing, and assembly of the components.
required to make a production ‘HMD’. For example, HTC’s ‘Vive’, a leading ‘Tethered VR’ product, includes chipsets from various vendors. Some of these hardware partners, such as Samsung, may have their own HMD VR products as they supply components for others. In this sense, the VR hardware world is a horizontal one and a partnership-friendly one, in a similar way to the smartphone industry.

It is noteworthy that there are several materials, semiconductor, and semiconductor equipment players that provide the electronic wafers required to create chipsets, displays, and casings that are used to create HMDs. Also, as ‘Mobile VR’ become more popular, traditional smartphone MDMs are expected to become, in part, HMD players. (Merel, 2016a; Sachs, 2016; CB Insights, 2017b)

AR ‘HMD’ (which includes ‘Mobile AR’) companies design, engineer, manufacture, and assemble the hardware core of the AR experience, including key enabling components such as displays, GPUs, Optics, needed to enable ‘Wearable’ or ‘Mobile AR’. These enabling technologies will be described further in subsequent sections. Similar to VR, these AR players participate in various levels of the design, manufacturing, and assembly of the components required to make a production ‘Wearable AR’ or ‘Mobile VR’ product. For example, Microsoft’s ‘Hololens’, a leading ‘Wearable AR’ product, includes chipsets from various vendors. Microsoft may have designed and engineered these components, but have chip vendors manufacture them. Some of these hardware partners may have their own ‘Wearable AR’ products while they supply components for others. In this sense, the AR hardware world is sometimes horizontal and a partnership friendly one, similar to the VR industry. (Perey, 2014; Sachs, 2016)

Like the VR industry, there are several materials, semiconductor, and semiconductor equipment players that provide the electronic wafers required to create chipsets, displays, and cameras that are used to create HMDs. Also, as ‘Mobile AR’ become more popular, traditional smartphone MDMs are expected to become, in part, ‘Mobile AR’ players.

Input

‘Input’ companies provide all the devices that are an ‘input’ to the user experience. The most common input devices are controllers, such as Oculus’ ‘Touch’ controller. There are several variants of input devices emerging that are adding to the experience. For example, omnidirectional treadmills capture the direction and rate that users are moving and translate that data to the VR system. Other input devices are related to eye detection, gloves, guns with haptic feedback, air pressure systems, and products that create olfactory experiences. Most of these devices share a common purpose of bringing the users’ body and senses in to a digital world.
Theoretically, the more inputs we have into a VR system, the more sophisticated and complex it becomes. However, more devices demand limited compute and energy resources and demand users to handle even more devices, increasing behavioral change.

Like HMD players, companies creating input devices can be horizontally or vertically oriented. Furthermore, many of them, such as Google, create both the HMD and the input device together, ensuring interoperability.

Finally, input devices are critical to the user experience as they often define the user experience and interface. Popular VR systems today, both ‘Mobile VR’ and ‘Tethered VR’, are designing their own ‘HMD’ and other ‘input’ devices, causing significant fragmentation in the user interface and experience across platforms. This has unintended consequences for the industry that will be discussed in subsequent sections. (Merel, 2016a; Sachs, 2016; CB Insights, 2017b)

Instead of ‘input’ stakeholders, AR has ‘component’ stakeholders. These companies include some of the key components that make AR possible. It is important to note, that ‘Input’ players are just one of many hardware components to enable AR, particularly ‘Wearable AR’. Other components are just as critical: display, 3D cameras, and computer vision are essential ingredients together with a Wearable HMD or Mobile device to create AR. For example, computer vision software provides the camera of ‘Mobile AR’ and ‘Wearable AR’ systems with the ability to understand its environment. Controllers are not popular as an input, rather, infrared or laser sensors are used to track a users’ natural hand motions. For example, the HoloLens detects when users have pinched their index and thumb together to create an event within the user interface.

**Reality Capture**

These players provide value to the industry by either or both manufacturing or using sophisticated cameras to capture the natural world. These companies often differentiate themselves and function differently in one or more of several ways. Some simply procure assembled cameras and only differentiate themselves through creative choices of the content they capture. Other companies will differentiate themselves by assembling a custom rig of cameras, increasing the quality and ease to develop content. Lastly, other players, such as Nokia, will create their own camera to increase the quality of capture. Although cameras are beginning to have higher fields of view, almost all of these reality players need to use software to ‘stitch’ together to the frames that their camera systems capture.

More recently, a new kind of capture, known as volumetric capture, creates more rich content by capturing more light rays from more directions than traditional cameras. However, the magnitude of data for this type of content is very high, requiring more compute resources than less
sophisticated VR systems, such as ‘Mobile VR’ and ‘360° Video’. (Merel, 2016b; Sachs, 2016; CB Insights, 2017b)

'Reality Capture' for AR can include similar players and content from the VR industry. However, a key distinction is that ‘Reality Capture’ in AR can include a camera that is on board the AR device, whether ‘Mobile AR’ or ‘Wearable AR’. Like the VR industry, some Reality Capture companies differentiate themselves and function differently in one or more of several ways. As in VR, some simply procure assembled cameras and only differentiate themselves through creative choices of the content they capture. Again, other players will differentiate themselves by assembling their own rig of cameras, increasing the quality and easiness to develop content. Lastly, other players, such as Lytro, will create their own camera to increase the quality of capture.

As will be discussed, content is critical to the adoption and evolution of VR and ‘Reality Capture’ players are core to the creation of such content.

3D Tools

Several companies create software tools that enable content for VR. Some of these tools are to create Computer Generated Images (CGI) while others are used to stitch together frames from reality capture.

A proportion of the content that is viewed in VR is CGI. The most popular VR tool for CGI design and development is a tool known as Unity, which is also used for the development of most popular games. Unity is a product platform used by ‘Application/Content’ developers to create experiences for users. It is a platform because it provides developers with the most common and core functions, libraries, and digital assets required to make VR experiences.

'3D Tools' providers are very central to the development of content in the industry. They invest in making their tools more powerful and educating developers. A key function of ‘3D Tools’ is to standardize various development functions and democratize best practices, making it easier for developers to collaborate and come up the learning curve.

These players also collaborate closely with HMD companies, such as Oculus, to bundle their products together for developers. Doing so creates an industry platform for other companies to build their solutions. (Merel, 2016a; Sachs, 2016; CB Insights, 2017b)

Distribution

Distribution companies in this industry help developer’s applications reach users who are interested. In essence, they act as a platform between content and application stakeholders and
users. Distribution companies usually create search functionality to help with content discovery. They differentiate themselves by search, the scope and availability of content, and the feedback functionality that they provide to users. These companies are similar to the ‘Play Store’ and ‘App Store’ of Android and iOS platforms.(CB Insights, 2017b; Chennavasin, 2017)

**Application/Content**

These companies are the closest to end users. They develop the applications and content that end consumers or enterprises ultimately consume. In some cases, these companies, such as Sony or HTC, can be the same as those who create HMDs, Input, and distribution channels. Most ‘Application’ companies, are startups who are looking to leverage the industry as a platform. They partner and use the HMDs, input devices, 3D tools, and distribution products and services of other companies to create unique applications that they can provide for end users.(CB Insights, 2016, 2017b; Sachs, 2016)

These companies, similar to application companies for other platforms, compete with one another to capture the attention of users. Because VR is a new medium for many of these companies, the learning curve for design is new and steep.

Below is a figure that summarizes these stakeholder types, including the value that they receive and deliver to the ecosystem.

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Description</th>
<th>Value received</th>
<th>Value delivered</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Applications/content</strong></td>
<td>Mainly software companies that develop industry specific applications to end users</td>
<td>Hardware platforms and distribution platforms</td>
<td>Experiences for end users</td>
</tr>
<tr>
<td>Distribution (apps/media)</td>
<td>Provide a platform for app players to reach their desired end users</td>
<td>Fees from users or content players</td>
<td>Enable users to discover, review, purchase, and experience applications</td>
</tr>
<tr>
<td>3D tools</td>
<td>Provide software tools for developers to build unique applications and stitch content</td>
<td>Money from application developers to subscribe to tools</td>
<td>Education and saved time for developers to build what they want</td>
</tr>
<tr>
<td>Reality Capture</td>
<td>Build rigs of cameras to enable capture of real life content</td>
<td>Money from select application players</td>
<td>Time and technical hardware required for high resolution capture</td>
</tr>
<tr>
<td>HMDs</td>
<td>Design, build, and or assemble HMDs that will be used as hardware to display content</td>
<td>Brand and money received from end users or application stakeholders</td>
<td>Difficult hardware that enables content consumption for the industry</td>
</tr>
<tr>
<td>Input</td>
<td>Usually hardware that brings users' movements or actions in to a digital environment</td>
<td>Brand and money received from end users, application stakeholders, and or HMD players</td>
<td>Create a better experience for end users and the ability to interact with digital content</td>
</tr>
</tbody>
</table>

**Figure 16 – AR/VR Stakeholder Value Exchange**

**IV. Industry Dynamics**
Building on the broad introduction to the structure of the AR/VR industry described above, this section will provide an understanding of the current dynamics within the industry. To do so, the section will describe players within the ecosystem, drivers pushing the industry forward, inhibitors holding it back, market trends and projections, user groups and behaviors, investments, and intellectual property. The purpose of this section is to provide a summary of where the industry stands now, to provide the foundation for a sound prognostication of the future.

**Key players and their activities**

There are many different types of AR/VR companies, both large and small. Given the infancy of the industry, many of the larger companies involved are companies with large legacy businesses in adjacent technologies such as mobile devices, gaming, or chipsets, such as Intel for example. The industry has until recently never seen this level of involvement from larger players.

Below are two figures that showcase the current VR and AR ecosystem, including companies' logos based on type of stakeholder, as defined in previous sections. This listing of companies is by no means exhaustive, but represents companies that have been recognized by industry experts for their importance and their progress. (Chennavasin, 2017)
Below is a similar figure for the AR ecosystem.

There are insights that can be drawn from these maps. Several companies, such as Oculus, Sony, and Google, are positioned in several different areas of the map. This demonstrates to some extent their vertical positioning and high level of commitment to the industry as a whole. The map also includes several startups, although with notably less representation in the bottom left corner (HMDs). This is consistent with the idea that HMDs are capital and resource intensive, much of which is made up of large traditional MDMs and hardware players.

Additionally, there are some companies such as Google, Facebook, and Intel that are involved in both AR and VR ecosystems, highlighting their significant involvement and importance to the industry. A series of figures below, describe some of the strategies, initiatives, investments, and key products of some of the most seminal companies in the industry. A brief synthesis of these companies will be described in the subsequent section.
Another key player in the VR industry is Google; the figure below describes its involvement in the AR/VR industry.

**Figure 20 - Google AR/VR Strategy, Initiatives, Investments, and Products (Alphabet, 2017)**
Another key player in the VR industry is Intel; the figure below describes its involvement in the AR/VR industry.

![Intel AR/VR Strategy, Initiatives, Investments, and Products](image)

Another emerging player in the AR industry is Apple; the figure below describes its involvement in the AR/VR industry. Apple’s CEO, Tim Cook, has repeatedly touted AR as the future rather than VR. Although no official products have been launched, there are rumors to support a ‘Wearable AR’ product as well as a ‘Mobile AR’ iPhone. Apple is one of the few consumer companies that can bring true AR to consumers given its loyal user base and excellent design capabilities.
Another important player in the AR industry is Snapchat; the figure below describes its involvement in the AR/VR industry. Snapchat's strength is its loyal, young, and trend-setting user base. It is also a leader in smart consumer sunglasses, known as 'Spectacles'. Although this product has not incorporated AR abilities, it includes a camera that allows users to capture and their point of view. Snapchat is incorporating 'Mobile AR' features in to its core mobile application and is well positioned to incorporate these features in to 'Spectacles'.

These figures demonstrate that multi-billion dollar companies are investing significant resources to develop AR and VR products. It is also highlights the different approaches that each of them are taking to integrate these products into their broader company strategies. Another point of differentiation is the content companies that each company is able to cultivate partnerships with. These partnerships are critical to the overall success of each company's success.

There are other important companies that will have an important impact on the industry. These include Samsung, Magic Leap, Microsoft, Sony, HTC, amongst others. A figure below illustrates how some of these larger companies participate in the industry from a hardware and software perspective. In aggregate, there is a noticeable shift towards AR technologies and less participation on the software side of the industry.
Drivers and Inhibitors

Because AR/VR is in its infancy phase, there are a lot of challenges that the industry needs to overcome to continue its growth. Some of these drivers and challenges are shared and some are differentiated based on the type of AR/VR. These challenges and drivers are important to understand and track the progress of the industry.

Although not exhaustive, the figure below illustrates some of the most impactful of the drivers and challenges facing the industry. Most of these are self-explanatory, however it is important to note some of the trends and white spaces. At a high level it seems that Mobile based systems, in aggregate, face fewer inhibitors than wearable or tethered base systems.

A major reason for this trend is that the mobile device ecosystem is already very mature and is the cause for much of the drivers across the industry. The smartphone industry has provided cheaper components and a large installed base for 'Mobile AR' & 'Mobile VR' platforms.
An important inhibitor to consider is the status quo. This requires an understanding how users use key content or computer platforms today. The average user in the United States, spends 44% of their daily life consuming some form of media. Current ‘media’ devices include smartphones, laptops, PCs, and radios. The key question is where AR or VR devices will substitute for these devices for users.

As described earlier in the literature review, smartphones, laptops, and TVs have created an ‘Endowment Effect’ for users, which is particularly strong given how long they have been in use for most users in the developed world.
Given today’s most developed types of content, it is presumable that AR/VR time will take time away from users’ time spent consuming TV content. However, most who watch TV do so because of the diversity of content available. Current AR/VR platforms do not provide nearly as much as content or features as traditional platforms do today. AR/VR platforms will struggle to replace consumers’ activities until they are able to perform enough functions well enough to convince users to switch. The status quo is a large inhibitor to adoption for AR/VR platforms.

Although it is difficult to quantify which of these challenges and drivers are most impactful, there are some that are generally recognized as critical to industry experts. The figure below demonstrates that industry experts believe that the user experience is the primary factor that is holding the industry back most from its progress and growth. (Upload & Perkins Coie, 2016)

User experience is critically tied to user behavior and the extent to which users need to change their tacit behavior to use a platform.

![Figure 27 - Top Challenges Holding Back the AR/VR Industry](Upload & Perkins Coie, 2016)

Critical to a user and their experience is the user interface (UI) that he or she uses to control and interact with the platform. The figure below demonstrates common examples of user input modalities. One such example is the keyboard and mouse, which became the dominant form of input for PCs. PC and smartphone platforms experienced the most growth once the industry standardized around a design and form for user input. (Battaglia, 2013)

AR/VR has yet to standardize around a user input. Stakeholders in the industry, both large and small, are still spending considerable resources experimenting to develop a user input that is intuitive. This diverts engineering and design resources, and creates fragmentation for users across the ecosystem, significantly stifling adoption of AR/VR and growth of the AR/VR industry. (Utterback, 1996; Upload & Perkins Coie, 2016)
The stakeholders in the AR/VR industry can also be divided by common platform architectures of AR/VR (Mobile AR, Wearable AR, 'Mobile VR', Tethered VR). These architectures will be described in depth in a later section. The figure below maps each stakeholder type by platform to two axes: relative importance to ecosystem; and their performance.

At the highest level, it is clear that most stakeholders have a high level of importance to the ecosystem. More specifically, it seems that content and application players, in the bottom right squares, are providing the least value despite their critical importance. On the other hand, HMD and Distribution stakeholders are performing relatively well. The key difference between AR and VR stakeholders is HMD enterprises, who are performing at a much higher level in VR than in AR.
Market trends and projections
There have been several attempts by industry analysts to make market projection for the growth of the AR/VR industry. Most estimates are between $80B – $120B in revenues by 2020-2025. One of the most cited figure is that of DigiCapital, who estimates that AR/VR is now expected to be a $110B market by 2021, mostly driven by AR – this is down from last year’s estimate of $150B. This new estimate is seen in the figure below. (Merel, 2016b)

DigiCapital’s estimate favors AR because of its potential to be more integrated into users’ daily activities, spanning more use cases than VR. In addition, another estimate, in the figure below, compares the growth and adoption of various types of AR/VR over time. In this figure ‘Console/PC VR’ is equivalent to ‘Tethered VR’ and ‘Smartglasses’ is equivalent to ‘Wearable AR’.

Figure 29 - Stakeholder Performance vs Importance by AR/VR Platform

Figure 30 - Market Projection by AR/VR (Merel, 2016b; DigiCapital, 2017)
Consistent with other analysis in subsequent sections, ‘Mobile AR’ is projected to capture the majority of projected units sold. These estimates are followed by ‘Mobile VR’, ‘Tethered VR’, and finally ‘Wearable AR’.

In addition, another widely cited source in the industry is Goldman Sachs’s 2016 report on the industry. Goldman is consistent with other sources as well, when it estimates a roughly even distribution of hardware and software revenues for AR/VR seen in the figure below. However, it is important to note that different forms of AR/VR have different states of maturity in software and hardware. ‘Wearable AR’, for example, is not as developed in hardware or form factors, as compared to ‘Mobile AR’. This has important implications for how the revenues are divided by software and hardware.

Figure 31 - Unit Projections by Type of AR/VR (DigiCapital, 2017)

Figure 32 - Projected Revenues by Hardware-Software (Sachs, 2016)
Goldman also estimates the distribution of software revenues by application. In the figure below, the report estimates that videogames will be the largest market by 2025 followed by enterprise applications in ‘healthcare’ and ‘engineering’. It is important to note that these market sizes are limited because they do not consider AR/VR types and which is most likely to be adopted. This will be analyzed further in a subsequent section.

The Diverse Potential of VR & AR Applications
Predicted market size of VR/AR software for different use cases in 2025

Figure 33 - Market Size of AR/VR Applications (Sachs, 2016)

Given these projections, it is important to consider where the industry stands today. The VR industry created $1.8B of revenue in 2016 and shipped a total of 6.3M units. The AR market saw about $1.2B in revenue, although most of this was from ‘Pokemon Go’, a ‘Mobile AR’ application that did not have what most would characterize as true AR technology. Together, $3B was less than the $4.4B that Digicapital projected, but in line with Goldman’s projections. Most of these VR revenues came from ‘Tethered VR’ systems, labeled as ‘PC’ in the figure below. This is consistent with the projections above, since ‘Tethered VR’ systems are predominantly used for gaming, the largest expected market for VR.

Figure 34 - 2016 VR Market Revenue and Devices Shipped
(Superdata & Unity, 2016)
Although the market for VR in 2016 was in line with base estimates, there is significant nuance in how some platforms performed compared to others. As seen in the figures below, industry researcher, SuperData, had significant expectations for console based ‘Tethered VR’ systems, in particular ‘Playstation VR’. This is because of the significant installed base of ‘PS 4’ consoles in the US market. As seen in the figures below, the ‘Playstation VR’ was expected to sell 2.6M units, but only shipped 750k instead. This expectedly caused underwhelming sales figures for the platform as well, only $389m instead of an anticipated $1.1B. The scenario is also similar with the Oculus Rift, which underperformed expectations as well because of ‘delayed shipments, cancellations, and a launch without controllers.’ (DigiCapital, 2017; Sanderink, 2017)

Alternatively, the ‘Samsung Gear VR’ significantly outperformed projections while the ‘HTC Vive’ performed as expected.

Figure 35 - 2016 Projected vs Actual Shipments by VR Platform (Sanderink, 2017)

Taken together, console and PC systems or ‘Tethered VR’ together, have underperformed, while ‘Mobile VR’ systems have outperformed the market's expectations.

Figure 36 - 2016 Projected vs Actual Revenue by VR Platform Type (Sanderink, 2017)
Another important metric to consider in the evolution of the industry is the number of companies created by year, as discussed in the literature review. The two figures below capture this data. It is important to note that these figures are limited in absolute volume, but the distribution and curve is likely not different.

These figures demonstrate that the number of companies created has peaked for both AR/VR. This has important implications for how the industry is expected to evolve. These implications will be described in the last section.

![Figure 37 - Number of AR/VR Companies Launched by Year](Crunchbase, 2017)

As described in the literature review, Geoffrey Moore's adoption curve can help understand where each AR/VR platform is in the adoption and diffusion curve. The figure below demonstrates that 'Mobile VR' has only been use by early adopters or visionaries. These users have high performance smartphones that VR capable and like to try new products. 'Tethered VR' is somewhere in between the 'innovators' and 'early adopters', many of these users have premium PCs or gaming consoles owned by gaming fans, predominantly young males. On the other hand, 'Wearable AR' users are mostly enterprises with a particular need or developers that have spent premium funds to experiment on the platform. Other than Snap's spectacles, 'Wearable AR' devices are owned by only 'innovators.' 'Mobile AR' is the only platform that has ever been adopted by the 'early majority', particularly with 'Pokemon Go' and more recently, Snapchat and Instagram, who are both rolling out AR functionalities in to their product roadmaps. (Constine, 2017)
User groups and behaviors

An important aspect to the industry's growth is dependent on the size and nature of users and potential users of AR/VR. Furthermore, it is important for producers of AR/VR products to understand their target audience and create solutions that exceed their expectations. The purpose of this section is to present and briefly synthesize data that can help industry stakeholders better understand the interests of existing and potential AR/VR users. Unfortunately, recent data for AR users is very limited and will have less representation in this section. Also, the data presented is more consumer rather than enterprise focused.

Survey data suggests that Generation Z, those born roughly from 1996-2010 are most passionate about VR. The data in the figure below confirms suspicions that interest in VR is directly proportionate to younger age. This does not necessarily mean that older user segments, such as 'Baby Boomers' are not inclined to try or extract value from VR, but the messaging of the product clearly needs to be targeted to accommodate an older target audience that are not digital natives. (Burch, 2016)
Survey data, conducted by Think Now, suggests that African Americans are generally most interested in Virtual Reality as compared to ‘Whites’, ‘Hispanics, and ‘Asians, as shown in the left chart in the figure below. However, the chart on the right in the figure below demonstrates that ‘Whites’ have a higher willingness to pay for VR headsets. It is important to note that these numbers may be different if the VR type was taken in to consideration. For example, ‘Hispanics’ or ‘African Americans’ might have a higher willingness to pay for ‘Mobile VR’ over ‘Tethered VR’. (Now, 2016)

Another helpful dimension to understand user demand is gender. The figure below demonstrates that males are willing to spend more on a VR product than their female counterparts. Unsurprisingly, the distribution of willingness to pay across race is similar for females as it is with males. In general, these average figures are considerably lower than any ‘Tethered VR’ system. This is consistent with earlier sections that describe cost as a considerable inhibitor to the adoption of VR. On the other hand, many ‘Mobile VR’ systems are offered at prices lower than $100, which is a contributing factor to their superior adoption and shipments over ‘Tethered VR’ variants. (Now, 2016)
Consistent with the first figure in this section, the right bar chart on the figure above demonstrates that younger consumers, ages 18-34, not only have more passion for VR but have a higher willingness to pay for VR systems than older generations. In aggregate, survey data suggests that VR is most demanded by a younger male population.

Another important topic to understand user demand is to analyze their intent with VR products. The figure below demonstrates the usage intent of users who are interested in VR. It is not surprising as described in prior sections, consumer VR remains predominantly a gaming industry, along with watching traditional TV or movies in a virtual environment.

The bottom bar chart in the figure above also demonstrates the strong intent of users to purchase gaming related content. However, the distribution is more even here than usage.
intent. This illustrates that while users intend to use VR for games, they have a willingness to spend on other forms of content as well.

The figure below illustrates the continued strong demand for 'Samsung Gear VR', the best selling 'Mobile VR' system, which aligns with the sales the platform garnered in 2016. This figure also includes the newer and older version of the 'Gear', further demonstrating its popularity. Surprisingly, the 'Playstation VR' has strong purchase intent, which might be positive information for Sony as its sales in 2016 were lower than anticipated. Conversely, the 'HTC Vive' has much less demand than prior sales suggest. This could suggest that supply has satisfied the demand of the platform.

Device Purchase Intent - 12 months

Figure 43 - Platform Purchase Intent (Llamas, 2016)

In aggregate, the awareness of AR/VR is on the rise, particularly among young users. Younger users, particularly those that are male, are most likely to adopt VR for mostly gaming use cases. However, their average willingness to pay, although the highest among other segments, is still significantly lower than the price of 'Tethered VR' systems. As a result, they are likely to continue adopting 'Mobile VR' products given their lower price point. This explains why young male users make up the majority of 'Tethered VR' owners.

These are helpful insights that will help drive the conclusions of subsequent sections.

**Investments, mergers, acquisitions, and exits**

The purpose of this section is to briefly describe some of the key and recent investment activities that have taken place in AR/VR industry. The availability and amount of capital is critical to the development of the industry. More capital helps producers develop and experiment with technologies and products that drive innovation and the industry forward.

The figure below demonstrates the funding into AR/VR companies over the last five years. It is clear that there has been tremendous growth in the industry, however a closer look will help understand relevant undercurrents. The investment periods Q4 2014 and Q1 2016 have record
setting capital investments. It is important to note that both of these periods consisted of investments predominantly to Magic Leap, a ‘Wearable AR’ company in Florida. As mentioned in prior sections, Magic Leap is notoriously secretive and has raised rounds from prominent investors.

More specifically, Magic Leap raised $542M of the total $630M in Q4 2014 and $793.5M in Q1 of 2016. This is approximately, 34% of the total $3.9B funding of AR/VR companies in the last five years. Although this has been a boon for the industry, it places a lot of importance on the company’s success, which has yet to be seen.

It is also helpful to see how these investments divide by AR and VR. Most of the deals in this period have been in VR companies. However, there are some periods of when AR was the majority of most deals. For example, in Q1 of 2015, there was about four times as much money invested in AR than VR and approximately two more AR deals than VR deals. (CB Insights, 2017a)

The figure below demonstrates that there are drastic changes in funding patterns when Magic Leap is discounted. Overall, as mentioned, there have been more VR deals than AR deals, approximately more than twice as many. (CB Insights, 2017a) However the overall dollars put in to the industry are pretty similar, with VR only having $100M more invested when discounting for Magic Leap.

This inherently makes the average AR deal size about $3M more than that of VR, or 75%. There could be several reasons for this difference in valuation. Some of the AR companies that happened to capture funding could have been later stage startups than those of VR companies who were funded. It could also be that investors see the potential of AR startups more than VR startups and price them accordingly.
Although the average deal size has been larger for AR than that of VR, it is clear that the growth in funding for VR startups has been growing faster than that of AR, particularly when Magic Leap is discounted.

There have been several different types of investors in AR/VR. Most of these investors are institutional venture capitalists as described in the literature review. Some are investing in AR/VR exclusively; these investors are typically seed stage. Other investors include those that are strategic and are looking for complementary technology to augment the existing product portfolio of their parent company. These are known as Corporate Venture Capitalists (CVCs). A third type of AR/VR investors has been generalists that are looking to invest in AR/VR along with other technology investments. These are typically Series A generalists.

There are many other investor types as well, but they are not the most common investor type. The figure below lists the most involved investors in the AR/VR space. ‘Rothenberg Ventures’, ‘Presence Capital’, ‘Venture Reality Fund’, and ‘Colopl’ are all AR/VR specific investors. The majority of their portfolio companies are in the AR/VR space. Furthermore, they tend to make smaller investments, pre-seed or seed, to get AR/VR companies off the ground. These investors are instrumental in providing capital to entrepreneurs who are interested in AR/VR. (Tom, 2017)

‘Intel Capital’, ‘Qualcomm Ventures’, ‘Comcast Ventures’, and ‘Samsung Ventures’, are all corporate venture capitalists who are the most involved in AR/VR. These investors typically invest in startups that have started to see product market fit and need the next round of capital, usually from a Series A VC. It is noteworthy that Comcast Ventures made seven of its last eleven
investments from April 2016 to April 2017. This demonstrates their significant investment and interest in the technology, and its potential to complement its existing business. (Tom, 2017)

<table>
<thead>
<tr>
<th>Investor</th>
<th>Investments*</th>
<th>Investments in last 12 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRESENCE CAPITAL</td>
<td>24</td>
<td>9</td>
</tr>
<tr>
<td>Intel capital</td>
<td>19</td>
<td>12</td>
</tr>
<tr>
<td>VENTURE REALITY FUND</td>
<td>18</td>
<td>4</td>
</tr>
<tr>
<td>QUALCOMM VENTURES</td>
<td>16</td>
<td>9</td>
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<tr>
<td>COMCAST VENTURES</td>
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<td>3</td>
</tr>
<tr>
<td>colopl</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>G/ 500 startups</td>
<td>11</td>
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<td>ANDREESSEN HOROWITZ</td>
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</tr>
<tr>
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<td>Series A</td>
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</tr>
</tbody>
</table>

*Figure 46 - Top AR/VR Investor Activity* (Tom, 2017)

Most of the investments made in AR/VR thus far have been seed stage investments, this has recently started to trend down, as some of these companies move on to Series A rounds and beyond. Unfortunately, in comparison to 'software as a service' (SaaS) businesses, AR/VR companies may not have moved on to follow on funding as quickly. The figure below demonstrates that the majority of investments made in 2016 and likely in 2017, will remain seed stage investments. This demonstrates and confirms the infancy of the industry, as new companies continue to be formed each year, as demonstrated in a previous figure.

*Figure 47 - Venture Activity by Round* (Tom, 2017)
The figure above demonstrates what types of AR/VR companies that VCs have chosen to invest in thus far. Infrastructure and commercial applications startups have received about the same amount of funding while content and hardware companies have received about 20% each as well. Distribution and social companies have only seen 7% of investments, which is expected given the industry’s infancy. As most other platforms, distribution and social will likely see more funding as more consumers and businesses adopt the technology and network effects take place. (CB Insights, 2016) Other investment data, from GreenlightVR, demonstrates that more than 75% of VR investments by the end of 2015 had gone to gaming or entertainment related startups. The distribution for AR companies is likely more distributed and less gaming focused. (Leibach, 2015)
V. Discussions, Implications, and Opportunities

Industry Evolution

This purpose of this section is to apply some of the frameworks introduced and synthesized industry data of prior sections to develop a hypothesis of how AR/VR, particularly its types or platforms, will evolve. Like most predictions, confidence levels decrease for those predictions downstream. The core of these hypotheses is to project how types of AR/VR will evolve over time, their market sizes, and use cases.

In general, AR/VR will have very different meanings and implications for business than for individuals or consumers. As a result, this will be a core lens to discussing this section.

Dominant design

In the prior section, a figures shows a graph of the number of companies that have been started each year in the industry. As discussed in the literature review, this curve is very informative in understanding innovation dynamics. Both of these curves have peaked in the last two to three years for AR/VR. This suggests that a dominant design for both technologies is imminent. As a result, although user inputs and interfaces remain fragmented, particularly at the software level, Utterback’s framework suggests the industry is approaching the ‘Transition Phase’, where process innovation will become the core competency for those building AR/VR hardware in particular.

This will have important implications for Series A investors, which will be addressed in the last section.

AR/VR Rogers Five Forces

As described in the literature review, Roger’s ‘Five Forces’ provides a robust framework to determine how a technology platform will diffuse in to the market. Below is a figure that benchmarks the four types of AR/VR against these five forces.
Although 'Wearable AR' and 'Tethered VR' have a relative advantage over 'Mobile AR' and 'Mobile VR', they do not score as well on other forces in aggregate. 'Mobile AR' does seem to score the highest on all forces, making it most likely to diffuse the fastest among these forms.

'Mobile AR' is most compatible because of the billions of users who already use smartphones and have tacit knowledge and user modalities that are consistent from how 'Mobile AR' will likely be implemented. This makes 'Mobile AR' both 'consistent with values and experiences of potential users' and 'easier to use' as compared to the other forms which require an external device and completely re-designed interface. 'Mobile AR' is also easy to experiment, as it has a much larger installed base for developers to launch and get feedback with 'AR' features applications. Lastly, 'Mobile AR' scores high on observability, as it allows other users to observe its capabilities and experiences.

'Mobile VR' ranks second in this framework. It scores well across most of these factors, yet it is relatively more complex than 'Mobile AR' because it requires a peripheral HMD and for users to change their behavior patterns to experience its relative advance. It is however relatively less complex and more familiar than 'Tethered VR' or 'Wearable AR', these systems force users on a different learning curve as they require completely new interaction modes. 'Mobile VR' is also relatively easy to trial as compared to 'Wearable AR' and 'Tethered VR'. As mentioned, smartphones are ubiquitous, but a simple, mobile, and inexpensive peripheral HMD, such as the
Gear, can be used to experience "Mobile VR." Users can also easily allow those around them to experience similar content. This is unlike ‘Tethered VR’ systems which requires users to be indoors and attached to a computer, limiting the exposure of the experience to others.

‘Tethered VR’, like ‘Wearable AR’, is clearly advantageous once learned and adopted. It enables users to be present and experience life like experiences in a simulated environment. However, it is considerable challenges with complexity and compatibility as it requires users to break away from their tacit knowledge and values to experience those advantage. Furthermore, those results are not necessarily easily seen by others.

AR/VR Gourville Framework

As described in the literature review, John Gourville’s framework is useful to analyze how new product platforms will be received in the market. This section will compare these four AR/VR types across this framework. The results will then be compared to those of Roger’s Five Forces.

The figure below illustrates how these four types map along the dimensions of required behavioral change and degree of product change involved. For similar reasons described in Roger’s Five Forces, ‘Mobile AR’ ranks as a 'Smash hit'. Relative to the other three platforms, ‘Mobile AR’ does not require users to change their existing usage patterns with their smartphones.

‘Mobile VR’ is considered an easy sell, there exists a large market of potential users, given the ubiquity of smartphone owners. Some behavioral changes are required since users do have to purchase new hardware, such as Google’s Daydream to experience ‘Mobile VR’. Users do not have tacit knowledge or values that align with this except for the fact that they are using a smartphone, making ‘Mobile VR’ less of a behavioral change than ‘Tethered VR’.

‘Wearable AR’ and ‘Tethered VR’ are both considered long hauls in the framework. ‘Wearable AR’ in particular requires the most effort to make the product advantageous for users. This means it has very high potential but it is held back by all the new interaction modalities that users have to learn to capture value from the architecture. This behavioral change for ‘Wearable AR’ is an even stronger factor in consumer use cases, as consumers are more concerned with form factor and style than users within an enterprise.
Observations

AR/VR Platform Evolution (B2B v B2C)

B2C – VR

Enthusiasts of VR have been bullish on the uptake of VR platforms for consumers, particularly since 2012. However, consumers have had several VR products, both Tethered and Mobile to select from over the last two years. The adoption thus far has been less than projected and there are several reasons for this that will likely persist, limiting the growth of VR for consumer use. These reasons include but are not limited to:

1) Price of Tethered systems
2) Lack of content and diversity
3) Business model for developers
4) Behavioral change
5) Lack of time and status quo

Prices of tethered systems will continue to decline to levels where mass audience can finally afford it. Even content will likely continue to grow, but this is incredibly expensive and resource intensive, and it is unclear if users or advertisers are willing to pay accordingly. Perhaps the
most difficult challenge is numbers four and five. Unlike prior successful computing platforms, such as laptops and smartphones, VR requires is a very distinct behavioral change, mainly wearing an HMD. As shown in prior sections, behavioral changes are a large barrier to adoption, particularly for consumers. Additionally, as shown in prior sections, it is difficult to see where consumers can fit VR in to their busy on-the-go schedules. Although there are many drivers as well for consumer VR, it is not likely they will overcome these inhibitors in the near future. Tethered systems are expected to be largely for gamers, but this is where a lot of the experimentation and design will happen.

'Mobile VR' systems will only get more performance, also start with gaming, but evolve in to other use cases such as live events, education, etc. Over time the line between Tethered and Mobile products will start to blur, as hardware and wireless gets better, smaller, and cheaper.

**B2B – VR:**

VR has a very different story for businesses. Many of the challenges described for consumer VR are not as relevant or don’t exist at all. Businesses typically have a higher willingness to pay than consumers, provided the payoff is there, and content diversity is not as important as focused and high quality, which is very feasible with today’s systems. This makes even more expensive ‘Tethered VR’ systems a fit for large enterprises. As a result, the majority of value for VR in the near term is likely to be in enterprise businesses such as healthcare, engineering, and military. Although the number of shipped units may not be so high, the value of the content and experience delivered likely will be.

**B2C – AR:**

For consumer AR, it is very clear that the near term future will be mobile based. ‘Mobile AR’ has already demonstrated significant demand and uses, such as ‘Pokémon Go’ and ‘Snapchat’. Neither of these represents a fully capable ‘Mobile AR’ product, however they can be considered Minimum Viable Products (MVPs) that have proven the deep interest of users. There are several drivers and inhibitors, as described before, behind ‘Mobile AR’. However, the following reasons are those that will drive the growth of 'Mobile AR' in the near future:

1) No peripheral device needed
2) Low behavioral change
3) Less steep design curve (‘Mobile AR’)  
4) Established business model (analogous to mobile apps)

Unlike ‘Mobile VR’, basic ‘Mobile AR’ attributes can work with many smartphones part of the installed base, particularly in the US. Furthermore, the largest MDMs, such as Google, are
including components required for AR as part of their product roadmaps. Perhaps most importantly, 'Mobile AR' requires very little effort for consumers, functionality and use is similar to how users interact with their devices today. (Singletary, 2017)

This means that companies with large installed bases of mobile apps that leverage camera functionality, such as Snapchat and Instagram, can simply roll out AR features and products. Furthermore, many of these features do not need to be fully built or sophisticated to begin testing with consumers. The number of users that will at least try the feature will be large and the feedback can be insightful. This significantly shortens the product development cycle.

The use cases of 'Mobile AR' in the short term will likely be social and discovery focused initially. Users will be begin using generated or selected filters to layer on top of their camera views. These filters can be used to share with friends or be used to add important contextual information. Later, these AR filters will be used by retailers and brick and mortar businesses to make advertisements for nearby customers.

Alternatively, 'Wearable AR' has and will continue to be a challenging sale to consumers. Some of these challenges were already exemplified by Google's Glass. Below are some of the factors that will inhibit the use of 'Wearable AR' products for consumers in the near future.

1) Expensive
2) Extra device required
3) High behavioral change
4) Very steep design curve
5) Demanding form factors
6) Hardware and software challenges

'Wearable AR' shares some of the near term adoption challenges of VR systems. This is largely because they require users to wear a device on their heads. 'Wearable AR' systems, such as Microsoft's HoloLens, are still costly, which is way more than the general public can afford. (Microsoft, 2017) Although these prices are expected to decline over time. 'Wearable AR' products require consumers yet another device to purchase, which is always more difficult. Most consumers have never trialed a 'Wearable AR' device or its interface. This inherently makes the device one that requires behavioral change for users. Given the brand new interface for engineers, the design is very difficult to figure out, not only from a form factor perspective but also User Interface (UI) perspective. Furthermore, consumers are generally concerned about what they wear, in particular what they wear on the face, which makes the standard for design much higher for 'Wearable AR'.

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Snapchat's Spectacles and MagicLeap's future product are the variables in the industry that may accelerate the adoption of consumer 'Wearable AR'. However, Spectacles does not include any display system, only camera capture. Also, MagicLeap is incredibly secretive and facing considerable skepticism and criticism from industry experts on the viability and likely success of its product. (Charara, 2017)

**B2B – AR:**

Businesses, particularly larger enterprises, do not have the same needs or concerns as consumers. As a result, these aforementioned challenges for 'Wearable AR' in the consumer market is not relevant in the market for enterprises.

Businesses have a higher willingness to pay and do not care about the larger, unaesthetic form factors, and less friendly user interfaces. The value provided by 'Wearable AR' products to businesses in manufacturing and healthcare is very clear. The cost from not adopting these 'Wearable AR' systems is significantly higher than their price, making it a value sale.

Below is a figure that summarizes the aforementioned observations:

![Figure 51 - Evolution of AR/VR Types, B2B vs B2C](image)

**Venture Capitalists**

These prognostications in the industry can have significant implications for Venture Capitalists who are already investing or interested in investing AR/VR. There are several types of Venture Capitalists, however Series A investors are arguably the most important for the industry. As shown in previous figures, the majority of AR/VR companies are in the 'seed stage', and their success will largely be influenced by their ability to raise Series A capital.
As a result, the rest of this section will attempt to uncover the AR/VR opportunities for Series A investors of most types, particularly ‘B2B’ or ‘B2C’ investors.

The first step is to determine the most suitable AR/VR platform type for a B2B or B2C investor. To determine this, specific investment criteria for Series A VCs are defined and the four AR/VR platform types are measured against this criterion. Subsequently, particularly high value opportunities will be described by their use case, industry, market size and growth, risk, and AR/VR platform type.

This section will conclude with a brief analysis of how VCs can best source these opportunities and add value to those companies that have become part of the portfolio.

### Key opportunities

The figure below lists some important investment criteria that was developed from public sources, personal experience in the industry engaging with practitioners in the industry. These criteria are relatively self-explanatory. However, it is important to note that Series A investors are usually looking to invest in startups that have already created product market fit. There are many definitions for this term, however, in this case it is considered when a startup has met the most critical needs of a user with its product, and most of the largest iterations of the product are complete. (Feld, 2016)

<table>
<thead>
<tr>
<th>Target enterprise qualities</th>
<th>Definition</th>
<th>B2C</th>
<th>B2B</th>
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<tbody>
<tr>
<td><strong>Opportunity</strong></td>
<td>• The total addressable market for the enterprise and the growth within the industry</td>
<td>At least $5B market size with</td>
<td>At least $1B market size with 100% YoY growth</td>
</tr>
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<td><strong>Scaleability</strong></td>
<td>• The ability of the enterprise to achieve the following:</td>
<td>$50-150k MRR with &gt;100% YoY growth</td>
<td>$50-150k MRR with &gt;100% YoY growth</td>
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<tr>
<td></td>
<td>• Revenue</td>
<td>-50k daily active users with 25% MoM growth</td>
<td>-3 to 5 major partnerships or enterprise customers</td>
</tr>
<tr>
<td></td>
<td>• Product Market Fit</td>
<td>-Significant organic growth</td>
<td></td>
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<td></td>
<td>• User engagement and limited churn</td>
<td>-Very high NPS with extreme positive reviews</td>
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<td></td>
<td>• 10x return for the portfolio</td>
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<tr>
<td><strong>Defensibility</strong></td>
<td>• Intellectual Property that helps the enterprise protect its technology</td>
<td>Usage of features uniquely differentiated from competitors, some brand and tech IP</td>
<td>Delivers value at a higher level that competitors</td>
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<td></td>
<td>• Enterprise has sustainable advantage over its competitors</td>
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<tr>
<td><strong>Team</strong></td>
<td>• Antifragility – a team that gets stronger through adversity</td>
<td>A strong background in consumer behavior, branding, and marketing</td>
<td>Strong enterprise sales relationships and experience</td>
</tr>
<tr>
<td></td>
<td>• Enterprise has a founding team of technical, visionary, and operational talent</td>
<td>At least $50 LTV</td>
<td>-3 to 5 major partnerships or enterprise customers</td>
</tr>
<tr>
<td><strong>Users</strong></td>
<td>• Enterprise has a large loyal user base with a high LTV to CAC ratio</td>
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**Figure 52 - Series A Investment Criteria, B2B vs B2C** (Bhashyam, 2014; Feld, 2016)

With this criterion defined, the next step is to compare these four AR/VR platform architectures against the criterion. The analysis in the figure below demonstrates that ‘Mobile AR’ makes the most sense for B2C investors and ‘Wearable AR’ is most fitting for B2B investors. The
A differentiating factor for both architectures is the sheer opportunity size, both in market size &
growth. 'Mobile AR' scores very well here because of the very large installed base of
smartphone owners with devices that are capable of simple AR features. 'Wearable AR' does
not have nearly the installed base, but the potential is almost just as large as many enterprises
are already demanding the integrative capabilities of the architecture.

<table>
<thead>
<tr>
<th>Target enterprise qualities</th>
<th>B2B</th>
<th>B2C</th>
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<td>Defensibility</td>
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<td>Team</td>
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<td>Users</td>
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<tr>
<th></th>
<th>Wearable AR</th>
<th>Mobile VR</th>
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<th>Tethered VR</th>
<th>Wearable AR</th>
<th>Mobile VR</th>
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<th>Tethered VR</th>
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<td>Defensibility</td>
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Figure 53 - AR/VR Types by Series A Investment Criteria, B2B vs B2C

The figure below demonstrates the current market size, potential growth, and use case of each
platform type, whether it is more software or hardware focused, and B2B or B2C. It is clear that
'Mobile AR', for example, is currently the smallest opportunity but most poised for growth (212%
CAGR) in the B2C space, particularly in social, retail, and search use cases. 'Wearable AR'
although less risky with a somewhat larger market is not poised to grow as fast as 'Mobile AR'.
It will be mostly used for industrial and healthcare related applications. The investment of
'Wearable AR' is more likely to be a hardware rather than software play given its lack of maturity
with hardware components.
More specifically, there are particular use cases or solutions that already have proven value in the market and make them more appealing for a Series A investor. 'Mobile AR' is currently seeing traction in the content creation, social, and location based gaming space. 'Wearable AR' is more enterprise focused with use cases in surgery and with assembly line workers. 'Mobile VR' may not grow as fast as the AR architectures, but it already enables more use cases such as wellness, live events, product visualization, and social applications as well. Finally, 'Tethered VR' enables more sophisticated use cases such as engineering or product design, but applications in gaming are clearly the largest opportunity. The figure below illustrates some particular use cases by platform, their opportunity size and timelines.
Figure 55 - AR/VR Startup Opportunity Space by Platform, Type, HW/SW, Industry, and Time (Downey, 2016; Sachs, 2016; CB Insights, 2017b)

Sourcing & Diligence

Another critical step for Series A VCs to get involved in these opportunities is to position themselves with the right partners who can help them source the most talented and promising startups that are building products on their desired AR/VR platform architecture.

There are four types of stakeholders that can help Series A VCs, ‘Seed Investors’, ‘AR/VR Organizations’, ‘Academia’, and related ‘Event Organizers.’ These partners are illustrated in the figure below. Each of these stakeholders, particularly seed investors, have networks that contain the most talented entrepreneurs. The partners presented here represent the most reputable enterprises in each of these stakeholder categories.
Partners that can help source

Seed investors
(leading in AR-VR)

Organizations

Academia

Events

Figure 56 - Partners for Sourcing (Sachs, 2016; Upload & Perkins Coie, 2016; CB Insights, 2017a)(Tom, 2017)

Finally, once Series A investors have made their investments, these startups become part of their portfolio. As portfolio companies, investors must provide the right support to make sure that they have commercial success. Investing in new platform architectures, such as those outlined earlier, is inherently riskier than investing in more mature platforms. Of course, the rewards are also higher if successful. The biggest challenge for these platforms, as described earlier, is user interaction and lack of content. Therefore, the most likely reason for failure is lack of user adoption.

Series A VC investors can help their portfolio companies by ensuring that they either minimize or accept the resistance of their customers to adopt their AR/VR products built on select platform architectures. To minimize resistance, portfolio companies can make sure that their AR/VR products are as compatible as possible to the products that are already being used by the customers they are selling to. Another strategy is to offer these new AR/VR products to those who do not already have a solution, circumventing behavioral change. Lastly, VCs can help portfolio companies by having them sell their solutions to those who are believers in their product and platform architecture. These customers, although rarer, overvalue the intrinsic benefits of a new platform.

On the other hand, VCs can instruct their portfolio companies to be patient and burn cash slowly while customers learn the behavioral changes associated with a new architecture. Separately or simultaneously, VCs can ensure that their portfolio companies build product architectures that enable performance that is ten times better than current solutions. With this kind of differentiation, the majority of customers are willing to adopt the architecture regardless of the costly behavioral changes incurred.
Minimizing Resistance

- Make behaviorally compatible products
- Seek out unendowed
- Find believers

Accepting Resistance

- Be patient
- Make 10x products
- Eliminate the old

Figure 57 - Strategies for AR/VR Portfolio Companies (J. Gourville, 2006)
VII. Conclusions

Summary

The purpose of this section is to provide a brief summary of the insights discovered in the thesis. AR/VR certainly has the potential to become the next dominant computing platform, however there are significant challenges that the industry needs to overcome before it can displace existing platforms, namely those related to behavioral change, content development, and price. During this transitional time, there are some high value opportunities that will lead the industry forward.

There are four major forms of AR/VR, 'Mobile AR', 'Mobile VR', 'Tethered VR', 'Wearable AR', each of them with different attributes and implications. The industry has seen unprecedented involvement from leading stakeholders in the technology industry. The criteria and frameworks discussed in the thesis demonstrate that 'Mobile AR' will diffuse the most rapidly and become the most dominant form in the near term future. This is followed by 'Mobile AR', 'Tethered VR, and finally 'Wearable AR.' 'Mobile AR' has the potential to span many consumer use cases and become the next interface for how users discover, interpret, and analyze information, particularly around their physical environment. The use cases of value for each of these platforms are somewhat different and have different potential sizes and returns, which are described in detail (figure 55) of the thesis.

This has significant implications for Series A VCs. 'Mobile AR' is the most promising platform architecture for those that are non-gaming B2C investors while 'Wearable AR' is best suited for B2B Series A investors. Finally, Series A VCs should partner with the presented stakeholders (figure 56) to maximize the quality of inbound startup enterprise opportunities, taking steps to maximize and accept the resistance that customers have of the solutions that they choose to invest in (figure 57).

Limitations

There are limitations of the thesis that are noteworthy. Listed below are some of the most relevant limitations and a brief description of their potential impact. Most of these limitations are topics or factors that were not covered in the thesis that could have an impact on its conclusions. These are divided by the evolution of the AR/VR industry and its forms, followed by those within the analysis for VCs:

1) AR/VR industry:
a. Macro-economy: the general economy and its health can have significant impacts on the adoption and diffusion of technologies. These trends were not covered in the thesis.

b. Competitive technologies: there are other computing interfaces such as voice/audio or next generation smartphones with AI technologies that may take away interest and adoption of AR/VR.

c. Micro-economy: there are several internal challenges that important companies within the AR/VR industry can run into. For example, if Facebook begins having profitability challenges with its most important products, this can divert attention and limit the growth of AR-VR.

2) VC analysis

a. Series B: an important part of a Series A VC’s time is spent helping portfolio companies raise follow on rounds of capital from Series B investors. Other rounds of capital were not analyzed.

b. Criteria: some of the criteria used to analyze Series A VCs was limited. These criteria are very idiosyncratic and difficult to capture for any study.

c. Investing: the thesis did not speak in detail about the nature or terms of investment for Series A companies.

References


Upload & Perkins Coie (2016) ‘*2016 AUGMENTED AND VIRTUAL REALITY SURVEY REPORT A CROSSROADS FOR AUGMENTED AND VIRTUAL REALITY’*. Available at: https://dpntax5jbd3l.cloudfront.net/images/content/1/5/v2/158662/2016-VR-AR-Survey.pdf


### Table 2: AR/VR Investment Analysis (CB Insights, 2016)

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**2012-2016 AR/VR Funding Trends**

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<th>AR Total Deals</th>
<th>AR Total Dollars ($)</th>
<th>AR Total Deals w/out ML</th>
<th>AR Total Dollars w/out ML</th>
<th>AR Average Deal Size ($)</th>
<th>AR Average Deal Size w/out ML ($)</th>
<th>AR Funding CAGR (2012-2016)</th>
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<td>134</td>
<td>2,507</td>
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<td>18.71</td>
<td>7.69</td>
<td>46.3%</td>
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<td>VR Total Deals</td>
<td>305</td>
<td>1,290</td>
<td>763</td>
<td>436</td>
<td>18.71</td>
<td>7.69</td>
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<tr>
<td>VR Total Dollars ($)</td>
<td>5</td>
<td>1,290</td>
<td>763</td>
<td>436</td>
<td>18.71</td>
<td>7.69</td>
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<tr>
<td>VR Average Deal Size ($)</td>
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<td>4.31</td>
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<tr>
<td>VR Funding CAGR (2012-2016)</td>
<td>60%</td>
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