Technology **Insights**

Riding the Augmented Reality Wave

A record $2.3 billion was invested in augmented reality ("AR") startups in 2016, representing a three-fold increase from the $700 million invested just a year earlier.[1]

AR hardware saw the largest investment, securing nearly 40 percent of total dollars. Key deals included $794 million raised by Magic Leap and capital raises by other AR hardware players, including ODG at $58 million, Meta at $50 million and Lumus at $45 million. The second largest investment area came in the AR services and solutions arena (including a $181 million investment in Unity, or nearly 20 percent of investment, the provider of a top game development platform and community.) Finally, AR apps also experienced large investments, driven by a $54 million raise by Blippar, a company that provides an AR mobile app and self-service suite of tools.[2]

Overall, the vast majority of investment in AR occurred at the top of the technology stack, as seen in Figure 2. In the future, as AR capabilities and communities become well-established, we anticipate the System Integration layer of the stack – creating integration of ecosystems – will be a focus investment area play.

2016 also witnessed pervasive media coverage of the AR landscape. While often mentioned together and in similar terms, AR and virtual reality ("VR") are different concepts and serve different use cases. In this article, we explore the quickly emerging and seemingly limitless world of AR. To provide clarity, both AR and VR are part of "Extended Reality," which includes virtual, augmented and mixed reality (Figure 1).

Although there are differing viewpoints on the potential market size for AR, it will certainly be huge. Analysts' forecast for 2020 vary from $7 billion (Goldman Sachs) to $31 billion (Citibank) and up to $90 billion (Digi-Capital).

[1] Digi-Capital, Augmented/Virtual Reality Report Q3 2016
[2] Digi-Capital, Greenlight Insights

FIGURE 1: Extended Reality

Reality	Description
Virtual	An immersive experience in a completely virtual world, in other words "you can see a different world."
Augmented	A real world environment enhanced digitally using sensory input (e.g., graphics, location, sound), in other words "you can see the world differently."
Mixed	The blending of augmented and virtual reality where real and virtual worlds co-exist and interact.

No matter who you choose to believe, the consensus is it will take longer to gain widespread penetration and adoption for reasons we articulate later in this article. AR likely will accelerate quickly over the next three years as the consumer and enterprise market spaces get defined and essential technologies, including the underlying software, chips, batteries, cameras and sensors, mature.

As numerous and complex technology ecosystems involved with AR develop over the next few years, there will be new wearables, devices and applications used to augment senses and physical capabilities, enhancing interactions with the real world. AR will change the way people interact with their environment and shape the way they see the world. It has the potential to be as disruptive as smartphones have been and could be the fourth computing revolution after the PC, the Internet and smartphones.

AR integrated devices will be the connectors between several other technology disruptions that we are or soon will be experiencing (e.g., smart cities).

AR has the potential to provide a complete framework for integrating new technologies into business and enterprise applications as they mature and become mainstream. These technologies include computer vision and pattern recognition, multi-sensor integration, artificial intelligence ("AI"), robotics and machine learning.

Augmentation Types

To understand viable AR business models, we must first understand the different types of augmentation available today. Current AR can be broken down into five major categories.

The first is **display augmentation**, where visual overlays are mapped to any surface, including screens, walls, floors, objects and people. Humans interact with these displays through sensory inputs (e.g., touch, movement, voice) to display information connecting the real world to virtual worlds. A simple example of this type of augmentation is the myriad of virtual keyboards that exist in the market.

The second type is **geospatial augmentation**. Geotagging and location-based services are assisted by sensory input (e.g., GPS, magnetometer, accelerometer) and used to

FIGURE 2: Augmented Reality Technology Stack and Value Chain

Apps and Content	Apps	• App developers and content providers (e.g., Creation, Assets Management)
Value-Add Services	Value-Add Services	• Value-add services for or using AR (e.g., expert field support, enhanced training, coding)
AR End Points	Integrated Devices	• End point devices (e.g., HoloLens, Rift, Body units, other devices/equipment by use case)
	SW Platforms and Software Development Kits ("SDKs")	• Software platforms and SDKs that enable and enhance the AR end points
Enterprise Systems	System Integration	• Integrators of ecosystems (e.g., healthcare, Mil/Aero, connected car)
Delivery Infrastructure	Data Aggregation & Processing	• Data manipulation and management
	CDN | Edge Computing	• CDN | distributed and edge computing
	Network | Protocols	• Transport and networking
	Data Pipeline	• Data and information channels (bandwidth and spectrum)
Software	Middleware and Engines	• Middleware and engines (e.g., A/V compression, 3D/3D Sound)
	OS, SDKs, APIs	• Infrastructure development platforms
	FW and Embedded Software	• Firmware and embedded software
Components	Hardware	• PCBs, hardware integration, sensor fusion
	Processors	• Data and signal processors
	Memory and Logic	• NVM, volatile memory and logic devices
	Sensors and Controllers	• MEMS and other sensors, microcontrollers

overlay real-time information on objects and people as the user moves through the real world. The Pokémon GO! app is a great recent example of geospatial augmentation where a user's location and climate affect the Pokémon they can catch.

The third type of AR is **recognition-based augmentation.** Sensors and imaging capabilities identify objects, shapes and patterns, which are then overlaid with elements, including images, 3D constructs, videos, sounds and other information. The recognition can be marker-based, where the images and commentary are identified in advance, or marker-less, where recognition is done real-time without using pre-placed markers. Real and virtual objects can be viewed in the same screen, enabling interactions. QR codes are an example of recognition-based AR using patterns.

Sensory augmentation is the fourth type of AR and involves the merger of sensory data across the virtual and real world, including touch, taste and smell. By levering a person's or shape's outline, touch can be mimicked and users can interact with virtual environments and objects (e.g., stacking virtual blocks on top of each other). Examples of this type of augmentation include the Microsoft Kinect (virtual touch), Sony's DualShock 4 (haptic) and Olorama's digital scent technology (smell).

The fifth type of augmentation is **hybrid augmentation**, which, as its name implies, is a combination of two or more of the aforementioned types of augmentation. The Microsoft Hololens, SportsMEDIA Technologies enhancements of live sports telecasts, Pokémon GO!, and Reach Robotics' MekaMon battling robots are all different examples of hybrid augmentation.

Pathways to Adoption

There are barriers inhibiting the speed of AR development and widespread adoption. These barriers are created by infrastructure, technology, security/privacy, safety policies, financial and ecosystem maturity considerations.

Infrastructure Considerations:

- **Scale complexity:** AR is constrained only by space limitations set by the real world. To take full advantage of all the possibilities, a myriad of inputs from the real world must be integrated and processed at a high velocity and in real-time. We are just beginning to explore this experience.
- **Relationship mapping:** Real and virtual object relationships must be well defined, established, translated and portable across platforms and technologies to provide a holistic AR experience at scale. These relationships can be established in a myriad of ways, including annotations, tags, labels, hyperlinks at the simplest level and highly adaptive hyperlinks at a complex level that enable decisions based on dynamic environment variables. Given the lack of definitions and standards, it will be some time before we experience portable cross ecosystem AR.
- **Interaction complexity:** People are accustomed to the real world and instinctively know how to interact with it. Over time, individuals train themselves to interact with the virtual world through man-made interfaces, such as a mouse, joysticks and peripherals. The world of AR is new and blends the real and virtual worlds. The level of seamlessness achieved will define, enable and drive the overall user experience and adoption.

Technology Considerations:

- **Sensors:** Vast amount of small, cheap and efficient (low power, high-speed) sensors are required to make AR a mainstream technology. Depth sensors in particular that estimate depth in all lighting conditions are in great demand in many industry verticals. This is a fast evolving space lacking major players with the capacity to develop and deploy these sensors on a grand scale.
- **Imaging:** Most camera modules are self-sufficient, accessible only through high level function calls intended for end user applications. Developers need the ability to control cameras through lower level APIs to fully utilize AR.
- **Memory:** To quicken adoption and drive scale, CPU-GPU shared memory architectures must be exposed to developers in easy to leverage development kits. In addition, given the vast data and throughput requirements for processing and manipulating images

in today's resolutions, memory and supporting architecture must continually be made smaller, faster and cheaper.

- **Power:** As in all portable devices, battery life is critical. Lower power technology coupled with new battery technology to enable all day operations is a must have to drive mainstream commercial adoption.
- **Sensory immersion:** True AR must be all-encompassing. 3D audio is rapidly maturing and needs to be integrated within appropriate AR offerings. Other areas of sense augmentation (e.g., smell, touch, and taste) are at various stages of evolution and a complete five sense reality is quite futuristic.
- **Connectivity:** Realizing mobile connectivity at bandwidths that enable an "always on" posture is critical to drive adoption.

Miscellaneous Factors:

- **Security and privacy concerns:** Security and privacy concerns have also become pervasive in the connected world. Current (and future) AR capabilities will rely on some level of capturing user data/information and linking it with things in the real world thereby driving needs for privacy and security.
- **Safety and policy barriers:** Safety and policy barriers will play their part in the AR adoption curve. Safety considerations range from the ever present "distraction factor" (akin to people texting while driving) to the underlying reliability of the technology for complex and risky tasks such as medical procedures and military use.
- **Financial barriers:** Financial barriers also exist — both to the businesses developing and manufacturing the AR capabilities and for consumers purchasing them. As sensor, memory, and processing capabilities continue to increase and manufacturing costs continue to decrease, cost of ownership will trend lower, increasing ROI and adoption.

There are plenty of AR use cases, which cannot be achieved without a foundational ecosystem being in place – the infrastructure, technology, and value chain players – all operating at or above a certain level of maturity. Interoperability across platforms, products and ecosystems is vital to drive faster adoption, avoid vendor lock-in and make the AR marketplace as competitive and compelling as possible.

In addition to the barriers to adoption, other challenges for AR to overcome before it can reach critical mass include:

- Unveiling of a "killer device" (e.g., an "AR iPhone", whether made by an OEM or others).
- Establishing an app ecosystem specifically designed to provide AR experiences.
- Achieving telco cross-subsidization.

AR Use Cases

As the AR market matures, a myriad of use cases continue to arise. They deploy various types of augmentation and are gated by specific barriers so far outlined. Figure 3 shows examples of currently existing use cases and highlights representative players, the augmentation types used, and primary pathways to adoption. Both the use case list and the representative players are by no means all-inclusive.

Business Models

Business models drive success and take into consideration many variables including the company's strategy, type of offering, use cases addressed, offering's value proposition, market, existing assets/capabilities, competitive landscape, routes to market, partner ecosystem, suppliers and end customers (including their consumption models and appetite), cost structure and monetization methods.

Many players exist across the AR value chain with different business models and underlying economic logic for each. In this paper, we focus on the top of the value chain and tech stack; however, companies lower down in the stack also stand to benefit from AR and need to develop appropriate strategies and business models to capitalize on the trend effectively (e.g., selling faster/better and more profitable bandwidth, silicon, infrastructure equipment).

FIGURE 3: Illustrative Use Cases

Focus	Sample Use Cases	Representative Players	Augmentation Types	Pathways to Adoption
Gaming	Location based and interactive gaming (e.g., Pokémon GO!)	• Niantic • CastAR • MekaMon	• Display • Geospatial	• Scale complexity • Relationship mapping • Safety and policy
Travel	Location based interactivity (e.g., popups, knowledge, games)	• Wikitude • Skignz • Flightradar24	• Display • Geospatial	• Scale complexity • Relationship mapping • Ecosystem
Sporting Activities/ Outdoors	Track and project activity metrics in real time View overlaid info at sporting events	• Six to Start • Fusar • SportsMEDIA	• Display • Geospatial	• Sensors • Imaging • Power • Security and privacy
Entertainment	Experiences for consumers to interact with events, shows, content, etc.	• Metagram • Olorama • Snapchat	• Display • Geospatial • Sensory	• Relationship mapping • Interaction complexity • Power • Financial • Ecosystem
Marketing / Branding	Interactive and immersive experiences for consumers with brands	• INDE • Blippar • Current Studios	• Display • Recognition	• Interaction complexity • Imaging • Ecosystem
Personalized Shopping	Enhanced shopping experiences delivered in-store (e.g., interactive display ads) or remotely (e.g., virtual fitting room)	• FittingBox • GoInStore • Zappar	• Display • Geospatial • Recognition	• Financial • Ecosystem
Automotive	Heads up display ("HUD") and interface for driving	• InfinityAR • Pelican Imaging • iOnRoad	• Display • Geospatial • Recognition	• Scale complexity • Relationship mapping • Sensors • Imaging • Memory • Safety and policy • Ecosystem
Productivity Improvement	Perform daily tasks such as email and text messaging	• Thalmic Labs • eyeHand • GlassUp	• Display • Sensory	• Power • Security and privacy • Financial
Medical and Health Services	Improve surgical and diagnostic capabilities including remote and robot assisted operations	• Meta • Pristine • Third Eye Health	• Display • Sensory • Recognition	• Sensors • Imaging • Memory • Security and privacy • Safety and policy • Financial • Ecosystem

Figure 4 shows potential business models with associated pros and cons. This list is by no means all-inclusive. It should be noted that a company can employ a combination of models as well as crossover categories based on its portfolio of offerings.

FIGURE 4: Representative Business Models

Type	Business Model	Pros	Cons
Hardware Only	Direct sales to businesses and consumers	• If successful the hardware can become the main human interface to the ecosystem (think Apple iPhone)	• Very crowded space and hardware comes with BOM and supply chain costs (it better be good)
Hardware Subsidized by Software or Services	Razor-blade (sell hardware near cost and monetize via software, apps, or support services)	• Provide more profitable and scalable avenues for growing revenues beyond just selling hardware	• Ability to monetize non-hardware elements is determined by ability to sell hardware (it better be good)
Software Only	AR platform (with hosting, transaction, or license fees)	• Digital development focused only (less complex supply chain) • If successful the platform provider can become the "glue" of the ecosystem	• Difficult to grow the ecosystem and attract users without developing a game changer or already having serious clout
Apps Only	Micro transactions /in-app purchases	• Digital development focused only (less complex supply chain) • Very profitable if successful	• Hard to maintain, user's attention can easily move to other sources
Ecosystem Play	Turnkey Solutions and Systems that provide Ecosystem glue (Software platform, Telco infrastructure, Data play)	• High barrier to entry once experience is built and complex solutions available • Very profitable if successful	• Difficult to build from scratch. Usually created through acquisitions

Conclusion

Regardless of which forecast you choose to believe, the opportunity for AR is big. Well known high-tech companies are rapidly building out their AR solutions and offerings.

2016 witnessed the global release of Microsoft's HoloLens v1, a self-contained holographic computer built into a headset. Microsoft has already announced plans to skip v2 so they can accelerate development of v3 with a target release of 2019. Recently, Microsoft also acquired Simplygon, a software firm focused on automatic optimization of 3D-game content and level of detail, to incorporate the technology and further enhance HoloLens' capabilities. In addition, Microsoft is busy filing AR-related patents to solidify its position, including one focused on grasping virtual objects in AR, one focused on providing additional comfort/eye relief for wearables and another on AR light guide display techniques.

According to Engadget, Amazon's hardware R&D division Lab126 is looking to turn whole rooms into an AR experience. Amazon was awarded several patents in 2015 focused on object tracking and reflector-based depth mapping; and, in 2017 the U.S. Patent Office published a license belonging to Amazon that included enhanced reality smartglasses. This capitalizes on Amazon's current footprint within the connected home and office, including Amazon Prime (streaming) and Alexa (Artifical Intelligence voice assistant) among others. Amazon is using Alexa as a platform to further penetrate markets, including use on third-party devices (e.g., Huawei's Mate 9 Android phone, Ford cars). Amazon can leverage these relationships and platform scale to complement its AR offerings and drive increased adoption.

In addition, acquisitions made by other high-tech players also show how tech executives are placing bets on AR:

- **Google:** Api.ai, Eyefluence, Thrive Audio
- **Facebook:** Two Big Ears, Pebbles Interfaces (via Oculus), Faciometrics, MSQRD
- **Apple:** PrimeSense, FittingBox, Metaio, Faceshift, Flyby Media
- **Snapchat:** Seene, Looksery, Cimagine Media, Scan

AR has a promising future, driven by the large and increasing venture capital investments and big bets placed by global corporations. The technology and underlying ecosystems for AR are maturing rapidly. AR has standalone potential; but, it also fits synergistically with the Internet of Things ("IoT") and rise of the connected world, which has already achieved solid market penetration. To capture maximum benefits and capitalize on the power of increased scale, companies should integrate AR capabilities into their IoT initiatiaves and roadmaps now.

We believe 2017 will see marked improvements in AR technologies (e.g., wireless, battery, and imaging), continued reduction of costs and the realization of additional use cases that provide real and tangible benefits to business users and consumers.

In 2020, people will remember 2017 not as the year AR went mainstream but the year in which the foundation needed to make AR mainstream was solidified.

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