What we are expecting from this presentation:

A We want to inform you on the most important highlights from this topic

B We need you to take the time to explore the presentation carefully and with a critical mind

C We would like you to write down every comment or idea that emerges while reading this presentation

D We exhort you to share with us a constructive feedback for further improvements

E We invite you to dialog with us if you have any doubt or want to dive into some specific aspects

Rapid Prototyping

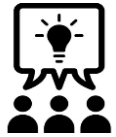
Content

Product Lifecycle Management (PLM) is the process of managing product-related conceptualization, design, production and maintenance information. The benefits of PLM focus on time, cost and quality

Conceptualization

Imagine – specify – plan – innovate

- Definition of product requirements taking into account:
  - Customers
  - Company
  - Market



Design

Describe – define – develop – test – analyze

- The detailed design and development of the product starts
- Testing is performed throughout the whole design

Product Validation

- Process of evaluating the current product during the design phase
- Determine whether it satisfies business and consumer requirements

Manufacturing

Build – make – produce – sell – deliver

- The choice of manufacturing methods and planning on equipment can begin even before the final design validation

Service

Use – operate – support – support – replace – sustain

- This phase involves the use of product information, such as documentation, help and support

Product Validation (PV) is a long phase during the product lifecycle management, improvements on it means a more efficient and faster PLM

Considerations for PV

- Clients don´t know what they really want until they see a physical design

- The costs in prototyping increase due to redesign requests

- Projects are delayed by the constant changes during product validation

- Today, prototype technologies are very expensive

- Improvements means better results for both company and customers

PV Conventional and Ideal Implementation

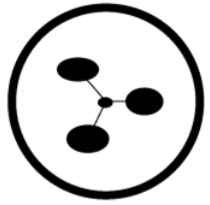
Conventional Implementation	Ideal Implementation
▪ Many design iterations	▪ Precise, robust digital design
▪ Numerous physical prototypes	▪ Few physical prototypes
▪ Expensive and time consuming	▪ Efficient employment of resources
▪ Use of old technologies	▪ Increased efficiency through better planning.

Maintaining agility during a PLM implementation and adopting a strategy that embraces a more iterative and collaborative solution design approach, has significant benefits and can lead to more optimal PLM solutions

Different design tools are used to physically validate fidelity, cost and usage of the design; mockups and functional prototypes are the most common in the automotive industry

Design Tools

- **Wireframes** model layout, behavior and interactions (wireframes and mockups can be worked in parallel)
- **Prototypes** build upon mockups and/or wireframes they are closer approximations of the products
- **Functional Prototypes** behave like the real product but may have limited functionality
- **Mockups** use graphics, styling guide and look like the end product



Attributes

Prototype	Fidelity	Cost	Use	General traits
Wireframe	Low	$	Documentation & quick communication	Sketchy (black, white & gray)
Prototype and functional prototype	Middle to High	$ $ $	User testing (reusable)	Interactive
Mockup	Middle to High	$ $	Gathering feedback and getting buy in from stake-holders	Static visualization

Interactive prototypes allow users to identify potential issues and mitigation plans early on in the design process

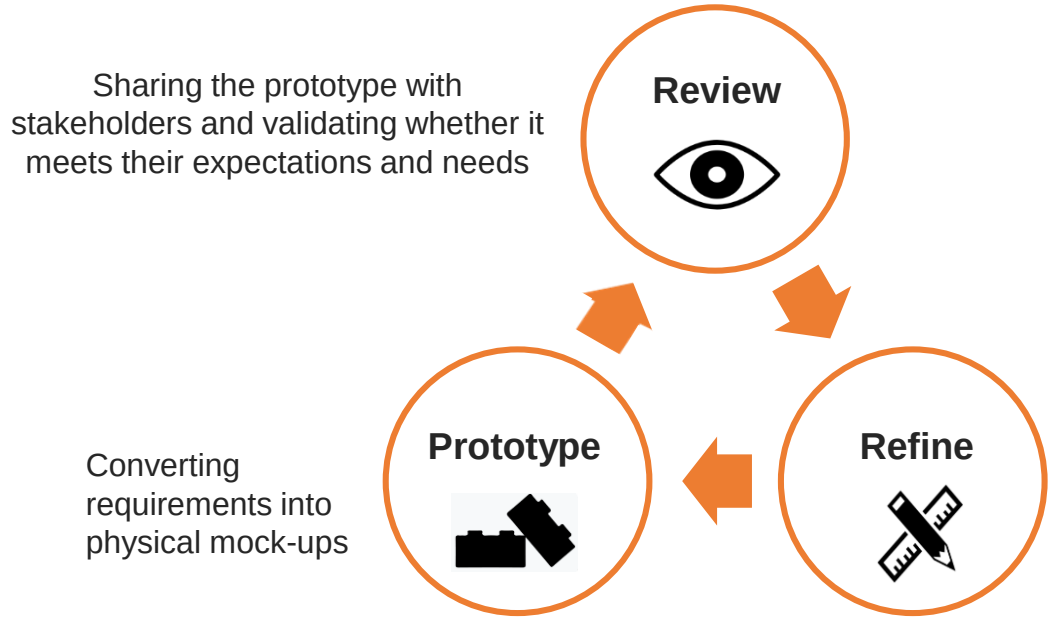
Rapid Prototyping (RP) allows for quick design iterations to test different attributes, the objective is to save time and money compared with the conventional prototyping techniques

What is Rapid Prototyping?

Rapid Prototyping

- The process of quickly mocking up the future state of a system for validation
- Allows quick validation from users, stakeholders, developers and designers
- Doing this rapidly and iteratively generates feedback early in the process, improving the final design and reducing the need for changes during development

The Rapid Prototyping Process



Benefits of Rapid Prototyping

- Allows agile adaptation to evolving requirements
- Consistently engages key stakeholders throughout the project
- Decreases product development time
- Saves resources and time, validating exhaustively before building functional products
- Demonstrates requirements with functioning prototypes instead of theoretical designs

Source: Stratasys Co.

Rapid Prototyping has several techniques, for industrial uses the most common are Additive Manufacturing and CNC Machining

Principal Rapid Prototyping Techniques

Technique	Cost-effective (approx.)	Time (approx.)	Materials Available
Injection molding	Large quantities (1000 pieces or more)	15 days (per mold)	Nylon, TPU, Steel, TPU, PEI, PPS, PP, ABS, Acrylic, PU, TPE, PC, PBT, HIPS Tungsten, Cobalt chrome, Aluminum, Nickel
3D Printing (Additive Manufacturing)	Low quantities (50 pieces or less)	3-5 days	ABS, Aluminum, Cobalt chrome, Digital photopolymer, Inconel, Nylon, PC, PP, Stainless steel, Titanium
CNC Machining (milling, turning, grinding, EDM, ECM)	Low quantities (200 pieces or less)	3 days	Aluminum, Nylon, Stainless steel, Steel, Titanium, Wood, MDF, Plexy glass, PVC, Brass, Cooper, Ceramic, Hastelloy, Molybdenum, Tungsten, Kovar,

*EDM: Electrical Discharge Machining. **ECM: Electromechanical Machining

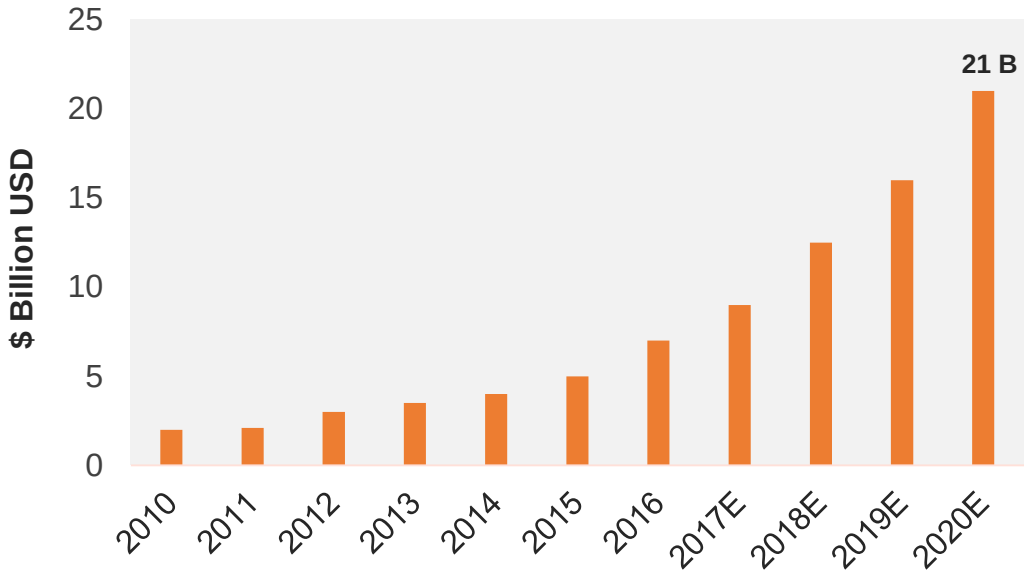
Source: Proto Labs Inc.

Rapid Prototyping in the Different Industries

Industry	Common Applications	Technologies Used
Automotive 	• Custom interiors • Paneling • Concept car frames • Spare parts	• 3D Printing • Investment Casting
Aerospace 	• Wind tunnel components • Liquid and fuel tanks • Surrogate parts	• 3D Printing • Investment Casting • CNC Machining
Medical 	• Anatomical models • Medical carts • Surgical tools	• 3D Printing • CNC Machining
Energy 	• Rotors • Turbine nozzles • Control-valve components	• 3D Printing • CNC Machining

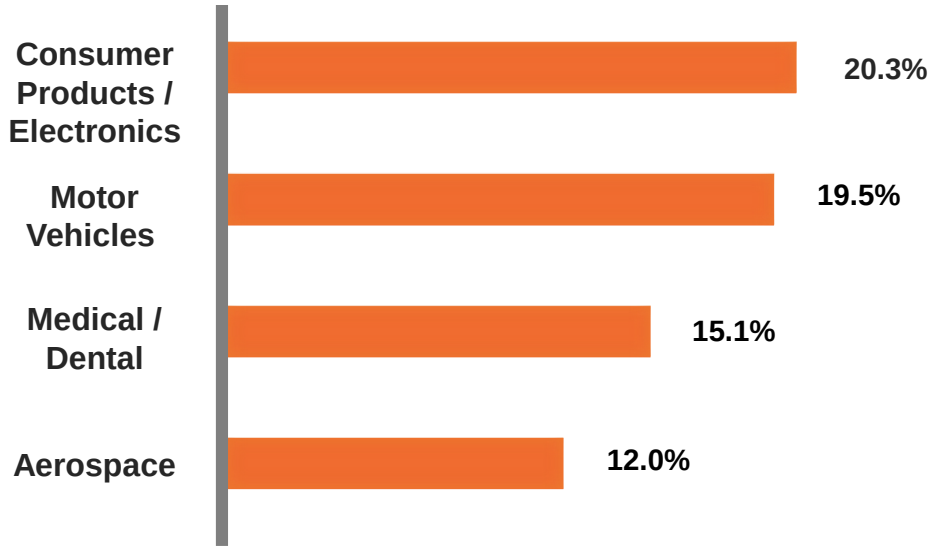
Rapid Prototyping is a growing market and new solutions are being developed at a fast pace, hence, most industries are introducing it into their product development processes

RP Revenue



- The Rapid Prototyping revenue reached $7 B USD in 2016
- According to IBIS World is expected to reach $21 B USD in 2020
- This means a rapid growth market for investment

Leading Industries Implementing RP



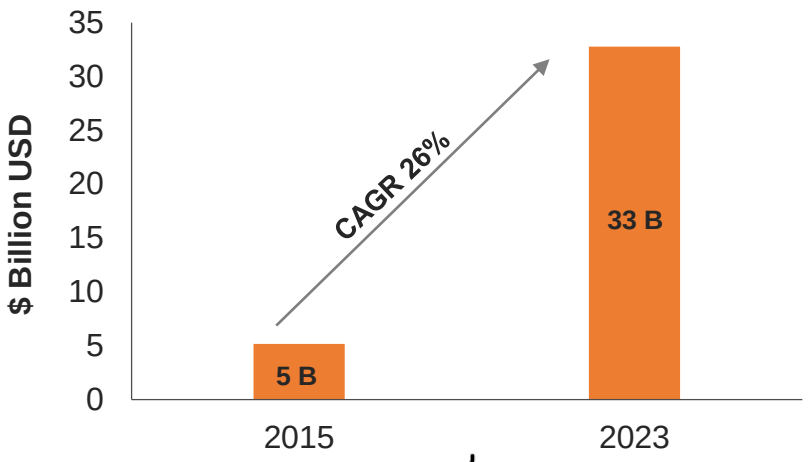
- Motor vehicles is the second industry where rapid prototyping is being implemented
- Many automotive companies are currently using new techniques for prototyping
- Some examples of these companies are Ford, Volkswagen and BMW

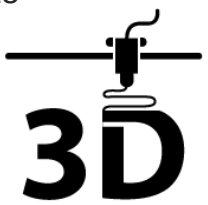
Source: IBIS World OD4581

3D Printing and CNC Machining are the most common techniques for Rapid Prototyping in the industry, these 2 technologies have a great potential for investment and are expected to grow

3D Printing

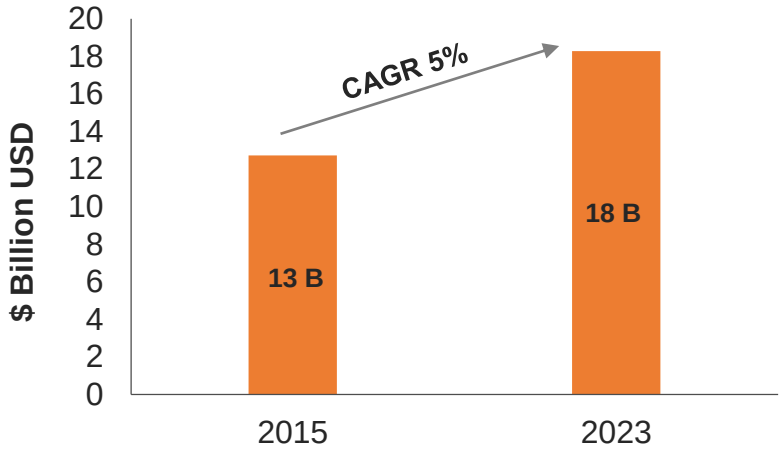
- Global market generated $5 B USD in 2015
- Projected to reach $33 B USD by 2023

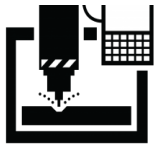




CNC Machining Market

- Global market generated $13 B USD in 2015
- Projected to reach $18 B USD by 2023





- CNC Machining market was 247% bigger than 3D Printing market in 2015
- AM is projected to grow so fast and could reach $33 B USD by 2023, 179% bigger than CNC market
- The rapid growth in AM market is due to the new technologies that are being developing in this area

Source: Markets & Markets

The Rapid Prototyping industry remains nascent but has been growing in the past 5 years, it attracted investment from consolidated companies in an attempt to capture the relatively untapped and expansive market

Major Companies have been approached Rapid Prototyping through acquisitions

Most of this Companies acquired Start-ups with focus on their own in-house tooling and production

Source: Capstone Partners LLC

We identified some of the Start-ups acquired during this same period

Acquirer	Target	Description	Enterprise value (M)	Revenue
Sunningdale Tech	**First Engineering**	Manufactures ultra-precision molds and plastic injection molded components for performance-critical engineering applications.	$80.00	.6x
Riverside	**Fisher/Unitech**	Provides Product Lifecycle Management (PLM) technology solutions to manufacturing companies including 3D printing and rapid prototyping.	-	-
Stratasys	**Solid Concepts**	Provides additive manufacturing/3D printing, rapid prototyping, tooling and injection molding services in North America and internationally.	$190.00	2.9x
Coral	**Tatra Plastics Manufacturing**	Designs, manufactures and prototypes round, oval and square plastic tube and profile extrusions, co-extrusions and injection moldings.	$4.20	.8x
Truelife	**Pro CNC**	Provides production CNC machining, prototype machining, prototyping, 3D printing, contract assembly and engineering services.	-	-
Alcoa	**RTI International Metals**	Offers a portfolio of titanium mill products, extruded shapes, formed and 3D-printed parts, as well as high speed machined components.	$1490.60	1.9x
Proto labs	**FineLine Prototyping**	Provides precision prototyping and manufacturing services including stereo lithography, selective laser sintering and 3D printing services.	$37.00	3.8x
Dassault systemes	**Realtime Technology**	Provides 3D visualization software, consulting and creative services.	$232.50	2.3x
Laird	**Model Solutions**	Engages in prototype model making and quick-turn tooling and production of injection molded parts in South Korea.	$67.60	2.2x

Source: Capstone Partners

Considering the breadth of capabilities unlocked by Rapid Prototyping, automotive industries are taking advantage of these technologies to stay ahead of the competition

Three important automotive companies that are currently using Rapid Prototyping processes are Ford, Volkswagen and BMW according to them the use of these technologies saved millions of dollars to their companies

FORD

Where are using Rapid Prototyping?

For prototypes of components such as cylinder heads, intake manifolds, and air vents

On Ford GT, designers used a series of prototypes to refine and perfect the square shaped F1-style steering wheel

Benefits

The company saved millions of dollars in product development costs

Cut down on the time that would usually be required to create investment castings

For an engine manifold, developing and creating the prototype usually costs about $500,000 USD and takes about 4-5 months with traditional methods, using AM, Ford developed multiple iterations of the component in just four days at a cost of $3,000 USD

VOLKSWAGEN

Where are using Rapid Prototyping?

Volkswagen Auto-Europa use Ultimaker 3D Printers to fabricate components in-house

Development of tools like: position and screw assembly, liftgate badge, triangular window gauge, etc.

Benefits

The company obtained a 95% reduction in development time and a 91% drop in costs

Improve tool ergonomics by 28% and the final product quality by 35%.

The implementation of 3D printers in Volkswagen Autoeuropa allowed the company to produce 93% of all previously mentioned outsourced tools inhouse. This adds up to an estimated $171,090 in savings for 2016 and a target of $285,150 in savings for 2017

BMW

Where are using Rapid Prototyping?

Making of components and hand tools used in testing and assembly

BMW Formula One department introduce rapid prototyping to test new components for races

Benefits

The use of new technologies of AM help to solve problems with prototypes quickly

AM give better ergonomic design and was 72% lighter than traditional hand tools

The customized tools helped save 58% in overall costs and reduce project time by 92%

Source: Corporate Ford. Volkswagen Auto Europa. BMW International

As the number of additively manufactured parts increases, one company's goal is to use AM as the primary production technique for building vehicles

URBEE is an electric car with as many as fifty additive manufacturing produced parts

URBEE 2011

- Built external frame comprised of 20 separate panels built through rapid prototyping
- Partnered with a major rapid prototyping service in production of the frame
- Used design and simulation software

URBEE 2 2015

- 3D printed interiors in addition to the external body
- More parts 40 - 50 major body and interior parts are 3D printed
- Greater complexity of parts which cannot be produced through traditional manufacturing methods

Source: Korecologic

Due to the emergent technologies in Rapid Prototyping there are many improvement opportunities and new applications in this area

New Materials	Speed	Accuracy	Distance Manufacturing	Rapid Tooling
Development of non-polymeric materials (metal, ceramic, etc.).	Faster computers, more complex control systems, and improved materials	Improvements in laser optics and motor control	You can remotely submit designs for immediate manufacture	**Production of molds quickly using rapid prototyping technologies**

The materials have big influence in the time to complete a prototype

The introduction of new materials would allow RP users to produce functional parts

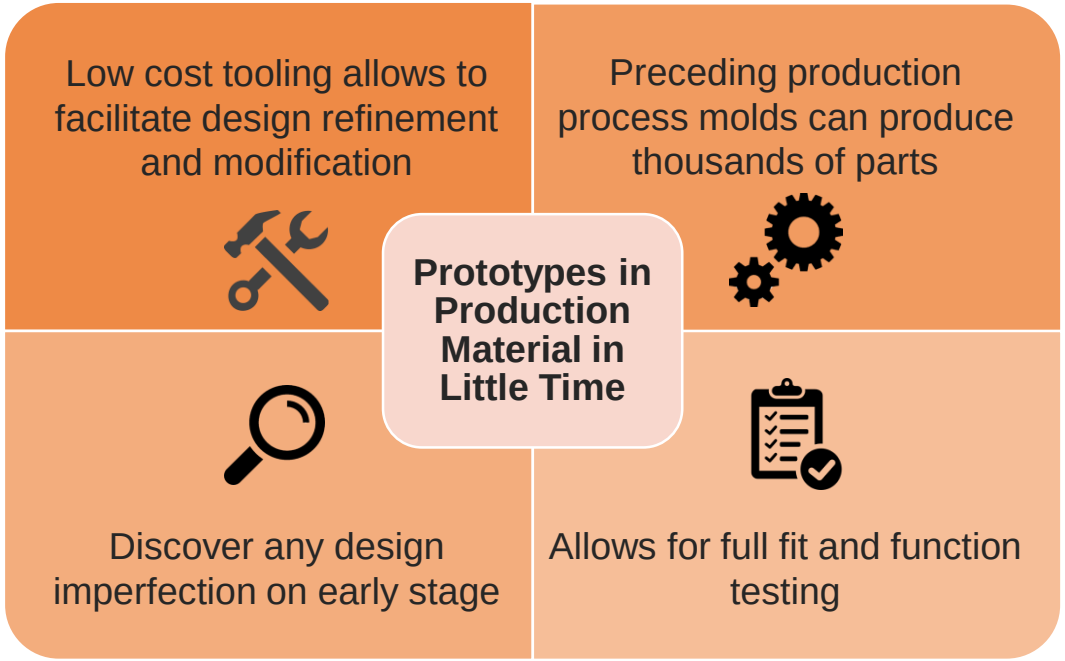
Plastic prototypes work well for visualization and fit tests, but they are often too weak for function testing

Expensive tooling cost can be well justified just when the production quantity is massive. The way to produce tooling quicker and more economically, especially for small quantity is becoming more significant

What is Rapid Tooling?

Rapid Tooling describes a process that is the result of combining **Rapid Prototyping techniques** with **conventional tooling practices** to produce a mold quickly or parts of a functional model from CAD data in less time and at a lower cost relative to traditional machining methods

Benefits of Rapid Injection Tool Molding



Types of Rapid Tooling Techniques

Direct Tooling	Resin tools, metal powder, ceramic powder, micro cast tools, laminated tools	
Indirect Tooling	Soft tooling	Silicon molds, castable resin, RTV process
	Hard tooling	Spray metal tooling, cast metal tooling, keltool tooling
Pattern for casting	Investment casting, sand casting	

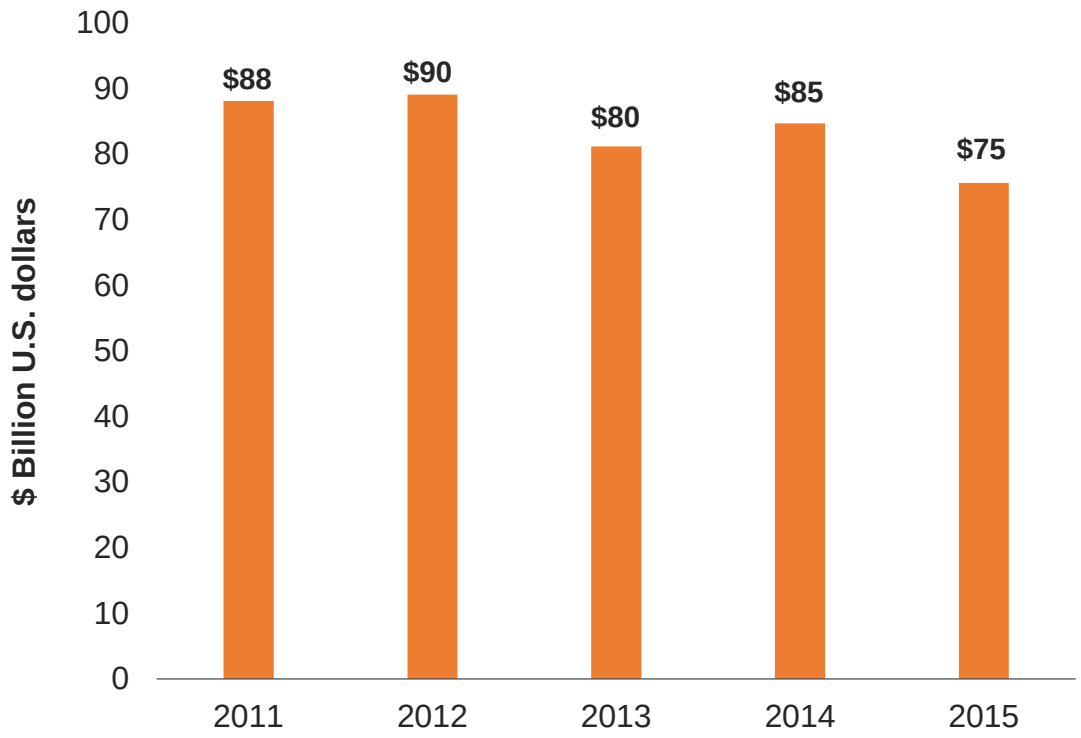
Tools in Automotive Industry

Typical car uses up to 3,000 tools for production. Tools may range from small components which require a $5,000 USD tool to more than $1 M USD for a complex mold for a part such as a front fascia. A complete fascia itself may consist not only of the main plastic part but also 35 additional tools

Source: Journal of Manufacturing and Industrial Engineering

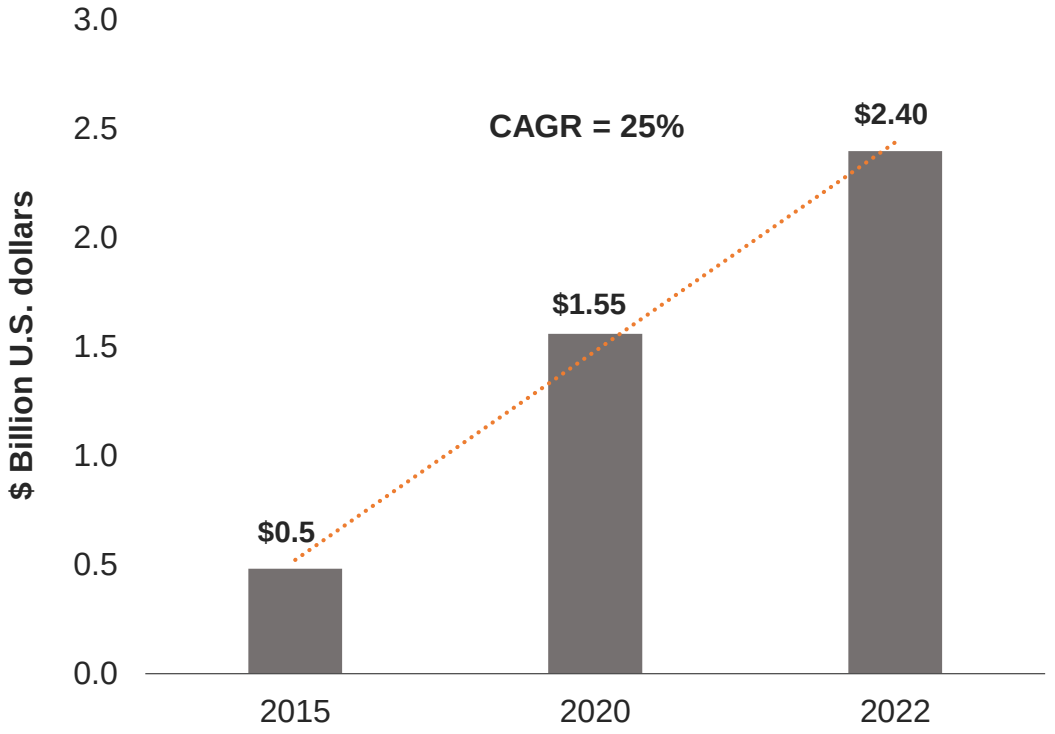
Rapid Tooling market have had a slightly increase the last few years due to the introduction of new Rapid Prototyping technologies

Global Tooling Market



- Across the last 5 years the global tooling market have had an slightly decrease
- With the introduction of Rapid Prototyping technologies is expected an increase in this market

AM Market in Tooling



- Additive Manufacturing is one of the main Rapid Tooling technologies, is projected to reach $2.5 B USD in 2022
- The high CAGR expected means good opportunities for investors and companies

Source: Harbour Results Inc & Statista

Prototypes are the core of every part produced, the use of new technologies to create them faster are changing the way of manufacturing

Takeaways

- 3D Printing and CNC Machining market is growing fast
- Costs to acquire a Rapid Prototyping machine are accessible and are expected to falling in the next years
- Rapid Prototyping market is having an exponential growth
- The materials available for 3D Printing are growing, this means more opportunities on the manufacturing industry
- CNC Machining can give a high level detail but the pieces need to have a medium level of complexity





“We really didn’t understand the potential of what the capabilities of this process were going to be. It’s incredible”

Roy Raymer - Project Coordinator. Rapid Manufacturing. Ford Motor Company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