Prototyping and Testing

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Introduction

You are developing the first nail gun ever.

How do you prototype it?

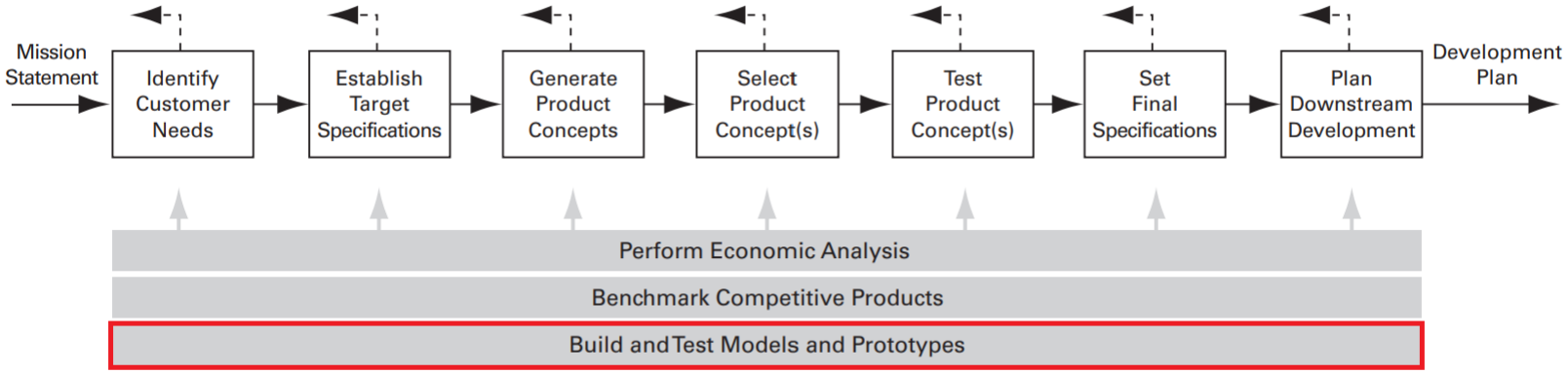
Stage of development	Prototyping ideas
Early (needs are known)	Mathematical model of nail penetration mechanics.
Middle (concepts are generated and selected)	3D CAD model Mechanical prototype for pushing the nails Foam model to see how it fits
Late stage	Physical ergonomics testing (handle shape, center of mass etc.) Mechanical prototype for repeated use testing

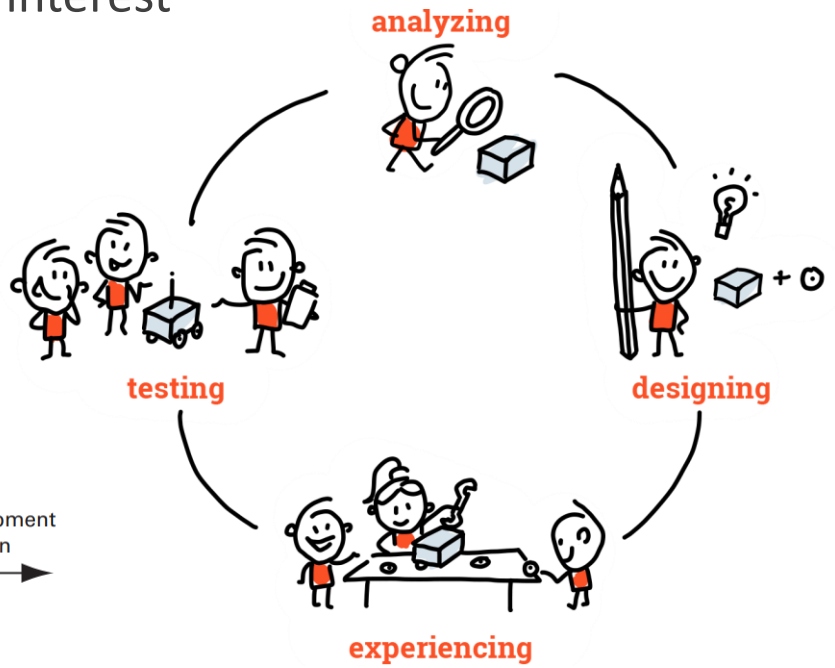
Prototype / Prototyping – Definition

”An approximation of the product along one or more dimensions of interest”

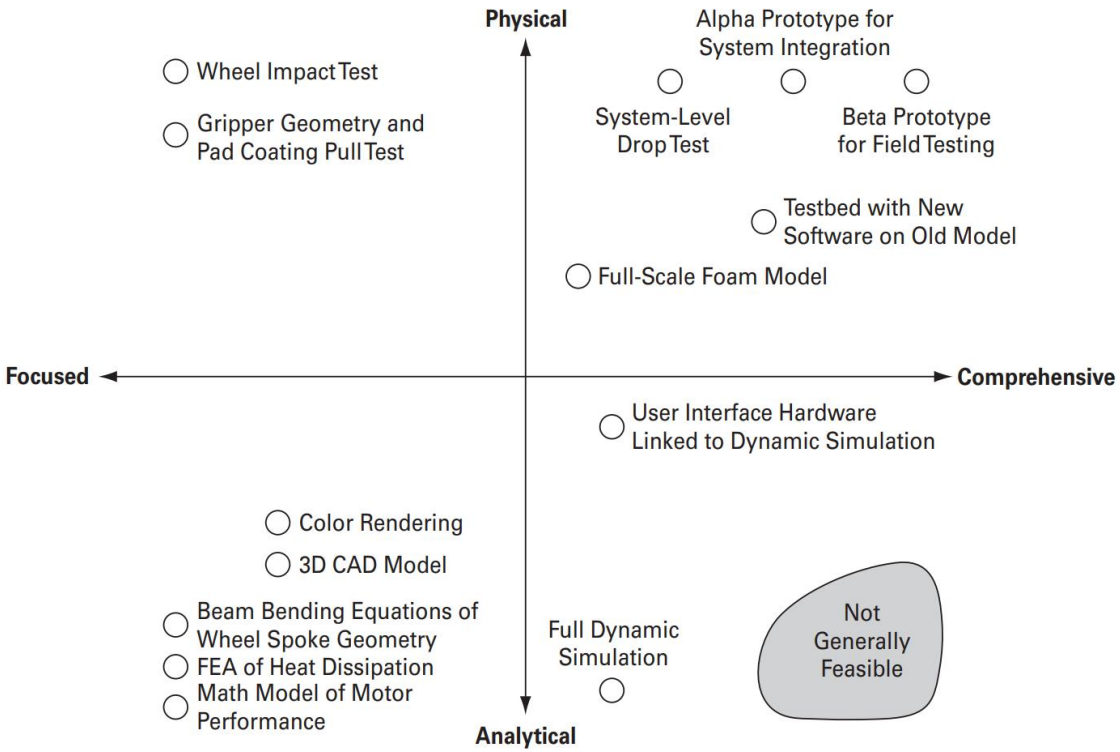
Prototyping examples

- Concept sketches
- Mathematical models
- Simulations
- Test components
- Functional ”pre-versions”



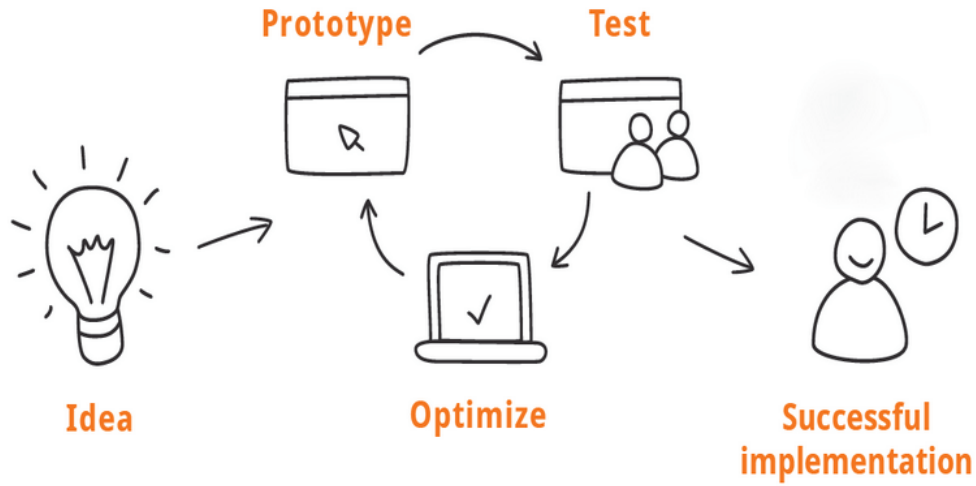


Types of Prototypes



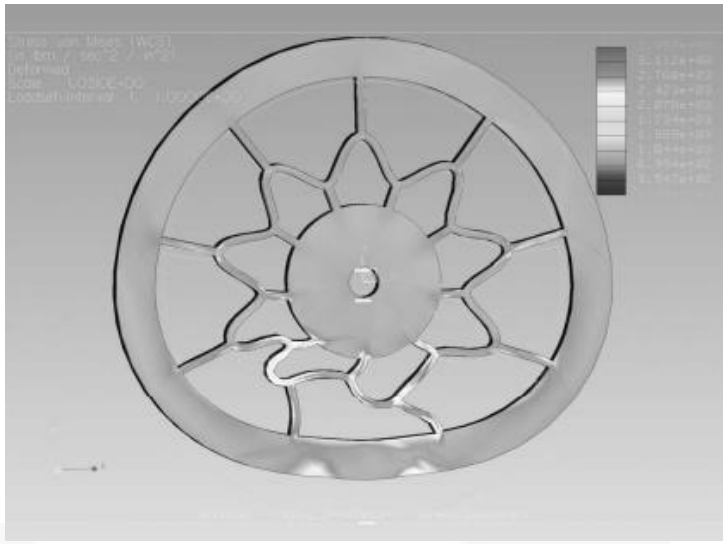
What are prototypes used for?

- Learning
- Communication
- Integration
- Milestones



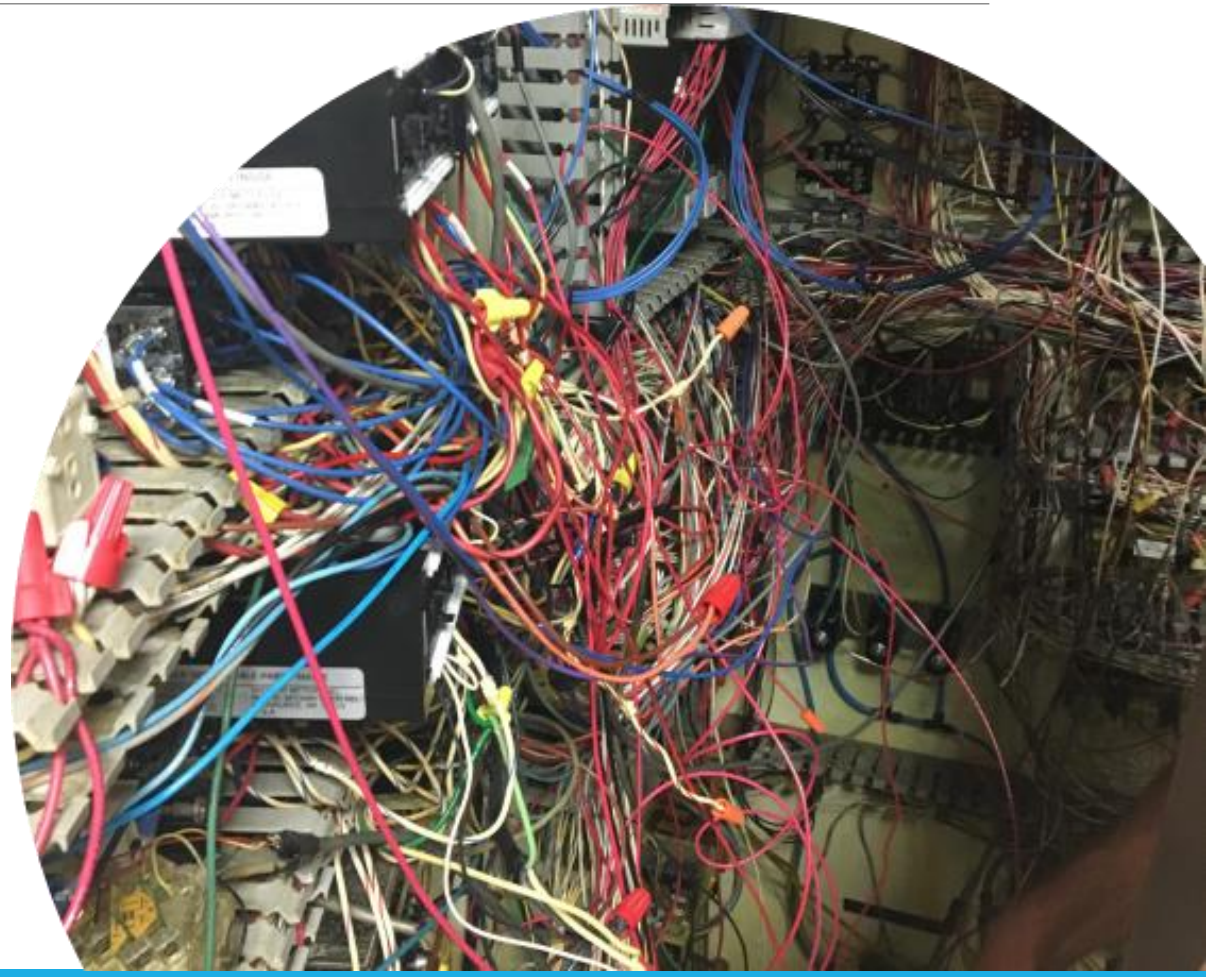
	Learning	Communication	Integration	Milestones
Focused analytical	●	○	○	○
Focused physical	●	●	○	○
Comprehensive physical	●	●	●	●

Planning for Prototypes



”Hardware Swamp”

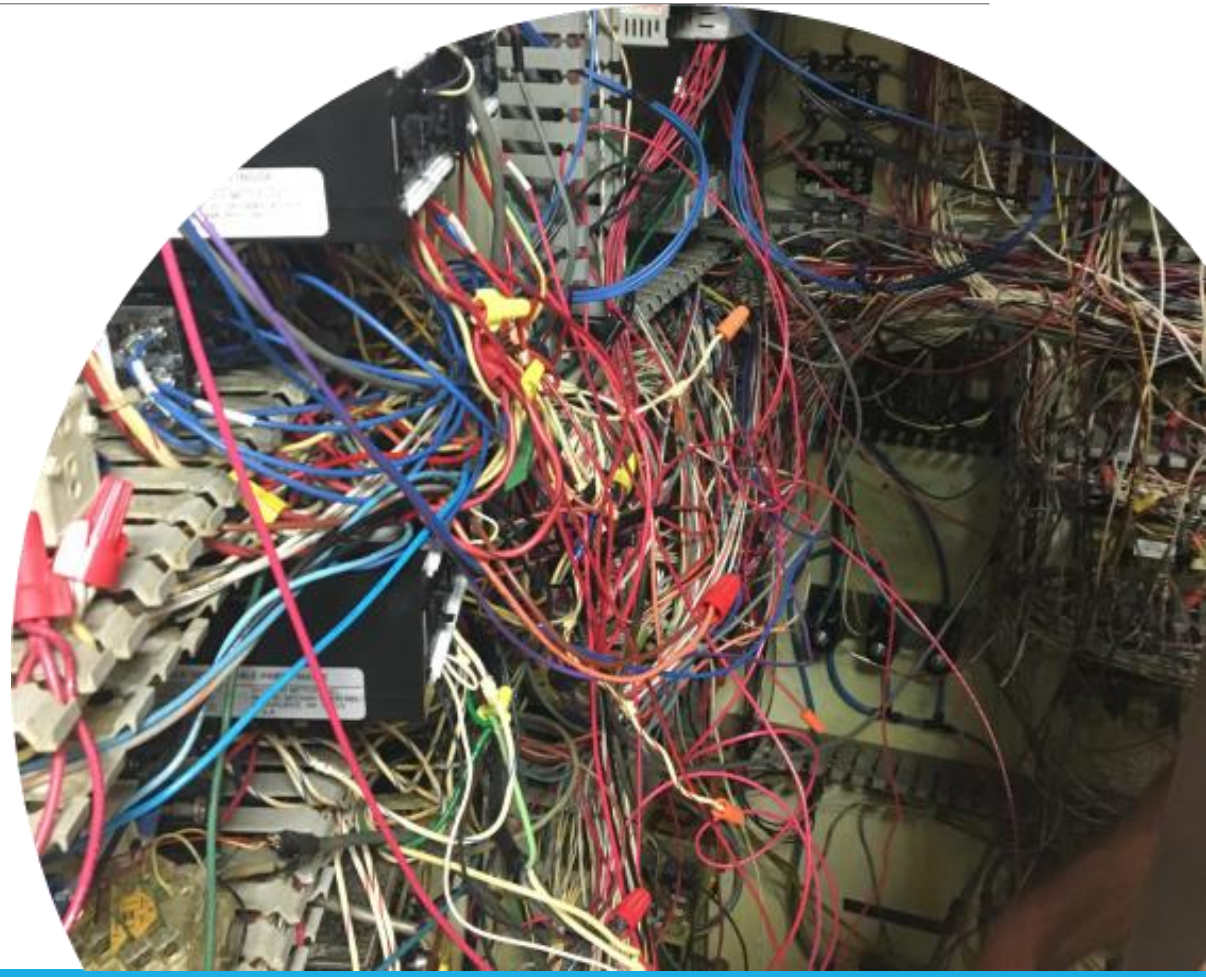
- Potential Pitfall in Product Depelopment
- Caused by misguiding prototyping efforts



Q:How to avoid ”Hardware Swamp”?

”Hardware Swamp”

- Potential Pitfall in Product Depelopment
- Caused by misguiding prototyping efforts



4 steps for planning prototypes might help…-> *(Case Study from coursebook: Pack Bot Prototypes)*

Step 1. Define the purpose of the Prototype.

Four main purposes of prototypes:

Learning

Communication

Integration

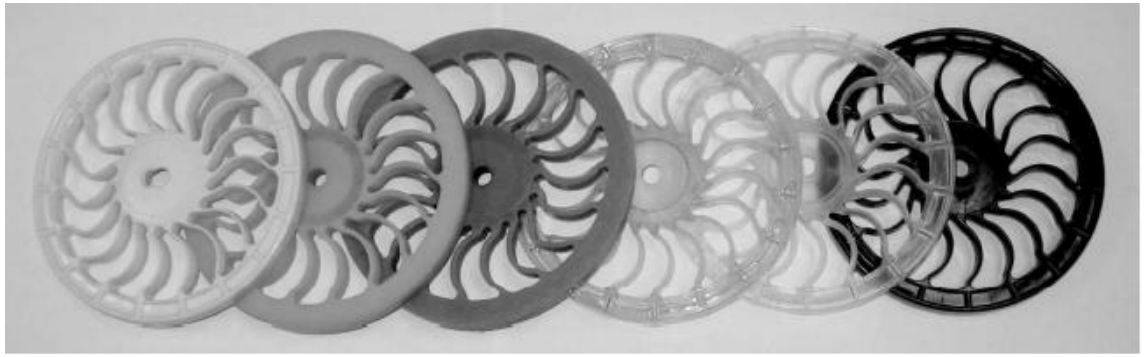
Milestones

->What is the purpose for this certain prototype?

->Clear definition must be done

Packbot-case. Purposes defined (Impact test)

Name of Prototype	PackBot Wheel Geometry/Impact Test
Purpose(s)	• Select final wheel spoke geometry and materials based on strength and shock absorption characteristics. 1 • Confirm that wheels absorb shock to withstand impact and protect the PackBot and its payload. 2.



PROTOTYPES

Courtesy of iRobot Corp.

IMPACT TEST

Step 2: Establish the level of Approximation of the Prototype.

Physical or analytical prototype?

Critical attributes related to the purpose?

(*e.g. material, geometry, color, appearance, production method*)

-> Define

(Keep it as simple as possible)

Q:Critical attributes in impact test?

Q: Less important?

Name of Prototype	PackBot Wheel Geometry/Impact Test
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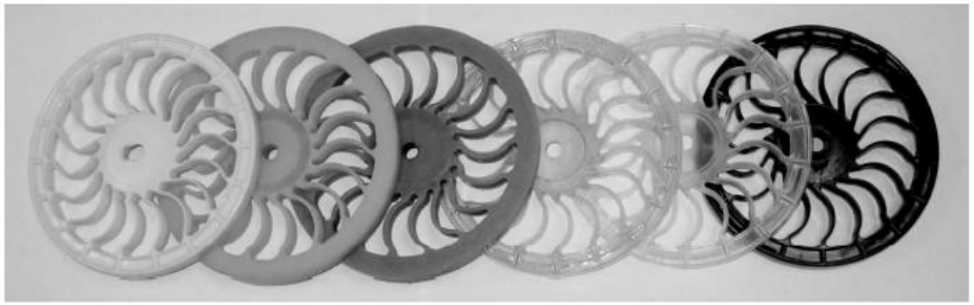

PROTOTYPES

Courtesy of iRobot Corp.

IMPACT TEST

Courtesy of iRobot Corp.

ENVIRONMENT

Q:Critical attributes in impact test?

A: material / wheel spoke geometry/platform load

Q: Less important?

A: production method / appearance / color

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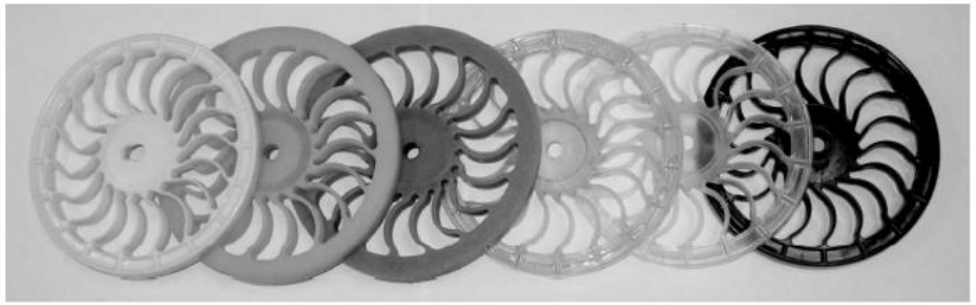


PROTOTYPES

Courtesy of iRobot Corp.

IMPACT TEST

Courtesy of iRobot Corp.

ENVIRONMENT

Step 3: Outline an experimental plan

- the identification of the variables of the experiment (if any)
- the test protocol
- an indication of what measurements will be performed
- a plan for analyzing the resulting data

PackBot case-Experimental Plan

Name of Prototype	PackBot Wheel Geometry/Impact Test
Purpose(s)	• Select final wheel spoke geometry and materials based on strength and shock absorption characteristics. • Confirm that wheels absorb shock to withstand impact and protect the PackBot and its payload.
Level of Approximation	• Correct wheel spoke geometry, materials, and platform load.
Experimental Plan	• Build 12 test wheels using six different materials, each with two spoke shapes. • Mount the wheels to the test fixture. • Conduct impact tests at a range of drop heights.
Schedule	1 August — select wheel designs and materials 7 August — complete design of test fixture 14 August — wheels and test fixture constructed 15 August — assembly completed 23 August — testing completed 25 August — analysis of test results completed

Courtesy of iRobot Corp.

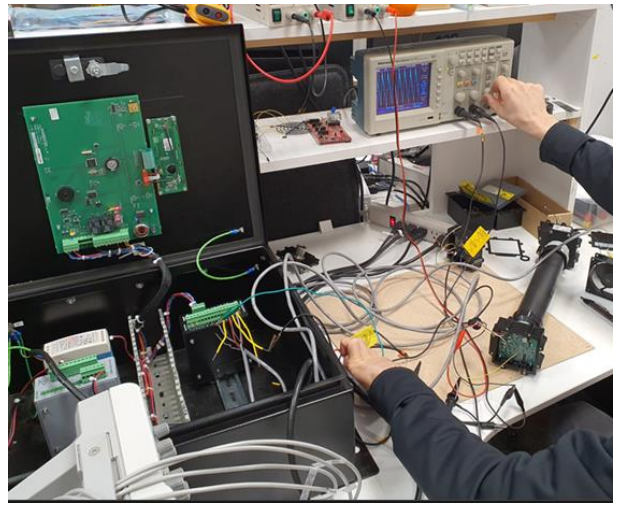
variables

What measurements and how

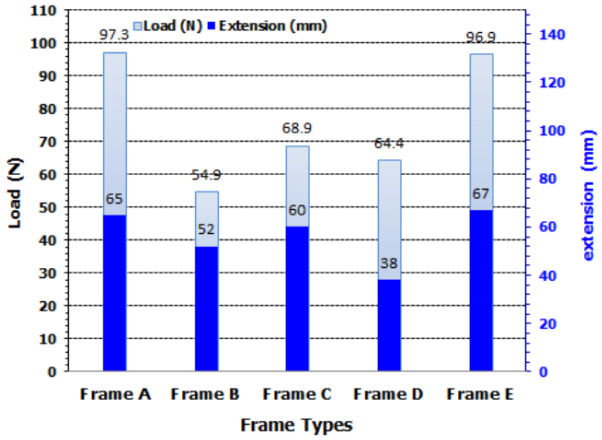
Step 4: Create a schedule for Procurement, Construction and Testing. (3 important dates)

1. When parts are ready to be assembled(=”bucket of parts”-date)

2. When prototype is tested for first time(=”smoke test”-date)



3. date when testing should be done, and results obtained.



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Courtesy of iRobot Corp.

Planning Milestone Prototypes.

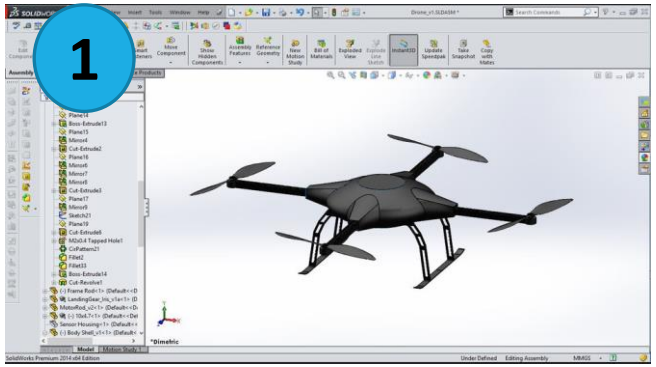
- Alpha prototypes : typically used to assess whether the product works as intended.
- Beta prototypes : typically used to assess reliability, and to identify remaining bugs in the product. (often given to customer for testing in the intended use environment)
- Preproduction prototypes : the first products produced by the entire production process.

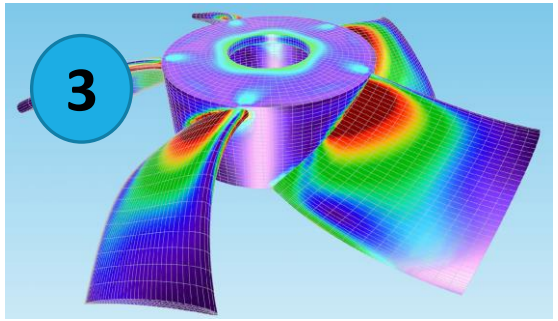
Tesla Model S Prototype, Detroit 2011,
Q: Alpha or Beta?

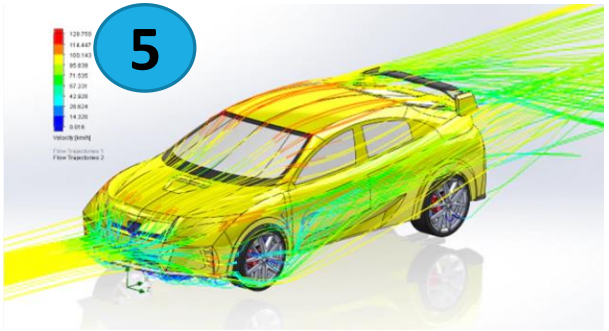
Principles of Prototyping?

Group A ?

Group B ?

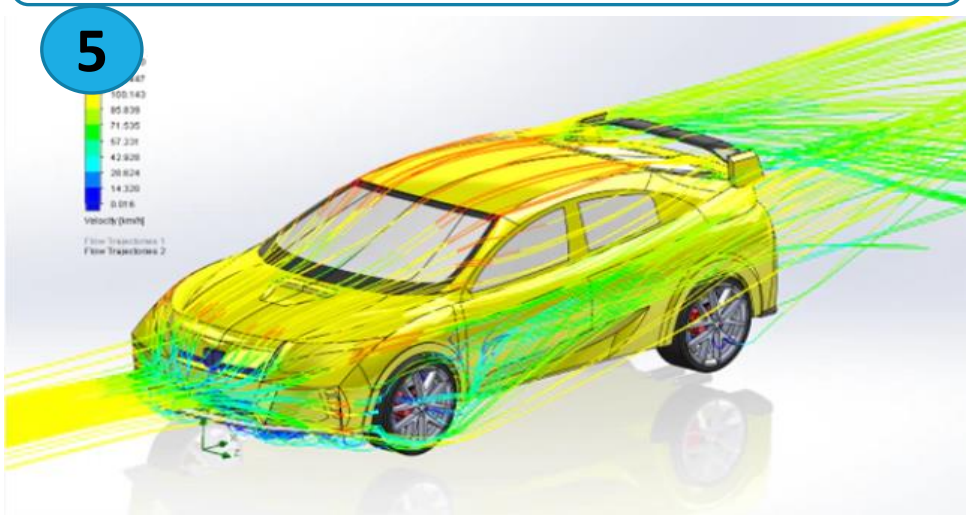


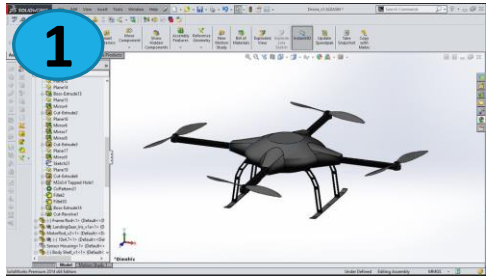


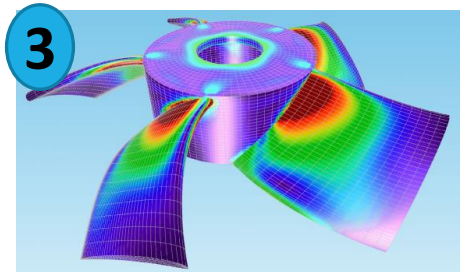


Principles of Prototyping

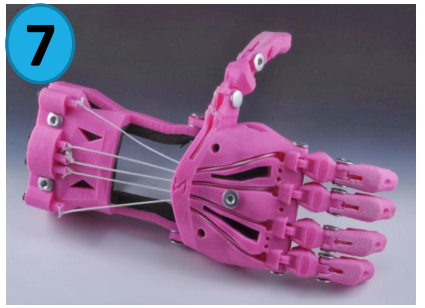
Analytical







Physical



Principles of Prototyping

Analytical Vs. Physical

Analytical

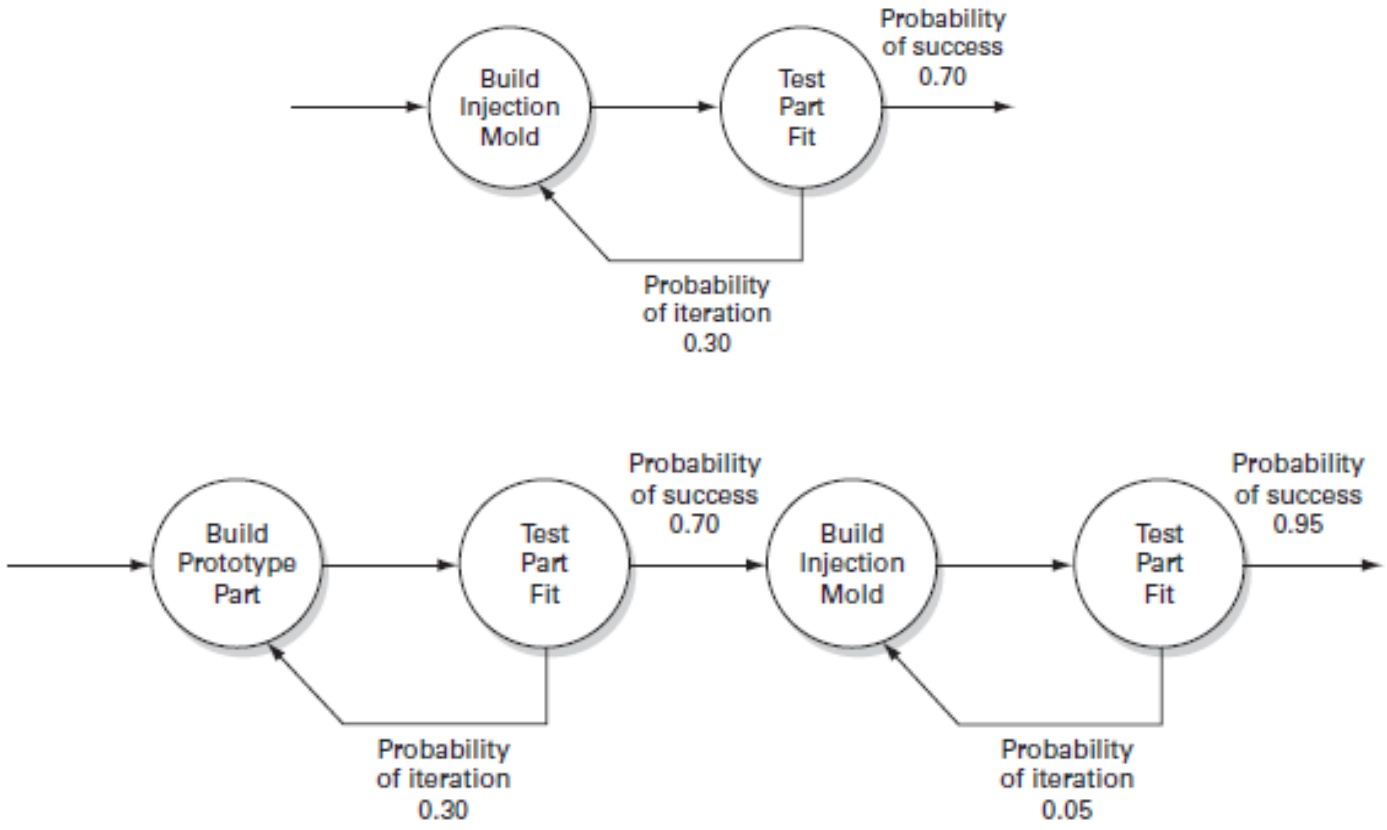
- A non-tangible model,
- Aspects are analysed rather than built
- More experimental freedom
- Less expensive and time consuming
- Are generally more flexible than physical prototypes

Physical

- Physical prototype is an object, or tangible approximation model of the product
- Best for communication
- Are used for detecting unanticipated phenomena
- is almost always built in a product development effort

Principles of Prototyping

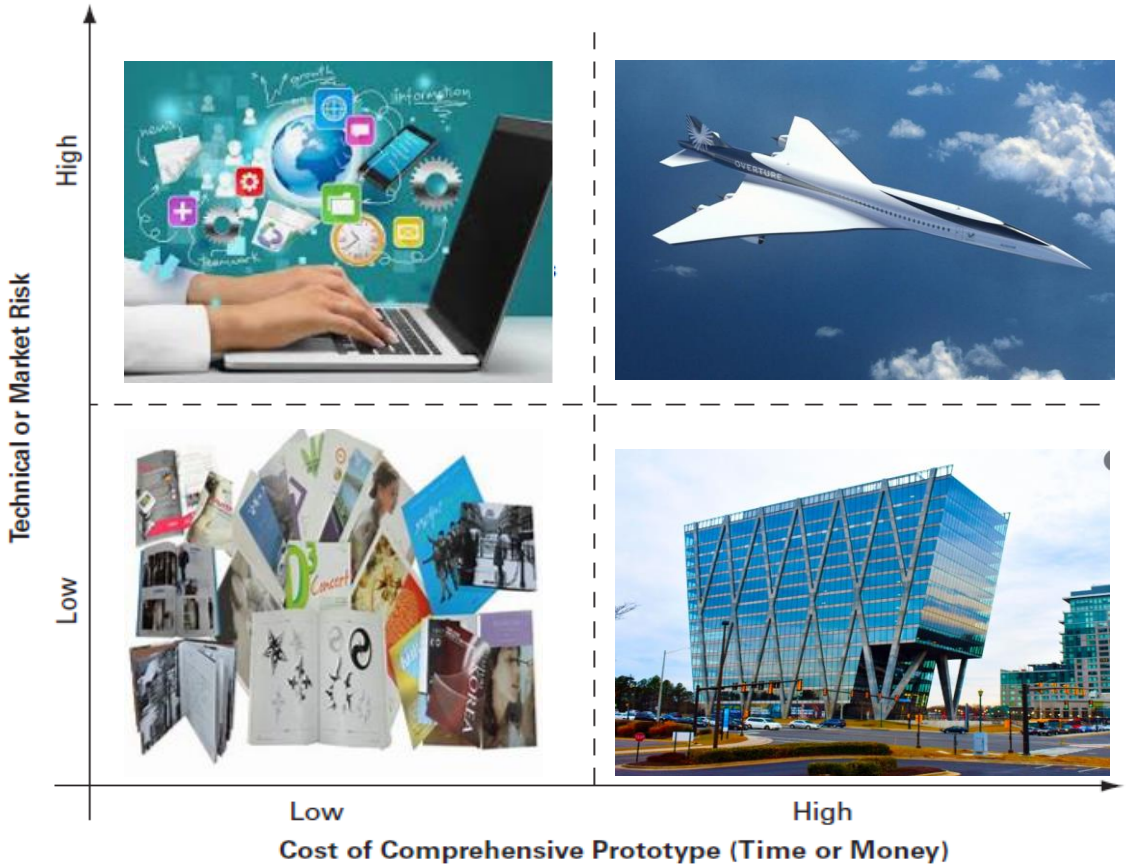
Prototype may reduce risk of costly iterations



Principles of Prototyping

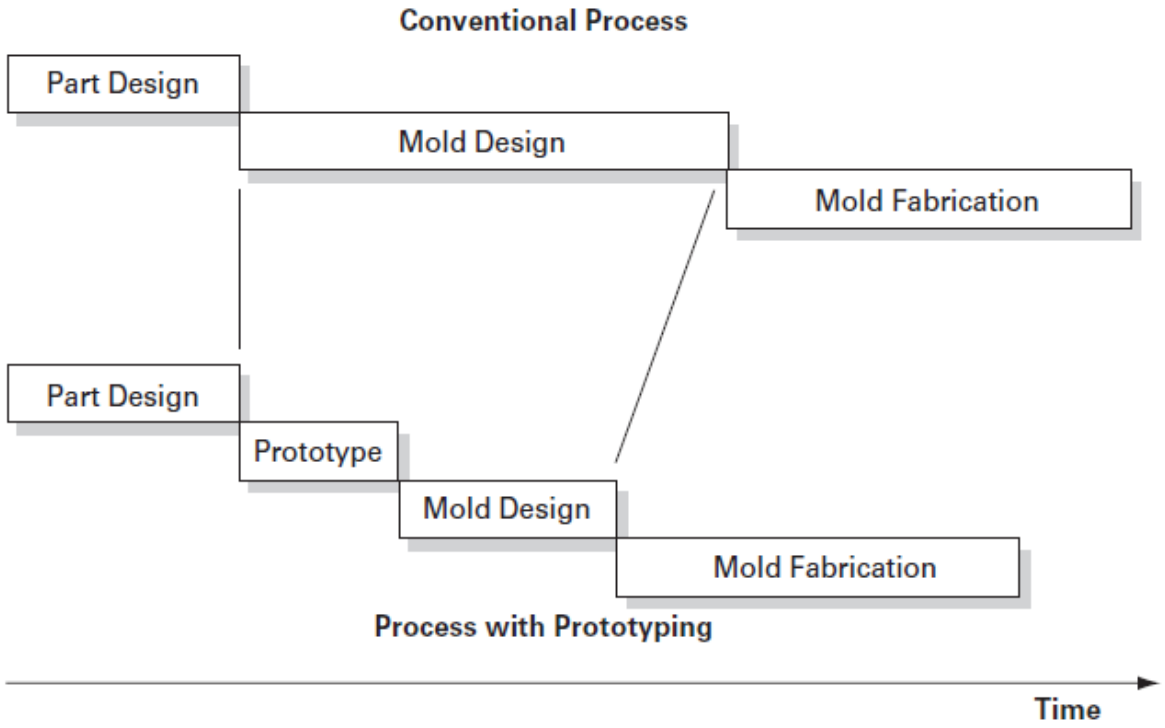
The use of comprehensive prototype depends on two factors:

- ❑ Cost of building a comprehensive prototype
- ❑ Level of technical or market risk



Principles of Prototyping

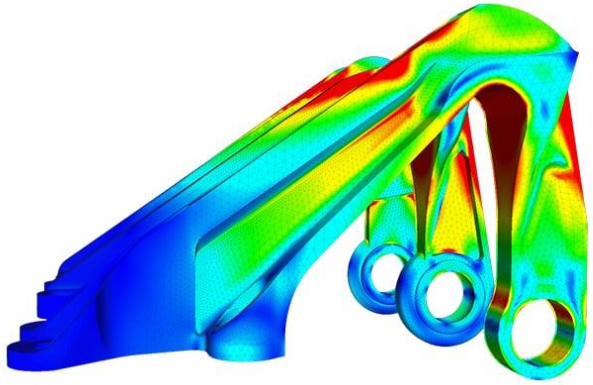
Prototyping Saves the time!



Prototyping technologies

Mock up prototypes

Virtual prototypes
(CAD, FEM, VR, AR)

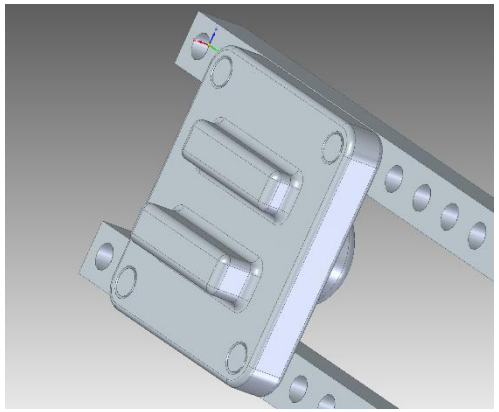


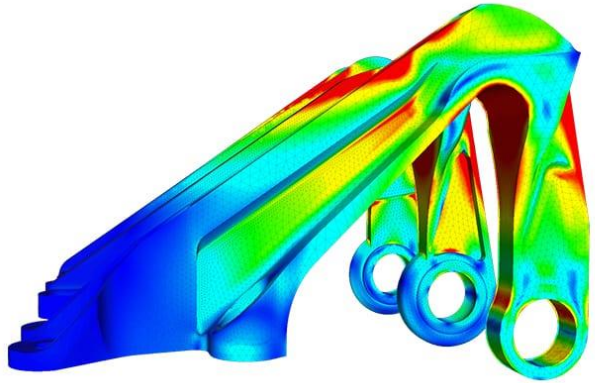
3D Printing

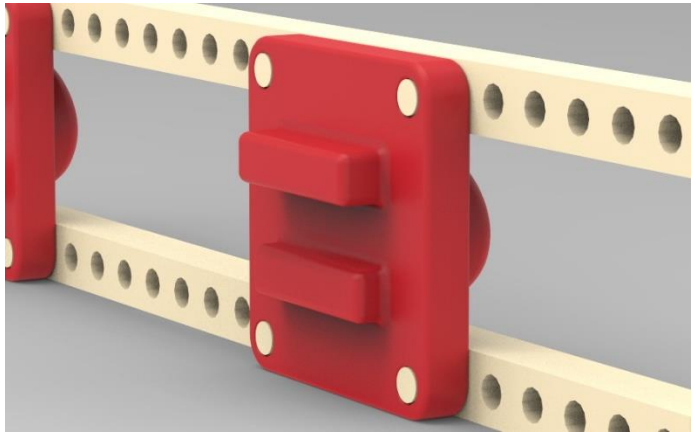
Mock up prototypes

Product development prototypes for cabinet maker's impact driver. The swivel head allows the driver to get into tight spots. (a) Cardboard. (b) Wood. (c) Foam. (d-e) Fused deposition modeling rapid prototypes.

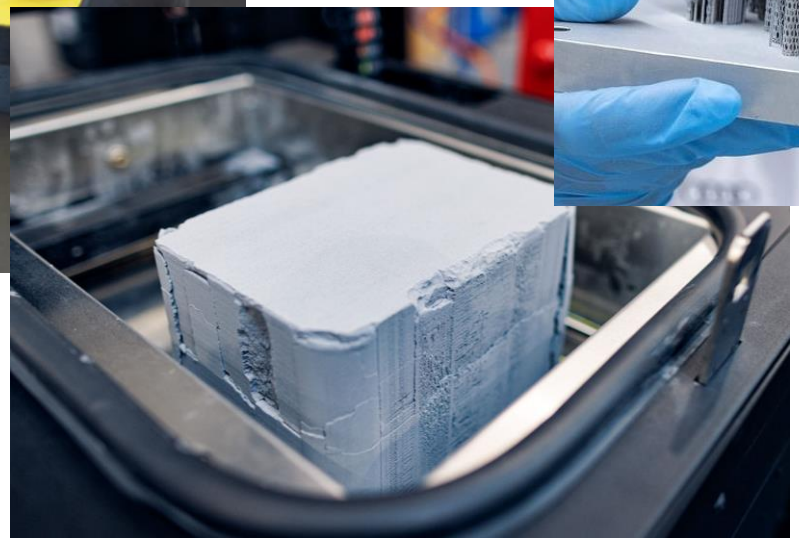
Virtual prototypes (CAD, FEM, VR, AR)

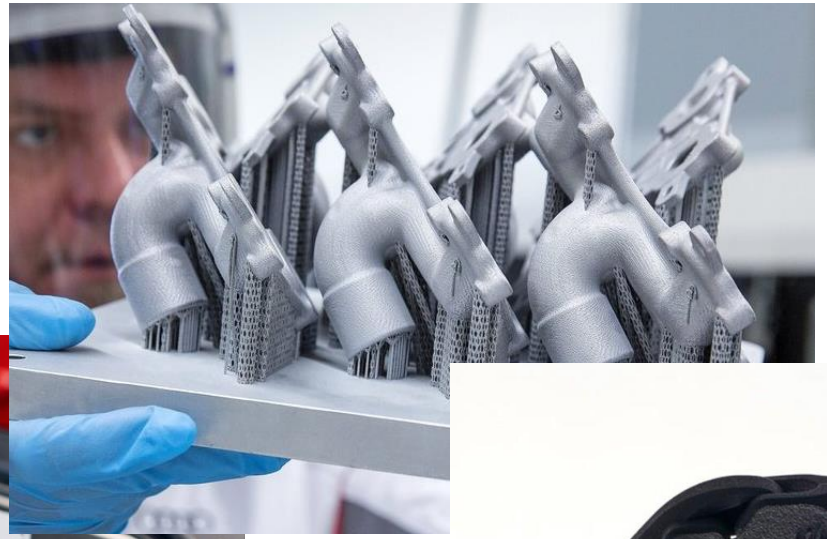






3D-Printing (Rapid prototyping, Additive manufacturing)





Testing

Will it work?

Testing can be considered a subproject within the overall development project

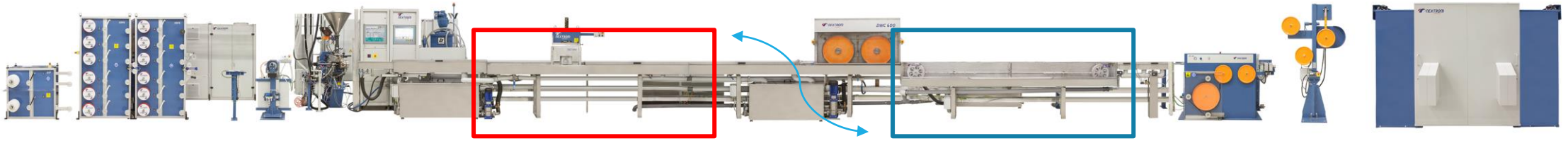
Real world testing vs simulation

Testbed, alpha, beta or preproduction prototype

Important dates

- Ready to assemble
- First test
- Final results

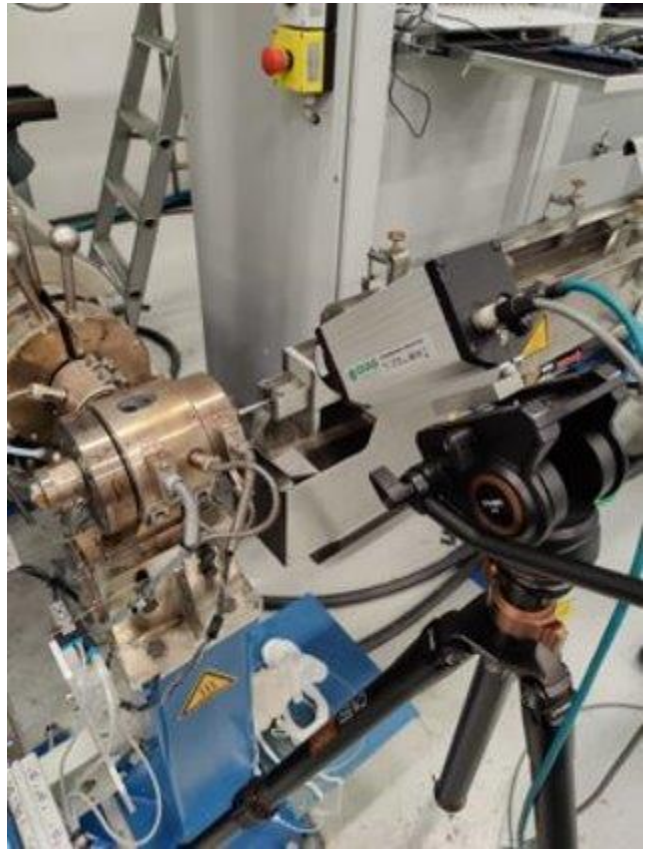
Prototype Testing Case

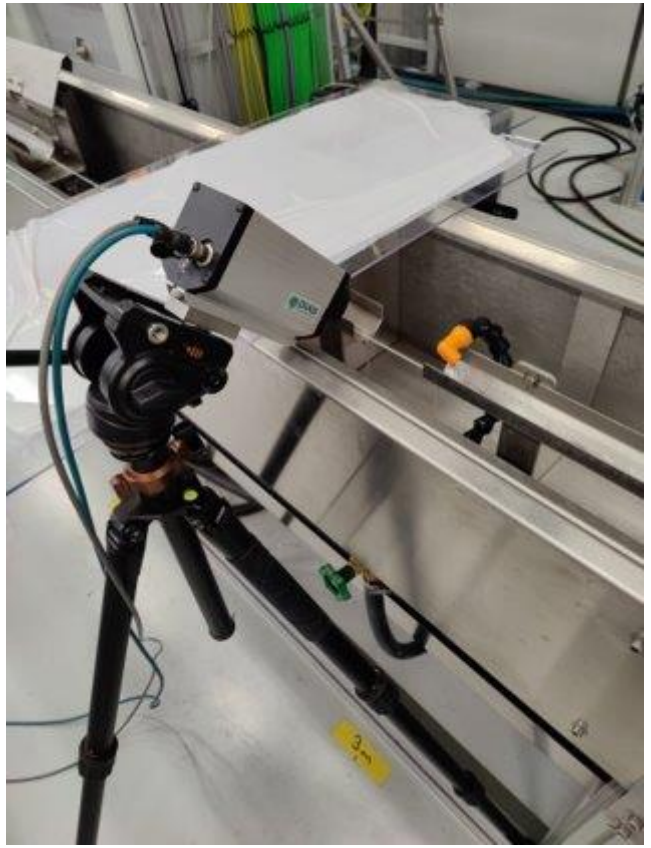


- Loose tube extrusion line for fiber optic cable
  - Product OD roughly 2 mm, 12 fibers
  - PP plastic
- The goal of the R&D project was to test new cooling method (Spray vs. Underwater cooling)
- Speed up to 800 m/min

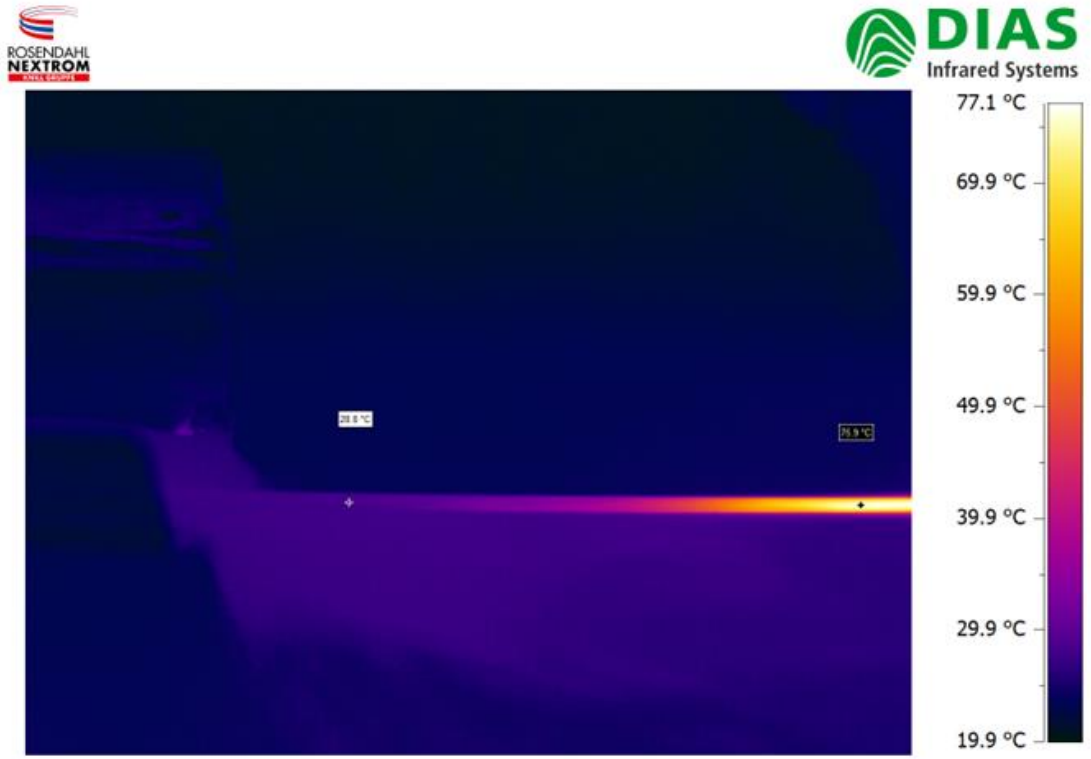
Ready to Assemble?

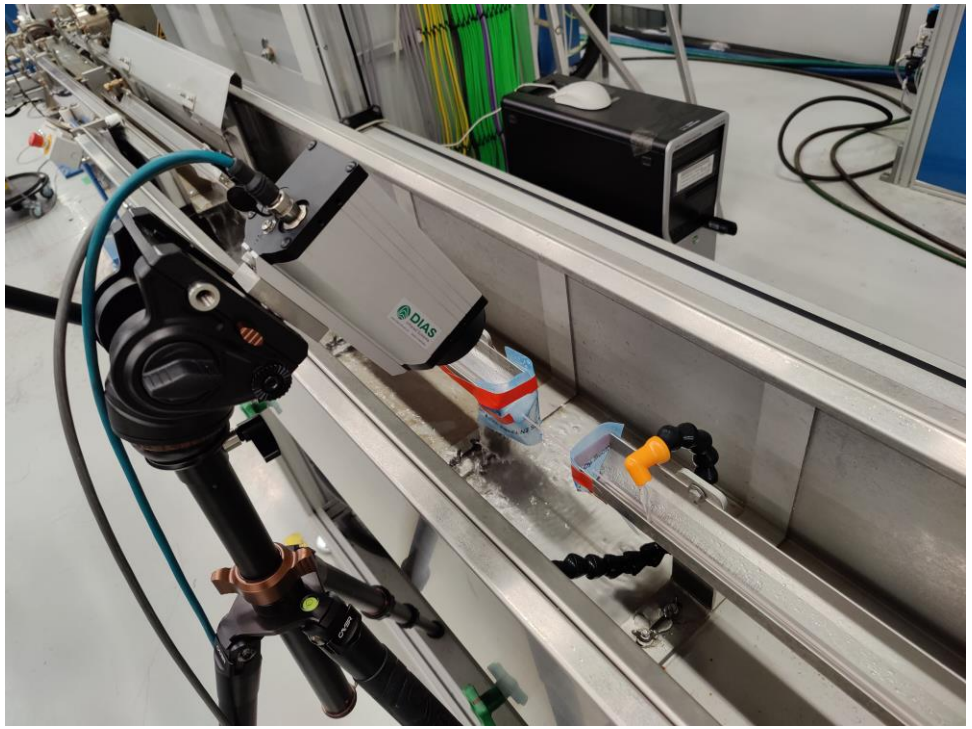
- First figuring out how to test the prototype
- Ordering parts
- Testing methods finalized
- IR Camera was used



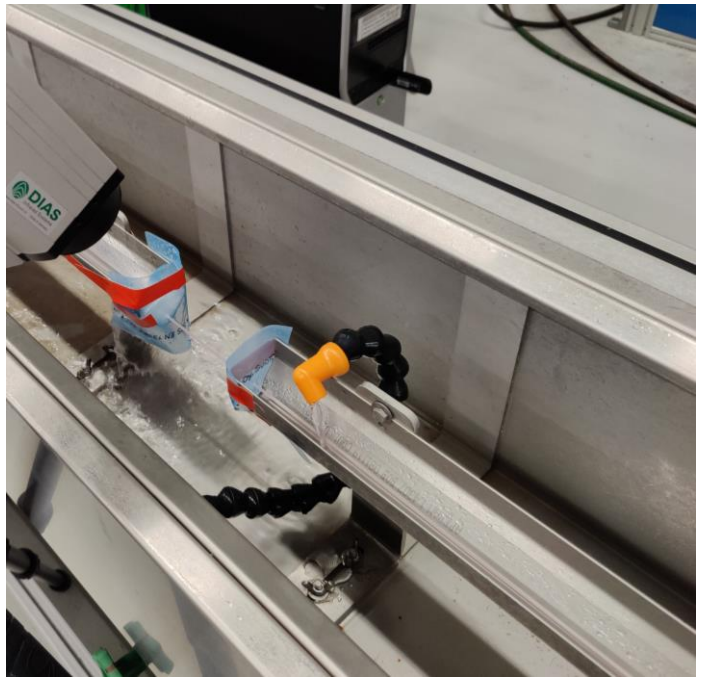


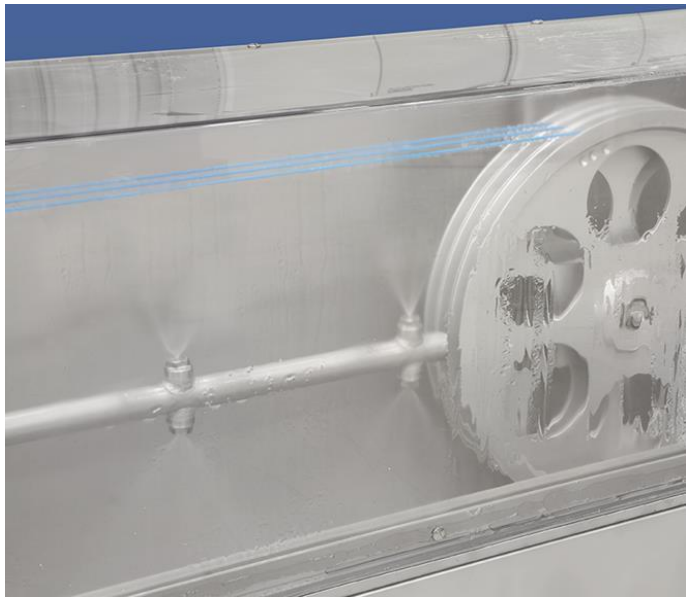
Ready to Assemble?

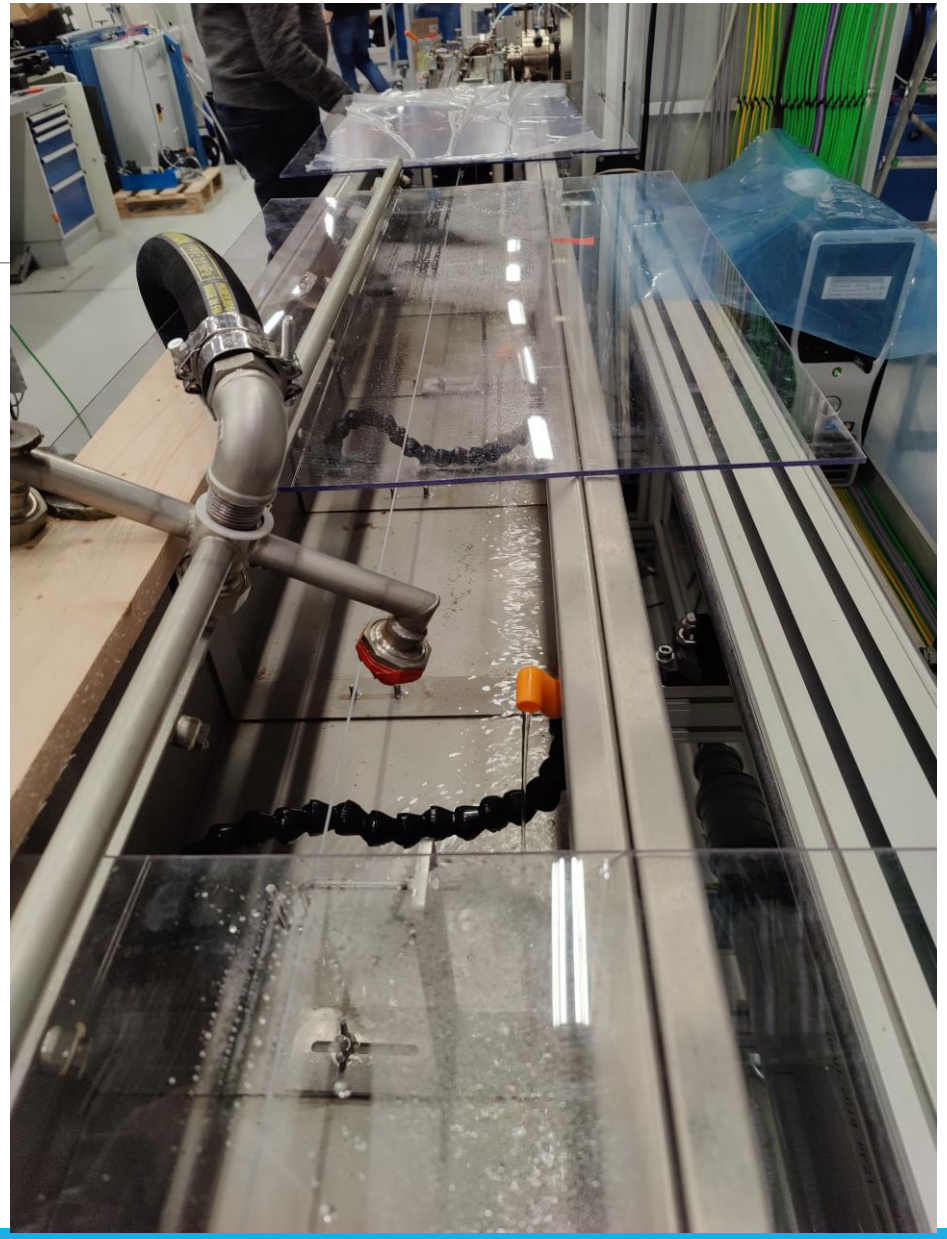




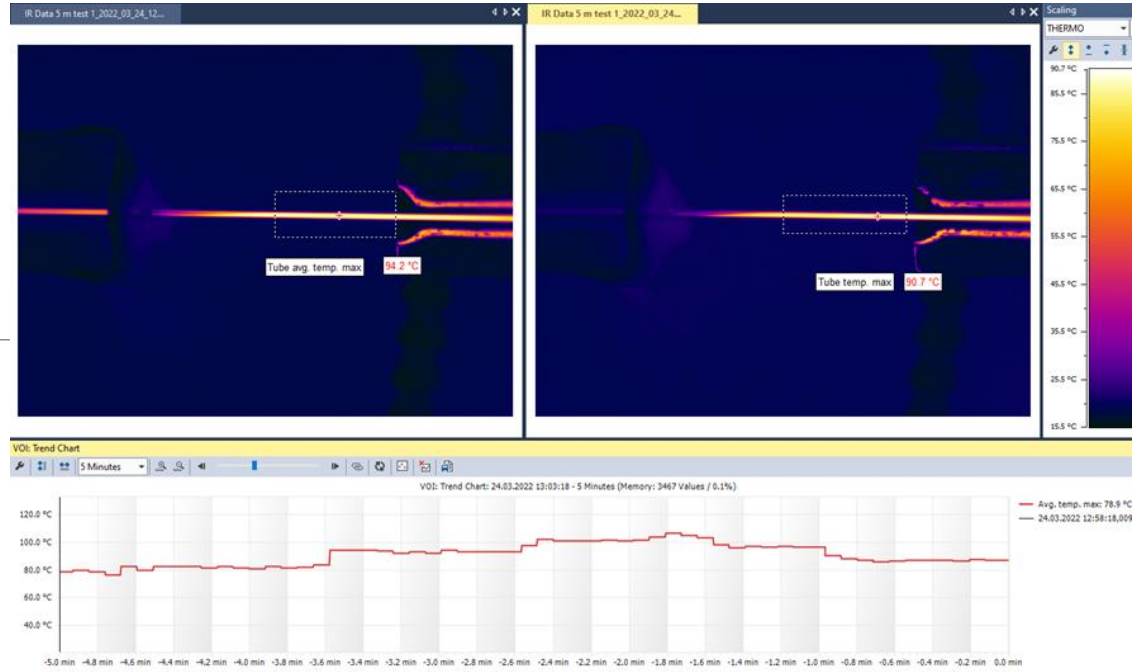
First test

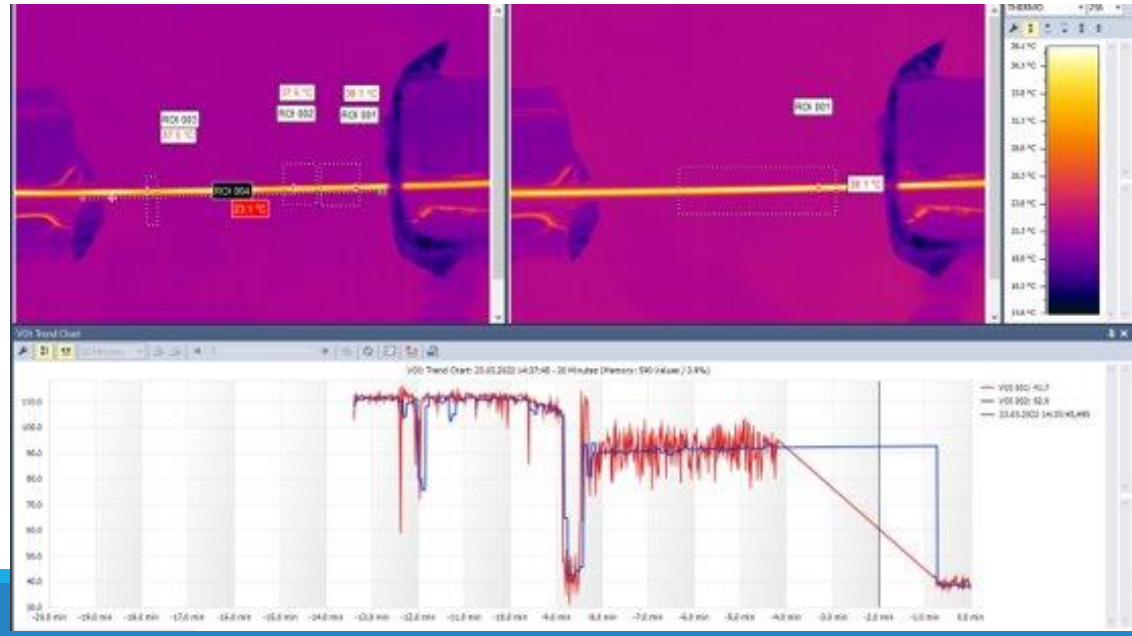






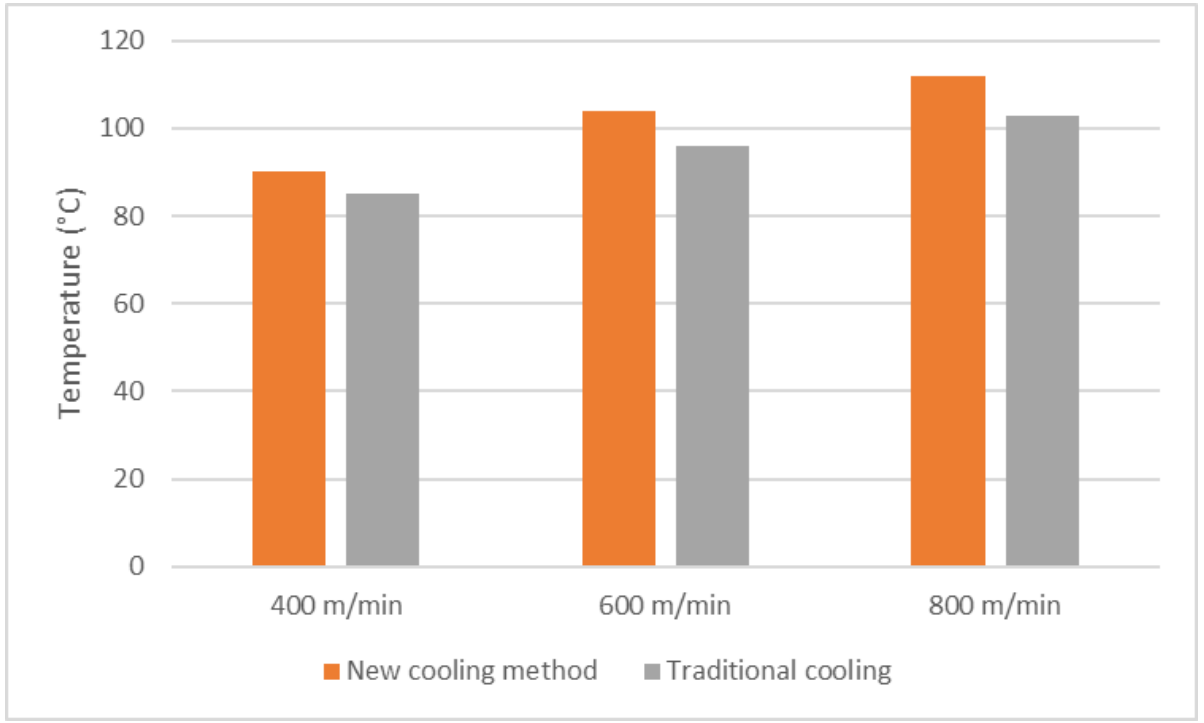
More testing & Iterations





Final results

- The results from testing of the prototype were very useful
- Much cheaper than building a completely new machine
- Results help defining new R&D projects



Remember these

- Prototyping can be done throughout the development process
- The prototype should always serve a purpose
  - ”Why did we spend resources on this prototype?”
- Approach the prototyping project with care
  - You already decided that this is worth your time and money!
  - Schedule, make a plan for testing, and document the results

Fin

Questions?

Aalto University
School of Engineering