Product Development & Entrepreneurship

Prototyping
Chapter 12: Prototyping
Product Development Process

Planning

Concept Development

System-Level Design

Detail Design

Testing and Refinement

Production Ramp-Up

Prototyping is done throughout the development process.
Prototypes: innovation facilitators

- Prototyping in the initial phase of PD serves several objectives:
  - Notion of work done
  - Something tangible
  - Immediately shows possible improvements
  - Ergonomics
Prototype

- Prototype is an approximation of the product along one or more dimensions of interest.
- This chapter explains why prototypes are built.
- This chapter also describes a method for planning prototypes before they are built.
Four Uses of Prototypes

- **Learning**
  - answering questions about performance or feasibility
  - e.g., proof-of-concept model

- **Communication**
  - demonstration of product for feedback
  - e.g., 3D physical models of style or function
Four Uses of Prototypes (cont)

- Integration
  - combination of sub-systems into system model
  - e.g., alpha or beta test models
- Milestones
  - goal for development team’s schedule
  - e.g., first testable hardware
Prototyping Strategy

- Use prototypes to reduce uncertainty.
- Make models with a defined purpose.
- Consider multiple forms of prototypes.
- Choose the timing of prototype cycles.
  - Many early models are used to validate concepts.
  - Relatively few comprehensive models are necessary to test integration.
- Plan time to learn from prototype cycles.
  - Avoid the “hardware swamp”. 
Types of Prototypes

- Prototypes can be classified along two dimensions
  - The first dimension is the degree to which a prototype is *Physical* or *Analytical*.
  - The second dimension is the degree to which a prototype is *Comprehensive* or *Focused*. 
## Physical vs. Analytical Prototypes

<table>
<thead>
<tr>
<th>Physical Prototypes</th>
<th>Analytical Prototypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>● Tangible approximation of the product.</td>
<td>● Mathematical model of the product.</td>
</tr>
<tr>
<td>● May exhibit un-modeled behavior.</td>
<td>● Can only exhibit behavior arising from explicitly modeled phenomena. (However, behavior is not always anticipated).</td>
</tr>
<tr>
<td>● Some behavior may be an artifact of the approximation.</td>
<td>● Some behavior may be an artifact of the analytical method.</td>
</tr>
<tr>
<td>● Often best for communication.</td>
<td>● Often allow more experimental freedom than physical models.</td>
</tr>
</tbody>
</table>
## Focused vs. Comprehensive Prototypes

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<thead>
<tr>
<th>Focused Prototypes</th>
<th>Comprehensive Prototypes</th>
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<tr>
<td>Implement one or a few attributes of the product.</td>
<td>Implement many or all attributes of the product.</td>
</tr>
<tr>
<td>Answer specific questions about the product design.</td>
<td>Offer opportunities for rigorous testing.</td>
</tr>
<tr>
<td>Generally several are required.</td>
<td>Often best for milestones and integration.</td>
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**Focused Prototypes**
- Implement one or a few attributes of the product.
- Answer specific questions about the product design.
- Generally several are required.

**Comprehensive Prototypes**
- Implement many or all attributes of the product.
- Offer opportunities for rigorous testing.
- Often best for milestones and integration.
Comprehensive Prototypes

- Many comprehensive prototypes are built.
- Some comprehensive prototypes build (and sold?).
- One prototype may be used for verification.
- Few or no comprehensive prototypes are built.

Technological or Market Risk

High

Low

Cost of Comprehensive Prototype

Low

High

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Product Design and Development - Chapter 12
## Appropriateness of prototypes

<table>
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<th>Integration</th>
<th>Milestones</th>
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<tr>
<td>Focused analytical</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Focused physical</td>
<td>●</td>
<td>●</td>
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<td>○</td>
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<tr>
<td>Comprehensive physical</td>
<td>●</td>
<td>●</td>
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</table>
Examples of prototypes to test ergonomics’ related issues
Principles of prototyping

- Analytical prototypes are generally more flexible than physical prototypes.

- Physical prototypes are required to detect unanticipated phenomena.
A prototype may reduce the risk of costly iteration.
A prototype may expedite other development steps
A prototype may restructure task dependencies
Planning for prototypes

- Step 1. Define the purpose of the prototype.
- Step 2. Establish the level approximation of the prototype.
- Step 3. Outline an experimental plan.
Planning Milestone Prototypes

- **Alpha**
  - To assess whether the product works as intended.

- **Beta**
  - To assess reliability and to identify remaining bugs in the product.

- **Production prototypes**
  - The first products produced by the entire production process.
PackBot mobile robot from iRobot
Examples of physical prototypes in the PackBot project. (a) Looks-like model for customer communication and approval, (b) wheel prototype under load during creep testing, (c) sand test of the complete system.
Examples of analytical prototypes of the PackBot. (a) 3D CAD rendering created for a customer proposal, (b) finite-element analysis of wheel spoke geometry, (c) dynamic simulation model.
EXHIBIT 12-5 Types of prototypes. Prototypes can be classified according to the degree to which they are physical and the degree to which they implement all of the attributes of the product.
Boeing 777 Testing

**Brakes Test**
- Minimum rotor thickness
- Maximum takeoff weight
- Maximum runway speed
- Will the brakes ignite?

**Wing Test**
- Maximum loading
- When will it break?
- Where will it break?
Structural testing of the horizontal stabilizer of a Boeing 777
Rapid Prototyping Methods

- Most are additive, not subtractive, processes.
- Build parts in layers based on CAD model.
- SLA = Stereolithography Apparatus
- SLS = Selective Laser Sintering
- 3D Printing
- FDM = Fused Deposition Manufacturing
- LOM = Laminated Object Manufacturing
- Others every year...
Rapid prototyping

Selective Laser Sintering – (SLS)
Rapid prototyping

Moldes de silicone

Cadeia de Produção

Corte e abertura do molde
Remoção do master

Enchimento com poliuretano ou outra resina
● That’s all folks!