Physical and Digital Prototyping Belong Together
Julie Reece – Z Corporation

MP6661 How do innovative companies combine physical and digital prototyping to deliver products that are consistently cutting-edge, affordable, reliable, and safe? You’ll learn: how prototyping needs evolve within each stage of the design process from form studies to visual prototypes to working prototypes; how to determine and evaluate which prototyping method is best suited for each design phase; and how Cisco, Steeda Autosports and other companies streamline design with a combined approach.

Learning Objectives
At the end of this class, you will be able to:

• Explain how prototyping needs evolve within each stage of the design process.
• Determine and evaluate which prototyping method is best suited for each design phase.
• Outline the differences between physical prototyping technologies.
• Select the best physical prototyping system for your needs.

About the Speaker
With more than 25 years of B-to-B and B-to-C marketing experience, Julie is responsible for Z Corporation’s marketing communications worldwide. Previously she was Director of Global Communications at Tele Atlas and has held similar positions at companies of all sizes and in a variety of industries, including Fidelity Investments, Talbots, Lotus Development, Progress Software and SupplyWorks. Julie holds a Bachelor’s degree in English from Trinity College and a Master of Science degree in Communications from Boston University.

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Prototyping needs evolve within each stage of the design process

Form studies: Conceptual Prototypes explore size, look, feel of product idea early in the process

<table>
<thead>
<tr>
<th>Digital Prototyping Pros</th>
<th>Digital Prototyping Cons</th>
<th>Physical Prototyping</th>
<th>Physical Prototyping Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Easy to create</td>
<td>1. Can’t be touched, felt, held</td>
<td>1. Increases understanding through touch, feel</td>
<td>1. Fast</td>
</tr>
<tr>
<td>2. Evaluate ideas from any angle</td>
<td>2. No sense of scale</td>
<td>2. Looks like the actual product</td>
<td>2. Office-friendly</td>
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<tr>
<td>3. Allows instant changes</td>
<td>3. Can’t see what product will look like in real setting</td>
<td>3. See how product will look like in actual environment</td>
<td>3. Low-cost materials</td>
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<td>4. Safe, easy to use</td>
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Example:

Cisco Consumer Business Group (CBG)

- **Business:** Develops home networking and networked entertainment solutions for consumers
- **Challenge:** Upholding Scandinavian design standards
  - Handcrafted prototypes time-consuming and expensive
  - Most automated rapid prototyping technologies are just as costly
• 2D screen images alone insufficient to create the quality that the Cisco demands

• **Results:**
  
  o Makes 10 prototypes/week resulting in more refined, elegant products
  
  o Creates prototypes in hours instead of weeks, at one-fifth the cost
  
  o Passes around physical models and marks on them with pencil
  
  o Applies specific design standards in a way that keeps the development cycle humming

**Visual Prototypes:** Accurately reflect detailed product appearance for production; serve product engineering; manufacturing engineering; marketing and sales

**Visual Prototypes: Product Engineering:**

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<tr>
<td>1. Designs product geometry</td>
<td>1. Insufficient to assess:</td>
<td>1. Provides greater understanding of form, texture, color, parts of assembly for better assessment of:</td>
<td>1. Fast</td>
</tr>
<tr>
<td>5. Generates bills of material</td>
<td>d. Reliability</td>
<td>d. Reliability</td>
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<td></td>
<td>e. Cost</td>
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<td></td>
<td>f. Production tooling</td>
<td>f. Production tooling</td>
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<td></td>
<td>g. Ability to disassemble</td>
<td>g. Ability to disassemble</td>
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<td></td>
<td>h. Accessibility of parts for repair</td>
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Visual Prototypes: Manufacturing Engineering:

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<tr>
<td>1. Simulates material-handling and assembly operations</td>
<td>1. Building and programming digitally simulated 3D production systems is difficult, requires special skills and is costly</td>
<td>1. Most cost-effective means of planning and verifying assembly procedures before production parts available</td>
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<td>2. Helps engineers design and check jigs, fixtures, gauges in assembly processes before stamped, cast or molded production parts available</td>
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<td>3. Enables function, assembly testing on tools, fixtures, gauges</td>
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<td>4. Accurate</td>
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Example:

**Hydroforming Design Light A/B**

- **Business**: Makes diversified products shaped with pressurized water
- **Challenge**: Communicating benefits of their unique process
Results:

- Implemented color models showing FEA results on physical geometry
- Customers impressed with physical models and better understand advantage
- Eliminated tooling and assembly errors, keeping costs low, reducing time to market, and increasing customer satisfaction

Visual Prototypes: Marketing and Sales:

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<td>2. Unable to provide physical samples for customers/photography</td>
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<td>2. Low-cost materials</td>
<td>2. Low-cost materials</td>
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Example:

Timberland

- Business: Global footwear/apparel manufacturer
- Challenge: Obtaining more prototypes sooner to better evaluate comfort, performance and marketability of new designs
- Results:
  - 30+ fold reduction in prototype cost
Reduced prototype creation time, from a week to 90 minutes
33 percent reduction in design time
Better communication of design intent through color
Closer collaboration between design & marketing professionals
Increased sales now that representatives use real 3D prototypes instead of 2D sketches

**Working Prototypes:** Functional prototypes test form, fit and function

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<td>2. Dynamic analysis</td>
<td>2. Incorrect loads or boundary conditions can generate incorrect answers</td>
<td>2. Some aspects of physical performance evaluated more cost effectively</td>
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<tr>
<td>3. FEA</td>
<td></td>
<td>3. Check snap and press fits quicker</td>
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<td>4. Computational fluid dynamics</td>
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<td>4. Assess consumer acceptance of design features prior to costly tooling investments</td>
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<td>5. Safety testing for regulatory agencies</td>
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<td>1. Material properties/finishes similar to actual product</td>
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<td>2. Provide sharp details</td>
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<td></td>
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<td>3. Ensure high accuracy</td>
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</table>
Example:

*Spirax Sarco*

- **Business:** Leader in steam-related products and services
- **Challenge:** Time and cost of tooling
- **Results:**
  - Makes burnout patterns using ZPrinter
  - Saves 3-4 weeks
  - Eliminates $3,000-$5,000 (USD) tooling charge
Understanding different physical prototyping technologies
ZPrinter Inkjet Technology

How it works

CAD software exports files in standard formats for 3D printing
ZPrint software slices the 3D model file into hundreds of digital cross-sections
Each layer is printed one atop the other until the model is complete

The exported file is a mesh that encloses a 3D volume
Each cross-section corresponds to a layer of the model to be printed

Feed Chamber deposits powder
Printer Axis spreads thin layer of powder
Print Heads selectively deposit binder to solidify
Advantages

1. Speed:
   
a. ZPrinters create models at rate of 1 vertical inch (25 mm) per hour. A team can print several handheld size parts two inches (50 mm) in just a couple of hours

b. High-throughput – Raster (vs. vector) approach. Print head encompasses multiple jets – 300 per half inch (12.7 mm) covering a half-inch (12.7 mm) swatch with each pass
   
   i. Ability to make multiple models in single build; stack/nest parts in build chamber

   ii. Can create 15 base-ball sized models in a single 5-hour build

   iii. ZPrinter 650 can build 2000+ prototypes in one month

   iv. Most useful build area

   v. One set-up procedure

   c. Spread build material over build platform, rather than forcing through nozzle. Dispense only binder through print heads. Loose powder supporting parts means ZPrinters don’t require disposable supports

   d. 5X-10X faster than other technologies
2. **Affordability**

   a. Low-priced machine – no lasers, complex thermal controls or special facility requirements
   
   b. Affordable, plaster powder used widely in industrial applications
   
   c. No wasted build material (no supports and unused powder automatically recycled for future builds)
   
   d. Water cure infiltration process – virtually free
   
   e. Ease of maintenance – off-the-shelf inkjet printing technology and modular design minimize downtime
   
   f. Total cost for completed models $2-$3 USD/in³($0.12-$0.18 USD) cm³

3. **Ease of use**

   a. No special training required; hands-on time for operation only a few minutes
   
   b. ZPrint software enables monitoring of powder, binder, ink levels from desktop and remotely red machine’s LCD display
   
   c. Most operations can be performed at the machine
   
   d. ZPrinters run unattended during printing process
   
   e. ZPrinters automate setup, powder loading, self-monitoring of materials and print status, printing and removal and recycling loose powder
      
        i. Powder and binder cartridges ensure clean loading of build materials
   
   f. Zero liquid waste
   
   g. Negative pressure in a closed-loop system to contain airborne particles
   
   h. Integrated fine-powder removal chamber reduces system footprint
   
   i. Quiet operation

4. **Accuracy**

   a. Electronic system precisely controls printing action
   
   b. Print head accurately and precisely deposits binder and color in areas indicated by ZPrint software
c. Delivers details as small as 0.004 in (0.1 mm) and structural walls as thin as 0.02 inches (0.5 mm)

d. Accuracy similar to basic injection molding

5. Multicolor Printing

a. ZPrinter technology based on inkjet document printer technology

b. Converts any color from RGB to CMYK for printing

c. Orders up correct combination of CMYK drops to be placed in the same area using dither patterns to blend elements into any color

d. File formats including color: 3DS, WRL (VRML), PLY, ZPR, etc.

e. ZEdit Pro enables addition of color, colored textures and labels to 3D model files

f. ZPrinter colors only shell of an object, using ink only where needed

**ZBuilder Ultra Digital Light Projection (DLP) Technology**

*How it works*

1. High-resolution DLP system instead of complex laser technology

2. Highly-controlled exposure for each voxel

3. Exposed photopolymer solidifies into robust solid plastic
Advantages

1. **Duplicates digital CAD models precisely**
   a. All features within +/- 0.008 inches (+/- 0.2 mm)
   b. Precision optics and motion systems for repeatability
   c. Only movement in the Z-direction

2. **Builds Durable Functional Parts**
   a. Strong and flexible
   b. Material rivals final parts
   c. Consistent regardless of orientation
   d. Materials performance
i. Tensile Strength: 6250 PSI (43.0 MPa)
ii. Tensile Elongation at Break: 4.50%
iii. Flexural Strength: 8740 PSI (60.2 MPa)
iv. Flexural Modulus: 263 kSI (1810 MPa)
v. Hardness: 86D
vi. HDT (0.45 MPa): 132.3 F (55.7 C)
vii. HDT (1.82 MPa): 116.3 F (46.8 C)

e. Thin walls and sharp detail
   i. Minimum feature size 0.005 inches (138 microns)
   ii. X/Y resolution from highest resolution DLP engine
   iii. Precise control of light source delivers sharp edges

f. Smooth surface finish
   i. Parts appear injection molded
   ii. Precise control of each voxel (3D pixel)
   iii. No “stair stepping”

g. Fast
   i. Build prototypes next day
   ii. Speed independent of how many parts in the build bed; entire cross-section imaged at once
   iii. Only seconds per exposure
Selecting the best physical prototyping system for your needs

8 Questions to Ask Yourself:

1. What is your primary application?
   - Design iteration, communication, collaboration
     - ZPrinters
   - Sales, marketing, presentation
     - ZPrinters
   - Form, fit, functional testing
     - ZPrinters (stiff part functional testing applications)
     - ZBuilder Ultra (flexible, snap-fit functional testing applications)
2. What part attributes and mechanical properties do you require?

- High strength and high stiffness
  - ZPrinters
- Higher strength and high flex
  - ZBuilder Ultra
3. How many models would you like to build?
   - 3-5 models / day; nested and stacked
     - ZPrinters
   - 1-2 models / day
     - ZPrinters
     - ZBuilder Ultra
4. How would you like your models to appear?

- Monochrome
  - ZPrinters
  - ZBuilder Ultra

- Multicolor
  - ZPrinters
5. What best describes your prototypes?

- **Thin walls**
  - ZBuilder Ultra

- **Medium walls**
  - ZPrinters
  - ZBuilder Ultra

- **Thick walls**
  - ZPrinters

![Diagram showing the range of wall thicknesses from thin to thick, with ZPrinter on the left and ZBuilder on the right. Most models have walls from 0.16 in (4 mm) to 0.005 in (0.13 mm).]
6. What type of surface finish do you require?
   - Standard
     - ZPrinters
   - Premium
     - ZBuilder Ultra
7. How important is a low cost per finished part?

- Critical
  - ZPrinters
- Not critical
  - ZPrinters
  - ZBuilder Ultra

**ZPrinter**

- Draft: $2-$3 USD / in³ ($0.12-$0.18 USD / cm³)
- Basic Functional
- Presentation

**ZBuilder**

- Functional: $10-$12 USD / in³ ($0.60-$0.72 USD / cm³)
8. Where will the prototyping system be operated and who will operate it?

- Anyone in an office or shop environment
  - ZPrinters
- Experienced operator in a shop environment
  - ZPrinters
  - ZBuilder

Summary: Making the Right Choices

1. Physical and digital prototyping complement one another
2. Both should be integral to product-development processes
3. Digital prototyping allows detailed models to be conceived and changed quickly
4. But...there is no substitute for reality
5. Additive manufacturing produces physical prototypes quickly and easily
6. Understand physical and digital prototyping methods
7. When evaluating physical prototyping, consider:
   a. Faster systems with high throughput are ideal for iterative design
   b. Low material costs may be more important than a low-priced system
c. Color systems eliminate the need for painting and finishing

d. Strong, flexible materials may be needed for evaluating snap fits

e. Some are well suited to making patterns for metal castings

f. Higher-strength materials may be necessary for physical testing

g. Fine surface finish may be required for working prototypes

To learn more about 3D printing and rapid prototyping, visit www.zcorp.com.

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