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EBU5608 Product Development and Management

Topic 10 – Detail Design & Prototypes

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Agenda

- **Phase 3 - Detail Design**
  - Aim
  - Control Documentation
  - Departmental responsibilities
- **Prototype**
  - Definitions: Prototype, Prototyping
  - Phases of prototypes
  - Uses of prototypes
  - Types of prototypes

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Phase 3 – Detail Design

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Phase 3 – Detail Design

- Phase 3 includes
  - the **complete specification** of the
    - geometry (i.e. physical dimensions)
    - materials, and
    - tolerances

    of **all** the unique **parts** in the product, and
  - the **identification** of all of the standard parts to be **purchased** from suppliers
- Two **critical issues** addressed in the detail design phase are
  - production cost and
  - robust design (or performance)

Today – Use of Prototype

See in Topic 11 and 12 for more details

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Control documentation

- The **output** of Phase 3 is the **control documentation** for the product
- The control documentation is:
  - The **drawings** or computer **files** describing the **geometry** of each part to be made and its production **tooling**
  - The process descriptions for the **fabrication** and **assembly** of the product
  - The specifications of the parts to be **purchased**

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Departmental responsibilities

- Departmental responsibilities in this phase are
  - **Marketing**
    - Develop marketing plan
  - **Design**
    - Define part **geometry**
    - Choose **materials**
    - Assign **tolerances**
    - Complete industrial design **control documentation**

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Departmental responsibilities (cont.)

- **Manufacturing**
  - Define piece-part **production** processes
  - Design **tooling**
  - Define **quality assurance** processes



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Design for X Topics

- Design for Manufacturing
- Design for Production
- Design for Assembly
- Design for Recycling/Disposal
- Design for Life Cycle
- Design for Environment

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Product Development Process

- Prototyping is done throughout the development process
- It becomes most important at the Detail Design stage, and Testing stage

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Use of Prototypes in Phase 3 - Detail Design

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What is a prototype?

- In some industries, a prototype is a **small-scale model**:
  - a miniature car
  - a miniature building or town

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What is a prototype / characteristics of a prototype?

Or, it can be (among other things):

- a series of screen sketches
- a storyboard, i.e. a cartoon-like series of scenes
- a Powerpoint slide show
- a video simulating the use of a system
- a lump of wood (e.g. iphone)
- a cardboard mock-up
- **a piece of software with limited functionality written in the target language or in another language**

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What is a prototype?

- A prototype is
  - "an **approximation** of the product along one or more dimensions of interest"
  - i.e.
    - Industrial designers produce **prototypes** of their concepts, such as models
    - Engineers **prototype** a design
    - Software developers write **prototype** programs
- **Prototyping** is the **process** of developing such an approximation of the product

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What is a prototyping?

Prototyping is the process of quickly putting together a **working model** (a prototype) in order to test various aspects of a design, illustrate ideas or features and gather early user feedback.- Wikipedia

IEEE defines **prototyping** as " A type of development in which emphasis is placed on developing prototypes early in the development process to permit early feedback and analysis in support of the development process."

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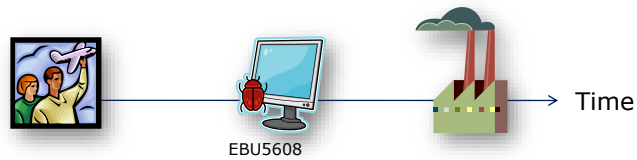
3 Phases of Prototyping

- There are **3 phases** of prototyping
- **Alpha** prototypes
  - Are typically used to assess whether the product works **as intended**
- **Beta** prototypes
  - Are typically used to assess **reliability** and to identify remaining **bugs** in the product
- **Pre-production** prototypes
  - Are the first products produced by the entire **production process**



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Alpha Prototypes

- Early (alpha) prototypes are usually built with **production-intent** parts
  - These are parts with the same **geometry** and **material properties** as intended for the production version of the product
  - They will look similar to and perform the basic functions of the product
  - They are **not** necessarily **fabricated** with the actual processes to be used in production
- Alpha prototypes are tested to determine whether
  - the product will **work as designed**
  - the product satisfies the key **customer needs**

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Beta Prototypes

- Later (beta) prototypes are usually built with parts supplied by the intended **production** processes
  - but may **not** be assembled using the intended final **assembly** process
- Beta prototypes are extensively evaluated **internally** and are also typically tested by **customers** in their own use environment
- The **goal** for the beta prototypes is usually to answer questions about **performance** and **reliability** in order to identify necessary engineering changes for the final product

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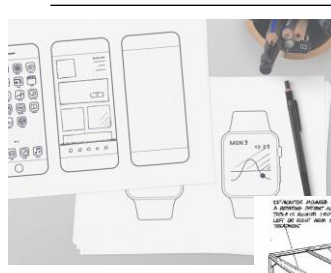
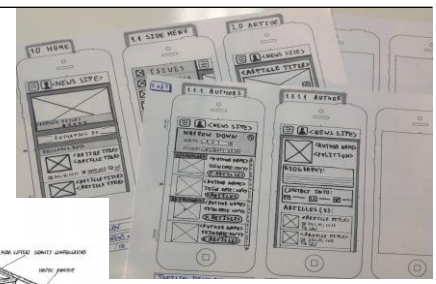
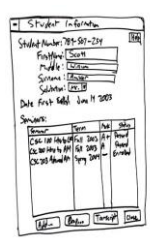
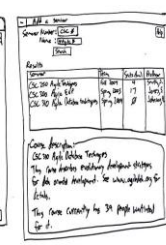
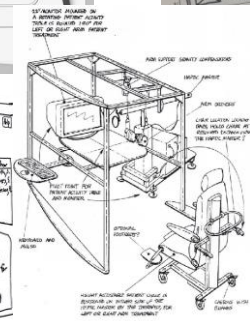
Prototyping example: Sketches

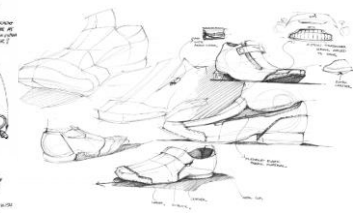












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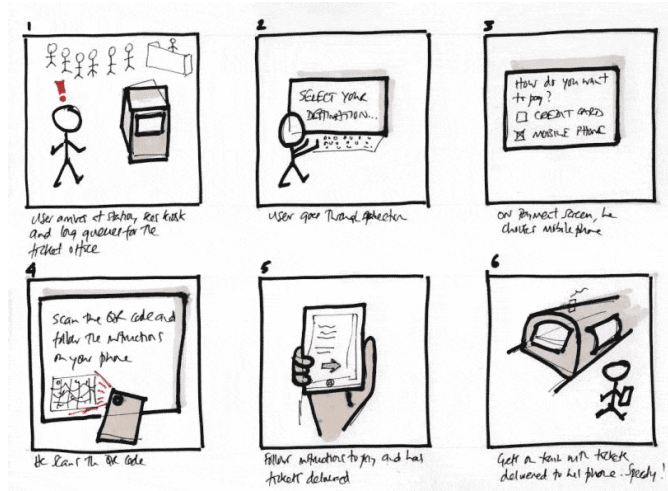
Prototyping example: Storyboard



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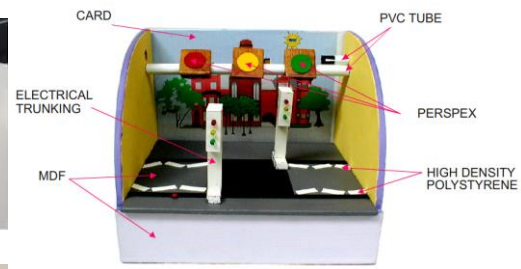
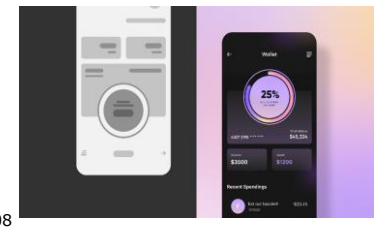
Soft and Hard Models





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Uses of Prototypes

- There are four main uses of prototypes:
  1. **Learning**
     - Answering questions about performance or feasibility , such as
       - "Will it work?"
       - "How well does it meet the customer needs?"
     - For example, a proof-of-concept model

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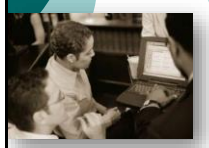
Uses of Prototypes (cont.)

2. **Communication**
   - Demonstration of a product to get **feedback** from all stakeholders
     - e.g. top management, vendors, partners, extended team members, customers and investors
   - A **physical**, tactile, 3D representation of a product is much easier to understand than a verbal **description** or even a **sketch** of a product
     - e.g. 3D physical models of style or function



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Uses of Prototypes (cont.)

3. **Integration**

- Prototypes are used to ensure that **components** and **subsystems** of the product **work** together as expected
- **Comprehensive physical** prototypes are the most effective as **integration** tools in product development projects because they require the **assembly** and physical **interconnection** of all of the parts and subassemblies that make up a product
- The integration of the prototype forces **coordination** between different **members** of the product development team
- For example: alpha or beta test models

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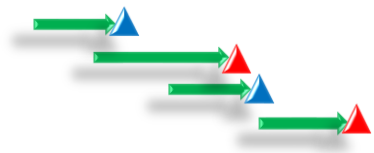
Uses of Prototypes (cont.)

4. **Milestones**
   - Provide goals for the development team's **schedule**
   - Milestone **prototypes** are defined in the product development project **plan**
     - 'Go/no go' decisions can be at these points



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Uses of Prototypes - milestones (cont.)

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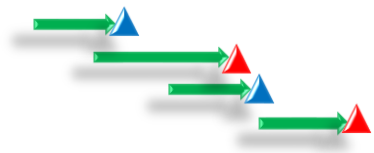
- The **number** of such prototypes and their **timing** is one of the key elements of the overall **development plan**
- As a **base case**, the development team should consider using alpha, beta and pre-production **prototypes** as milestones
  - e.g. first testable hardware



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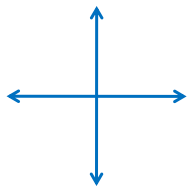
Types of Prototypes

- Prototypes can be classified along two dimensions
- **Physical** v **analytical**
  - Physical – e.g. a wooden model
  - Analytical – e.g. a computer model
- **Comprehensive** v **focussed**
  - Comprehensive - **most** of the **attributes** of the real product
  - Focussed – **one or a few attributes** of the real product



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Prototyping Example: iRobot PackBot Mobile Robot

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Physical prototype

- Physical prototypes are **tangible artefacts** created to approximate the product
- Aspects of the product of interest to the development team are actually **built** into an artefact for **testing** and **experimentation**
- **Examples** of physical prototypes include
  - **models** which look and feel like the product
  - **proof-of-concept** prototypes used to test an idea quickly
  - experimental **hardware** used to validate the functionality of a product

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Physical Prototypes

Looks-like model for customer communication and approval

Wheel prototype under load during creep testing

Sand test

Ulrich and Eppinger (4th ed., 2008) Exhibit 12-3

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Analytical prototype

- Analytical prototypes represent the product in a non-tangible, usually **mathematical**, manner
- Interesting aspects of the product are **analysed**, rather than built
- Examples of analytical prototypes include
  - computer **simulations**
  - systems of **equations** encoded within a spreadsheet
  - computer models of three-dimensional **geometry**

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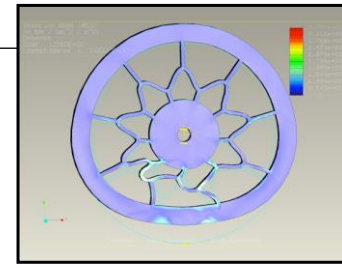
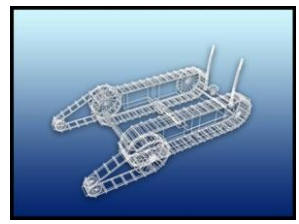
Analytical Prototypes

3D CAD rendering



Finite-element analysis



Dynamic simulation model

Ulrich and Eppinger (4th ed., 2008) Exhibit 12-4

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Comprehensive prototype

- Comprehensive prototypes implement **most**, if not all, of the **attributes** of a product
- A comprehensive prototype corresponds closely to the **everyday use** of the work prototype – i.e. it is a **full-scale**, **fully operational** version of the product
- An example of a comprehensive prototype is one given to customers in order to identify any remaining design flaws before committing to production

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Focused prototype

- Focused prototypes implement **one**, or a **few**, of the attributes of a product
- Examples of focused prototypes include foam models to explore the **form** of a product and wire wrapped circuit boards to investigate the **electronic performance** of product design
- A common practice is to use **two or more** focused prototypes together to investigate the **overall** performance of a product
  - One of these prototypes is often a "looks-like" prototype, the other a "works-like" prototype
- By building two separate focused prototypes, the team may be able to answer its questions much earlier than if it had to create one comprehensive prototype

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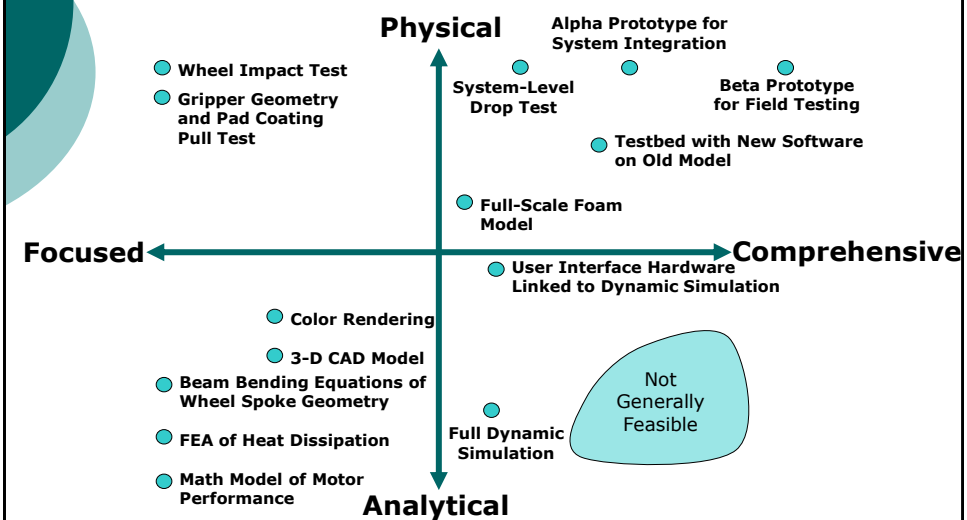
Types of Prototypes



Ulrich and Eppinger (4th ed., 2008) Exhibit 12-5

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Physical vs. Analytical prototypes

Physical prototypes

- **Tangible** approximation of the product
- May exhibit **unmodelled** behaviour
- Some behaviour may be a consequence of the **approximation**
- Often best for **communication**

Analytical prototypes

- **Mathematical** model of the product
- Can only exhibit behaviour arising from **explicitly modelled** phenomena (However, behaviour cannot always be predicted)
- Some behaviour may be a consequence of the **analytical method**
- Often allow more experimental **freedom** than physical models

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Focused vs. Comprehensive prototypes

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**

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Prototyping technologies

- There are **many** technologies for prototyping including **high-speed machining, casting, moulding and extruding**

Some are very **old** – e.g. clay models

Two **newer** ones are

- **3D CAD modelling and analysis**
  - Allow easy, rapid changes
  - Can calculate dimensions accurately
  - Can feed into manufacturing tools

- **Free form fabrication**
  - also known a 3D printing
  - allows very rapid production of physical prototypes

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Principles for choosing a Prototype type

- Analytical prototypes are in general more flexible than physical prototypes
- Physical prototypes are required to detect unanticipated phenomena
- Prototypes may reduce the risk of costly iterations
- Prototypes may expedite other development steps
  - Example: add a prototyping step in the part design-mold design-molding process
- A prototype may restructure task dependencies

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A prototype may restructure task dependencies

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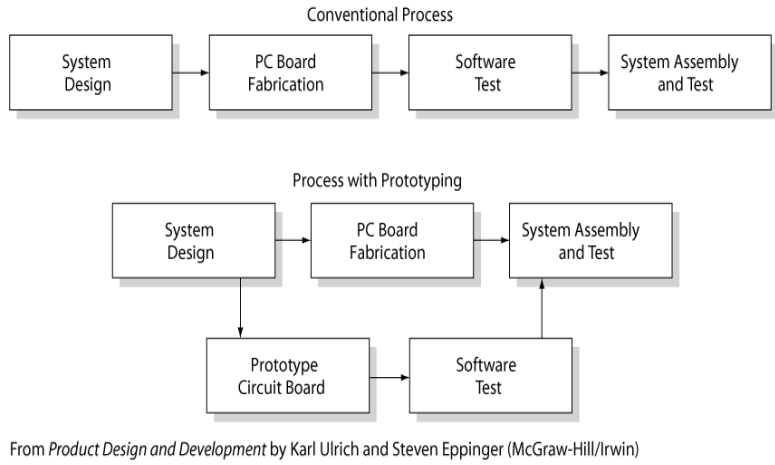

From *Product Design and Development* by Karl Ulrich and Steven Eppinger (McGraw-Hill/Irwin)

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Planning a prototype - the 4 steps (Ulrich and Eppinger)

Step 1 – Define the **purpose** of the prototype

Step 2 – Establish the level of **approximation** of the prototype

Step 3 – Outline an **experimental** plan

Step 4 – Create a **schedule** for procurement, construction and testing

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Planning a prototype - step 1

- Step 1 - define the **purpose** of the prototype
  - The team lists its specific **learning** and **communication** needs
  - Team members also
    - list any **integration** needs
    - decide whether or not the prototype is intended to be one of the **major milestones** of the overall product development project



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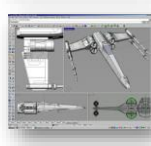
Planning a prototype - step 2

- Step 2 – Establish the level of **approximation** of the prototype
  - The degree to which the **final** product will be **approximated** in the prototype must be defined
  - The team should consider whether a **physical** prototype is **necessary** or whether an **analytical** prototype would best meet its needs
  - In most cases the best prototype is the **simplest one** that will serve the purposes established in **Step 1**

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Planning a prototype - step 3

- Step 3 – Outline an **experimental** plan
  - The use of a prototype in product development can be thought of as an **experiment**
  - Good **experimental practice** helps to make sure that you get the maximum value from the prototyping activity
    - i.e. that you get useful test results

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Planning a prototype - step 3 (cont'd)

- The experimental plan includes:
  - the identification of the **variables** of the experiment
  - the test **protocol**
  - an indication of what **measurements** will be performed
  - a plan for **analysing** the resulting data
- When **many variables** have to be explored, good experimental design makes this process much easier and more effective

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Example of a prototype planning template

- Consider a computer trackball

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Example of a prototype planning template

Name of Prototype	• Ball Support
Purpose (Communication, Learning, Integration, Milestones)	• What combination of spacing between ball supports and ball inertia yields the best trackball feel? (Learning) • How much variation is there in users' preferences for feel? (Learning)

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Example of a prototype planning template

Name of Prototype	• Ball Support
Purpose (Communication, Learning, Integration, Milestones)	• What combination of spacing between ball supports and ball inertia yields the best trackball feel? (Learning) • How much variation is there in users' preferences for feel? (Learning)
Level of Approximation	• Ball surface material as planned for production design • Support material as planned for production design • Support contact geometry as planned for production design

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Example of a prototype planning template

Name of Prototype	• Ball Support
Purpose (Communication, Learning, Integration, Milestones)	• What combination of spacing between ball supports and ball inertia yields the best trackball feel? (Learning) • How much variation is there in users' preferences for feel? (Learning)
Level of Approximation	• Ball surface material as planned for production design • Support material as planned for production design • Support contact geometry as planned for production design
Outline of Test Plan	• Build two sets of five different spacings for ball support • Test two balls with different inertias • Test spacings of 12.75, 13.00, 13.25, 13.50, 13.75 mm for each of the two ball inertias • Verify that all the spacings provide at least minimally acceptable performance • Have at least 20 users rank order the prototypes according to feel

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Example of a prototype planning template

Name of Prototype	• Ball Support
Purpose (Communication, Learning, Integration, Milestones)	• What combination of spacing between ball supports and ball inertia yields the best trackball feel? (Learning) • How much variation is there in users' preferences for feel? (Learning)
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Schedule	12 August Parts available 12 August Parts assembled 20 August Tests completed 22 August Analysis of results completed

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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" - where you keep building different ways out of a problem without stopping to think

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Summary

- Product development almost always requires the building and testing of prototypes.
- A prototype is an approximation of the product on one or more dimensions of interest.
- Prototypes are used for learning, communication, integration, and milestones.
- Prototypes can be usefully classified along two dimensions: (1) the degree to which they are physical as opposed to analytical and (2) the degree to which they are comprehensive as opposed to focused.
- Several principles are useful in guiding decisions about prototypes during product development.

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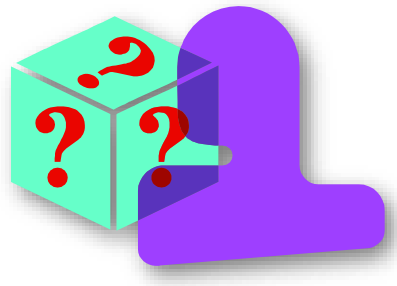
Questions?



Go to www.menti.com to post your questions

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Reading

- **Core Textbook** (Ulrich & Eppinger, 7th Edition)
  - Chapter 14. Prototyping
    pages 295 – 313

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