

UNIT 6

# Prototyping

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# Product Development Process



Prototyping is done throughout the development process.

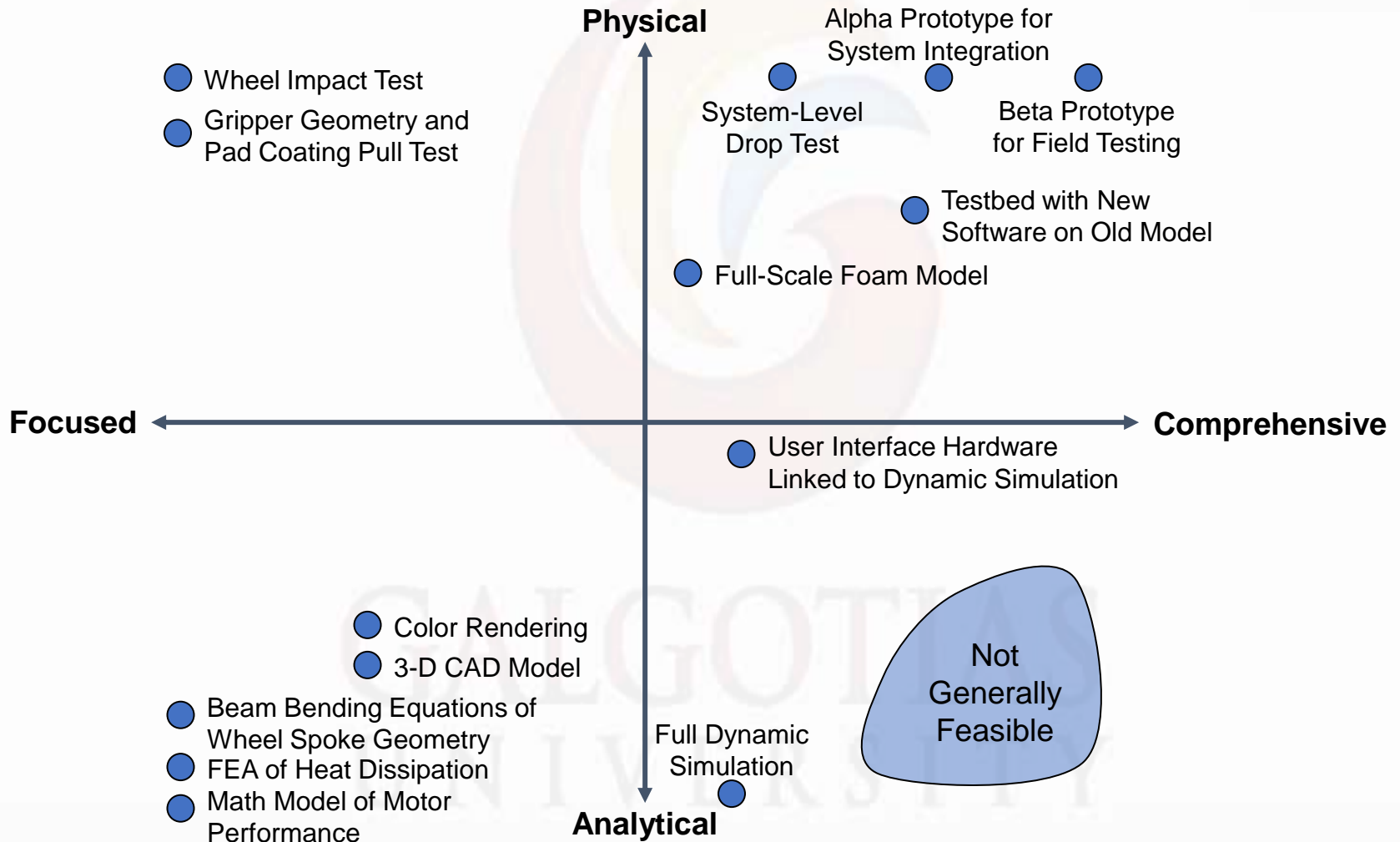
# Prototyping Example: iRobot PackBot Mobile Robot



# 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
- 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

# Types of Prototypes



# Physical vs. Analytical Prototypes

## Physical Prototypes

- Tangible approximation of the product.
- May exhibit unmodeled behavior.
- Some behavior may be an artifact of the approximation.
- Often best for communication.

## Analytical Prototypes

- Mathematical model of the product.
- Can only exhibit behavior arising from explicitly modeled phenomena. (However, behavior is not always anticipated.)
- Some behavior may be an artifact of the analytical method.
- Often allow more experimental freedom than physical models.

# Physical Prototypes



Looks-like model for customer communication and approval



Wheel prototype under load during creep testing



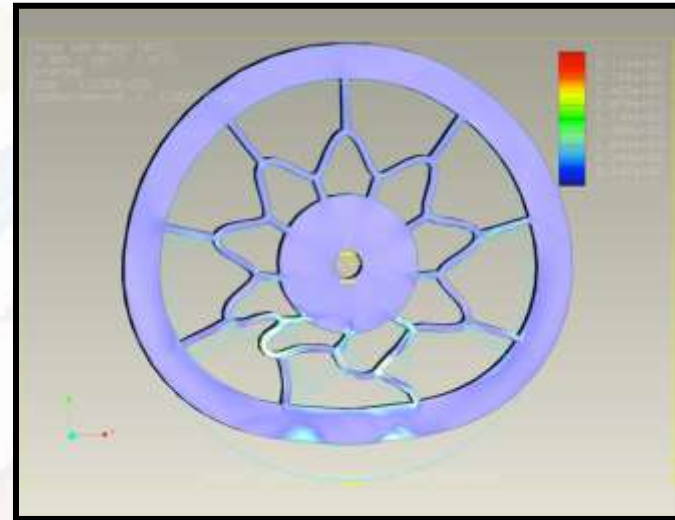
Sand test



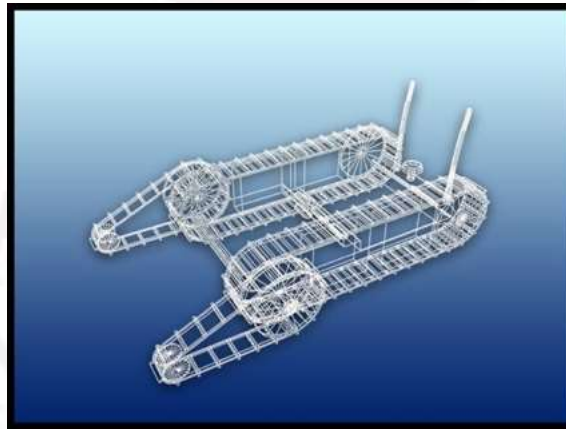
# Analytical Prototypes



3D CAD rendering



Finite-element analysis



Dynamic simulation model

# 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.



Wheel impact test

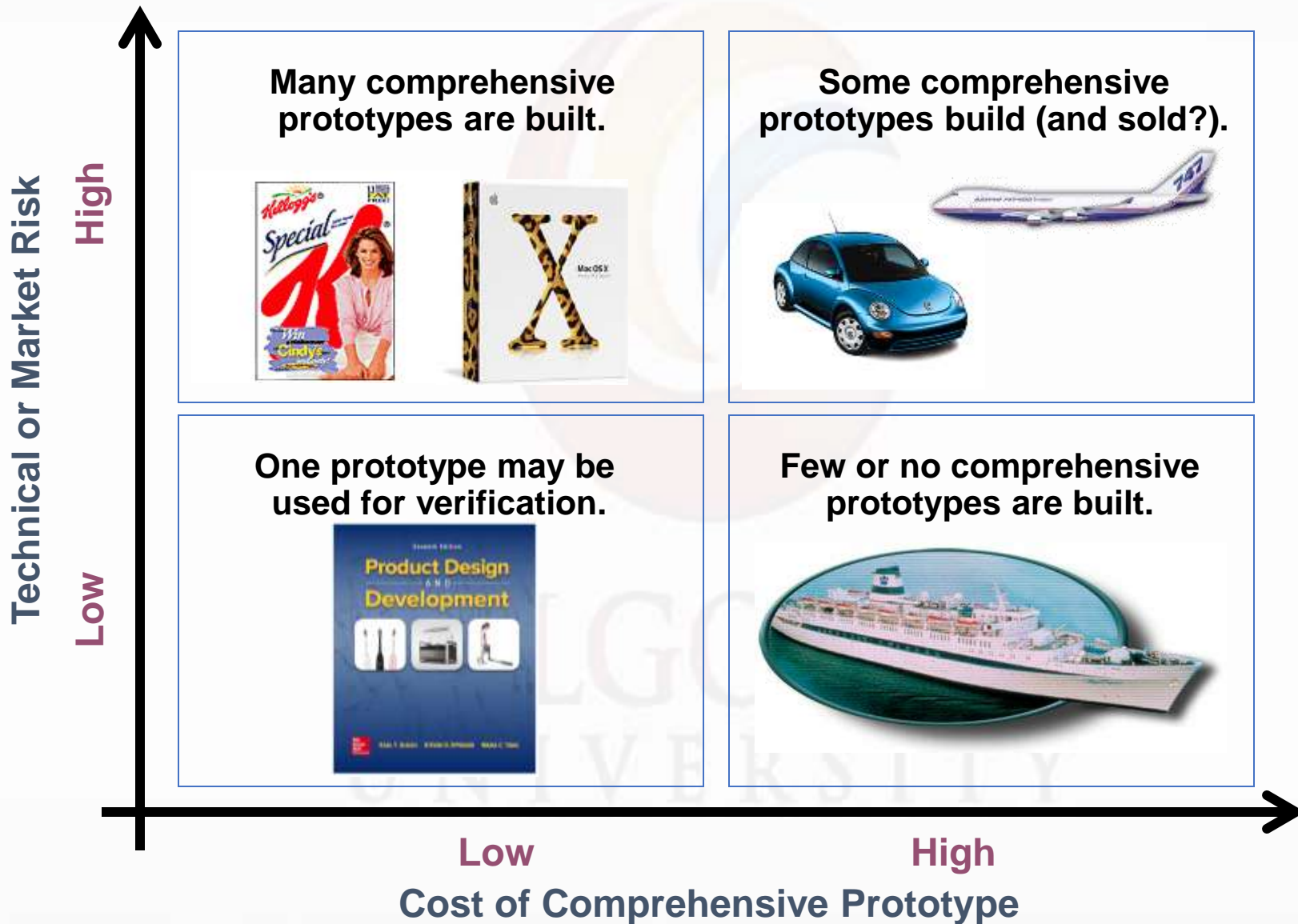
## Comprehensive Prototypes

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



Beta prototype

# Comprehensive Prototypes



# 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”.

# Rapid Prototyping Methods

- Most of these methods are additive, rather than subtractive, processes.
- Build parts in layers based on CAD model.
- SLA=Stereolithography Apparatus
- SLS=Selective Laser Sintering
- LOM=Laminated Object Manufacturing
- 3D Printing
- better every year...

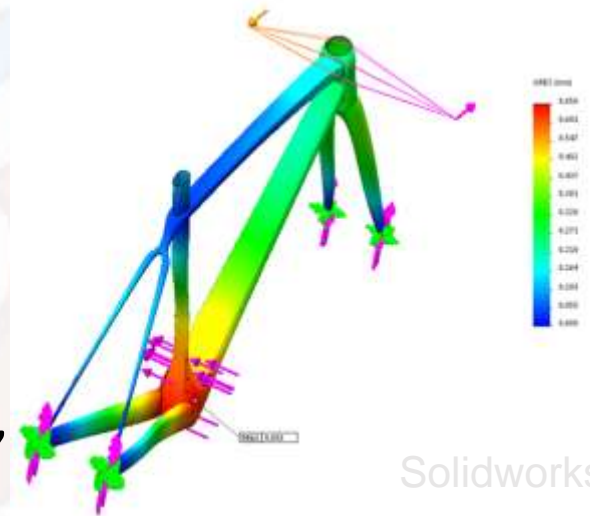


SLA component model

# Virtual Prototype Testing

3D CAD models enable many types of analysis:

- Fit and assembly
- Manufacturability
- Form and style
- Kinematics
- Finite element analysis (stress,
- Crash testing
- better every year...



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# Traditional Prototyping Methods

- CNC machining
- Rubber molding + urethane casting
- Materials: wood, foam, plastics, etc.
- Model making requires special skills.

# Boeing 777 Testing

## Brakes Test

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

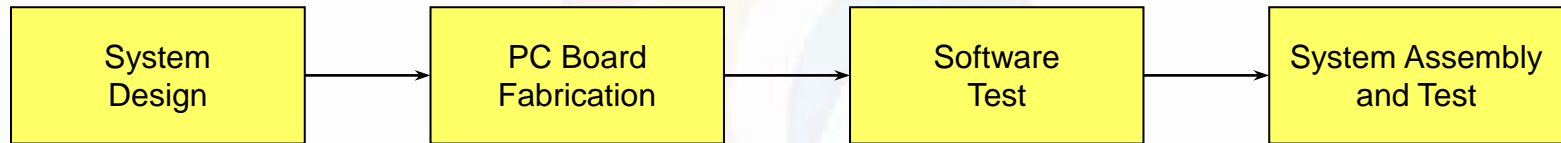
## Wing Test

- Maximum loading
- When will it break?
- Where will it break?

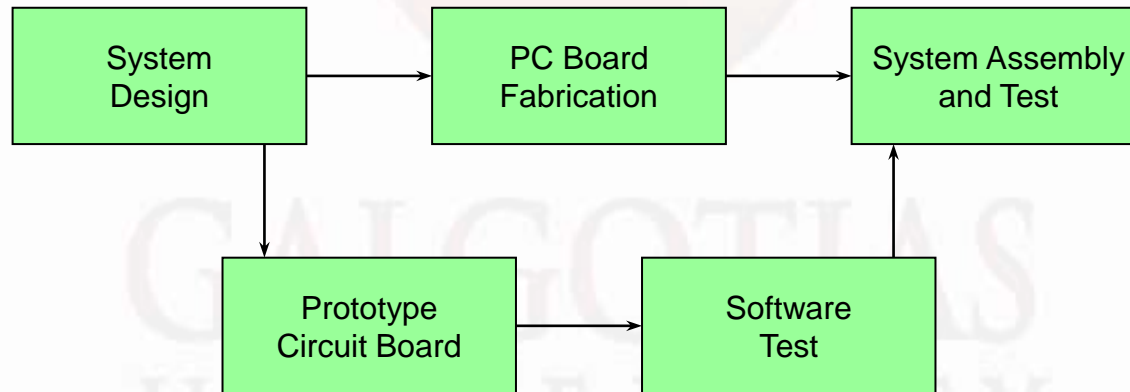


# Accelerating the Critical Path

## Conventional Process



## Process with Prototyping





# References

1. Karl T. Ulrich and Steven D. Eppinger (2009), Product Design and Development, 4<sup>th</sup> Edition, Tata McGraw-Hill Publishing Company Limited, ISBN: 978-0-070-14679-2
2. Stephen C. Armstrong (2005), Engineering and Product development Management– The Holostic Approach, Cambridge University Press, ISBN: 978-0-521-01774-9.
3. IbrahimZeid (2006), Mastering CAD/CAM, 2<sup>nd</sup> Edition, Tata McGraw-Hill, ISBN: 978-0-070-63434-3.
4. [Anoop Desai](#), [Anil Mital](#) and [Anand Subramanian](#) (2007), Product Development: A Structured Approach to Consumer Product Development, Design, and Manufacture, 1<sup>st</sup> Edition, Butterworth-Heinemann, ISBN: 978-0-750-68309-8.

**Thank you**

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