

## Reverse Design: Reverse Engineering and Benchmarking A Presentation for the MSTC Program-2011

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## Reverse Engineering:

- **Reverse engineering** is a legal process to make new products (drug, device or program) that does the same thing as existing products, but without duplicating the original. Reverse engineered products should be better than original. This covers the technology, economy, and availability aspects.

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## Reverse Engineering

- Reverse Engineering is the process of taking a finished product and reconstructing design data in a format from which new parts or molds can be produced.  
*The Society of Manufacturing Engineers (SME)*
- Reverse Engineering is the process of duplicating an item functionally and dimensionally by physically examining and measuring existing parts to develop the technical data (physical and material characteristics) required for competitive procurement."  
*Military Handbook MIL-HDBK-115 (ME)*
- In the United States reverse-engineering is lawful as long as it is done legitimately. {Wikipedia}

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## Content versus Context

- Reverse Engineering is the main topic and content of this presentation. But allow me to start with the Context of this topic.
- The presentation will covers a brief review of Classification of Innovation. This provides the Context for this presentation.
- Then I will concentrate on Reverse Engineering as the main Content.

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## U.S. Code for Reverse Engineering

- U.S. Code collection, TITLE 17—COPYRIGHTS, CHAPTER 9—PROTECTION OF SEMICONDUCTOR CHIP PRODUCTS, ([http://www.law.cornell.edu/uscode/17/uscode\\_sup\\_01\\_17\\_10\\_9.html](http://www.law.cornell.edu/uscode/17/uscode_sup_01_17_10_9.html))
- § 906. Limitation on exclusive rights: reverse engineering; first sale
- (a) Notwithstanding the provisions of section 905, it is not an infringement of the exclusive rights of the owner of a mask work for— (1) a person to reproduce the mask work solely for the purpose of teaching, analyzing, or evaluating the concepts or techniques embodied in the mask work or the circuitry, logic flow, or organization of components used in the mask work; or
- (2) a person who performs the analysis or evaluation described in paragraph (1) to incorporate the results of such conduct in an original mask work which is made to be distributed.
- (b) Notwithstanding the provisions of section 905 (2), the owner of a particular semiconductor chip product made by the owner of the mask work, or by any person authorized by the owner of the mask work, may import, distribute, or otherwise dispose of or use, but not reproduce, that particular semiconductor chip product without the authority of the owner of the mask work.

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## Innovation Classification

Major enterprise activities are classified into 4 main groups:

1. **How to Make:** Technology
2. **How to Sell:** Customer/Market
3. **How to Recruit and Retain Employees:** Human Resources
4. **How to Integrate Altogether:** Organization

Innovation and development happen in all aspects of enterprise activities. Innovation and development are not limited to technology.

- 1) **Technology Innovation / Development**
- 2) **Customer Development & Market Innovation**
- 3) **Human Resources Development (Learning and Creativity)**
- 4) **Organizational Development (Change and Leadership)**

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## The Innovation Map Model

- The different aspects of innovation have nonlinear relationship with each other. They are distinct; though they are linked.
- Technology often holds the most visible aspect of innovation and development. Technology, however, is not necessarily always the most important aspect of innovation. Examples: Dell, Southwest Airlines, Wal-Mart, Virgin Group.
- Organizational development often is the most important one; it plays the role of linking those to each other.
- The four aspects of innovation like four puzzles, and they are analogous to the continents of the World

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## Technological Innovation versus Organizational Innovation in America

This is a Technological Innovation

This is an Organizational / Social Innovation

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## Organizational Change: Easy or Difficult?

This picture represents a deficiency in organization, rather than in technology. Organizational innovation is difficult and time consuming! Organizational development/change is often the most challenging aspect of innovation.

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## Inception: The Origin of Business Ideas - 1

Each new business ideas has a distinctive patterns of development form its inception (origin). New business ideas may originate form many sources, which can be classified into 12 overlapping groups:

Technology  
Push

1. Research and Development (R&D)
2. Invention and Patent
3. Design and Development (D+D) – Forward Design
4. **Reverse Design: Reverse Engineering and Benchmarking** (Copying, Imitation and Adaptation)

Market  
Pull

5. Extensive Market Research to explore business opportunities: Societal changes, Demographic changes, etc.
6. Feedbacks from customers, suppliers, employees, etc. to uncover unarticulated needs

To be continued in next slide

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## Organizational Change: Easy or Difficult?

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## Inception: The Origin of Business Ideas - 2


7. Previous experience, education and hobby of entrepreneurs
8. Creative Thinking: 1) Individual creative thinking, e.g. metaphors, lateral thinking, mind mapping, etc., 2) Group creative thinking such as brain storming and 3) Organizational creative thinking and collective knowledge creation.
9. Symbiotic Ideas: Combining two or more existing ideas for a new application
10. Biomimetics (Biomimicry): Innovation Inspired by Nature, new business ideas based on observing natural phenomena. Example: Kook-and-loop fasteners (Velcro).
11. New regulations: Example Child's Car Seat
12. Eureka and Serendipity: New business ideas due to unexpended events!

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## Business Ideation: Inception and Distillation of business ideas

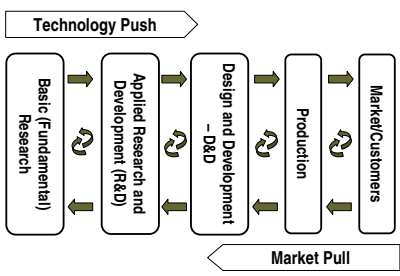
The beginning is the most important part of the work. Plato

- 1) **Inception:** Articulate the origin of the business idea
- 2) **Distillation:** Describe the evolution of the business idea from its inception to specific products (goods and services).



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## Technology Push vs. Market Pull



Technology Push / Market Pull  
is NOT the same as Forward / Reverse Design!

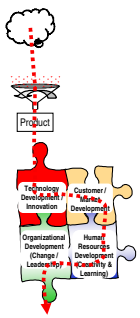
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## Ideation and Innovation

**Inception:** Articulate the origin of the business idea

**Distillation (Idea Funnel):** Describe the transformation of the business idea into specific products .

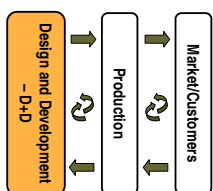
**Innovation Map Model:** Four aspects of innovation have nonlinear relationships with each other. They are distinct but are linked, like a map overlap each other. Organizational development often links them all.



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## Design and Development – D+D

Design and Development – D+D is one of the key aspects of Technology Innovation/Development

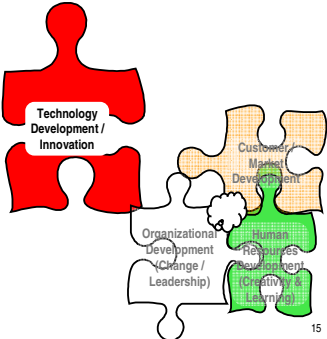


D+D aims at Production, which always intends at satisfy specific Market/Customer needs.

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## Design and Development – D+D in the Innovation Map Model

- The concept of Design and Reverse Design is applicable to all aspects of innovation
- In this presentation the emphasis is on the Design and Reverse Design for Technological Innovation.
- The role of Design Reverse Design in other aspects of innovation is reviewed separately.



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## Forward and Reverse Design

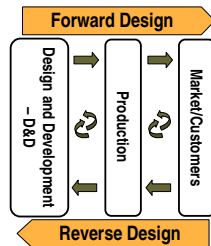
- **Forward Design** includes the forward flow of information that initiates from Design and Development to provide information needed for Production which leads to new products for the Market. Example: developing a new idea and take it from design to the market
- **Reverse Design** involves the activities to legally make a product similar or superior to one already available on the market. Example: taking an existing product in the market and then re-design it
- Forward and Reverse Design actually work hand in hand with each other. Reverse Design is often complementary to Forward Design that including activities from D&D to production and then marketplace.

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## Forward versus Reverse Design

Design and Development (D&D) embraces both **Forward Design** and **Reverse Design**.

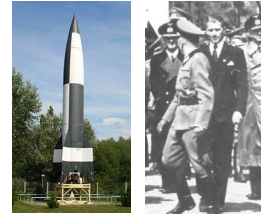
Forward engineering: From D&D to Product. Reverse Engineering: From an existing Product to D&D and back to Product, to improve it.



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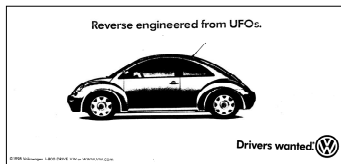
## Reverse Engineering of German Rockets

- The Allied forces at the end of WWII captured German V2 Rockets and related technologies.
- They initiated their postwar rocket program by using the technology of German rockets.
- The postwar Soviet program included R-1 (a reverse engineered model of V2).
- Soviets captured the rockets. Americans captured rocket designers!



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## Reverse Engineering



The most successful innovators are the creative imitators.

Peter Drucker (Interview with *The Wired*, Issue 4.08, August 1996)

First we observe and digest a new product. Then we imitate it. In the end, we understand it well enough to design a new product independently.

Zhang Ruimin, CEO of Haier, a Chinese Manufacturer of Refrigerator

SIS: Steal Ideas Shamelessly. (Steve Jobs?)

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## Reverse Engineering at GM

- "Inside GM's Vehicle Assessment and Benchmarking Activity Center, they take (apart) the competition very seriously."
- **The Teardown Artists**, "Wired Magazine", Feb. 2006, By Carl Hoffman:
- The GM Vehicle Assessment and Benchmarking Activity donates automotive parts to MIT PACE (Partners for the Advancement of CAD/CAM/CAE Education).



GM's Vehicle Assessment and Benchmarking Activity center is a reverse engineering graveyard. (Wired Magazine, Feb. 2006)

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## Reverse Engineering of Military Airplanes



On September 6, 1976, Lieutenant Viktor Belenko defected with his MiG-25 to Japan. The MiG-25, after being inspected by the Foreign Technology Division of the United States DoD, was returned to the Soviet Union. The MiG-25 was returned in **pieces, and in boxes!**

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## Reverse Engineering in the PC Industry: A Brief Case Story

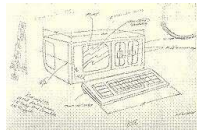
A study of the development of Personal Computer (PC) demonstrates the power of reverse engineering, building on the achievements of the competitors to advance the system.

1. **Hardware:** MITS, 1974 → ISAMI, 1976 → I.B.M. PC, 1981 → Compaq PC, 1983 → Dell PC, 1984
2. **Operating System:** Digital Research, CP/M → Seattle Computer, Q-DOS → Microsoft, MS DOS
3. **GUI (Graphical User Interface):** XEROX → Apple → Microsoft
4. **BASIC Language:** John Kemeny and Thomas Kurtz (Dartmouth College), 1964 → Microsoft (MS BASIC), 1975
5. **Spreadsheet:** VisiCalc, 1979 → Lotus 1-2-3, 1983 → Microsoft Excel, 1985
6. **Word Processing:** Word-Star, 1985, → WordPerfect, 1987 → Word, Microsoft, 1989

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## Compaq: Reverse Engineering of IBM-PC

- Rod Canion, Jim Harris and Bill Murto, were three senior managers at Texas Instruments (TI). After they were not able to convince TI to develop an IBM PC compatible computer, they left TI and pursued an independent (spin out) venture.
- **Inception:** Origin of the idea: Design and Development (major reverse engineering) and previous experiences of the founders.
- **Distillation:** Specific product: A "portable" personal computer able to run all of the software available for the IBM-PC.



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## Product Tear-downs



Figure 1. NTT FOMA Cellphone

**Product Tear-downs:** Identify the product, package, internal boards, and components

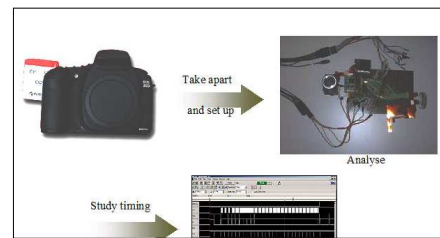
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## Reverse Engineering for Generic Drugs

- A **generic drug** is "a drug product that is comparable to brand/reference listed drug product in dosage form, strength, route of administration, quality and performance characteristics, and intended use. Generic drugs are subject to the regulations of the governments of countries where they are dispensed.
- According to the FDA, generic drugs are identical or within an acceptable bioequivalent range to the brand-name counterpart with respect to pharmacokinetic and pharmacodynamic properties. A generic drug must contain the same active ingredients as the original formulation.
- In most cases, generic products are available once the patent protections afforded to the original developer have expired. When generic products become available, the market competition often leads to substantially lower prices for both the original brand name product and the generic forms. The time it takes a generic drug to appear on the market varies. In the US, drug patents give 20 years of protection, but they are applied for before clinical trials begin, so the "effective" life of a drug patent tends to be between seven and 12 years.

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## System-Level Analysis



**System-Level Analysis :** Analyze operations, signal paths, and interconnections

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## Reverse Engineering of Electronics

**Reverse Engineering of Electronics** classifies Reverse engineering of electronics products into four major groups:

1. **Product tear-downs:** Identify the product, package, internal boards, and components
2. **System Level Analysis :** Analyze operations, signal paths, and interconnections
3. **Circuit Extraction:** De-layer to transistor level, then extract interconnections and components to create schematics
4. **Process Analysis:** Examine the structure and materials to see how it is manufactured and what it is made of.

Source: **Reverse Engineering of Electronics** (Dick James, 2006)

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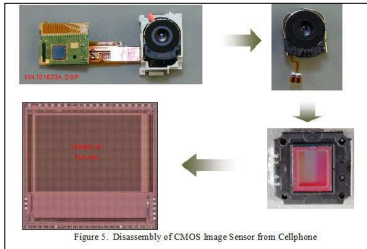
## Circuit Extraction



**Circuit Extraction:** De-layer to transistor level, then extract interconnections and components to create schematics

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## Process Analysis



**Process Analysis:** Examine the structure and materials to see how it is manufactured and what it is made of.

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## Wal-Mart and Reverse Engineering

- I (Sam Walton) read an article about these two Ben Franklin stores up in Minnesota that had gone to self-service—a brand-new concept at the time. I rode up the bus all night long to two little towns up there. They had shelves on the side and two island counters all the way back. No Clerks with cash registers around the store.
- I liked it. So I did that too. I became only the third self-service variety store in the whole country. It was a big deal.
- Source: Sam Walton Autobiography:

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## Benchmarking: Reverse Process Engineering

- Reverse Engineering is not limited to product design, it also covers process design.
- Benchmarking (also called "best practice benchmarking") is a **Reverse Process Engineering** used in management.
- In benchmarking organizations evaluate various aspects of their processes in relation to best practice, usually among its main competitors, or sometimes in other sectors.
- Benchmarking (Reverse Process Engineering) allows organizations to learn from their competitors, as well as from other prominent players to adopt such best practice, usually with the aim of increasing some aspect of performance.
- Benchmarking may be a one-off event, but is often treated as a continuous process in which organizations continually seek to challenge their practices.

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## Xerox: American Samurai for Benchmarking

- In the 1950s, 1960s and 1970s Japanese companies used Benchmarking to learn from their major counterparts, like Deming statistical analysis.
- Canon used a combination of extensive reverse product engineering, reverse process engineering, intensive D+D efforts (and may be spice of R&D) to become a major player in the paper-based copying (xerography).
- Xerox in the mid 1995, when faced tough competition from major Japanese companies in his own backyard (paper-based copying) used **benchmarking to learn from Japanese companies**. This is discussed in *Xerox: American Samurai*.
- But Xerox's has done reverse engineering many times before.
- On April 22, 1970 IBM introduced its first office copying machine, the Copier I. ... Xerox was so concerned that it purchased one of the first machines available and ran it.

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