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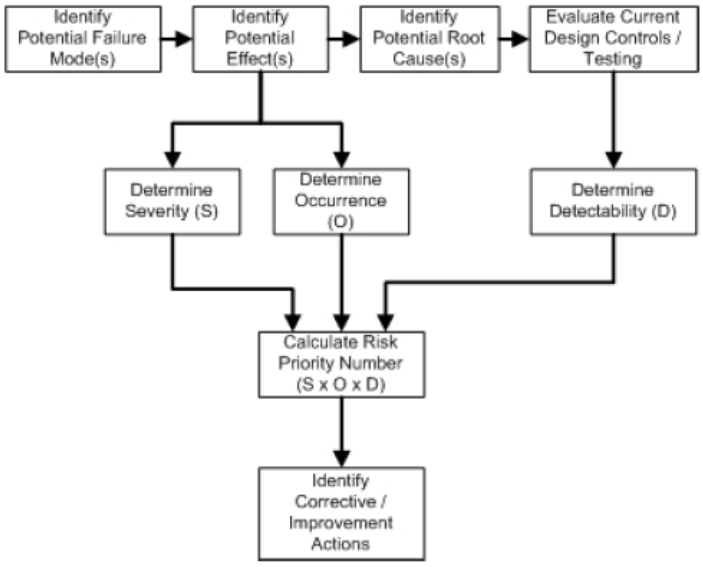
Automating FMEA:
Next-Generation Failure Analysis from NANEVA

By Bruce Jenkins, President, Ora Research LLC

Failure mode and effects analysis, or FMEA, is a systematic technique for failure analysis originally developed by reliability engineers in the 1950s to study problems that might arise from malfunctions of military systems. Broadly defined, FMEA today is "a systematic group of activities intended to: (1) recognize and evaluate the potential failure, (2) identify actions that could eliminate or reduce the chance of the potential failure occurring, and (3) document the entire process" *(AIAG, "Potential Failure Mode and Effects Analysis (FMEA)," 3rd ed., 2001).* Primarily a qualitative rather than quantitative analysis, FMEA is an inductive process based on experience with similar products and processes, or on common physics of failure logic.



Standard FMEA development process

Source: "The Role of Automated FMEA in Automotive Reliability Development,"
Bradley W. Semp, Ayaz Pathan, Patrick E. Dessert, *SAE Technical Paper Series 2006-01-1619*

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For any given product or process design, FMEA seeks to answer five key questions:

- How can the application fail? (failure mode)
- How likely is each mode of failure? (occurrence)
- What is the effect of the failure? (failure effect)
- How critical is the failure effect? (severity)
- What can be done to reduce the risk of this failure? (design controls)

In practice, an FMEA involves reviewing as many components, assemblies and subsystems as possible to identify failure modes and their causes and effects. For each component, the failure modes and their resulting effects on the rest of the system are recorded on an FMEA worksheet.

NANEVA: Need and opportunity

Despite a half-century of application, FMEA practice clearly has yet to deliver on its full potential. The daily news is rife with reports of product after product failing or malfunctioning in the course of ordinary use, often with dramatic impact. The exploding-tire episode suffered by Ford and Firestone resulted in 203 fatalities, more than 700 injured, over 1000 lawsuits, and costs that ultimately topped $3 billion. Battery fires in Dell, Sony and Apple products led to 5.9 million units recalled, $400 million in costs, and untold damage to users' property and effects. The costs of NASA's Challenger and Columbia tragedies of course included loss of life, monetary damages in the billions, and deep blows to NASA's reputation and standing.

At present, global manufacturers spend between 15% and 30% of annual revenues on correcting existing quality problems.[1] Some 60% of these defects arise from inadequate designs, while another 32% stem from manufacturing process deficiencies.[2] The resulting costs in annual reported product warranty claims total $30 billion in the U.S. alone.[3] Indeed, just in consumer-product incidents in the U.S., costs associated with death, injuries and property damage are $700 billion.[4]

Failure discovery today: Meager and unreliable

The primary method used by manufacturers to identify potential failures, FMEA is legally mandated in the automotive, medical device, aerospace and many other industries. However, as currently implemented, it is too often a hit-or-miss affair.

[1] "The Juran Institute Research on Cost of Poor Quality," Juran Institute, Inc., August 2005.
[2] *Product recall research*, commissioned by Consumer Affairs Directorate, U.K. Department of Trade and Industry, carried out by Sambrook Research International, April 2000.
[3] "Product Warranty Claims, 2003-2006," *Warranty Week*, April 11, 2007.
[4] Testimony of the Hon. Hal Stratton, Chairman, U.S. Consumer Product Safety Commission, Submitted to the House Appropriations Subcommittee on Transportation, Treasury, and HUD, the Judiciary, DC, April 14, 2005.

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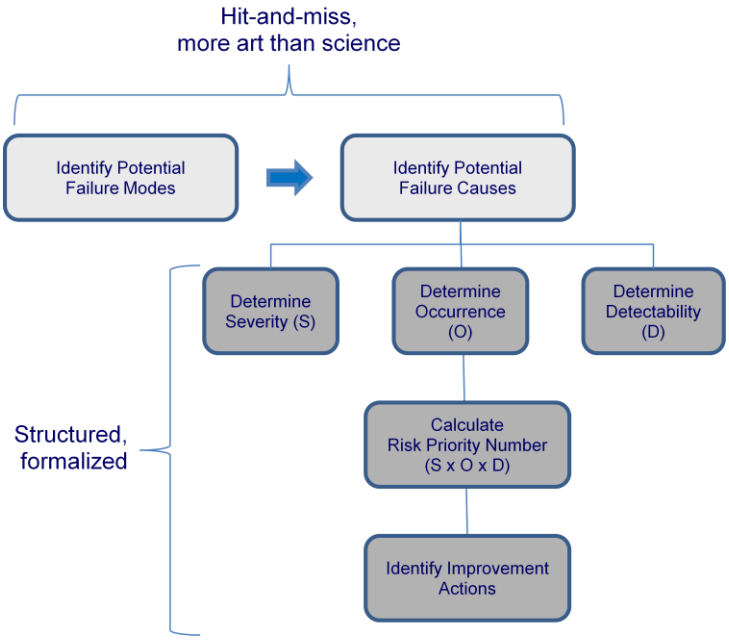
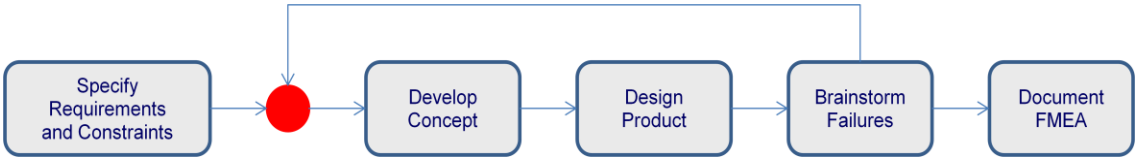


Drawbacks in contemporary practice abound. Most often FMEA takes place late in the product development process. It's mostly component-based, thus it begins only after a design has been locked. It adds to overall development costs. It's time-consuming, taking weeks if not months, and its duration grows nonlinearly with increasing product complexity. It's subjective, being based on the experience and expertise of individual practitioners – and even seasoned experts often miss critical failures.



FMEA in a typical product development process

NANEVA's solution: Automated, knowledge-based prediction

The founders of NANEVA, Inc. (West Bloomfield, MI) set out to address these shortcomings. The company's solution, called TechScan, is a tool for *automated predictive system diagnostics*. In sum, the software is designed to:

- Automate failure mode and failure cause discovery
- Model functional behavior of the system
- Be domain-independent
- Identify failure propagation paths across all levels of a system's hierarchy

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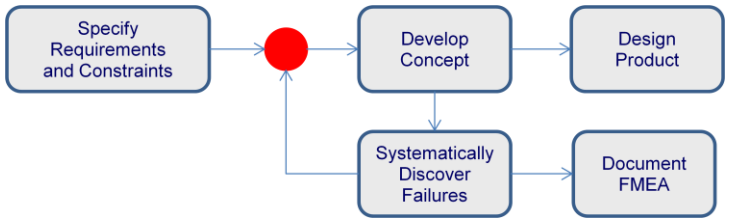


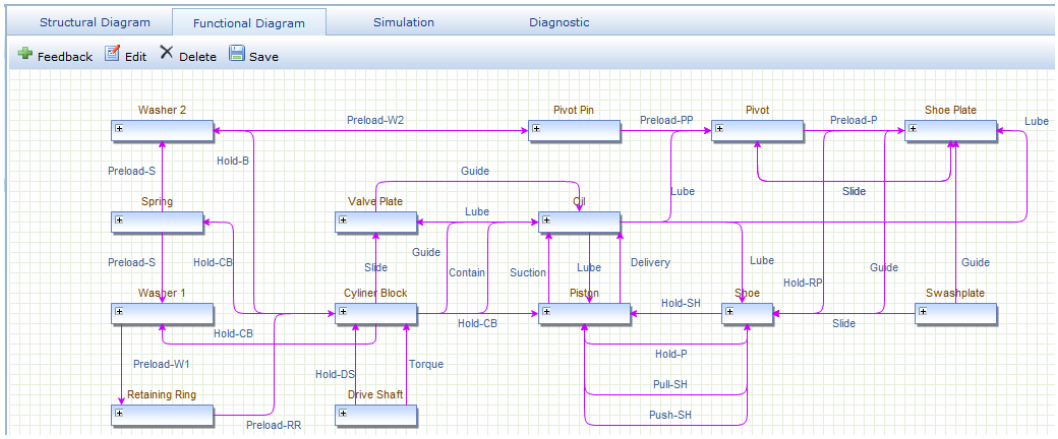
TechScan-supported product development process

Key improvements in the product development process enabled by TechScan are that FMEA:

- Takes place early in product development
- Is both component- and system-based, thus begins at the inception of product development
- Reduces overall development costs – a critical cost-saving factor is a 70%-90% reduction in time that would be spent by engineers performing the required FMEA analysis conventionally
- Is knowledge-based, utilizing knowledge from various areas of science and engineering, and covering a very large failure space

How TechScan works

1. Create behavioral model of the system ("streams" of functions, energy, and materials that flow through system components)
2. Generate an array of potential system behaviors
3. Isolate faulty behaviors and reveal failure propagation paths (failure modes and failure causes)
4. Result: Auto-populated, customized failure (FMEA) report showing all system components and associated failure modes and causes



Generic variable-displacement pump:
TechScan functional diagram

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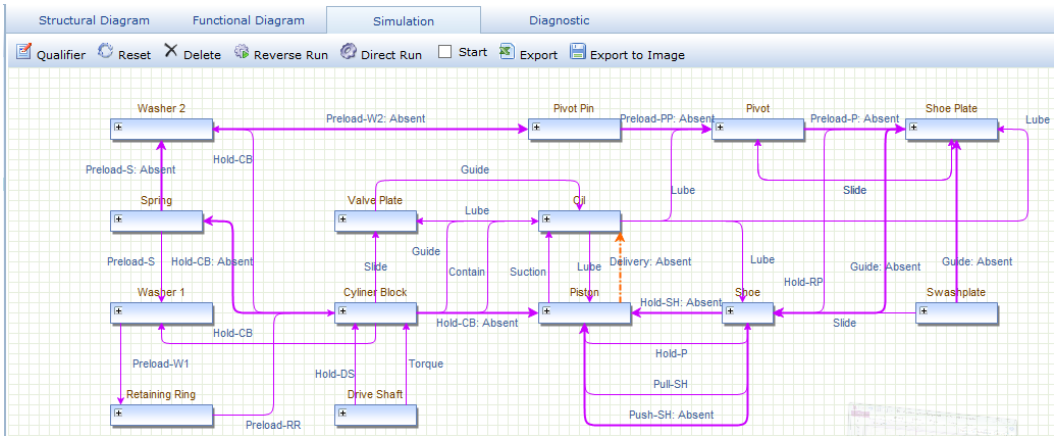

Generic variable-displacement pump:
TechScan simulation diagram
The red arrow shows a major failure: absent pumping action.
The bold blue arrows show cause-effect chains leading to this failure.

Failure Mode and Effects Analysis
(Design FMEA)

___ System
___ Subsystems
___ Component :
Model Year / Vehicle (s) :
Core Team :

Design Responsibility :
Key Date :

Item / Function	Potential Failure Mode	Potential Effects of Failure	S E	Cla ss	Potential Causes / Mechanisms of Failure	Current Design Controls Prevention	O C	Current D
Piston/Delivery	Absent				1.Water corrosion			
					2.Clearance cylinder block-piston too low.			
					3.Cavitation errosion			
					4.Shoe/Push-SH:Absent Shoe does not transmit force to piston			
					4.1.Clearance cylnder block-shoe too low			
					4.2.Retainer Plate/Guide:Absent Retainer plate does not transmit force to shoe			
					4.2.1.Excessive heat causes excessive deformation			
					4.2.2.Pivot/Preload-P:Absent Pivot preload absent			
					4.2.2.1.Pivot Pin/Preload-PP:Absent Pivot Pin preload absent			
					4.2.2.1.1.Washer 2/Preload-W2:Absent Retaining Ring preload absent			
					4.2.2.1.1.1.Spring/Preload-S:Absent Absent sping force			
					4.2.2.1.1.1.1. Spring:Not installed Spring not installed			

Generic DFMEA report automatically generated by TechScan, partial view
Contains 64 potential failure causes of this one potential failure mode

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Competitive positioning

Existing software products for FMEA fulfill the functions of tracking, re-using and leveraging existing data to provide increased visibility and collaboration, in NANEVA's assessment, but do not enable the primary objective of *discovering* failures, nor do they *automate* failure discovery. This table is how NANEVA summarizes TechScan's advantages over conventional failure analysis tools and work processes:

Parameter	Vs. Conventional Failure Analysis
Time savings	70%-90%
Failure discovery	10%-25%
Failure cause discovery	Up to 300%
Tool for NPD/concept development	Rapid what-if testing
Tool for problem solving	Exhaustive list of causes provides directions for investigations
Tool for understanding impact of design changes	Changes are quickly modeled and analyzed to determine potential failures and their causes
Tool for developing a comprehensive troubleshooting guide	Significantly shortens the time to develop troubleshooting guides

TechScan is designed for use as a fully functional standalone tool. Potential future collaborations envisioned by the company include TechScan complementing existing FMEA applications, serving as an add-on to simulation applications, and broad integration with PLM (CAD/CAE) solution suites.

Beyond engineering, NANEVA foresees potential for non-technological applications of its software in health care, insurance, banking and other fields where FMEA principles and practices can deliver value.

Status and direction

To date NANEVA has completed a functional prototype of TechScan and conducted proof-of-concept engagements with several Fortune 500 manufacturers, to what it reports has been enthusiastic reception. It's now targeting product release and go-to-market for the fourth quarter of 2013.

The company is currently working to form co-development partnership(s), establish marketing/sales channels, and secure venture backing.

Who is NANEVA?

NANEVA's founders are seasoned technology innovators with deep expertise in enterprise-scale software product and service delivery.

David Mayer, CEO and co-founder, brings a decade of experience in marketing and selling to C-level executives, as well as previously running the day-to-day operations of The TRIZ Group, LLC, a Michigan-based consulting firm specializing in product concept and solution development. For the past eight years

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he has been responsible for shaping The TRIZ Group's marketing and sales agenda. Through his initiatives, The TRIZ Group garnered the business of such diverse clients as Avon, Borden Chemical, Dow, Phillip Morris, Sherwin-Williams, TRW Automotive, USG and Whirlpool. Prior to The TRIZ Group, Mayer was marketing and sales director at PHLburg Technologies, a Philadelphia-based technology transfer firm specializing in technology transfer projects between the U.S. and Russia.

Victor Fey, CTO and co-founder, is responsible for overall product development. Fey is a founding partner of The TRIZ Group. Since The TRIZ Group's inception in the early 1990s, he has acquired nearly two decades of corporate business experience serving the Global 500; in this project management capacity, his work includes teaching, coaching, consulting, facilitating and leading corporate cross-functional teams in delivering critical breakthrough product and technology solutions. Fey is recognized as one of the world's leading experts in the TRIZ methodology for systematic innovation, and has lectured on the subject at MIT, Stevens Institute of Technology, Chalmers University, Technion and elsewhere, and is an adjunct professor in Wayne State University's Mechanical Engineering Department. He used TRIZ to develop the predictive system diagnostics algorithms (PSDA) that are the foundation of TechScan. He has authored or co-authored eight patents, over 30 papers, and four books. His latest books include *Effective Innovation: The Development of Winning Technologies*, published by ASME Press in 2004 (co-authored with Dr. Don Clausing of MIT), and *Innovation on Demand: New Product Development Using TRIZ*, released by Cambridge University Press in 2005 (penned with Dr. Eugene Rivin).

Dr. George Davelman, Chief System Architect and co-founder, has more than three decades of software development experience architecting and managing development of new solutions in varied industries including biomedical, aerospace and corporate finance. Responsible for overall system development at NANEVA, Davelman has previously designed and implemented software solutions for General Motors, Ford, Chrysler, Borders.com, Bosch and other large, medium and small companies. He was the lead architect on several multi-million-dollar projects including the Engineering Portal and Design Verification System at Ford Motor Company, data delivery and search systems at Borders.com, and the eContracting solution at Chrysler Financial Services. Over the past several years he has held leading positions at EMC/Documentum and Tata Consultancy Services Limited – Automotive Division (TCS Automotive), charting strategic directions and developing technical polices for the companies. Together with NANEVA CTO Fey, he developed the TechScan prototype.

For more information, visit www.nanevacorp.com.

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About Ora Research

Ora Research's focus is the business and technology of twenty-first century engineering practice. Our mission is to identify best practices for creating highly engineered manufactured products and high-performance built assets using the latest digital technologies. We seek to identify technologies and attendant work processes that are yielding high return for initial adopters, and are on the cusp of crossing over to first-wave mainstream acceptance.

We aim to inform and guide professionals with fresh information about these technologies and their successful adoption and application. For engineering, manufacturing and construction organizations and capital asset owner/ operators, we offer reports, consulting services and white papers to aid in selecting and deploying new technologies. For technology developers, we qualify and quantify new market opportunities and validate demand drivers. Our goal is to foster insight and action to strengthen the industries we serve.

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