Managing Risk and Uncertainty: Traditional Methods and the Lean Enterprise

Presented By
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MIT/LAI
April 18, 2006

Introduction

- My background
  - USAF Academy, BS Engineering Sciences, 1994
  - Experience in Air & Space Acquisition, Space Operations
    - Logistics Center (Ogden)
    - Product Center (SMC)
    - Space Operations (Buckley)
  - Spectrum of Duties
    - Chief Systems Engineer
    - Deputy Program Manager
    - Executive Officer
    - Branch Chief
  - Major in USAF

- Previous LAI experience
  - Master's Student at MIT 1998-2000, SDM Program
    - Thesis title: Best Practices in User Needs/Requirements Generation

"The views expressed in this presentation are those of the author and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the U.S. Government. "

Agenda/Overview

- **Review of Recent LAI research**
  - **Josef Oehmen**
  - **Steve Bresnahan**
  - **McManus/Hastings**
  - **Research Conclusions**

- **My Proposed Research**
  - **Motivation for study**
  - **Areas of Interest**

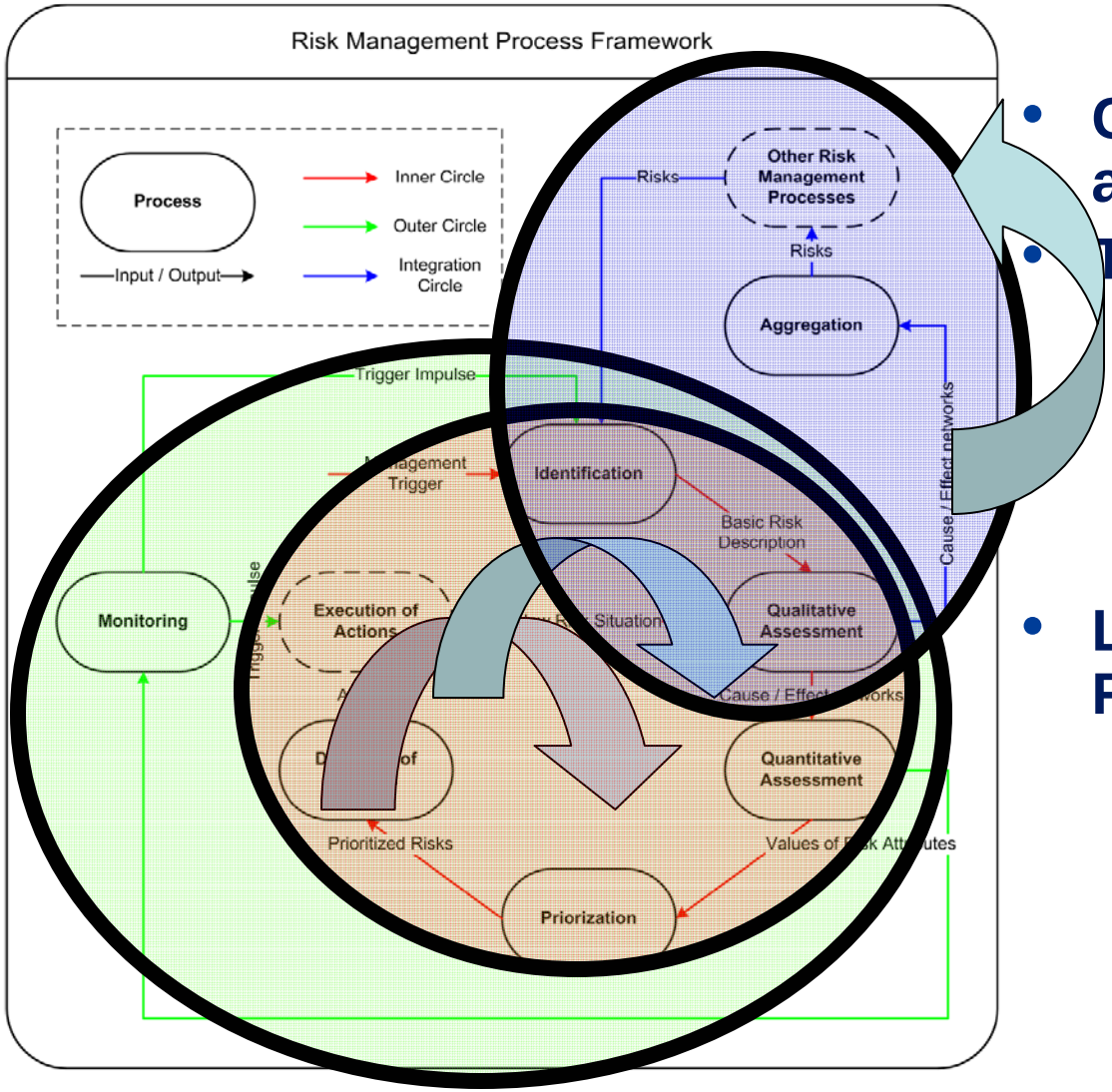
Snapshot of Recent Research

- **Josef Oehmen– Approaches to Crisis Prevention in Lean Product Development by High Performance Teams and Through Risk Management**
- **Dr. Hugh McManus & Professor Daniel Hastings - A Framework for Understanding Uncertainty and its Mitigation and Exploration in Complex Systems**
- **Steven Bresnahan – Understanding and Managing Uncertainty in Lean Aerospace Product Development**

Previous LAI Research

- **Dr. Tyson Browning – Reducing Uncertainty in Product Development Projects**

A *Risk Management* Framework



- **Collection of Processes and Inputs/Outputs**
- **Three Basic Loops**
  - **Project Risk Management**
  - **Risk Monitoring and Metrics**
  - **Integration with Higher Management**
- **Literature Review of Risk Management**
  - **75 different RM methods found**
  - **Only 1 method for Higher Management found ("Aggregation")**

Oehmen, J., *Approaches to Crisis Prevention in Lean Product Development by High Performance Teams and Through Risk Management*, Master's Thesis, Technical University of Munich, 2005.

Literature Review of Different Risk Management Methods

General Methods	Methods for Identification	Methods for Qualitative Risk Analysis	Methods for Quantative Risk Analysis	Methods for Prioritization	Methods for Definition of Actions	Methods for Monitoring	Methods for Aggregation
Fault Modes, Effects and Criticality Analysis	Identification by Failure Modes	Qualitative analysis with Risk Scenarios	General Classes of Impact, Likelihood, and Time Component	Top 10 Risk Ranking	Classification of Actions	Review of Actions initiated	Total Risk Scenarios
- FMECA 2-4	Cause Structure – Failure Mode Matrix	Decision Tree Analysis	Risk Data Quality Assessment	Pareto Analysis	Action Plan	Project Risk Management Panel	
- FMECA 5-6	Identification by Checklist	5 Whys	Quantification by Group Consensus	Sensitivity Analysis	Application of Problem Solving Cycle	Monitoring of Expected Losses	
- FMECA 7,8,11	Interviews	Ishikawa or Fishbone Diagram	Quantification by Assignment to Experts	Utility Function	Risk Reduction Leverage	Measuring Risks Prevented	
- FMECA 9, 10	Review of Documentation	Risk Categorization	Quantification by team-based Delphi	Nominal Group Technique		Measuring Impact Mitigation	
RISK Value Method	Identification by Brainstorming	Cause-oriented Event Sequence Diagrams	Failure Rate Tables	Weighted Multivoting		Counting New Risks Identified	

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Literature Review of Different Risk Management Methods, pg 2

General Methods	Methods for Identification	Methods for Qualitative Risk Analysis	Methods for Quantative Risk Analysis	Methods for Prioritization	Methods for Definition of Actions	Methods for Monitoring	Methods for Aggregation
- RVM 1	Identification by SWOT	Fault Tree Analysis	Statistical Quality Control			Reserve Analysis	
- RVM 2	Identification by Work Breakdown Structure	Reliability Block Diagram	Statistical Reliability Test			Unidentified but later occurred risks	
- RVM 3	Requirements Analysis	Part Count Method	Calculation-based quantification of likelihood			Risk Management Index	
- RVM 4	Identification by Key Characteristics	Impact-oriented Event Sequence Diagram	Risk Timeframe/ Urgency Assessment			Other Tactical Metrics	
- RVM 5	Geometry-based Variation simulation		Calculation of Expected Loss			Risk Inventory	

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Literature Review of Different Risk Management Methods, pg 3

General Methods	Methods for Identification	Methods for Qualitative Risk Analysis	Methods for Quantative Risk Analysis	Methods for Prioritization	Methods for Definition of Actions	Methods for Monitoring	Methods for Aggregation
	Identification by Stress Factors		Risk Matrix for Likelihood and Impact			Monitoring of Risk Map	
	Identification by Project Schedule		Expected Monetary Value Analysis			Scenario-based Tracking	
	Identification by Generic Development Process		Probability Distribution of Impact				
			Monte Carlo Simulation				
			Risk Severity				

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A Notional *Risk* Framework

Uncertainties

- Lack of Knowledge
- Lack of Definition
- Statistically Characterized Variables
- Known Unknowns
- Unknown Unknowns

Risks/ Opportunities

- Disaster
- Failure
- Degradation
- Cost/Schedule (+/-)
- Market shifts (+/-)
- Need shifts (+/-)
- Extra Capacity
- Emergent Capabilities

Mitigations/ Exploitations

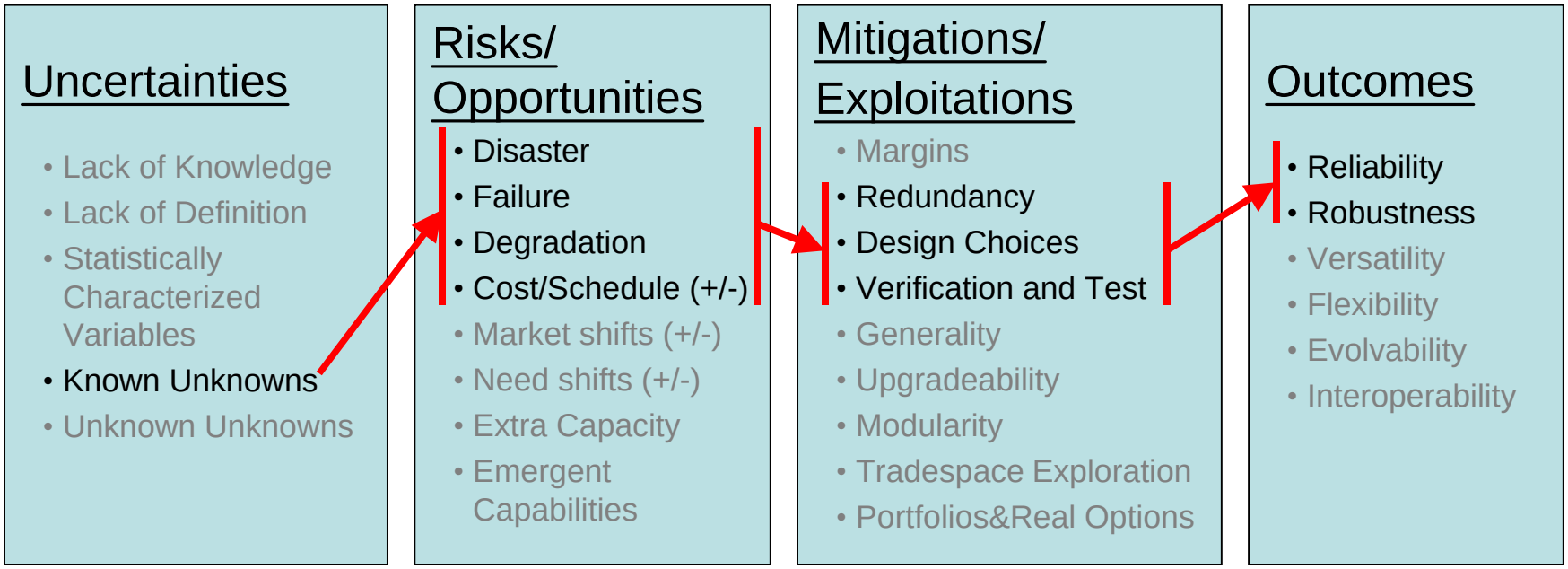
- Margins
- Redundancy
- Design Choices
- Verification and Test
- Generality
- Upgradeability
- Modularity
- Tradespace Exploration
- Portfolios & Real Options

Outcomes

- Reliability
- Robustness
- Versatility
- Flexibility
- Evolvability
- Interoperability

<Uncertainty> causes <Risk> handled by <Mitigation> resulting in <Outcome>

Application of Risk Framework



Bottom Line: The type of risk encountered dictates the path to take. Not all risks have the same attributes and pathways.

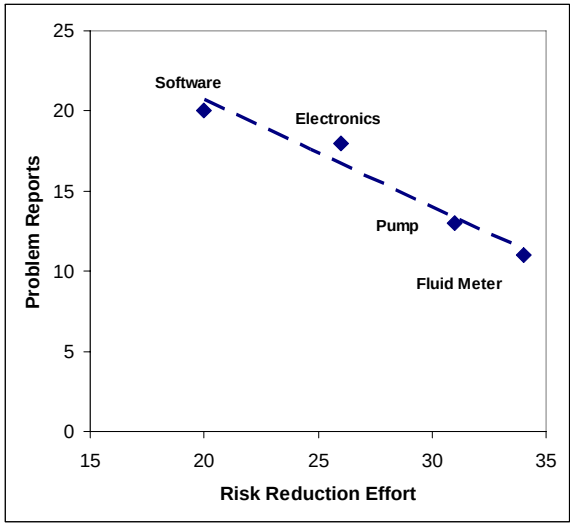
Risk Management Case Study

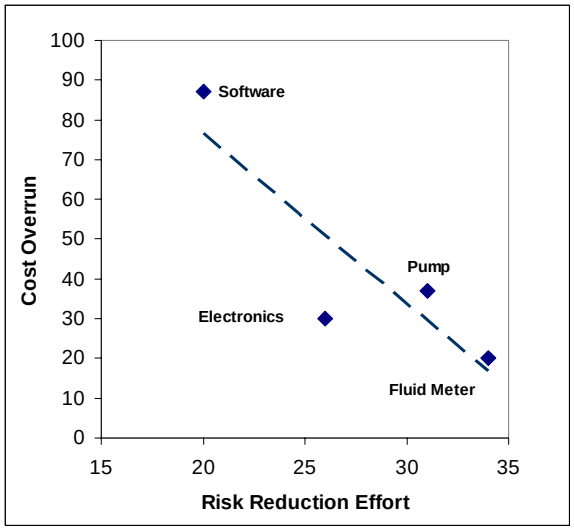
- **Scenario: an aerospace commercial aircraft system in product development**
  - **Four different teams responsible for numerous subsystems**
  - **Relative success of each team is summarized**
    - **All of the teams experienced problems – and most were not technical in nature**

Generation of value is linked to the reduction or elimination of product risks and uncertainties

Bresnahan, S. M., *Understanding and Managing Uncertainty in Lean Aerospace Product Development*, Massachusetts Institute of Technology, 2006.

Case Study Results: Performance





- **Horizontal axis shows relative amount of risk reduction effort applied during subsystem development**
- **Vertical axes show number of problem reports and cost overrun percentage**

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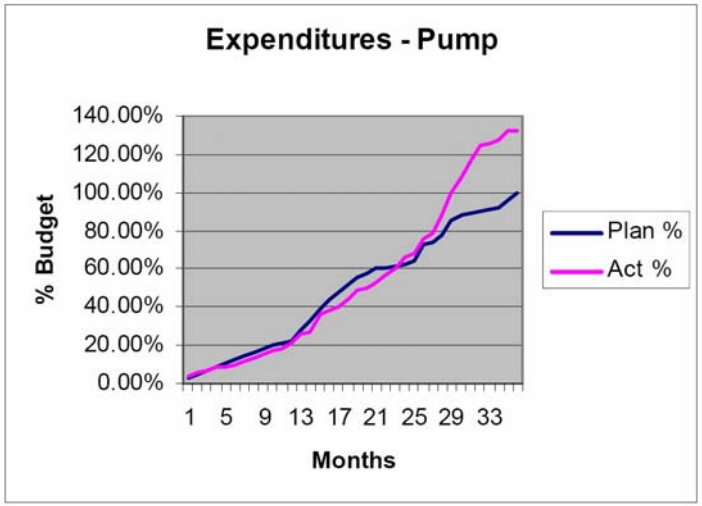
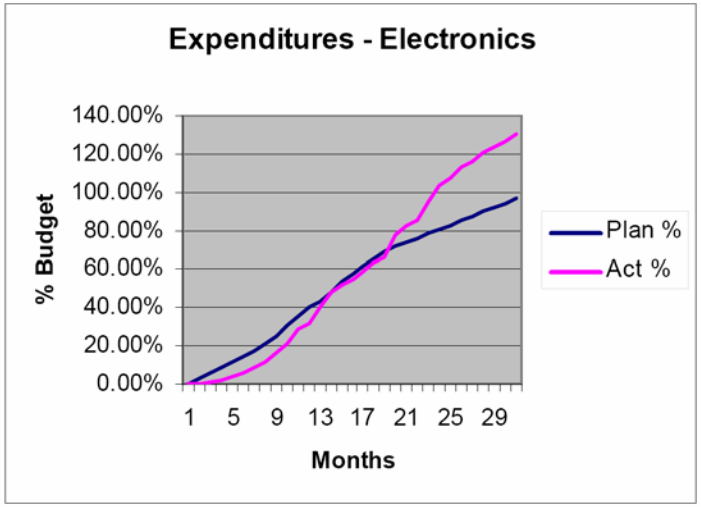
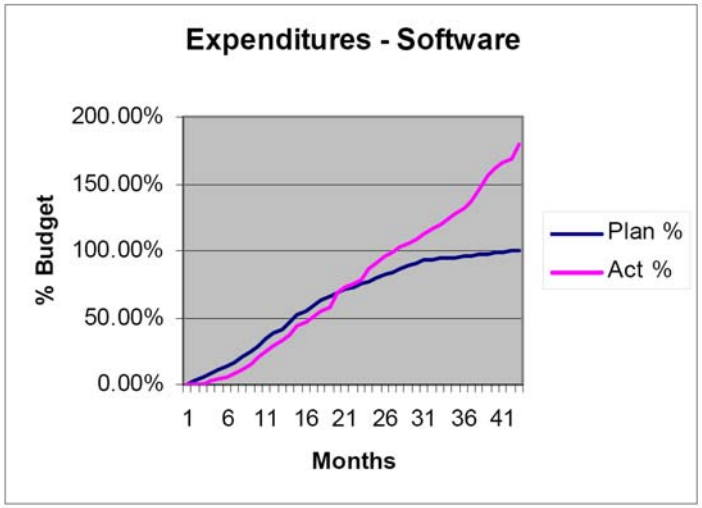
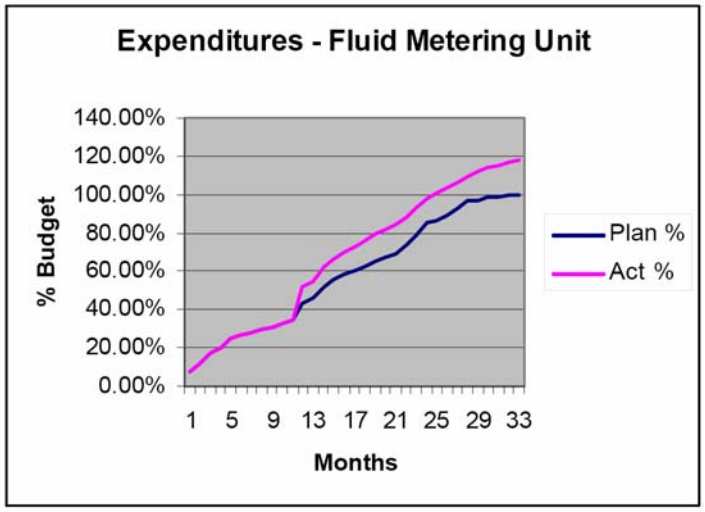
Case Study Results: Economic Impact

Artifact of Risk: spending of the budget vs. the planned budget expenditure over time









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Mitigation Activity Effectiveness: Survey Results

Leading engineers and managers asked "Which classical risk mitigation activities were effective versus these types of uncertainty?"

Uncertainty type / Mitigation activity	Variability	New Technology	Enterprise Capability	Customer	System Interactions	Design errors	Life Cycle Concerns
Simulation	✓	✓			☑		
Supplier Integration	✓	✓	☑		✓		☑
Customer Integration				☑	✓		
Prototyping	✓	☑	✓	✓	✓	☑	
Design Reviews				✓	✓	✓	✓
Set-Based Design		✓					
Resue	✓			✓	✓	☑	✓
Standard Work	✓		✓		✓	☑	
Upgradeable Architectures		✓	✓	☑	✓	✓	☑
Design Margin	☑				✓		✓
Integration Test	✓	✓	✓	✓	■	✓	
Tolerance Control	■				✓		
Industry Standards	✓		✓	✓	☑	✓	✓
DFX	✓	✓	✓	✓	✓	✓	☑
Sensitivity Analysis	✓	✓			☑	✓	✓
Organizational Mitigation			✓				

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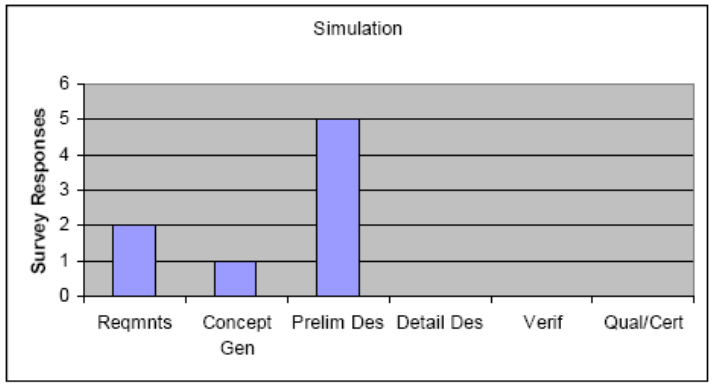
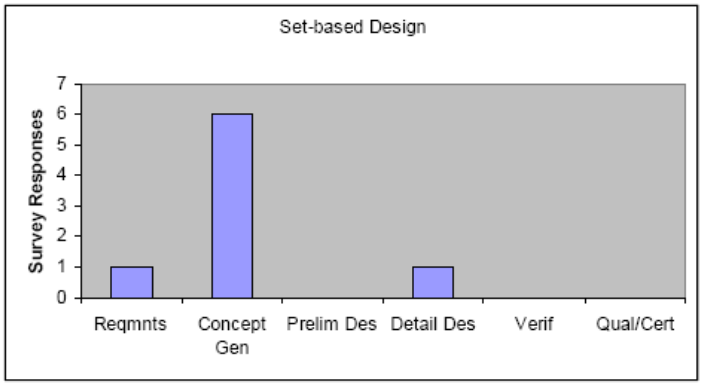
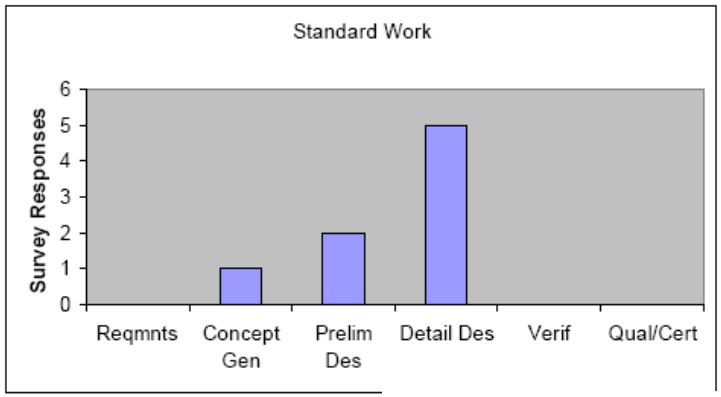
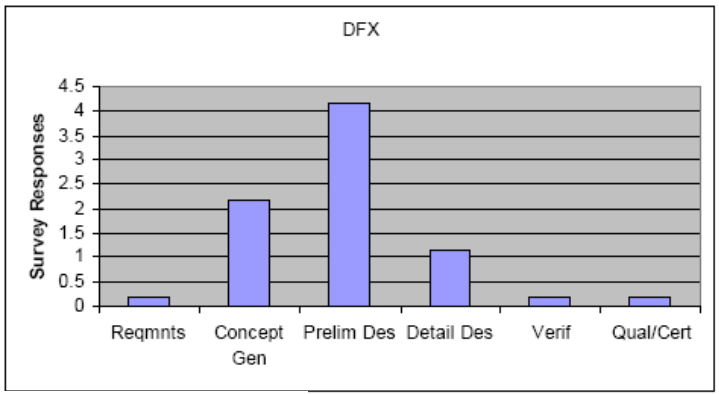
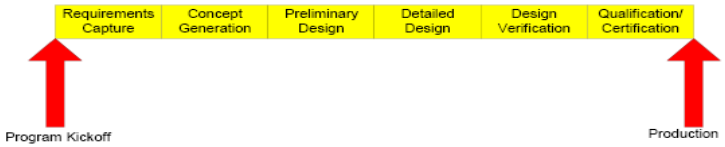
Selected Examples of Program Timing: Survey Results











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Framework for Risk Mitigation by Program Phase

Recommendations based on survey results

Review	Recommended Criteria
Stage Gate 1 – After requirements capture and prior to concept generation	• Review customer integration activities which should be complete (customer risk) • Establish plans or targets for reuse(design errors, variability), set-based design (new technology), supplier integration (enterprise capability) and/or, upgradeable architectures(life cycle concerns, interactions) for the next phase of the program
Stage Gate 2 – After concept selection and prior to preliminary design	• Review results against plans established in stage gate 1 • Establish plans or targets for prototyping (new technology, design errors, enterprise capability, customer), simulation (interactions), sensitivity analysis(variability, interactions) and/or DFX(life cycle concerns).
Stage Gate 3 – After preliminary design and prior to detailed design	• Review results against plans established in stage gate 2 • Establish plans or targets for standard work (design errors, interactions, enterprise capability), tolerance control and margin allowances (variability), design reviews (customer, life cycle)
Stage Gate 4 – After detailed design and prior to verification	• Review results against plans established in stage gate 3 • Establish plans or targets for integration test (interactions)
Stage Gate 5 – After verification and prior to certification	• Review results against plans established in stage gate 4 • All risks should be reduced adequately by this time

Different methods are useful in different program phases…using multiple methods simultaneously is useful in different program phases

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LAI Research Take-aways

- **Frameworks for Risk, Risk Management, and Risk Mitigation developed**
  - **Oehmen suggests additional RM tools and provides a thorough RM methods literature search**
  - **Bresnahan, McManus/Hastings have frameworks for approaching Risks/Risk Management depending on task or program phase.**
    - **Frameworks provide different ways to approach and understand Risk and Uncertainty for the practitioner**
- **Bresnahan shows the tangible impact of overall RM performance as well as effective methods based on experience from leading engineers and managers.**
  - **Data illustrates the positive relationship between reducing waste in lean product development (risk and uncertainty) and adding value**

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Why Study Uncertainty & Risk (even more)?

- Risk Management can still be improved
  - Young Commission
  - Blue-ribbon panel
  - DAPA panel report
- Acquisition of systems have run into trouble
  - Space portfolio missteps (cost, schedule, performance)
  - Other portfolios
- USAF putting together a "Risk-based Decision Making" process for Portfolio Managers
  - Outgrowth of Future Acquisition Team discussions on metrics
  - Designed to bring "Risk-Based Decision-Making" to the USAF in Acquisition
- New PD Enterprise Framework implies strong link
  - Dynamic nature of uncertainty and risk & Proposed metrics suggest its importance at the Enterprise level

Observations

- **Risk Management methods and tools are rich in number, variety, and application**
  - **Given the experiences of the past, what makes or breaks these methods?**
    - **Organizational design? "Cognitive capability of organizations?"**
- **Coping with uncertainty gets "harder" when viewed in context of the overall Enterprise**
  - **Multiple programs can create cascading effects among other programs or cause unforeseen interactions**
  - **Causal paths originating outside of program / company / Enterprise impossible to predict and foresee**
    - **What are the best ways to prepare for and handle them?**

Are these issues important to you? What kinds of things relating to uncertainty and risk be valuable to you?

My Interests

- Understand the causal relationships between communication paths, different project types, and Enterprise Uncertainty
  - Hypothesis: Different organizational structures (for various project types) exist that effectively mitigate uncertainty and minimize risks
    - At Enterprise level
    - At Project level
  - Want to examine:
    - Multiple Companies portfolios of projects
    - AF Acquisition portfolio(s) (e.g. Space, Aircraft)
- Goal: Tool/methodology to predict organizational effectiveness vs. uncertainty in Product Development and way to select appropriate org design for uncertainty

Backups

Conclusions

- **Part I: Overview of past LAI research**
  - **Useful frameworks exist**
  - **Methods/tools/literature robust at project & system level**
  - **Demonstrated goodness of risk management (cost, schedule, performance) in Product Development**
- **Part II: My research**
  - **Enterprise interactions/contributions to uncertainty**
  - **Aggregation methods are underrepresented in RM literature**
    - **an opportunity for further research?**
  - **Provide an original contribution to the body of knowledge**

Areas of Interest

- **Enterprise Management: practiced daily by portfolio managers and others**
  - **What methods and metrics are they using and how effective are they?**
  - **Are method outcomes and metrics selectively used by decision-makers to make decisions? Why?**
- **Additional Focus Areas:**
  - **Decision Analysis**
  - **Portfolio Management**
  - **"Traditional Risk Management"**
    - **Scaling attributes to an Enterprise level**
  - **Explore gap noted in the research literature**
    - **Good methods of "Aggregation" (corporate level RM) are notably lacking or not mature**

Personal Motivation

- **Previous research on the Front-End leads to Risk Management**
  - **Evidence suggests if done well early; better outcomes**
- **Personal experience**
  - **Risk – often emphasized & used differently in programs**
  - **Difficult to predict problems trouble a priori**
- **New area of research: just starting**
  - **I also see AF team activities and recognize its importance**
  - **Part of team's effort to arrive at integrated product for Enterprise PD.**

Basic Attributes of Risk

- ***The probability of occurrence**, based on a (more or less complex) causal structure.
- ***The type of the risks impact****
- ***The timeframe of the risks development****
- ***Causal networks describing the causes and effects of the risk**** **(e.g. scenarios).**
- ***Hazards*** **arising from the product itself or the processes used to produce the product**

Research will scale these attributes to the Enterprise Level

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How & Where Does RM tie into Lean Product Development?

- **Lean PD should manage and decrease the uncertainty surrounding *product attributes* (Lead Time, Lifecycle Cost, Performance)**
- **Lean PD should manage and decrease the uncertainty surrounding *process attributes* (Schedule adherence, Budget, Quality)**
- **At Enterprise level - strong tie to the PD framework. For example:**
  - **Quality:** Measures the degree of effectiveness of a method in a decision environment and captures the strengths and weaknesses of the method.
  - **Capacity:** Measures whether the enterprise has the resources (i.e. time, money, people, etc.) required to do a job on schedule and on budget that meets customers' needs at a specified risk level. This is measured across all decision environments.
  - **Continuity:** Measures the ratio of information that is available but unused vs. the information that is being used at a state.

  - **...and if these aren't nailed you'll have problems with handoffs, information flows, etc. This is why RM is so important at the enterprise level.**

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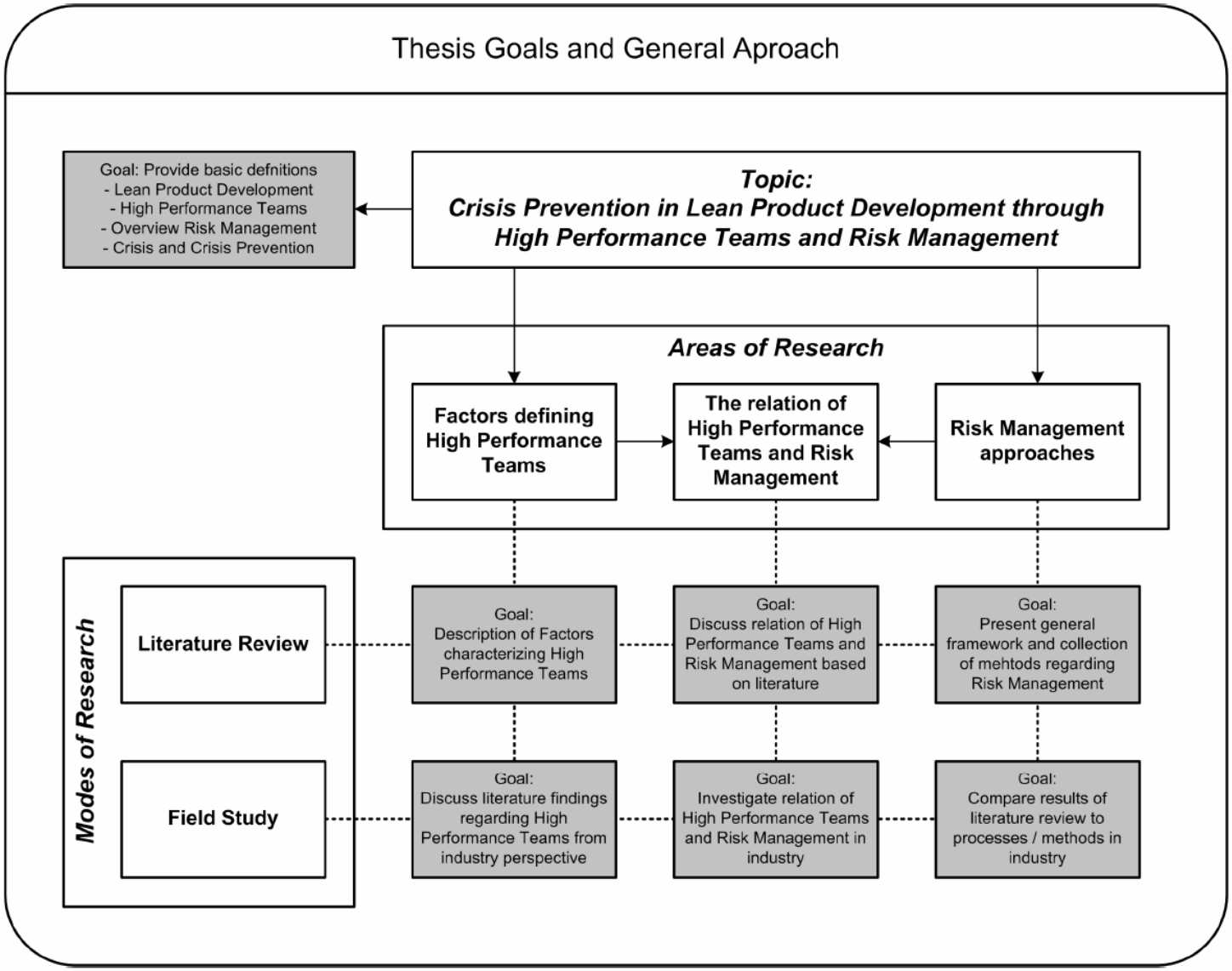
Josef Oehmen Thesis Framework



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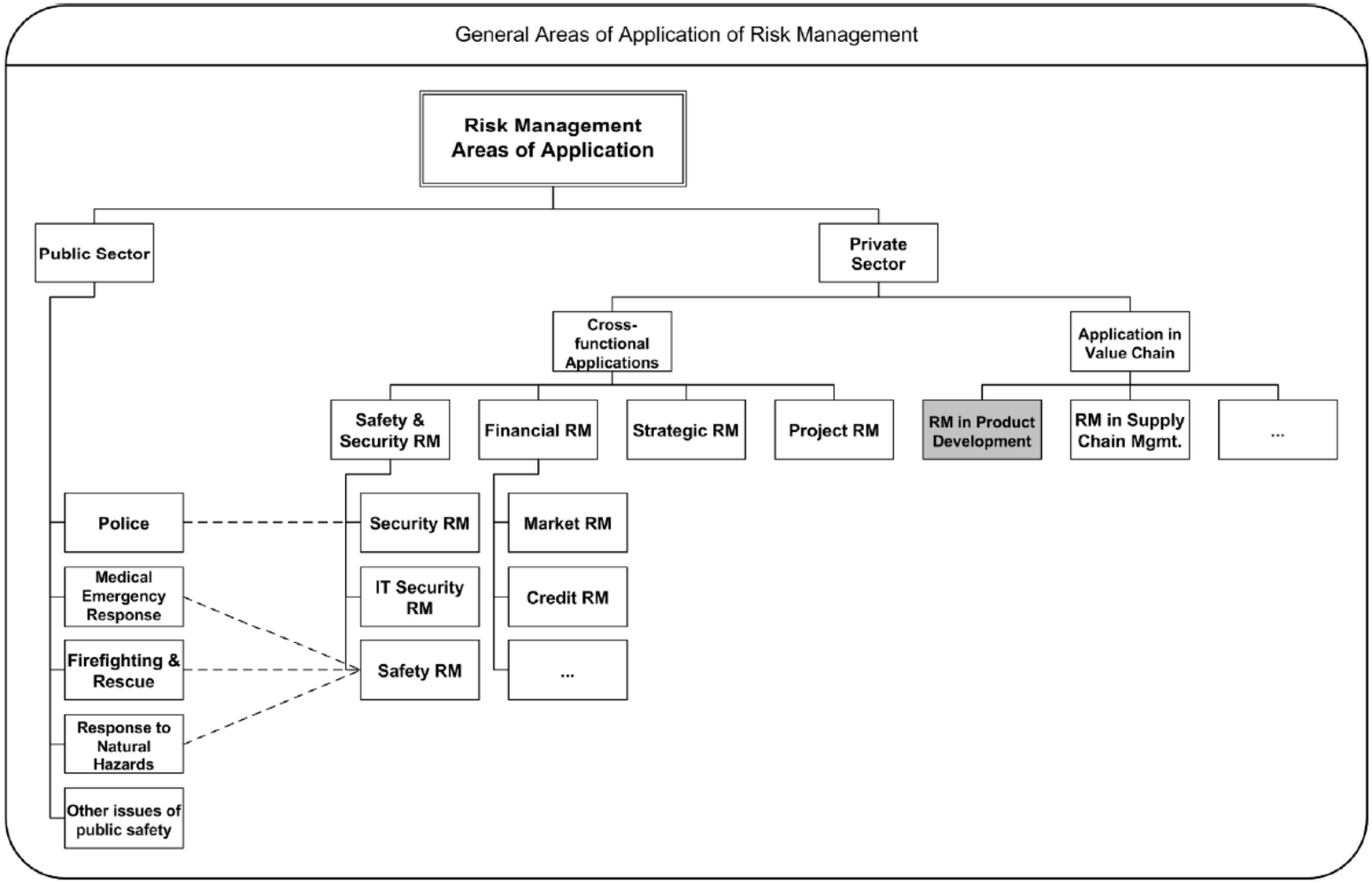
General Areas of Application of Risk Management



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Strength of Assertions from Case Studies

Observation	Correlation Coefficient
Increased effort spent on risk mitigation activities produces fewer problems	-0.9767
Risk effort expended and the amount of budget overrun	-0.8777
Number of significant problems and the amount of cost overrun	0.7551

Highly correlated! Data illustrates the relationship between minimizing risk and reducing waste in a lean product development environment

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Research Design

- **Use various methodologies**
  - **Case Studies**
    - **Commercial & Military applications**
  - **Survey Research**
  - **Econometric Models**
  - **Framework development with Key Metrics**

Timeline

• Start	Jan 06
• Stop	Aug 08
• Presentations	Apr 06, Apr 07, Apr 08, Other Conferences
• Journal Papers	Aug 06, Mar 07, Aug 07, Mar 08, Aug 08
• General Exams / Orals	Jan 07
• Defend Dissertation	May 08
• Final Revisions	May-Jul 08
• PCS	22 Aug 08

Expected Products

- **Working Reports** **Yes**
- **Conference Presentations** **Yes**
- **Papers for Publication** **Yes**
- **Dissertation** **Yes**

Definition of Risk*

- **An uncertain,**
- **Time-related**
- **Loss of Value,**
- **Being part of and influenced by complex dynamic networks of factors and/or events**

*Based on several references and inference from his data collection and study

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Six Categories of Value in Lean Product Development

Stakeholders		Objects	Generic Goals: Time	Generic Goals: Cost	Generic Goals: Quality
Customers	→	Product	1: (low) Lead Time	2: (low) Lifecycle Cost	3: (high) Performance
Shareholders	→	PD Process	4: (high) Schedule Adherence	5: (high) Budget Adherence	6: (high) Conformity to Standards

The inverse of these generic goals are termed the "General Failure Modes" of Lean Product Development

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Ties to LAI Research Framework

- **Lean Basics: Add Value and Minimize Waste**
  - **Browning: *Value creation* in Product Development is through *uncertainty reduction***
- **Key assertion: Product Development is a decision-making activity**
  - **Consider all of the decisions made during development: which interface to use? What methods to reduce risk? What features to include/develop?**
- **Therefore, a *key area* of decision-making in product development is in risk and uncertainty management**

Current Application Example: USAF Risk Team

- Background
  - Outgrowth of Future Acquisition Team discussions on metrics
  - Designed to bring "Risk-Based Decision-Making" to the USAF in Acquisition
- Aggressive Timeline
  - Pilot projects (Mar – June)
  - Prototyping (July – Sep)
  - Full-scale AF-wide rollout – NLT Dec 2006
- All product centers participating (AAC and SMC are co-leads)
- Leaning toward adopting a modified version of the Army's Probability of Success Model as the preferred USAF Portfolio Management Tool
  - Movement within OSD to mandate use of Army tool across all services uniquely tailored to each service

Which RM methods are effective? Survey Results

- **Leading engineers and managers asked "Which classical risk mitigation activities were effective versus these types of uncertainty?"**
  - **Types of Uncertainty: Variability, New Technology, Enterprise Capability, Customer, System Interactions, Design Errors, Life Cycle Concerns**
- **Risk Mitigation Activities: Simulation, Supplier Integration, Customer Integration, Prototyping, Design Reviews, Set-Based Design, Reuse, Standard Work, Upgradeable Architectures, Design Margin, Integration Test, Tolerance Control, Industry Standards, DFX, Sensitivity Analysis, Organizational Mitigation**

All of the Risk Mitigation Activities were considered "Very Good" in at least one phase of development* *except Organizational Mitigation

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