Economics of Human Systems Integration:
A Systems Engineering Perspective

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Loughborough University, UK

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Overview

1. What is HSI?

2. Why is HSI Relevant to Systems Engineering?
    1. Case Study

3. An approach to cost estimation of HSI in the context of Systems Engineering

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HSI Domains

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Background

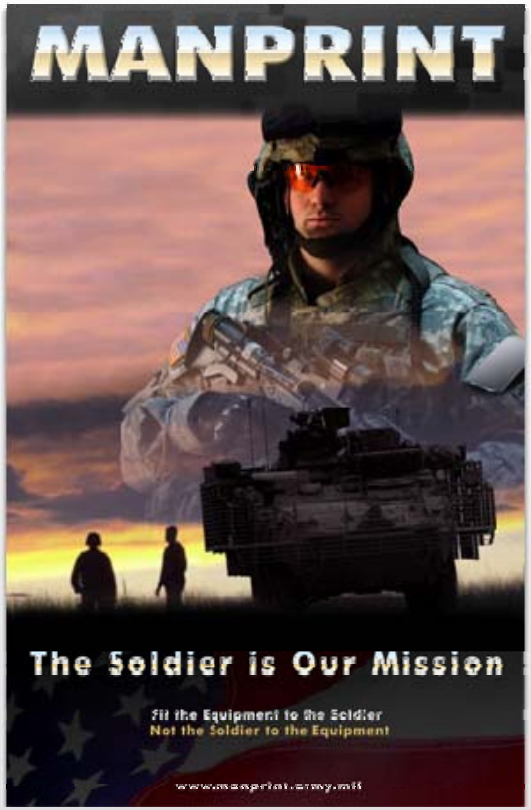
Industrial Revolution

Industrial Engineering
Human Factors Engineering (HFE)

WWII

Human Factors Societies

1980's- Present



Manpower

Personnel Capabilities

Training

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HSI in the Air Force

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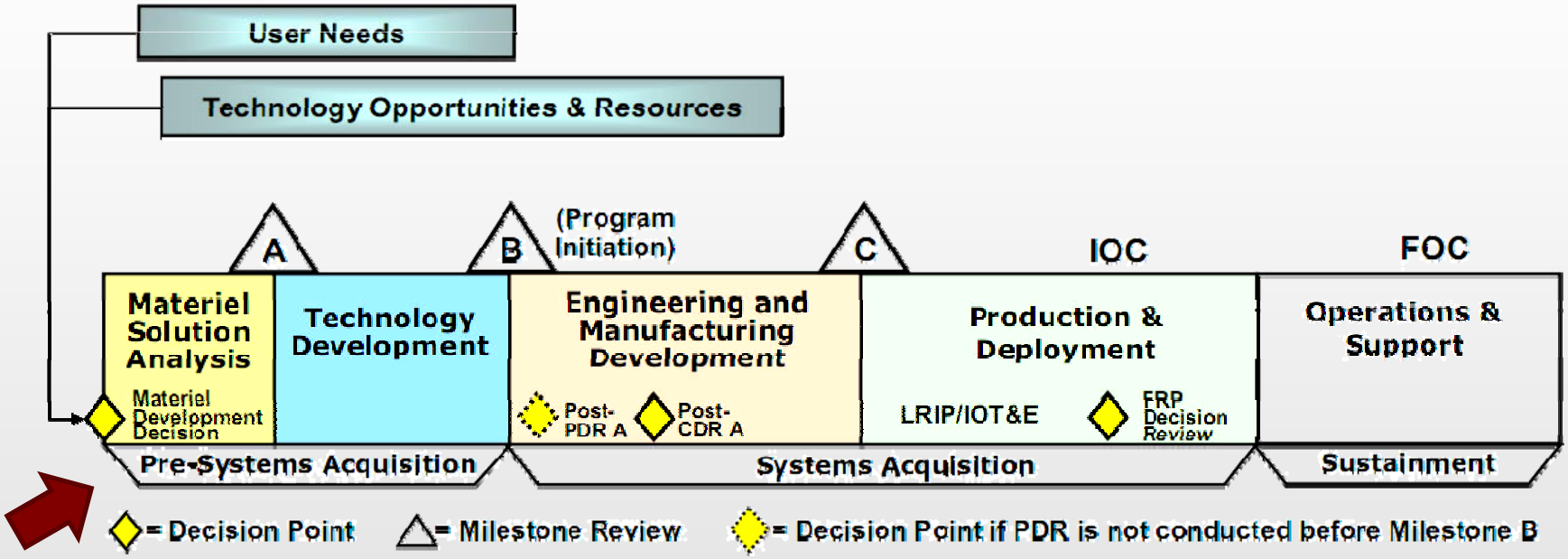
HSI & SE



DoDI 5000.02, Operation of the Defense Acquisition System

HSI

(Begins)

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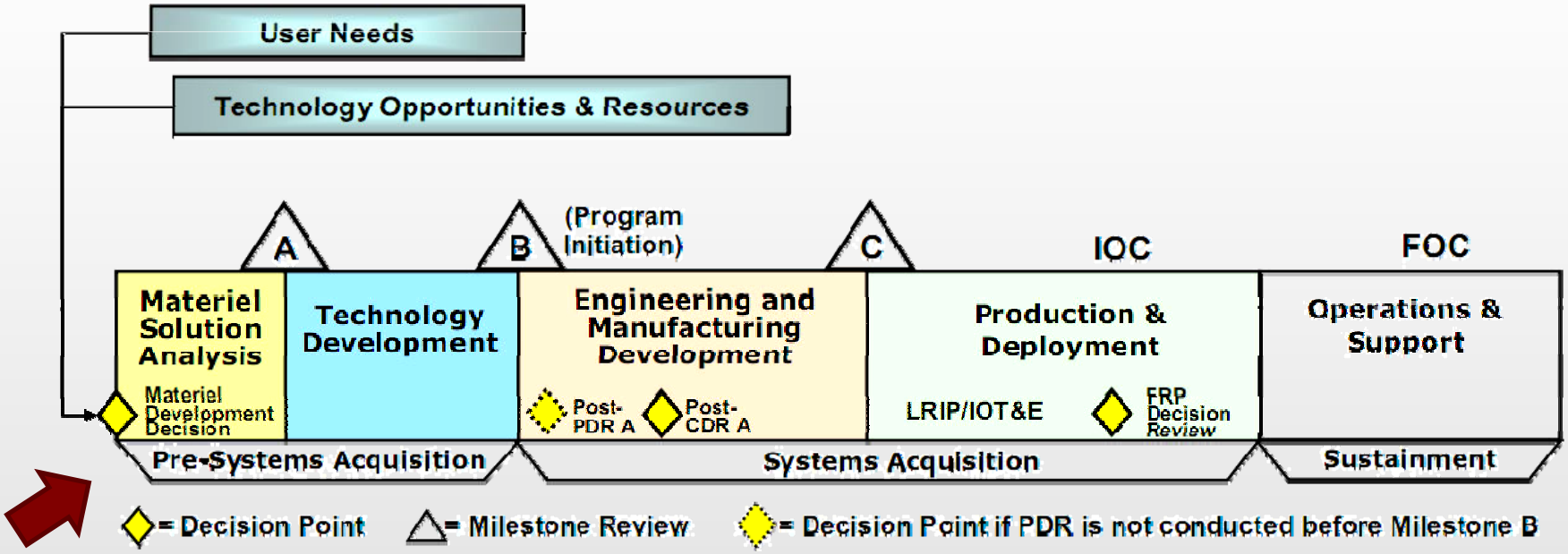
Economics of HSI



Cost Drivers

Size Drivers

Leading Indicators

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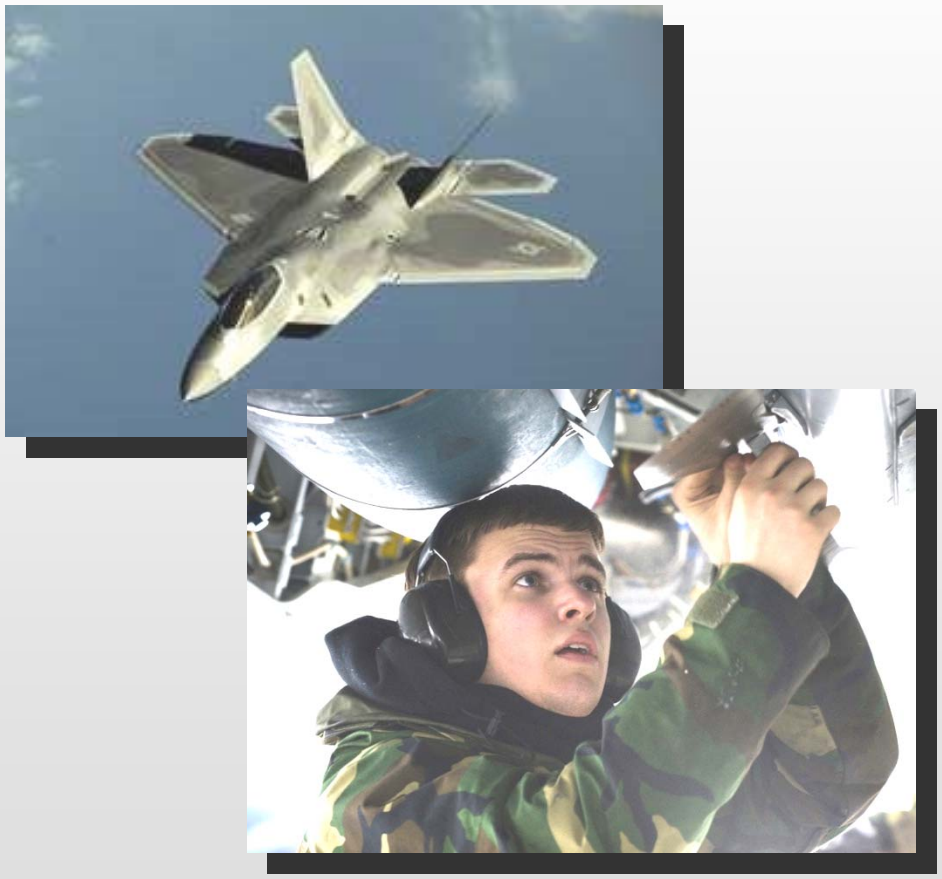
Case Study: Pratt & Whitney F119 Engine



First Look – First Shot – First Kill

Air dominance, multi-role fighter

Dominance through *stealth, speed, agility, versatility, supportability*

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Research Questions

- How did Pratt & Whitney predict how much HSI effort would be needed?
- How much did HSI effort eventually cost?
- How did HSI fit into the larger systems engineering picture?

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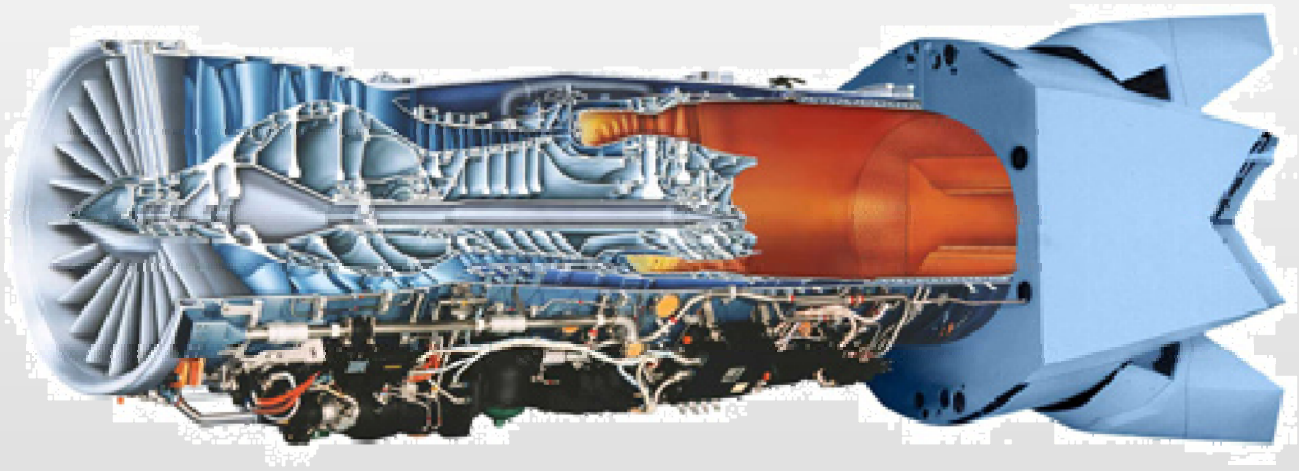
Early Emphasis on HSI

1981 & 1985 – GAO reports recommend integrating MPT

1983 – Memorandums emphasizing readiness, availability, cutting costs

1983 – F-22 supportability goals established

1984 – AF Reliability, Maintainability & Supportability (RM&S) Program



Formal Human Systems Integration Requirements

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Trade Studies Account for HSI

Types of studies
- Technology assessment
- Engine size and cycle
- Design life optimization
- Stage count, configuration, rotor speeds
- Evolution from demonstrator to prototype

Tradeoff alternatives
Design and programmatic alternatives based on cost, schedule, and performance requirements

Evaluation criteria
- Safety
- Weapon system life cycle cost
- Supportability
- Reliability/maintainability
- Weight
- Operability/stability
- Manpower, personnel, and training

Planned trade studies
- Affordability
- Design refinement
- Pre-planned product improvement
- Materials and manufacturing technology

Balanced design

- Low-risk
- Affordable
- Achieves all ATF / NATF requirements

Yankel, J., & Deskin, W. (2002). "Development of the F-22 propulsion system."

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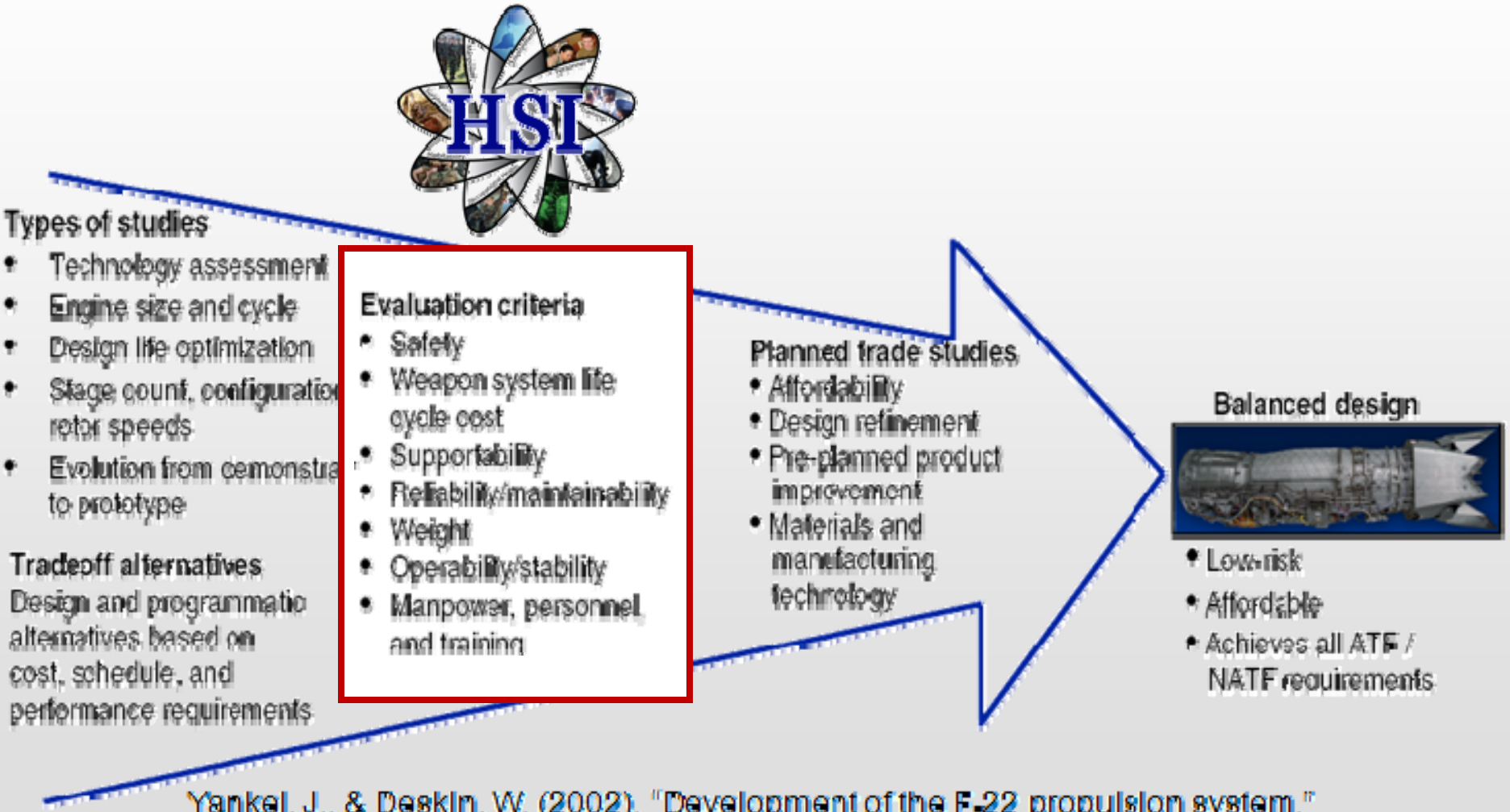
Trade Studies Account for HSI



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HSI/SE Processes (Integrated Product Development)

IPD->IPT->CIPT

CCB's/CICR's

Engineering groups covered 7/9 domains

Led to $2M mock-ups = Proof of HSI

$1.375B contract awarded 02 Aug1991

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Observations

- ***How did Pratt & Whitney predict how much HSI effort would be needed?*** ⇨ **USAF Requirements-driven**
- ***How much did HSI effort eventually cost?*** ⇨ **"HSI Slice" unclear**
- ***How did HSI fit into the larger systems engineering picture?*** ⇨ **IPD, CICR, CCB, IPT, CIPT, etc.**

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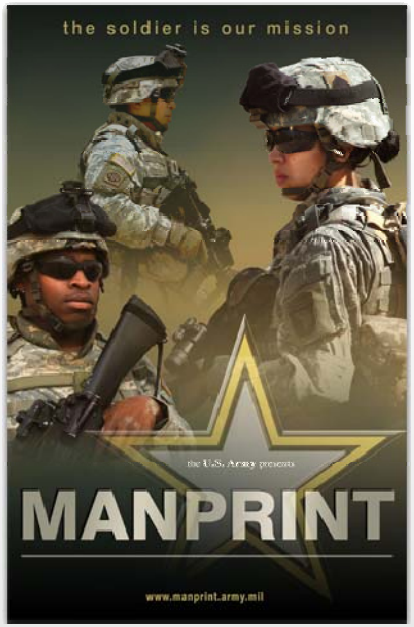
HSI in Guidance Documents



"the PM shall have a plan for HSI in place early in the acquisition process to optimize total system performance, minimize total ownership costs, and ensure that the system is built to accommodate the characteristics of the user population that will operate, maintain, and support the system" – DODI 5000.02

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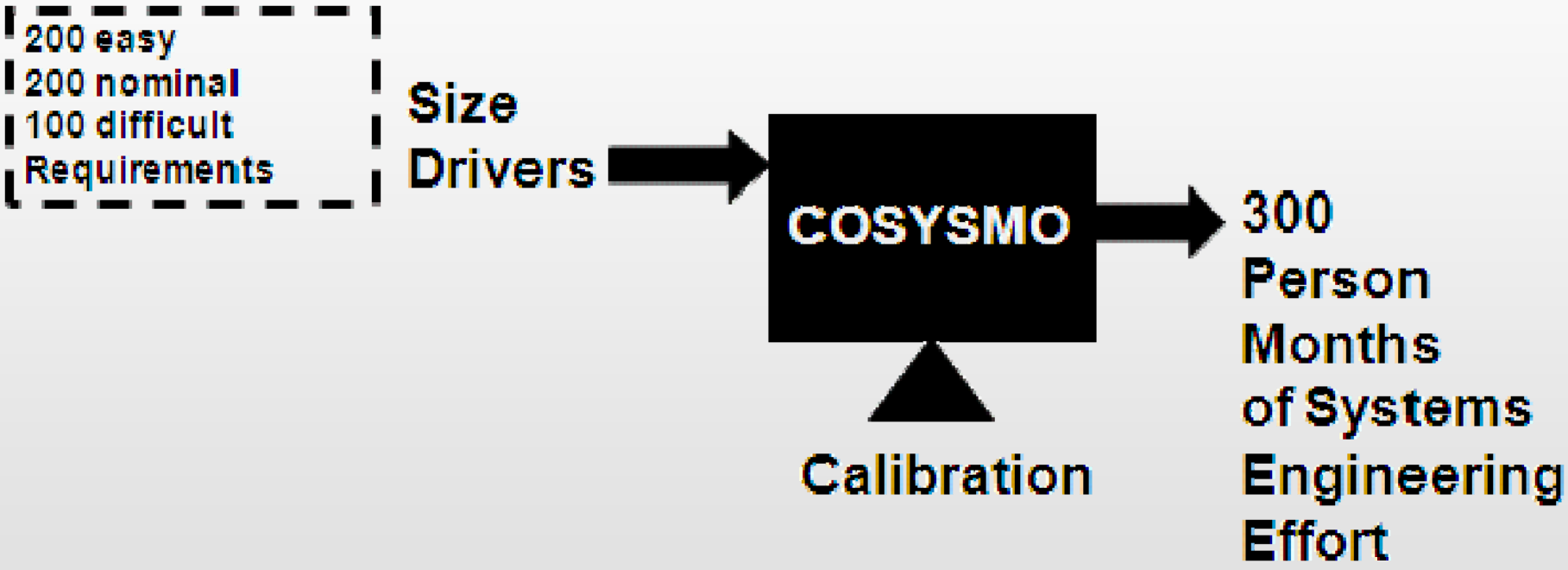
Parametric Cost Estimation



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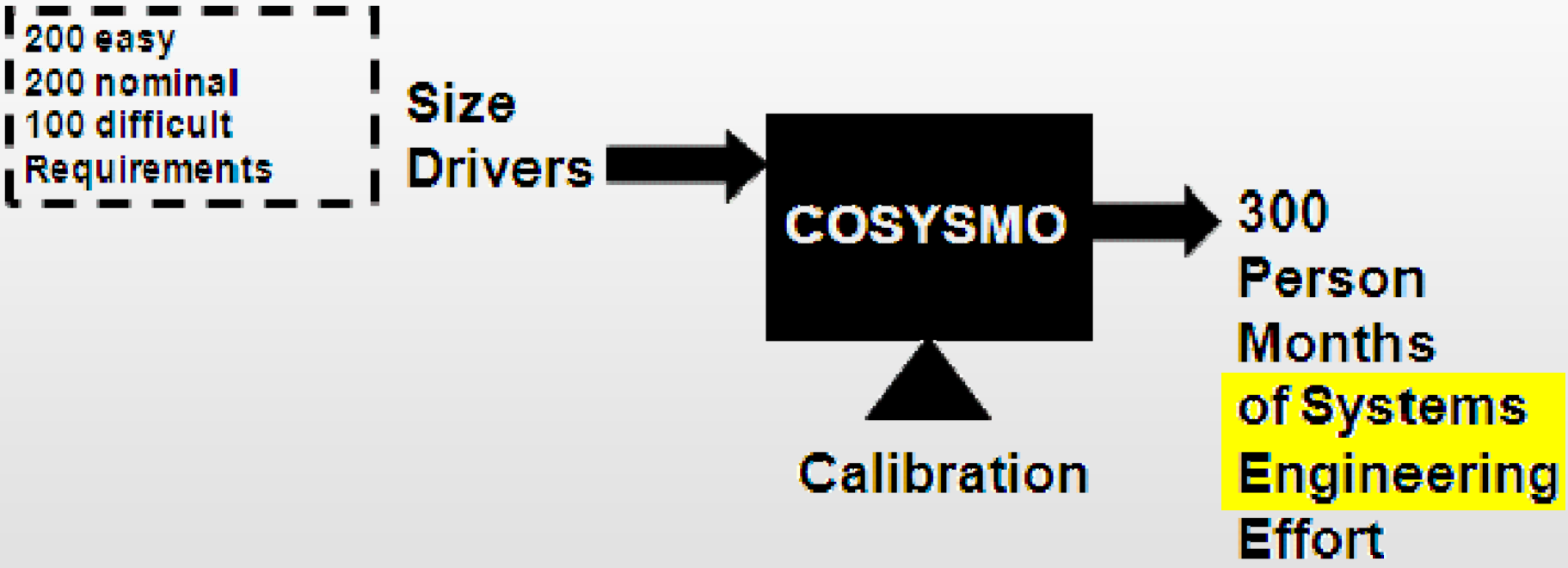
Parametric Cost Estimation



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Parametric Cost Estimation

Operational Scenarios

Algorithms

Architecture Understanding

Technology Risk

$$PM = A \times Size^{E} \times \prod_{i=1}^{n} EM_i$$

Interfaces

Requirements

Tool Support

Personnel/team capability

and diversity of installations/platforms

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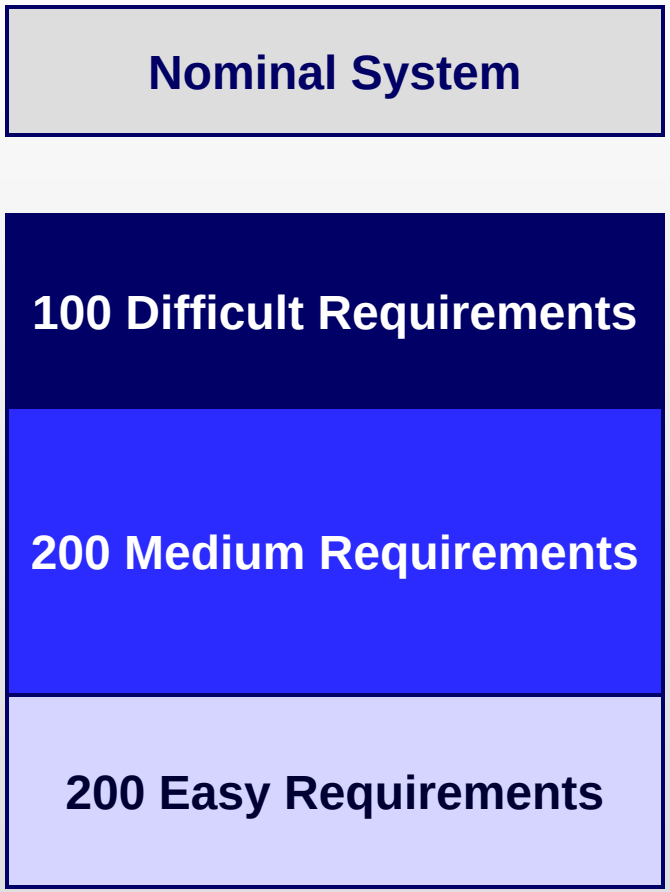
Illustrative Example



SE Effort = 300 Person-months

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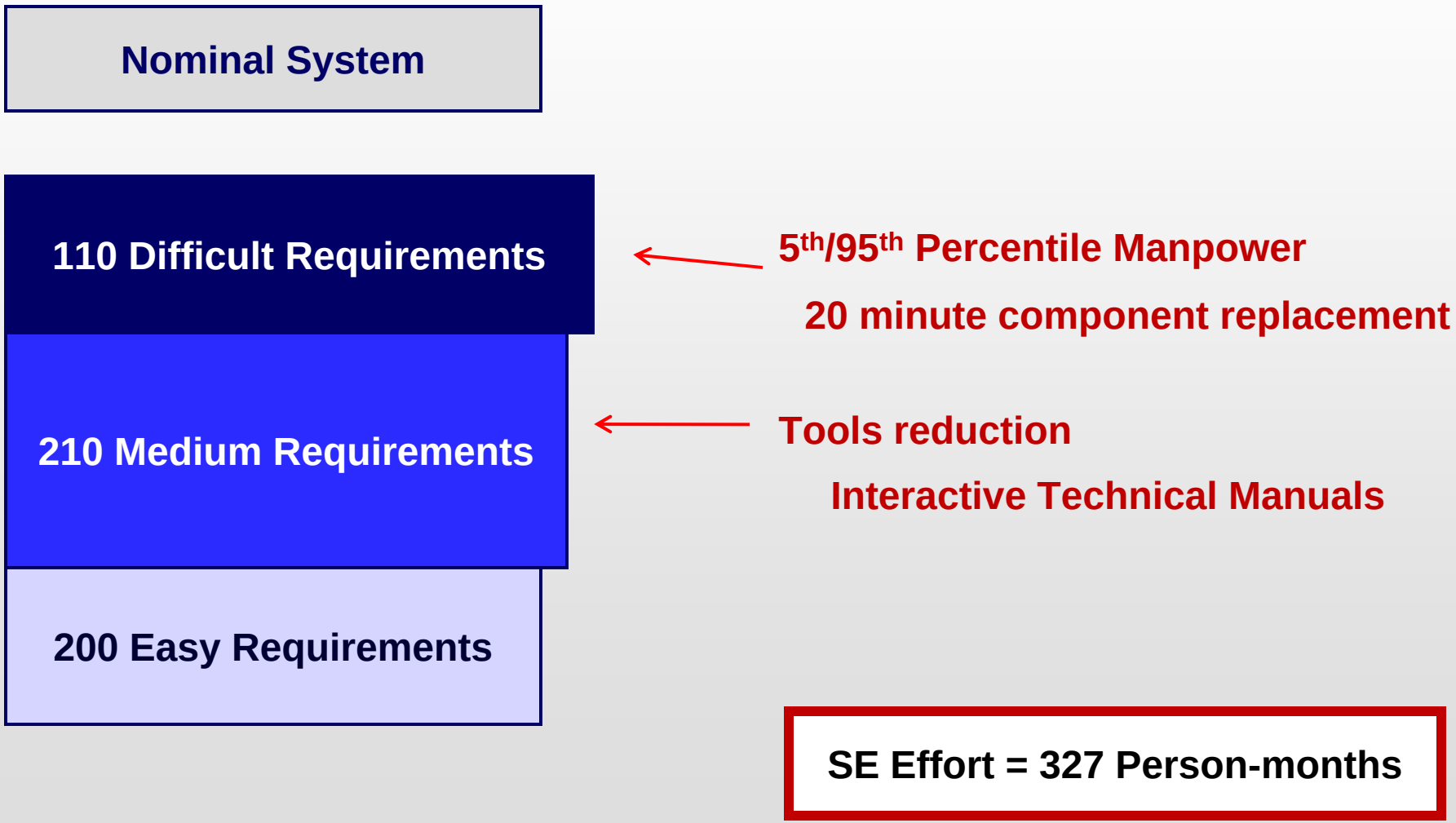
Illustrative Example



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Illustrative Example

Nominal System

110 Difficult Requirements

210 Medium Requirements

200 Easy Requirements

effect of effort multipliers:

High Level of service requirements
High HSI Tools support

SE Effort = 368 Person-months

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HSI Requirements

JCIDS

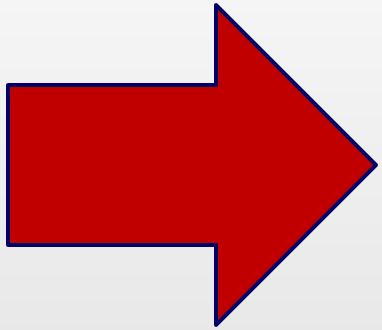
Defense Acquisition Guidebook

DoD 5000 Series

Service Publications

Pratt & Whitney Case Study

INCOSE IW09 HSI Working Group Meeting



Importance of standard definition, format, interpretation, and counting of “HSI Requirements”

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Conclusions

HSI is integral to SE

HSI can be integrated into existing SE cost models

Need for better understanding of "HSI Requirements"

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Acknowledgments

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