Economics of Human Systems Integration:
Early Life Cycle Cost Estimation Using HSI Requirements

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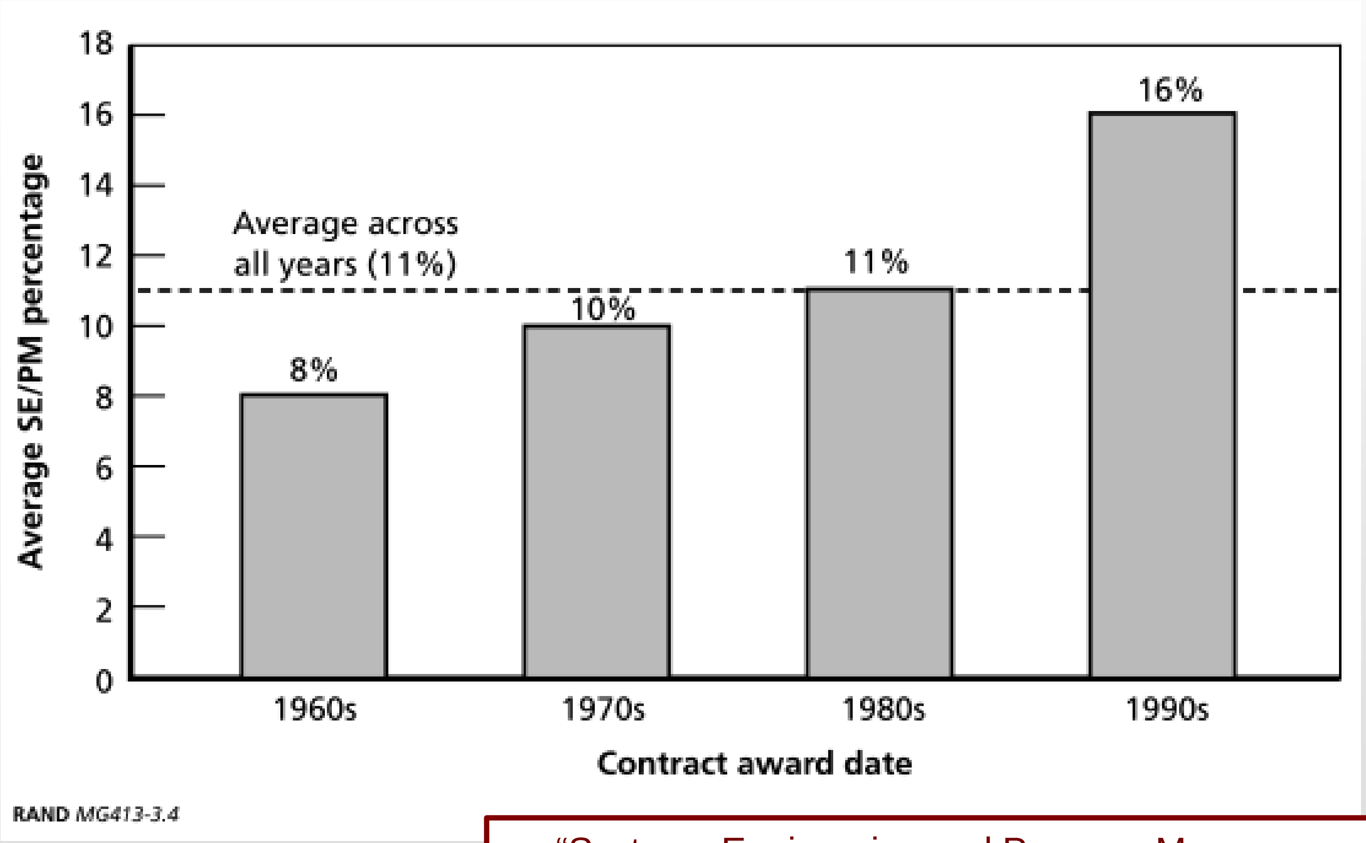
Why Measure HSI Cost?

Aircraft SE/PM as a Percentage of Total Aircraft Development Cost Minus Outlier Development Programs, 1960s–1990s



"Systems Engineering and Program Management Trends and Costs for Aircraft and Guided Weapons Programs" – RAND Corp.

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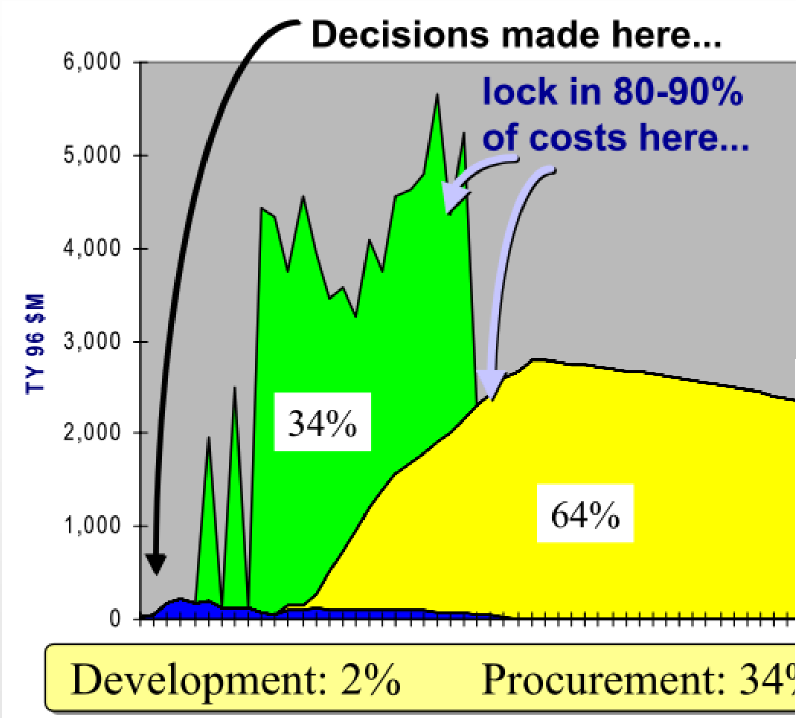
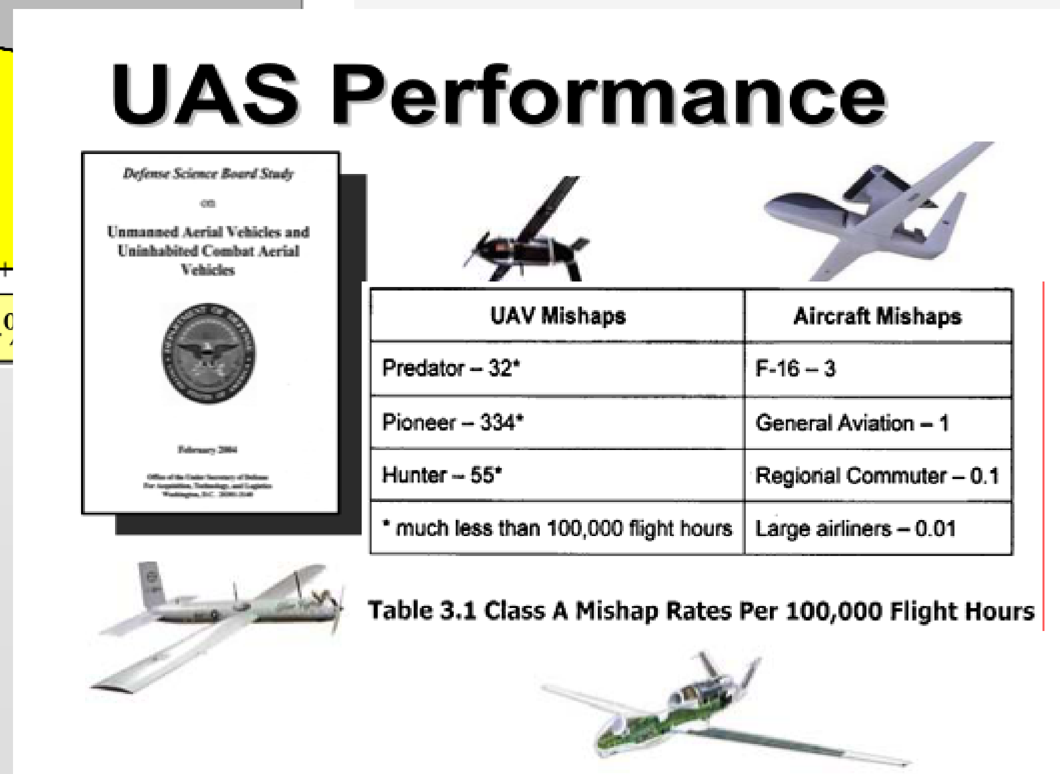
HSI for Reduction of Total Ownership Cost





UAV Mishaps	Aircraft Mishaps
Predator – 32*	F-16 – 3
Pioneer – 334*	General Aviation – 1
Hunter – 55*	Regional Commuter – 0.1
* much less than 100,000 flight hours	Large airliners – 0.01

Table 3.1 Class A Mishap Rates Per 100,000 Flight Hours

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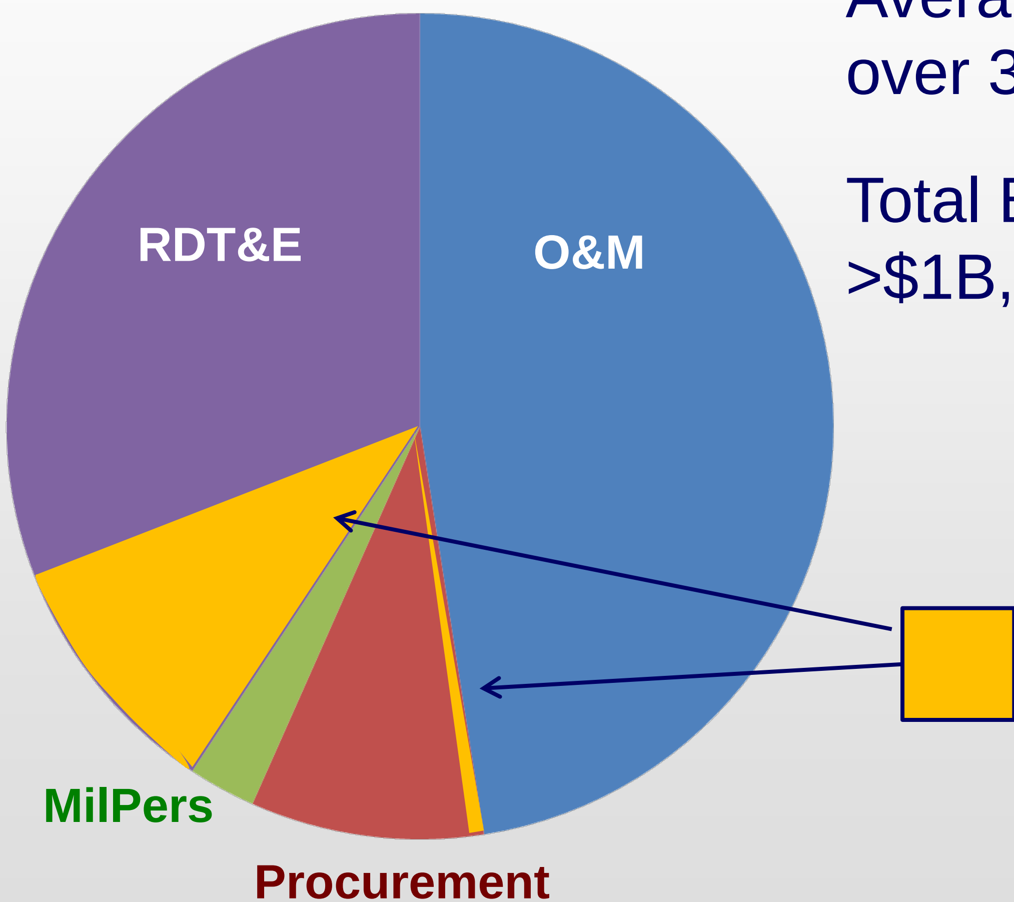
PM Concerns about HSI Cost

Major Recent UAS

Averaged over 3 years

Total Budget >$1B, <$5B



= SE/PM Costs

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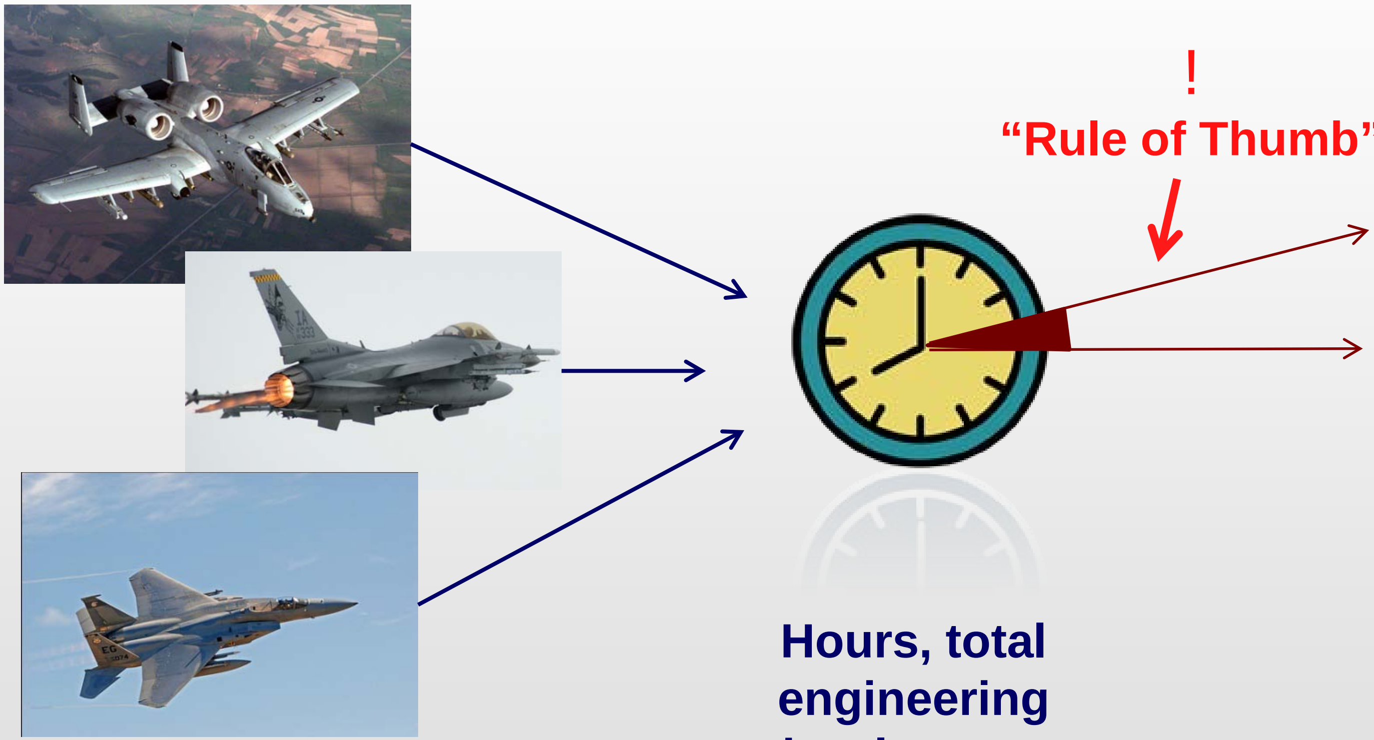
Current Estimation Methods



Estimate of SE/PM as Ratio of Total

Hours, total engineering development

Data from Historical Systems

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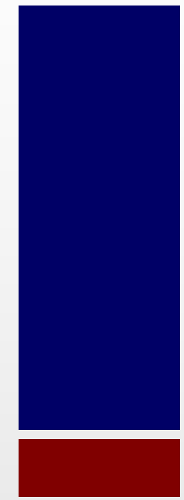
Current Estimation Methods

Data from Historical Systems



Factors influencing Estimate

Expert opinion
Technology Changes
Aircraft Weight
Units

New Program

Estimated 12% SE

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Parametric Estimation of SE: COSYSMO

CO SYS MO

CONSTRUCTIVE SYSTEMS ENGINEERING COST MODEL

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Parametric Estimation of SE: COSYSMO

CO SYS MO
CONSTRUCTIVE SYSTEMS ENGINEERING COST MODEL

Size Drivers

Requirements
Interfaces
Scenarios
Algorithms
+
3 Volatility Factors

Effort Multipliers

- Application factors
  - -8 factors
- Team factors
  - -6 factors
- Schedule driver

COSYSMO

SE Effort

Calibration

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Inputs Needed to Implement COSYSMO

Requirements

- Counted from Requirements Documents (CDD, ORD)

- “shall” “will”, “must”

Requirements Decomposition

1. Determine system of interest
2. Can requirements be *test, verified,* or *designed?*
3. Sketch system of interest relationship to rest of system
4. Count only requirements at the level of the system of interest
5. Assess complexity of requirements

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Inputs Needed to Implement COSYSMO

Effort Multipliers

Requirements understanding
Architecture understanding
Level of service requirements
Migration complexity
Technology risk
Documentation to match life cycle
Tool support

and Diversity of installations/platforms
of Recursive levels in the design
Stakeholder team cohesion
Personnel/team capability
Personnel experience/continuity
Process capability
Multisite coordination needs

Data source: input from high-level IPT.

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Application of COSYSMO to HSI

HSI requirements include, but are not limited to, any requirement pertaining to one or more domains of HSI, or the integration of those domains. Broadly, the term encompasses any requirement that contributes to the integration of human considerations into the system being developed.

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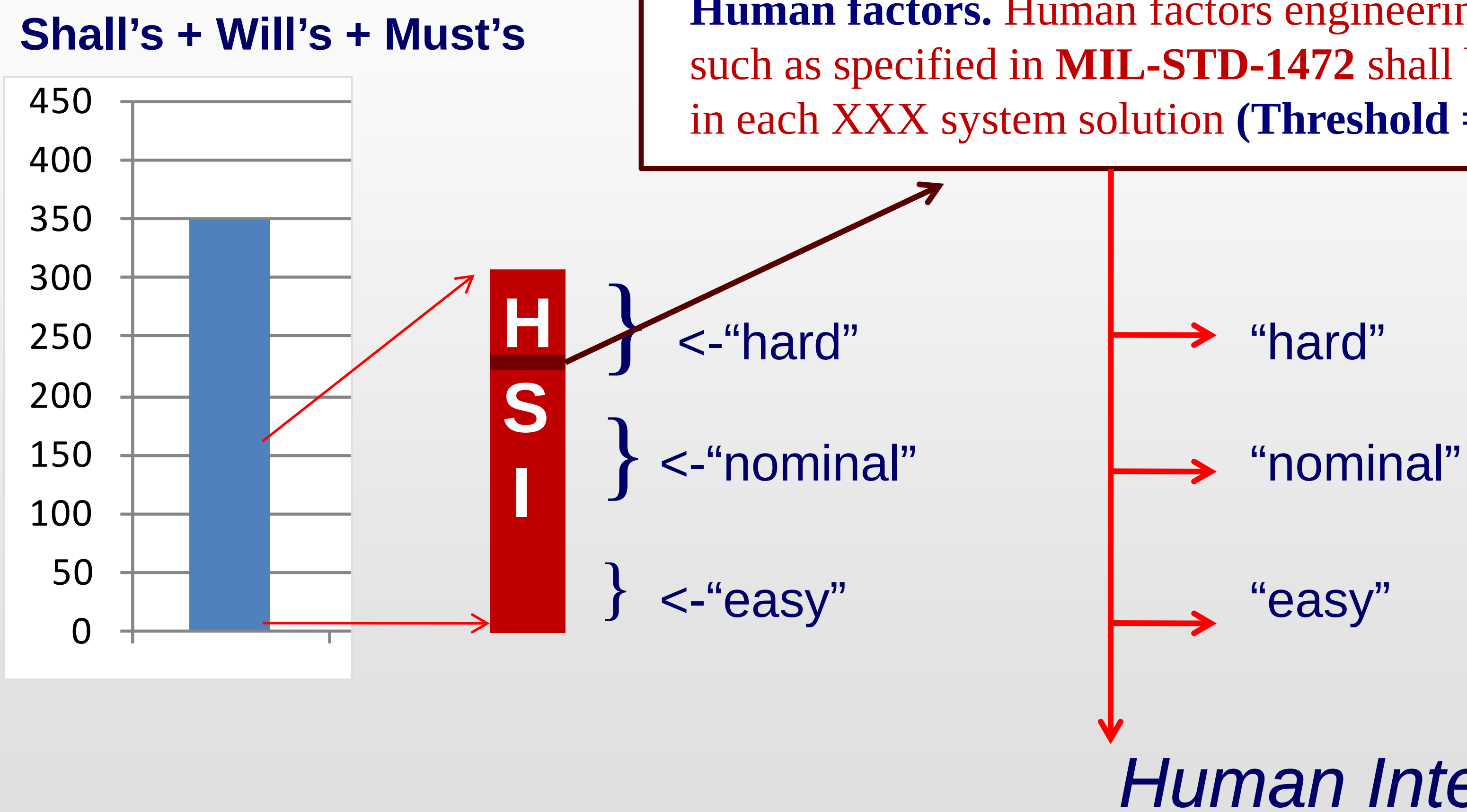
Application of COSYSMO to HSI Notional Example

Human factors. Human factors engineering principles such as specified in **MIL-STD-1472** shall be employed in each XXX system solution **(Threshold = Objective).**



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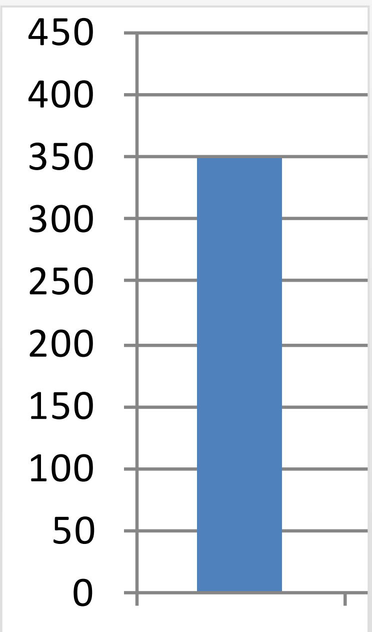
Application of COSYSMO to HSI Notional Example

Shall's + Will's + Must's



COSYSMO 1.1 — CONSTRUCTIVE SYSTEMS ENGINEERING COST MODEL — © 2007 Ricardo Valerdi — 5-Mar-07

ENTER SIZE PARAMETERS FOR SYSTEM OF INTEREST

	Easy	Nominal	Difficult	
# of System Requirements	100	200	50	500
# of System Interfaces				0
# of Algorithms				0
# of Operational Scenarios				0
			equivalent size	**500**

SELECT COST PARAMETERS FOR SYSTEM OF INTEREST

Requirements Understanding	N	1.00
Architecture Understanding	N	1.00
Level of Service Requirements	H	1.32
Migration Complexity	N	1.00
Technology Risk	N	1.00
Documentation	N	1.00
# and diversity of installations/platforms	N	1.00
# of recursive levels in the design	N	1.00
Stakeholder team cohesion	N	1.00
Personnel/team capability	H	0.81
Personnel experience/continuity	L	1.21
Process capability	N	1.00
Multisite coordination	N	1.00
Tool support	N	1.00
	composite effort multiplier	**1.29**

SYSTEMS ENGINEERING PERSON MONTHS **238 Person-Months**

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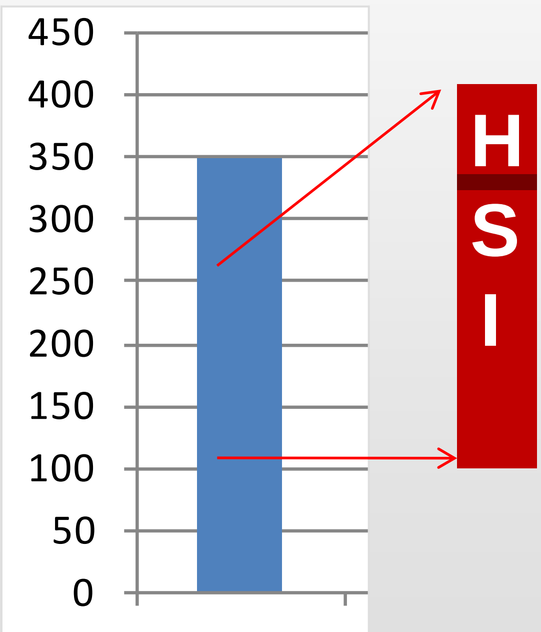
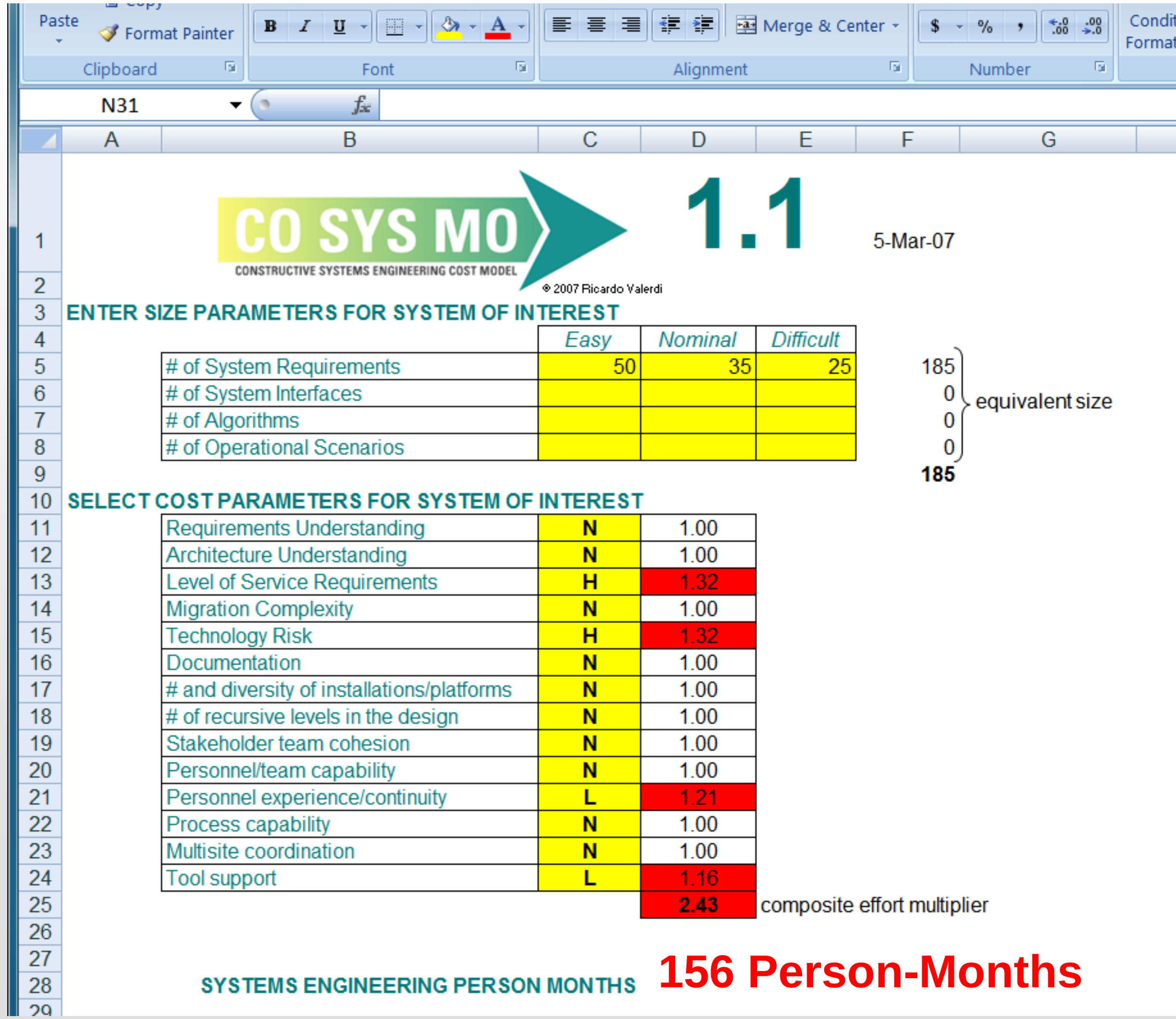
Application of COSYSMO to HSI Notional Example





ENTER SIZE PARAMETERS FOR SYSTEM OF INTEREST

	Easy	Nominal	Difficult	
# of System Requirements	50	35	25	185
# of System Interfaces				0
# of Algorithms				0
# of Operational Scenarios				0
				185

equivalent size

SELECT COST PARAMETERS FOR SYSTEM OF INTEREST

Requirements Understanding	N	1.00
Architecture Understanding	N	1.00
Level of Service Requirements	H	1.32
Migration Complexity	N	1.00
Technology Risk	H	1.32
Documentation	N	1.00
# and diversity of installations/platforms	N	1.00
# of recursive levels in the design	N	1.00
Stakeholder team cohesion	N	1.00
Personnel/team capability	N	1.00
Personnel experience/continuity	L	1.21
Process capability	N	1.00
Multisite coordination	N	1.00
Tool support	L	1.16
		2.43 composite effort multiplier

SYSTEMS ENGINEERING PERSON MONTHS **156 Person-Months**

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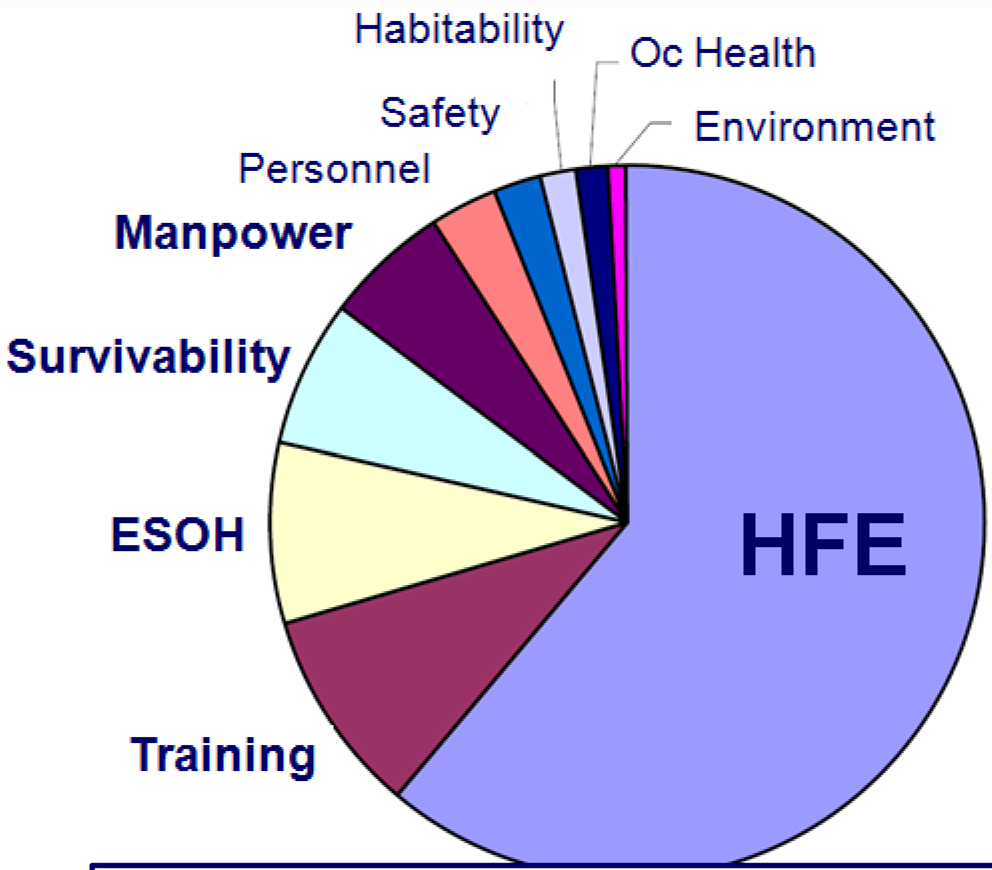
Application of COSYSMO to HSI
Application to HSI Domains



HSI-related requirements found in Government-furnished requirements documents

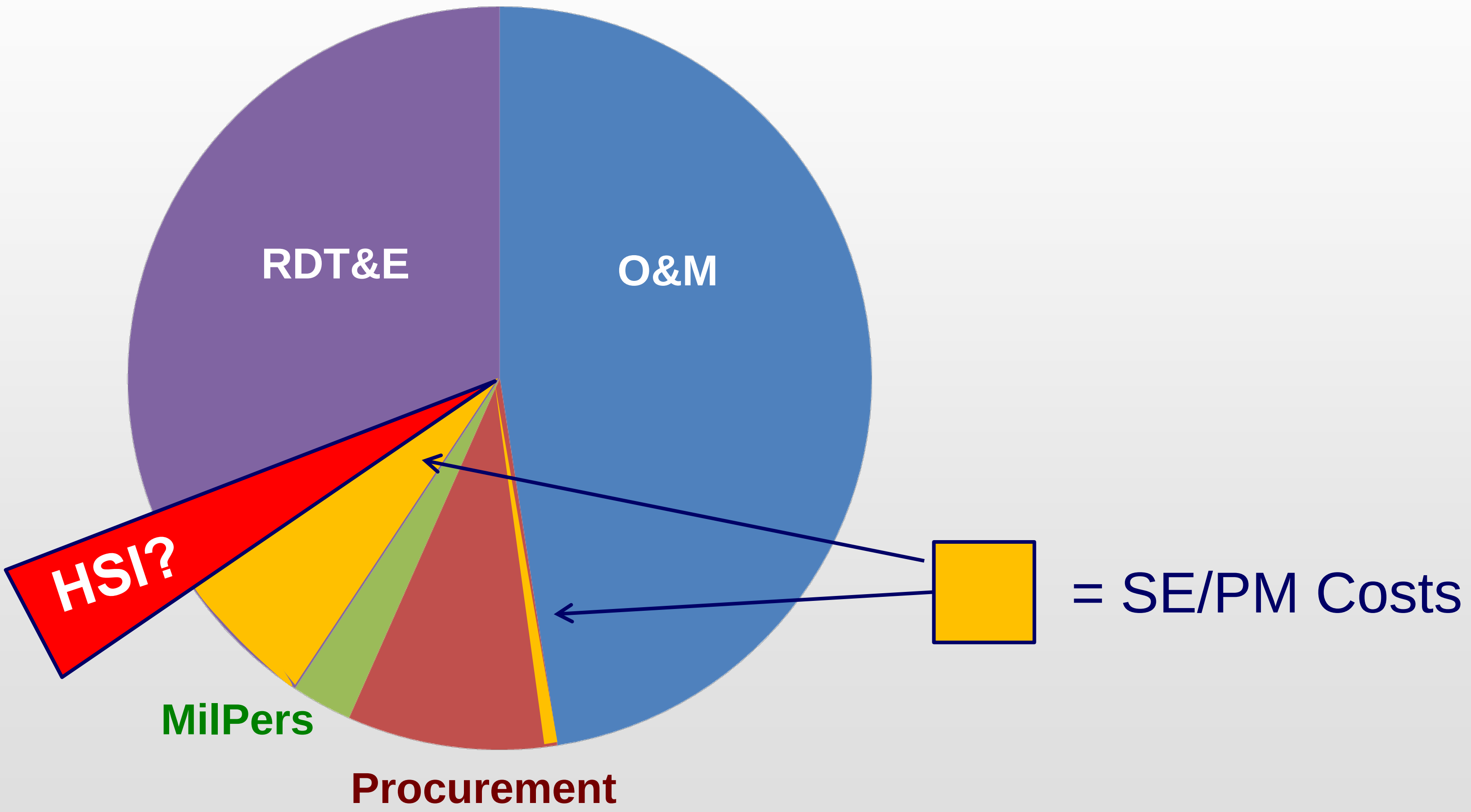
How complex are the safety requirements?

What tools are available for survivability analyses?

How verifiable are the environmental requirements?

How do these factors affect level of effort?

Application of COSYSMO to HSI Takeaways



HSI Already Integrated Into Systems Engineering

F119 Engine

On time

Within Cost

Superior Performance

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

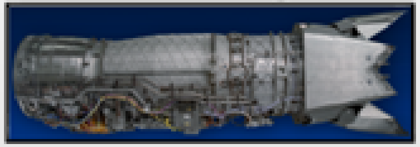
Tradeoff alternatives

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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“Essentially, all models are wrong, but some are useful”

George E. P. Box, statistician

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How/When to Use COSYSMO for HSI

Use #1: "Are my ballpark estimates of SE/PM and HSI reasonable?"

Required Inputs:

- **Existing SE/PM Cost Estimate (rule-of-thumb, analogy, etc.)**
- **Existing draft requirements document**
- **IPT or expert analysis of requirements to identify HSI Requirements**
- **Optional: High-level DoDAF views for Operational Scenarios**

Useful Outputs:

- **Identification of SE/PM and HSI cost drivers**
- **Identification of major issues (risk, technology maturity, difficulty)**
- **Early warnings of large discrepancies**

Application:

- **Pre-Milestone A**
- **Can use any available information (DoDAF, Draft Requirements, etc.)**

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How/When to Use COSYSMO for HSI

Use #2: "What is the *right* amount of SE/PM and HSI for my system?"

Required Inputs (in addition to Use #1):

- **Calibration using cost data from previous systems**
- **Decomposition of requirements into "sea-level" requirements or interfaces**

Useful Outputs (in addition to Use #1):

- **Better understanding of relative effort impact of each requirement**
- **Improved cost estimate compared to traditional methods**

Application:

- **Full System Life Cycle**
- **Can be constantly updated in response to new information or external pressures**

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Future Work

Recently Developed Resources Useful for Implementation of COSYSMO for HSI

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Acknowledgments

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