

Air Force Materiel Command

Developing, Fielding, and Sustaining America's Aerospace Force

The Macro Dynamics of Weapon System Acquisition: Shaping Early Decisions to Get Better Outcomes



U.S. AIR FORCE

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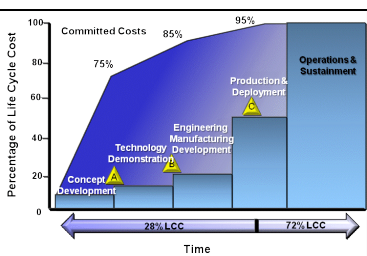
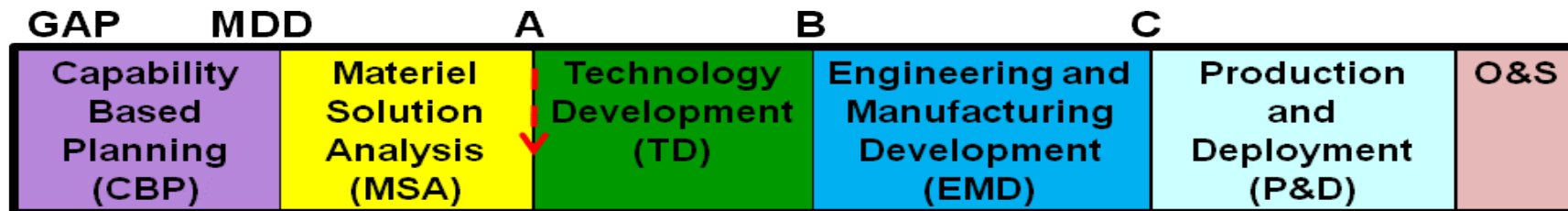
Challenges



- **Defense acquisition is already broken**
 - **Systems Engineering – event driven vs effects based**
 - **Reduced Capacity – “procurement holidays” increase cycle time and costs**
 - **Complexity – A&D community self inflicted wound**
 - **Requirements – not necessarily connected to mission, physical reality, affordability, and ability to deliver on time**
- **Reduced budgets are a fact of life**
 - **Fewer acquisition new starts**
 - **Reduced infrastructure, reduced capacity**
 - **Not if or when, but how much**
- **Over the next decade the US could loose technological superiority, economic competitiveness in key areas**
- **We have to get past policies to systemic root causes to overcome pending reductions and increase the output of the US Aerospace and Defense industry**

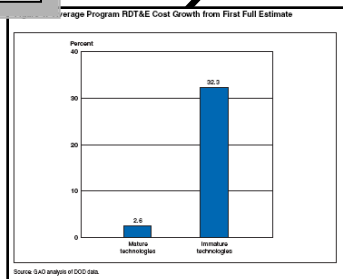


Key Systems Engineering Leverage Points Marked by Events – Mired by Lack of Effectiveness

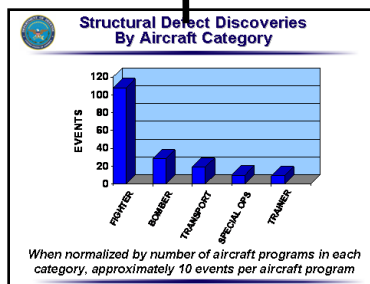
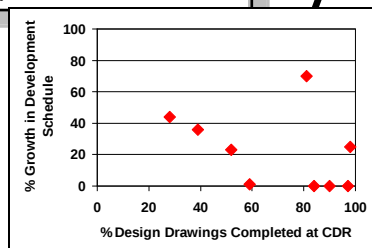


1. 75% LCC
fixed @ MS A

2. Technology
Maturity
@ MS B



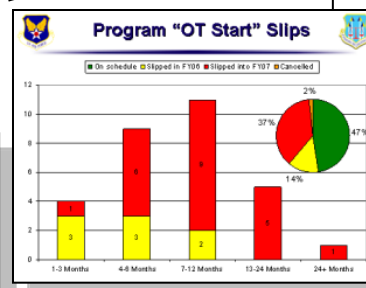
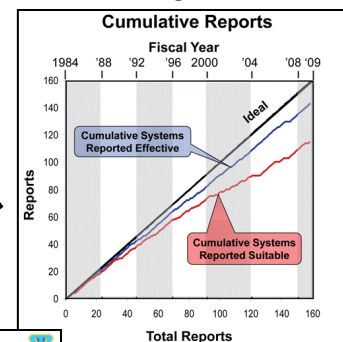
3. Design Closure @ CDR



4. Late Defects

Discovery

6. Suitability

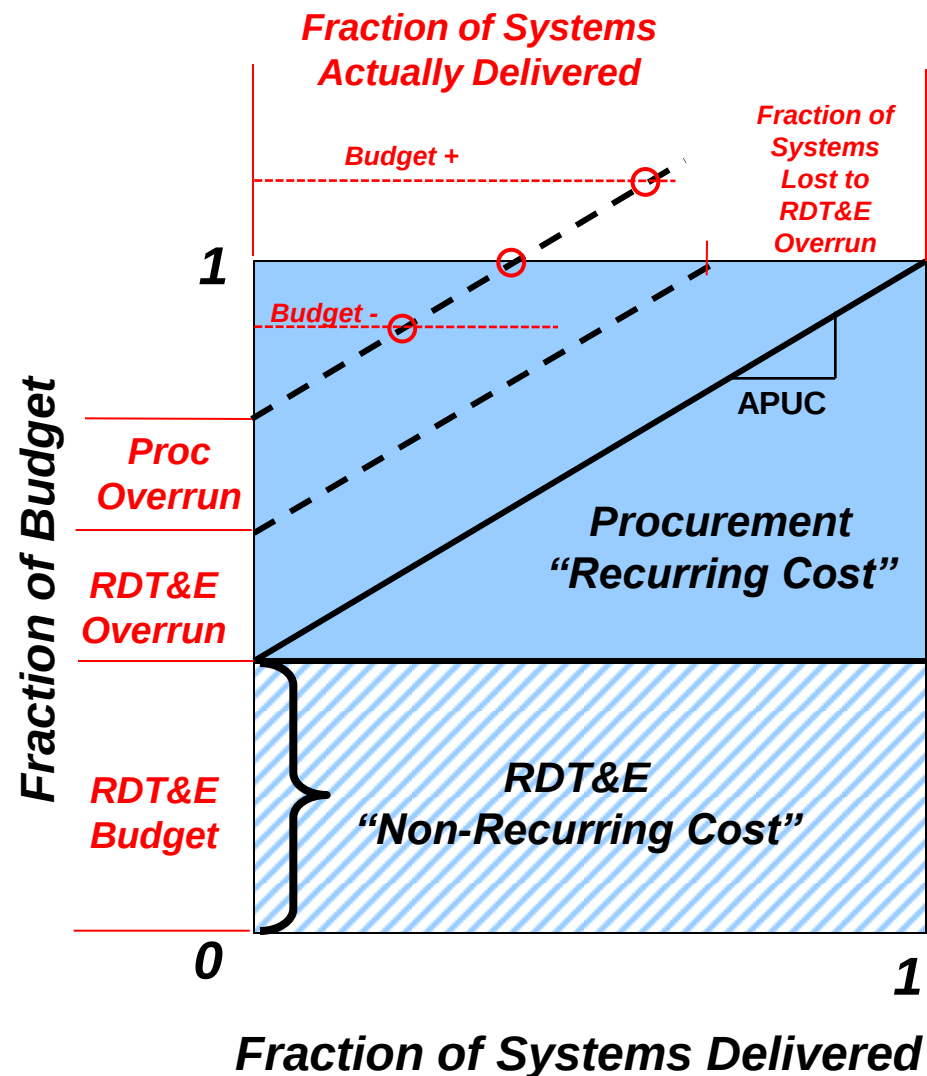


5. IOT&E Pause Test Rate



Top Line Economic Model

Understanding Impact of Reduced Capacity



Final number of systems actually delivered driven by:

- Overruns
- Congressional or DoD dictates
- Final Budget constraints

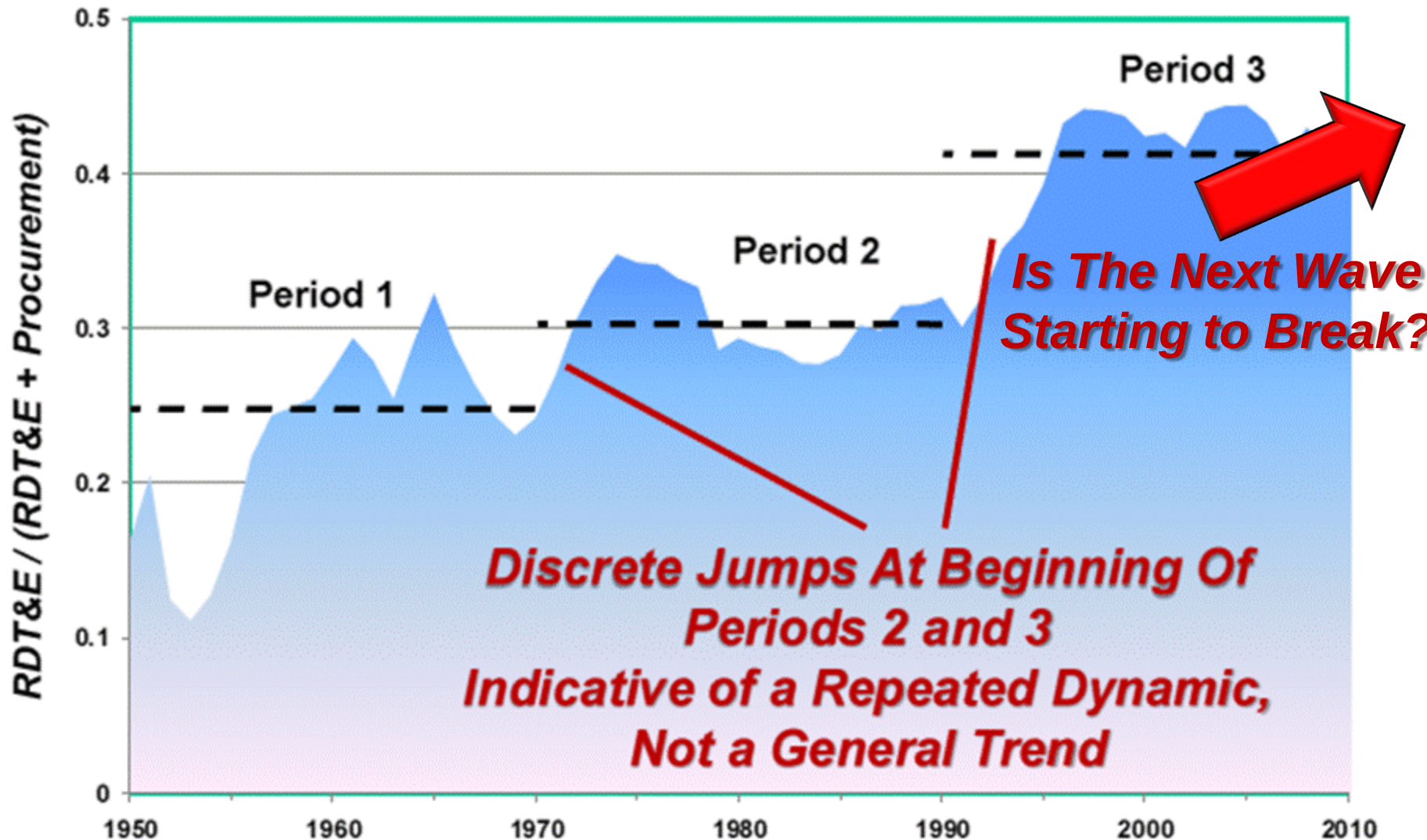
$$\text{Fraction of Systems Actually Delivered} = 1 - \frac{\text{RDT\&E Overrun} + \text{Proc Overrun} + \text{Delta Budget}}{1 - \text{RDT\&E Budget}}$$

RDT&E Budget fraction amplifies the RDT&E and Procurement overruns plus Budget changes!



RDT&E Fraction of the DoD Acquisition Budget

AFMC





Macro-Dynamics of Acquisition

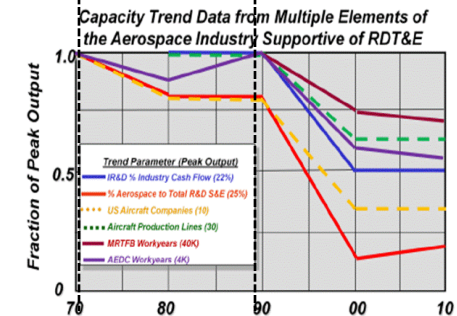
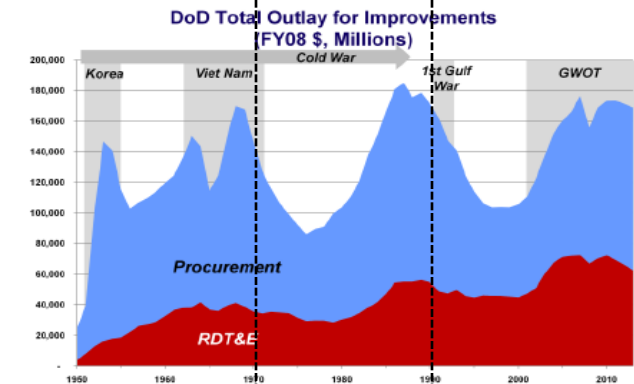
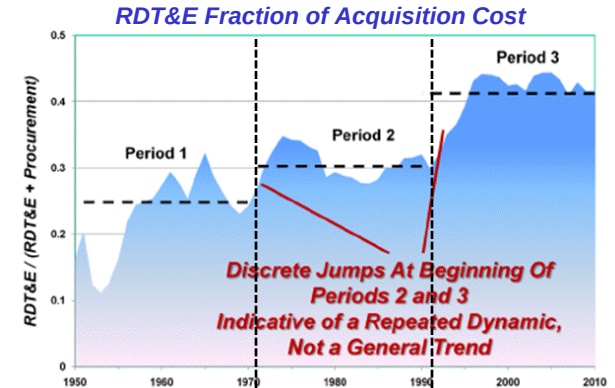
Moving From Symptoms to Systemic Causes



- Acquisition output impacted by RDT&E Fraction of acquisition costs

$$\text{Fraction of Systems Actually Delivered} = 1 - \frac{\text{RDT\&E Overrun} + \text{Proc Overrun} + \text{Delta Budget}}{1 - \text{RDT\&E Budget}}$$

- Discrete jumps in RDT&E Fraction align with “Procurement Holidays” – not a general increase attributable to complexity
- Fundamental dynamic cycle –
 - At onset of each period, procurement decreases but RDT&E stays constant because of backlog
 - At end of each period, procurement increases and so does RDT&E because of new starts added to backlog
- Correlating causative factor –
 - Capability and capacity of system reduced at beginning of each cycle but not rebuilt during the ascending end of the cycle – bathtub effect, more RDT&E coming in but less going out



Acquisition system has passed a tipping point leading to pathological firefighting



Doesn't Matter Which Way the Budget is Headed



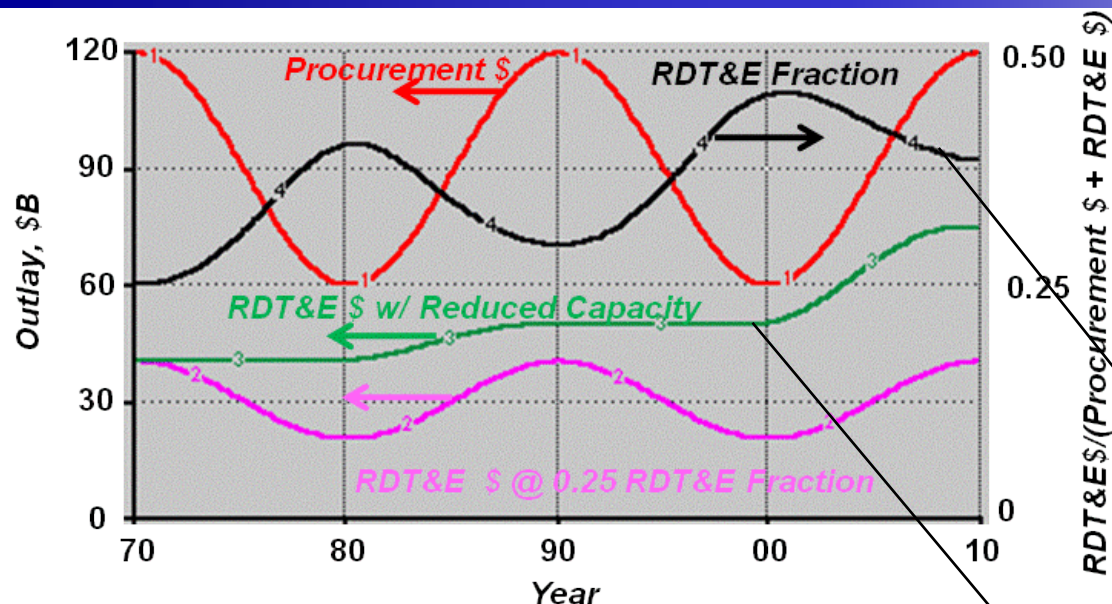
- Declining Acquisition Budget
 - Reduced capacity, capability, intellectual capital
 - Programs already in development continue with less capacity for development
- Increasing Acquisition Budget
 - Increase in new starts added to programs already in development
 - Capacity, capability, and intellectual capital not increased to meet new demand

Both scenarios lead to a mismatch between capacity and demand leading to *pathological firefighting* for all programs



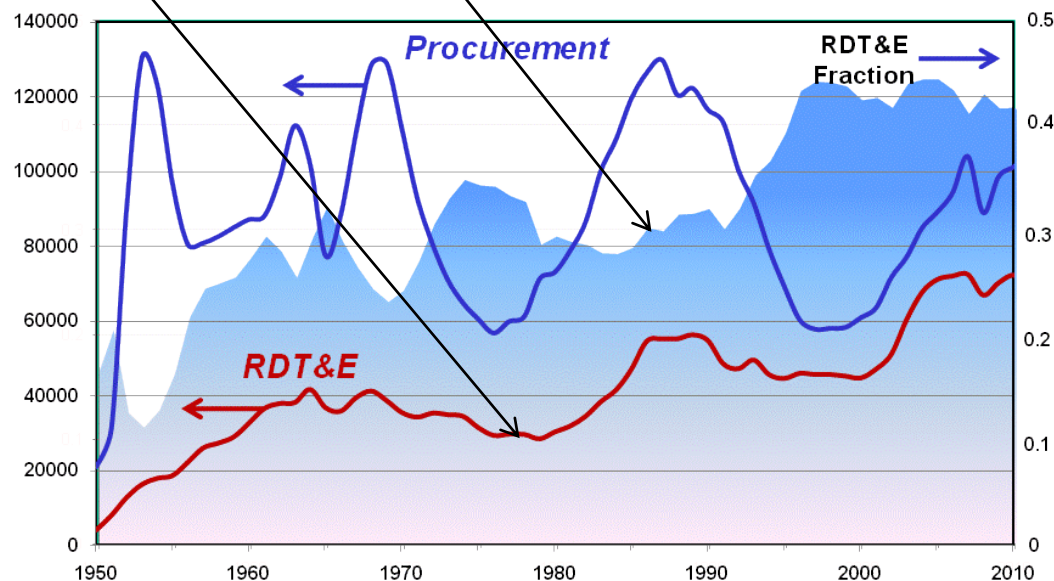
Simple Dynamic Model

Effect of Reduced RDT&E Capacity



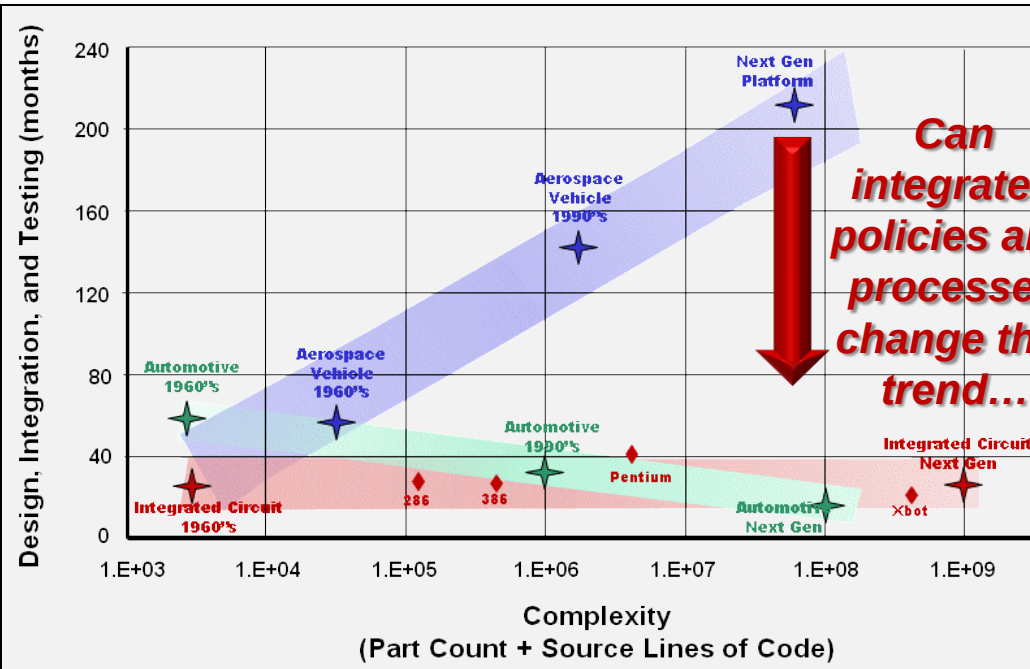
- Simple sinusoidal Proc \$ with 20 yr period , \$90B±\$30B
- Baseline RDT&E \$ expended at 0.25 Acq \$
- With perfectly balanced, infinitely elastic capacity RDT&E \$ would stay at 0.25 Acquisition \$

- Reduced capacity consistent with previous chart
 - -15% in 70's,
 - constant in 80's @ 85%,
 - further reduced 25% in 90's
 - constant in 00's @ 60%
- Replicates major trends, Total RDT&E \$ and RDT&E Fraction escalate after each cycle





Complexity A Self Inflicted Wound?



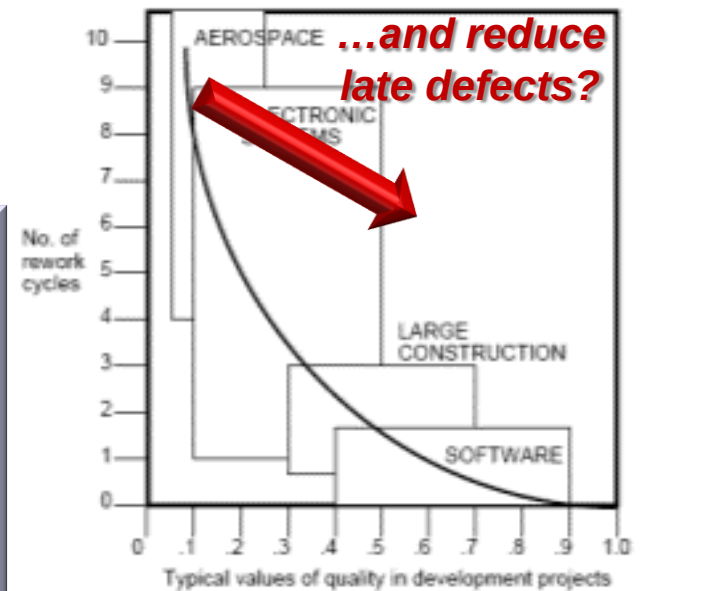
Runaway cycle time not inherent to added complexity

- Architecture choices
- Processes
- Process ownership
- Lack of Accountability

Aerospace industry rampant with late defects and rework

- Design tools and processes
- Lack of feedback to key design and SE processes
- Lack of quantified risk and uncertainty at key decision points

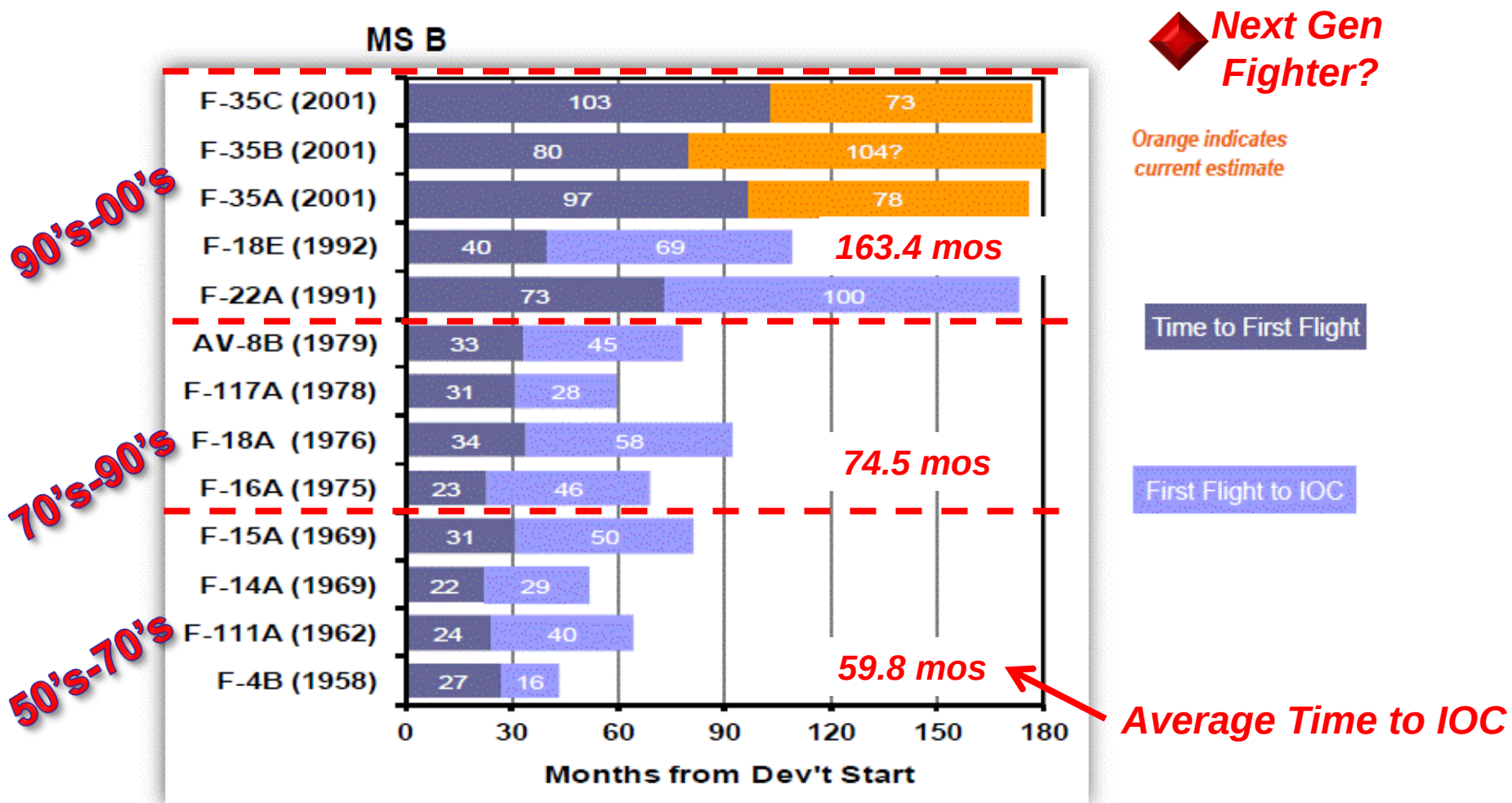
Number of Rework Cycles as a Function of Product Quality





Impact of Reduced Capacity and Increased Complexity

AFMC



Complex Systems + Reduced Capacity/Capability → Long Development Cycle

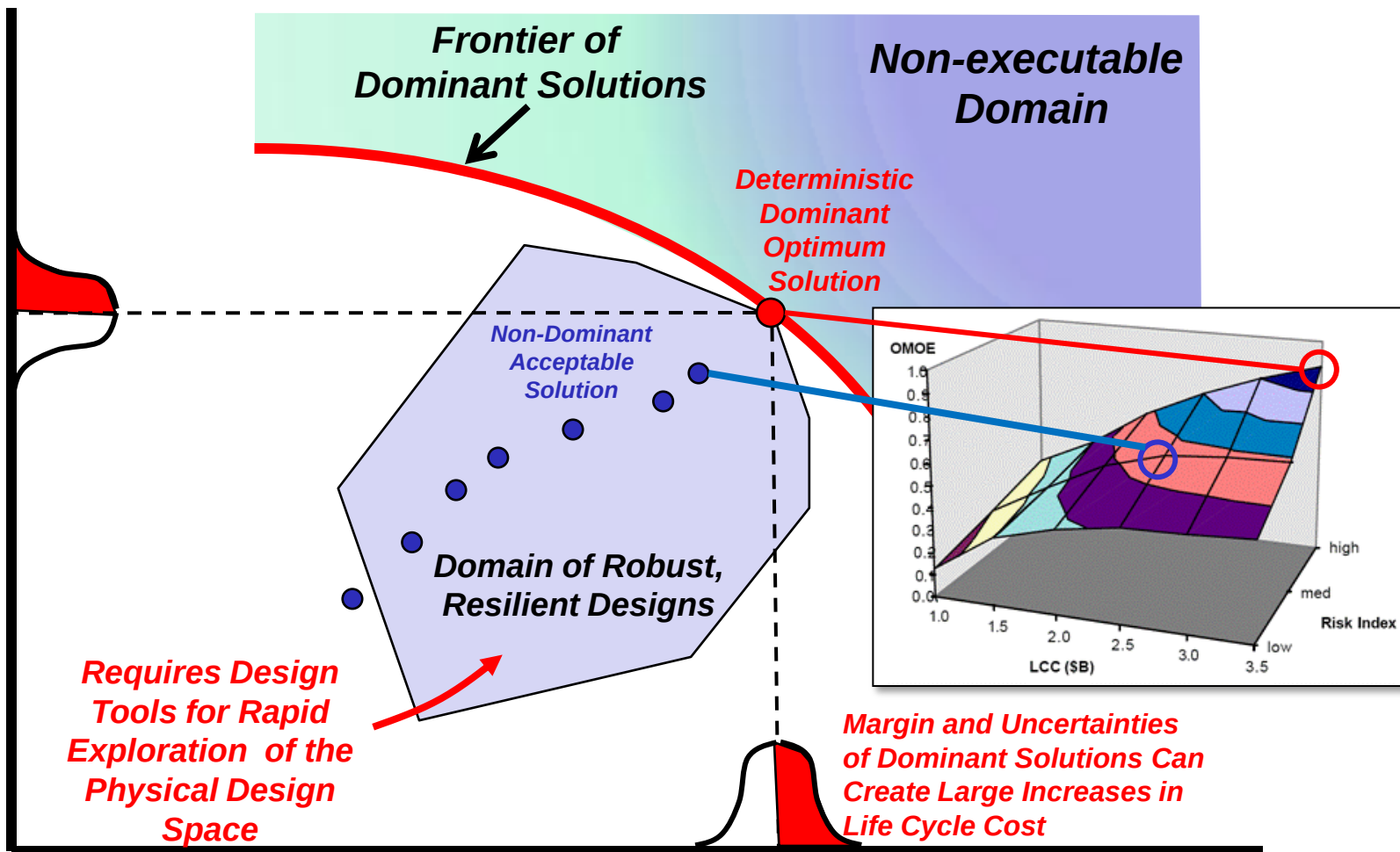


Requirements Setting

Robust, Resilient Design Vice Single Point Optimum Solution



Design Variable "B"



Design Variable "A"



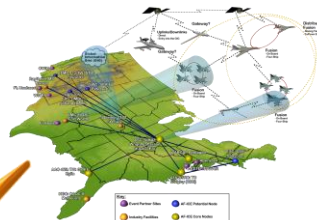
Coupling Operability, Interoperability, and Physical Feasibility Analyses – a Game Changer



Simulator

- Discrete Event Simulation
- Real Time
- High Resolution Time –Space Visualization
- Event Engineering Models
- Table Look Ups

Comm Models



L-V-C Interface



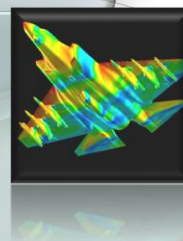
Operational Modeling

- Discrete Event Simulation, Agent Based Modeling
- < Real Time
- Scenario Visualization
- Event Engineering Models
- Table Look Ups

**Common Interface
Built on Reducing
Physics Models to
Light Weight Algebraic
Relations**

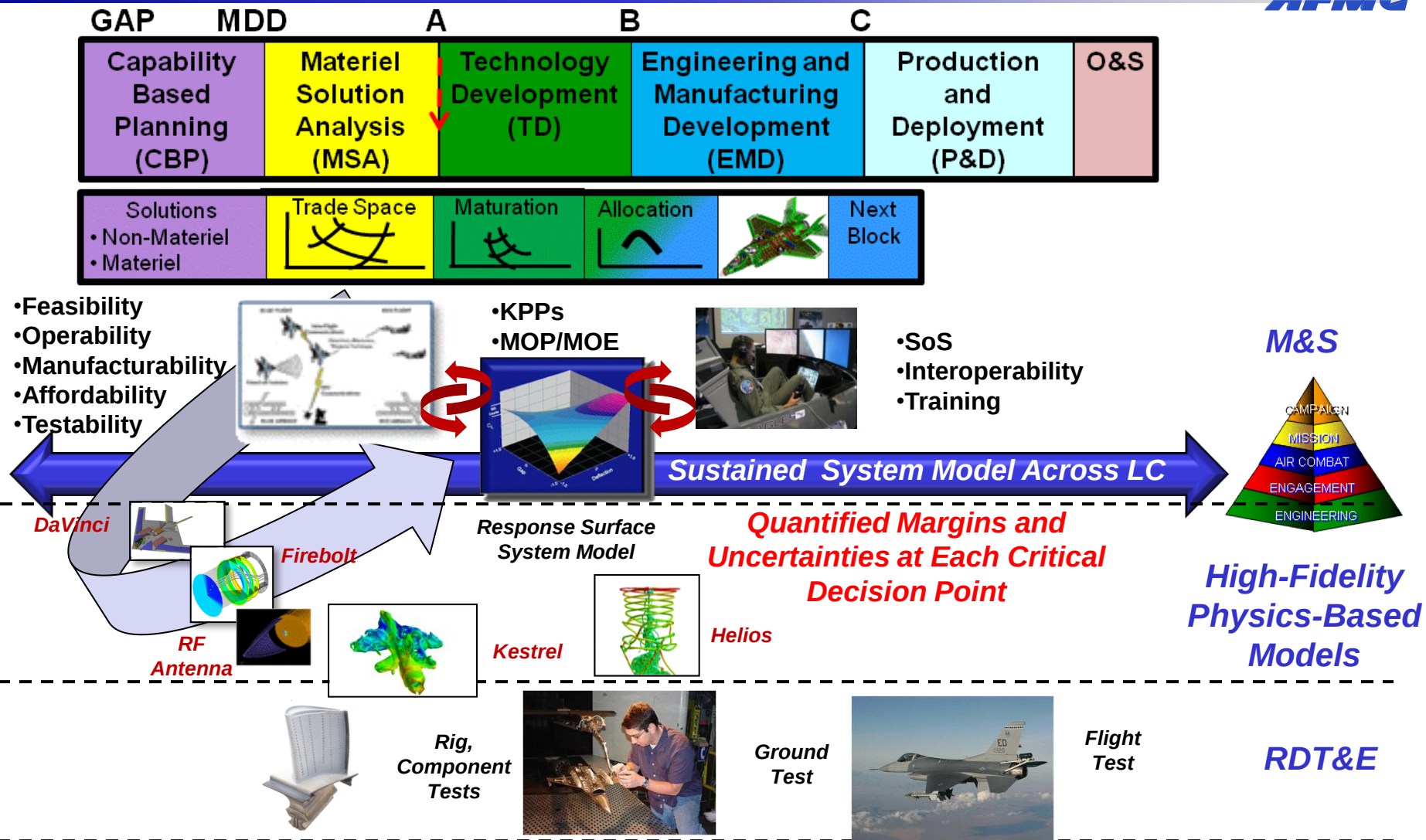
Physics Modeling

- Discretized Physics
- > Real Time
- Phenomena Visualization





Integrating M&S, RDT&E, and Statistical Engineering for Life Cycle Support



A Continuum of Tools Underpinned with Statistical Engineering to Quantify Margins and Risks at Key Decision Points



Early Decisions for Better Outcomes

Better Tools and Processes Applied Earlier



- **Systems Engineering – event driven vs effects based**
 - Quantified margins/uncertainties at key decision points, particularly MS A/B
 - Accountability for risk management
- **Reduced Capacity – “procurement holidays” increase cycle time**
 - Increase effective capacity by reducing total workload and late defect discoveries through better design tools and technical process changes
- **Complexity – aerospace/defense community self inflicted wound**
 - Platform based engineering, common architectures for most software systems vice clean sheet approach
 - Increases in complexity have to “buy” their way onto the system during the requirements setting phase, including impact on acquisition cycle time
- **Requirements – not necessarily connected to mission or physical reality**
 - Integrated wargames, flight simulators, and physics-based modeling support early insertion of physical reality into operational assessments and cost/risk projections
 - Resilient system designs for flexibility to meet changing missions

A Final Thought from Winnie-the-Pooh



*It is, as far as he knows,
the only way of coming
downstairs,
but sometimes he feels
there really is another way,
if only
he could stop
bumping for a moment
and think of it.*