Modeling Dynamic Relationships in DoD Weapon System Acquisition

J. Robert Wirthlin, PhD, Lt Col, USAF

Air Force Institute of Technology

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

Overview

- Foundation and Review of Past Efforts
- Model of Enterprise
- Key Insights
- What about Risk?
- Conclusions

Foundations of Research

- Acquisition system outcomes (cost/schedule) are not doing well.
  - MDAPs are behind schedule/over cost (GAO 06-368 and others)

A closer look at program cost growth

Percentage of DOD cost overrun per decade for the past 30+ years*

1970-1979	1980 - 1989	1990 - 1999
Development cost overrun: 30% above initial investment estimate **($13 billion)**	**Development cost overrun:** 39% above initial investment estimate **($12 billion)**	**Development cost overrun:** 40% above initial investment estimate **($15 billion)**

(Fiscal year 2005 dollars)

*** For large programs totaling more than $1 Billion in Research, Development, Testing and Evaluation (GAO 06-368)**

Similar evidence exists regarding schedule adherence

Typical System Interventions

- Let's study it, make a policy, or pass a law….
  - Some well-known and far-reaching – others not

1970 – 1979	1980 - 1989	1990 - 1999
Key Studies and Initiatives Impacting the Defense Acquisition Process		
•1970 Fitzhugh Commission •1972 Commission on Government Procurement	•1981 Carlucci Initiatives •1982 Grace Commission •1986 Packard Commission	•1994 Federal Acquisition Streamlining Act •1996 Clinger-Cohen Act
DOD Acquisition Policy Changes		
•1971 DOD 5000 policy established •1975 DOD Policy revised •1977 Policy revised	•1980 Policy revised •1982 Policy revised •1985 Policy revised •1986 Policy revised •1987 Policy revised	•1991 Policy revised •1996 Policy revised

Source: DOD (data); GAO (Analysis and presentation) GAO 06-368

- Notable actions in the 2000s
  - DAPA Report – September 2006
  - DoD Acquisition Policy rewritten ~ 2002, 2008
  - Non-Acquisition changes: JCIDS Revised 2009; PPBES changed

Maybe the Focus is Wrong

- DoD programs have problems because they "do not capture the requisite knowledge when needed to efficiently and effectively manage program risks" (GAO 05-391)
- Undesirable outcomes are tied to deficient program risk management (GAO 04-53, 06-110,06-257T,06-368, 06-391, 06-585T, DAPA 2006, PMIBOK, DSMC Risk Management Guide Book), Browning, T. R. and E. F. H. Negele (2006). Lambert, J. H., R. K. Jennings, et al. (2006). Lévárdy, V. and T. R. Browning (2005).
- Risk Management is an important tool
  - Numerous methods and frameworks available for use

Exploratory Studies

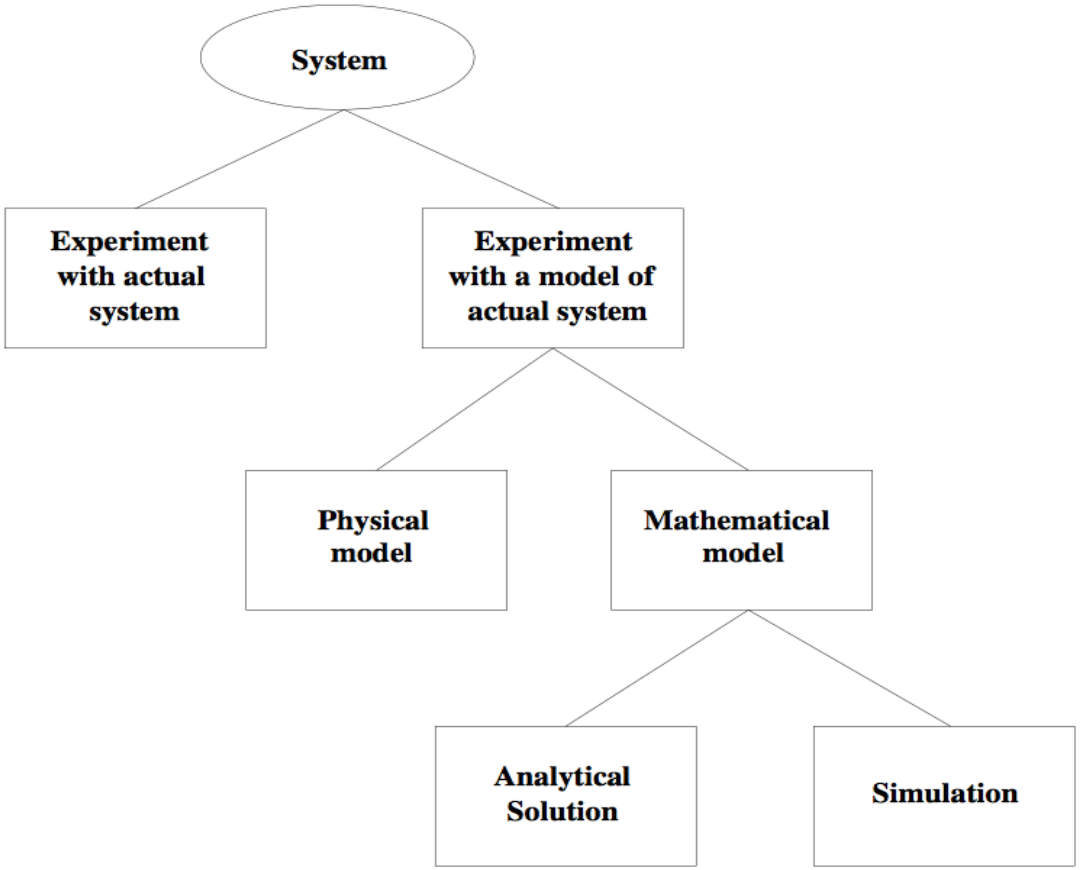
- Two separate studies conducted
  - Acquisition system; JCIDS and PPBE
    - Initial focus of these was on the subjects of “risk” and “portfolios” but expanded to much larger issues very quickly.
- Details of both studies led to a need to better understand the entire system.

Better Systemic Understand Needed

- Could a model help explain Enterprise Acquisition behaviors and outcomes?
  - What models exist?
    - DAU's Integrated Defense AT&L Life Cycle Management Chart
    - ?

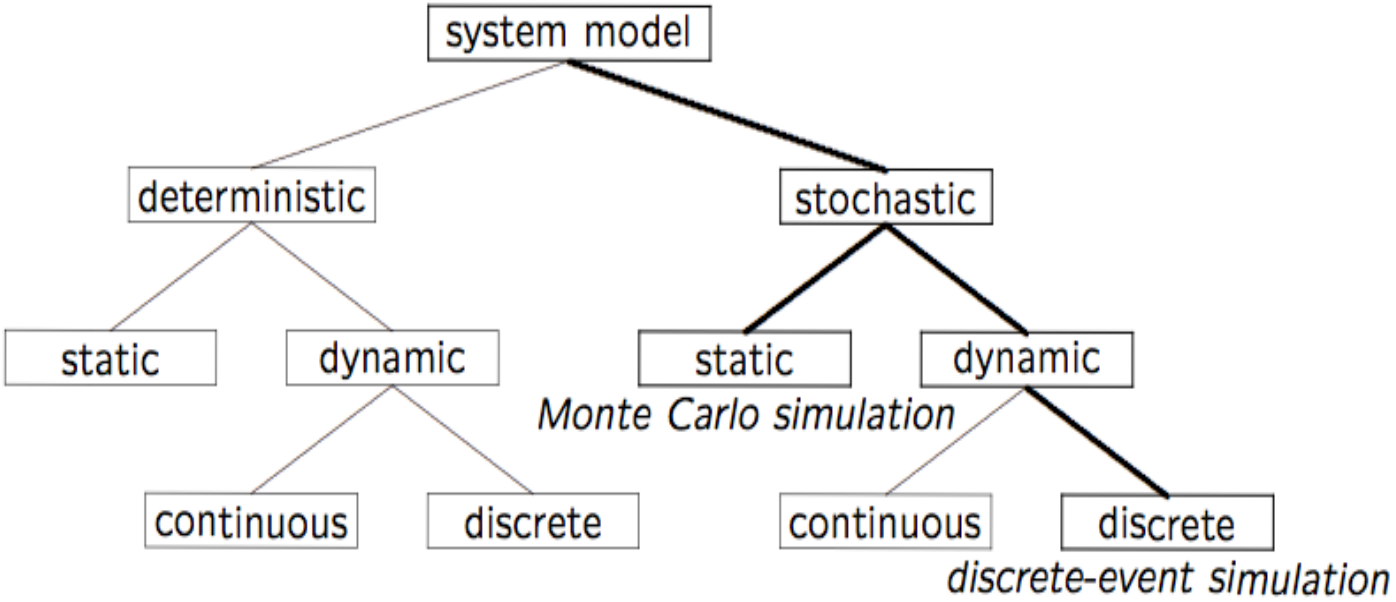
A systems approach in analysis may yield heretofore unknown insights about the overall system

Ways To Study A System*



Simulation, Modeling & Analysis (3/e) by Law and Kelton, 2000, p. 4, Figure 1.1

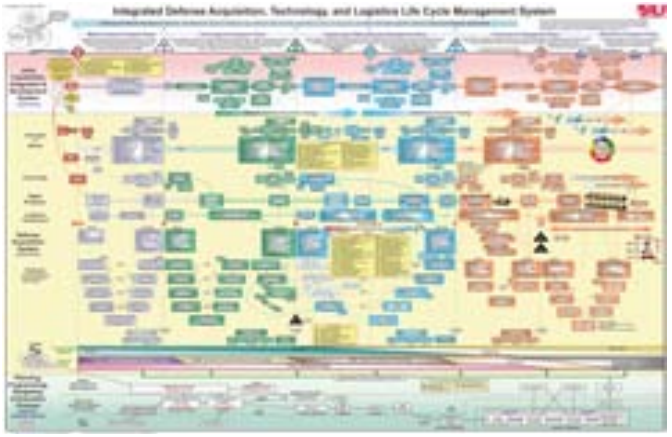
Model Taxonomy



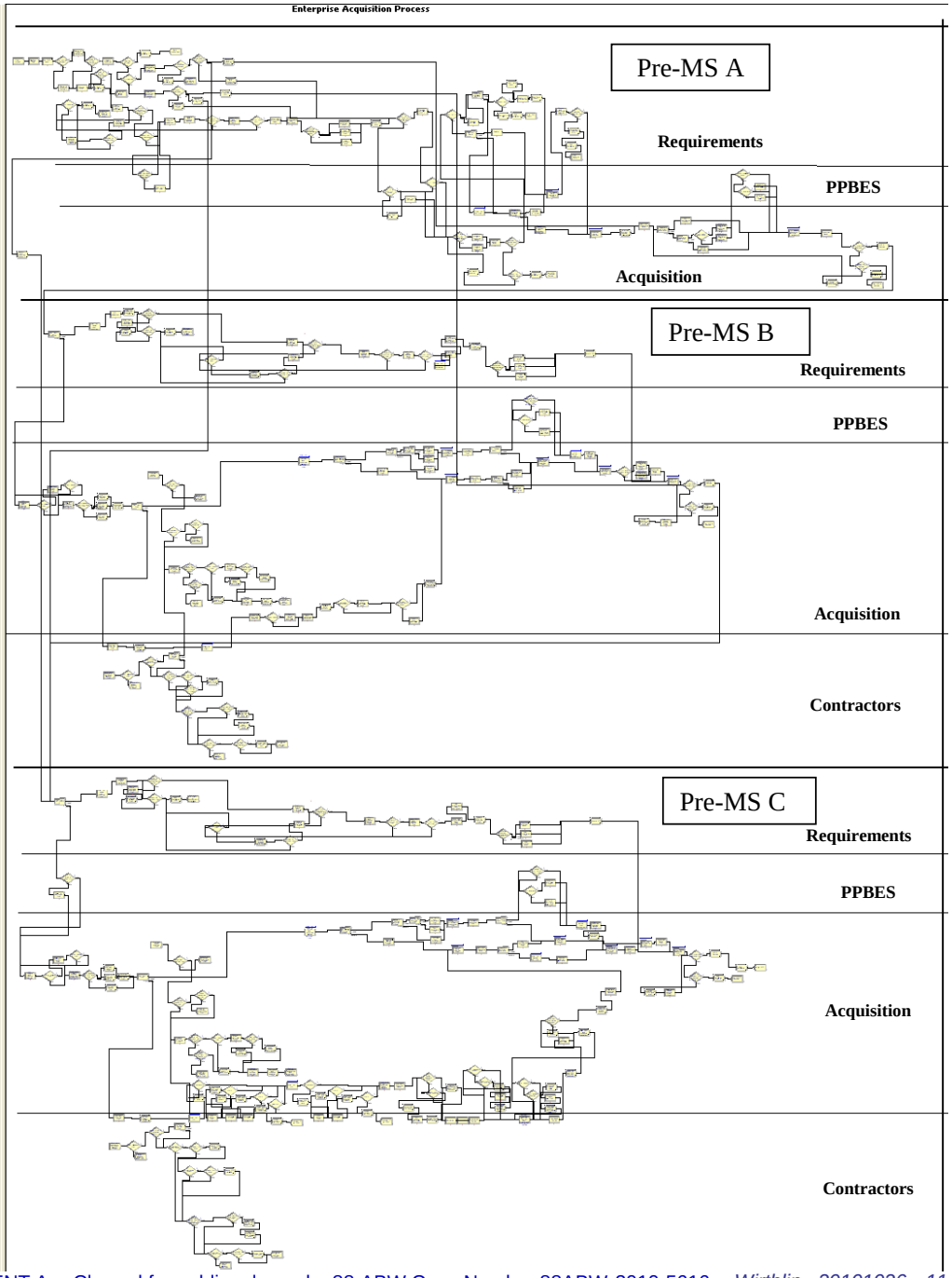
Simulation, Modeling & Analysis (3/e) by Law and Kelton , 2000

Acquisition Enterprise Model

Transform's DAU's Wall Chart



Into this…



Model Development

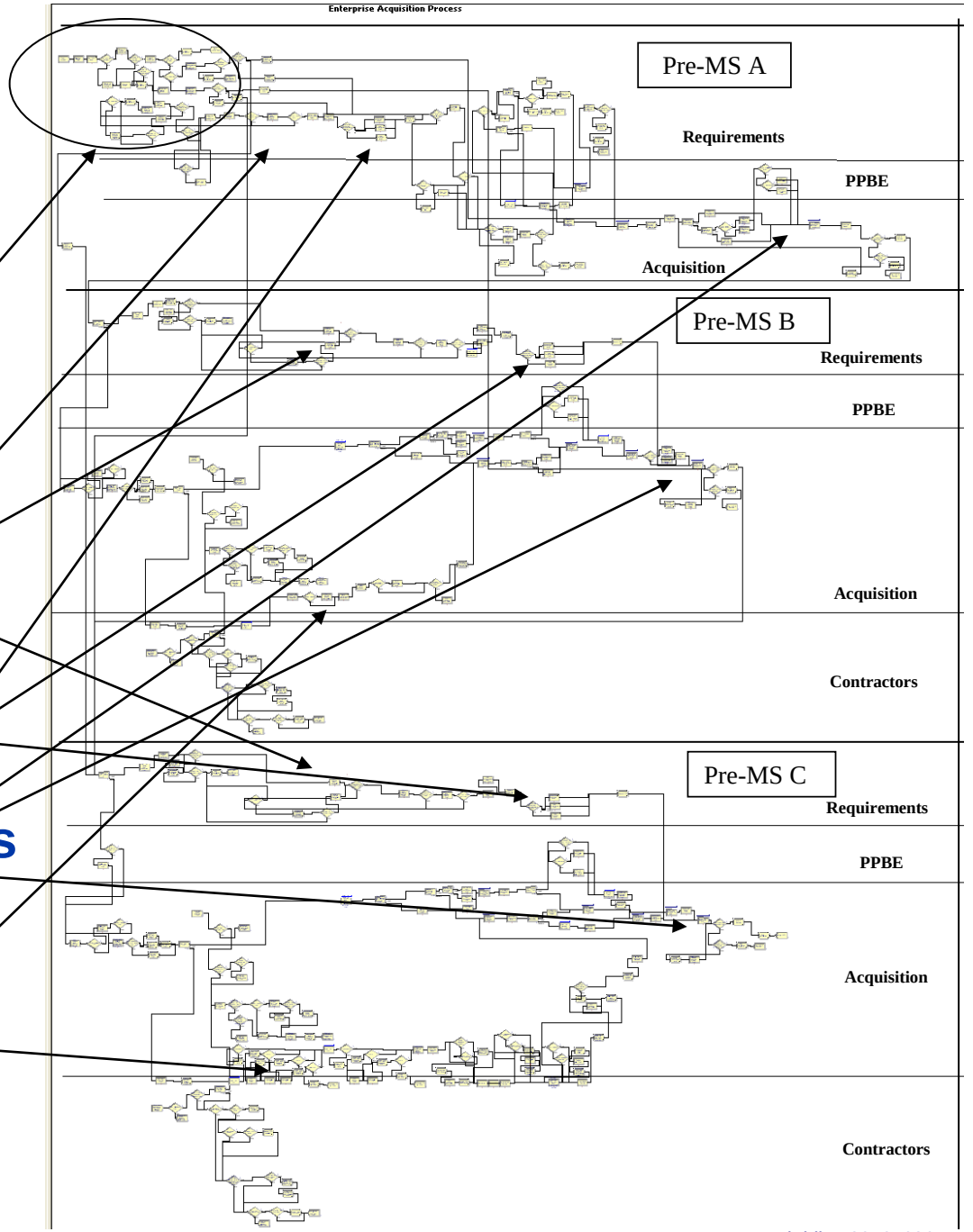
- Assumes AF as representative surrogate of DOD processes
- Based upon official process documentation to understand the process "should be"
- Augmented by multiple interviews indicating the process "as is"

Model is a representation of the current, "as is," system

A Model of the Acquisition System

- Structure of model
  - Scope: Pre-MS A to MS C
  - Model Outputs:
    - Total number of programs arriving at MS C
    - Total time through the system

- **Informal entry processes and screening**
- **Requirements approvals (MAJCOM)**
- **Joint requirement approvals**
- **Acquisition Panels**
- **Systems Engineering reviews and testing**



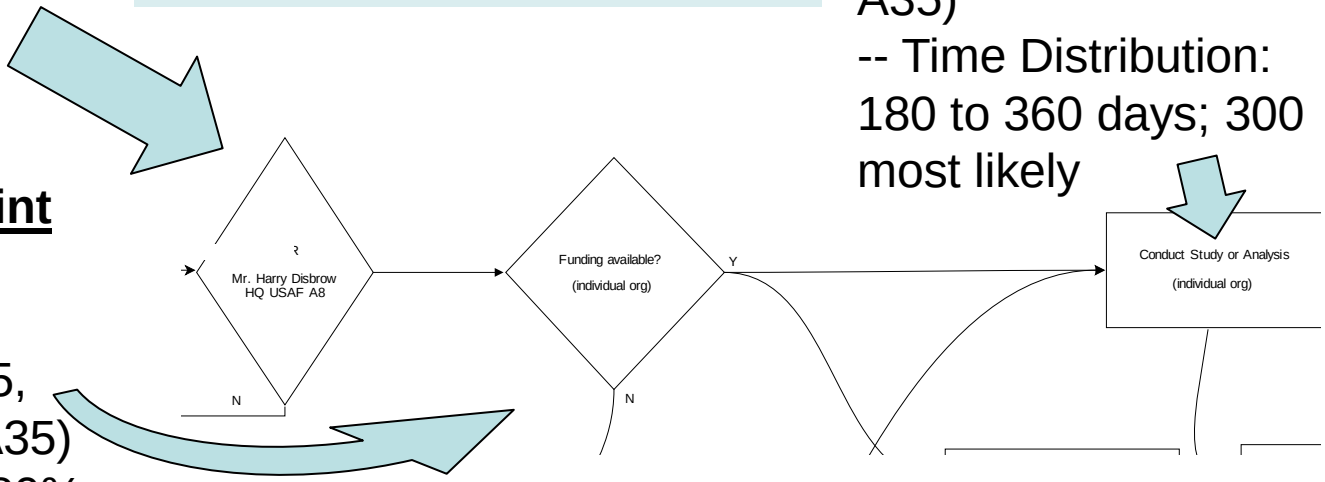
Acquisition System Model Built from Extensive Data

Model Design: Every decision point, every process task, where possible, is thoroughly documented and sourced

RSR – **Decision Point**
-Sources: Official Docs, Interviews (MAJCOM A5, HQ A3)
-Probability: 98%

Funding Available? – **Decision point**
-Sources: Interviews (MAJCOM A5, HQ A3, HQ A35)
-Probability: 80%

Conduct study or analysis – **Task**
-Sources: Official docs, Interviews (MAJCOM A5, HQ A35)
-- Time Distribution: 180 to 360 days; 300 most likely



How can the Model be used?

- What kinds of questions is this model well-suited to try?
  - Using simulation, what kinds of issues can be explored with this model?
    - What is the range of potential system outcomes?
    - How can our understanding of the current system be enhanced?

Experimental Model outcomes of 48500 samples

Initial MAJCOM / JCIDS PROCESSES

34% outright rejection (16982)

27% rejected after waiting period (13111)

21% are sent to sustainment (10424)

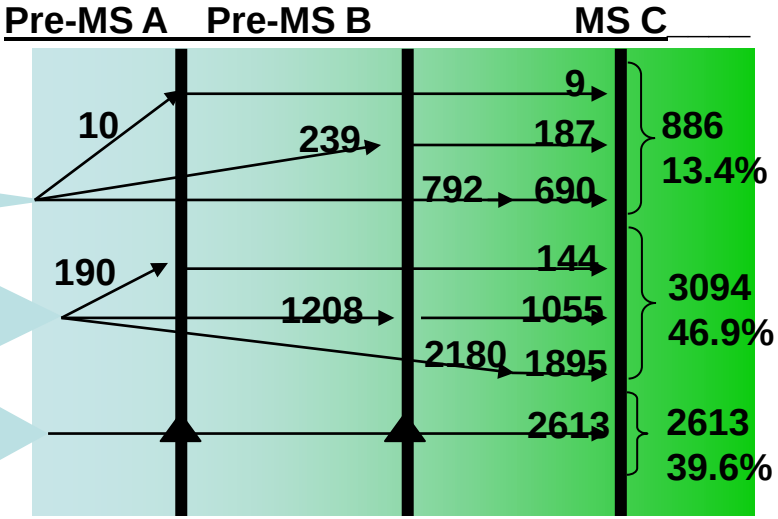
2.1% back into process (1041)

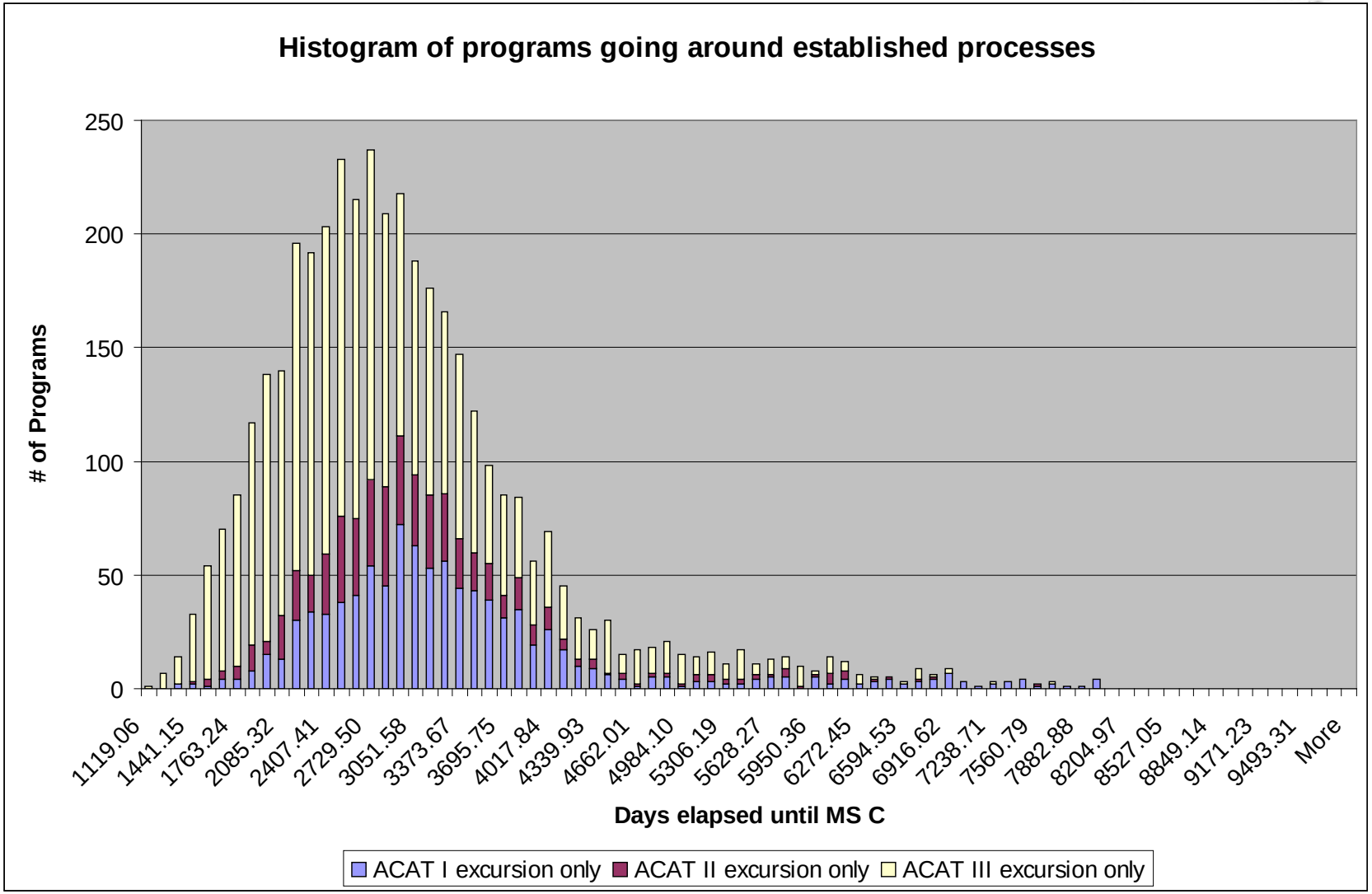
7% by-pass parts of formal system (3578)*

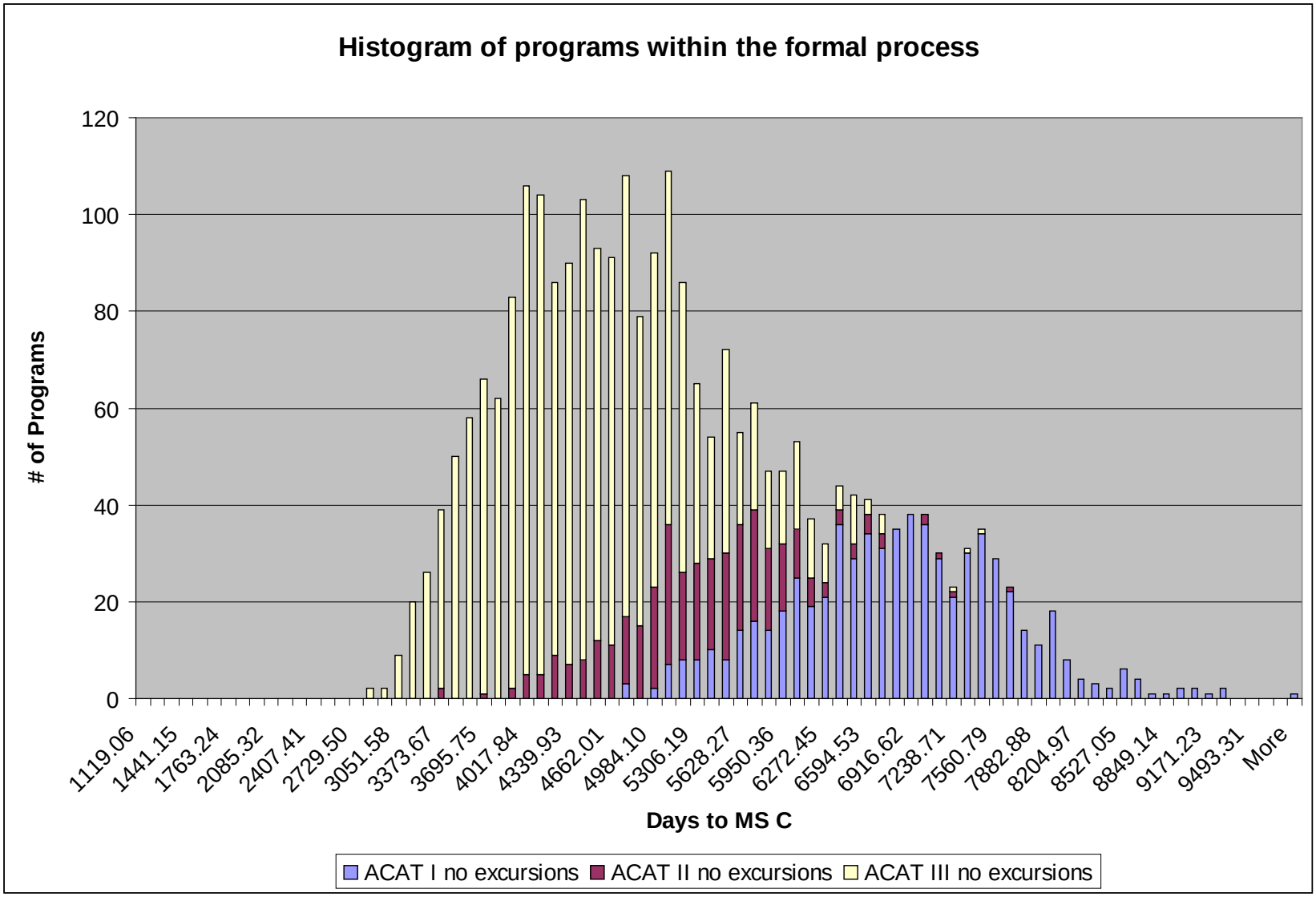
* In scope of existing Requirements document

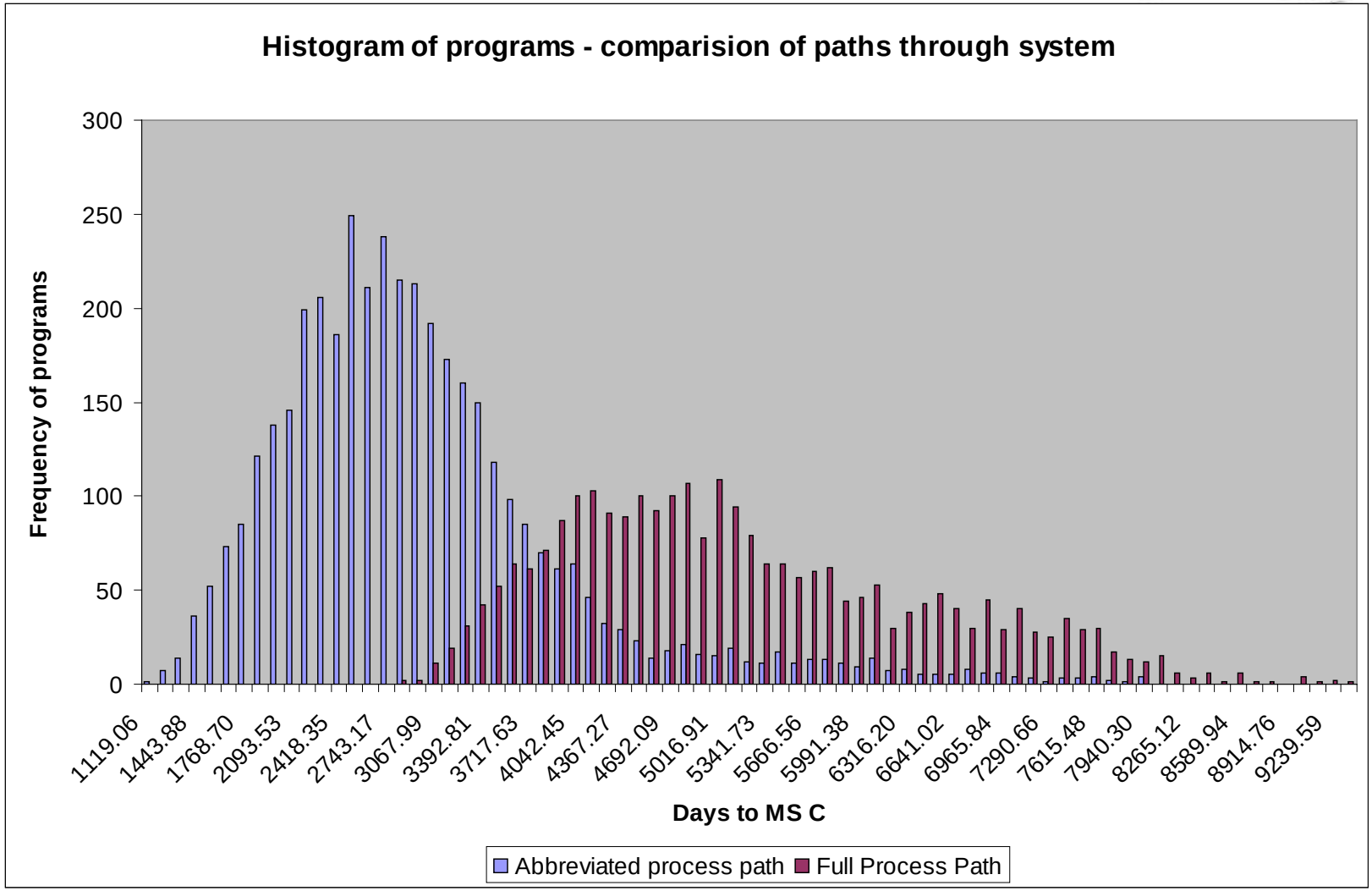
9% enter formal system (4405)

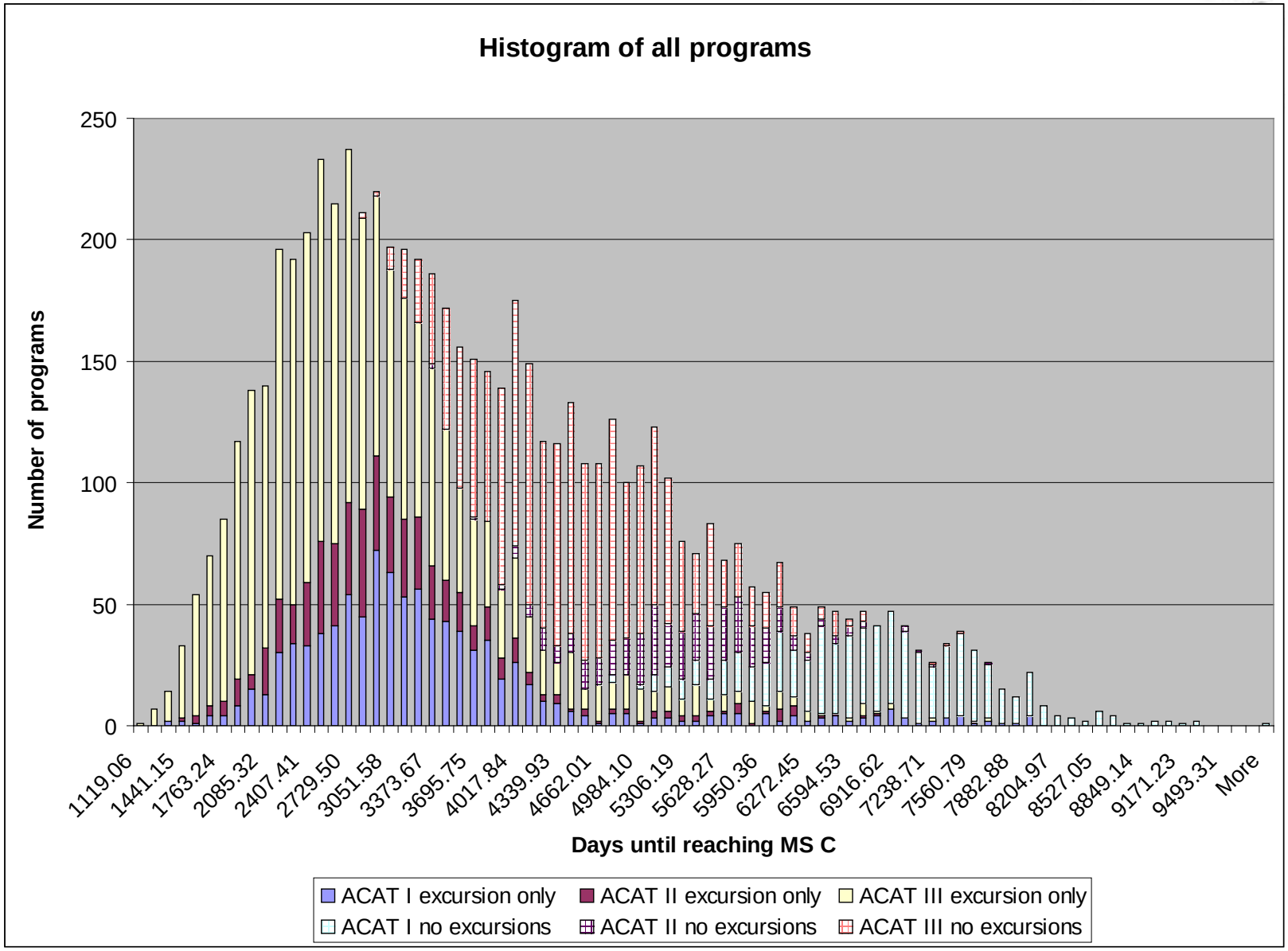
Formal Acquisition Processes



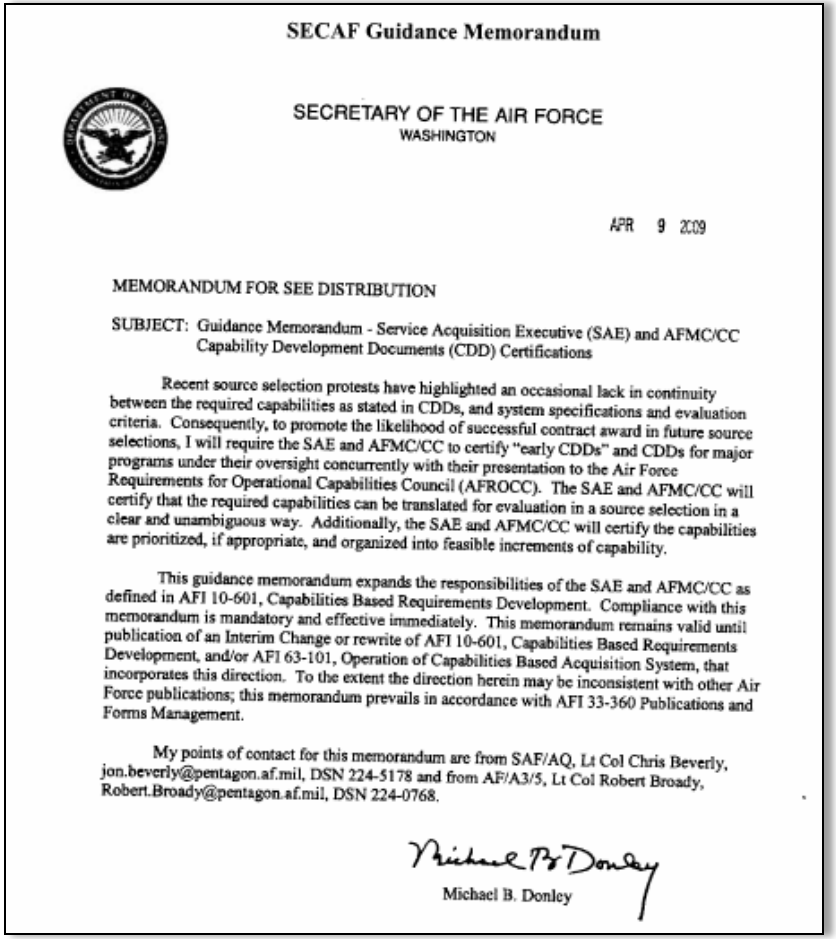

Histogram of programs going around established processes
# of Programs
250
200
150
100
50
0
1119.06
1441.15
1763.24
2085.32
2407.41
2729.50
3051.58
3373.67
3695.75
4017.84
4339.93
4662.01
4984.10
5306.19
5628.27
5950.36
6272.45
6594.53
6916.62
7238.71
7560.79
7882.88
8204.97
8527.05
8849.14
9171.23
9493.31
More
Days elapsed until MS C
ACAT I excursion only
ACAT II excursion only
ACAT III excursion only


Histogram of programs within the formal process
# of Programs
120
100
80
60
40
20
0
1119.06
1441.15
1763.24
2085.32
2407.41
2729.50
3051.58
3373.67
3695.75
4017.84
4339.93
4662.01
4984.10
5306.19
5628.27
5950.36
6272.45
6594.53
6916.62
7238.71
7560.79
7882.88
8204.97
8527.05
8849.14
9171.23
9493.31
More
Days to MS C
ACAT I no excursions
ACAT II no excursions
ACAT III no excursions


Histogram of programs - comparision of paths through system
Frequency of programs
300
250
200
150
100
50
0
1119.06
1443.88
1768.70
2093.53
2418.35
2743.17
3067.99
3392.81
3717.63
4042.45
4367.27
4692.09
5016.91
5341.73
5666.56
5991.38
6316.20
6641.02
6965.84
7290.66
7615.48
7940.30
8265.12
8589.94
8914.76
9239.59
Days to MS C
Abbreviated process path
Full Process Path


Histogram of all programs
Number of programs
250
200
150
100
50
0
1119.06
1441.15
1763.24
2085.32
2407.41
2729.50
3051.58
3373.67
3695.75
4017.84
4339.93
4662.01
4984.10
5306.19
5628.27
5950.36
6272.45
6594.53
6916.62
7238.71
7560.79
7882.88
8204.97
8527.05
8849.14
9171.23
9493.31
More
Days until reaching MS C
ACAT I excursion only
ACAT II excursion only
ACAT III excursion only
ACAT I no excursions
ACAT II no excursions
ACAT III no excursions

Newer policy – unknown impact



SECAF Guidance Memorandum

SECRETARY OF THE AIR FORCE
WASHINGTON

APR 9 2009

MEMORANDUM FOR SEE DISTRIBUTION

SUBJECT: Guidance Memorandum - Service Acquisition Executive (SAE) and AFMC/CC Capability Development Documents (CDD) Certifications

Recent source selection protests have highlighted an occasional lack in continuity between the required capabilities as stated in CDDs, and system specifications and evaluation criteria. Consequently, to promote the likelihood of successful contract award in future source selections, I will require the SAE and AFMC/CC to certify "early CDDs" and CDDs for major programs under their oversight concurrently with their presentation to the Air Force Requirements for Operational Capabilities Council (AFROCC). The SAE and AFMC/CC will certify that the required capabilities can be translated for evaluation in a source selection in a clear and unambiguous way. Additionally, the SAE and AFMC/CC will certify the capabilities are prioritized, if appropriate, and organized into feasible increments of capability.

This guidance memorandum expands the responsibilities of the SAE and AFMC/CC as defined in AFI 10-601, Capabilities Based Requirements Development. Compliance with this memorandum is mandatory and effective immediately. This memorandum remains valid until publication of an Interim Change or rewrite of AFI 10-601, Capabilities Based Requirements Development, and/or AFI 63-101, Operation of Capabilities Based Acquisition System, that incorporates this direction. To the extent the direction herein may be inconsistent with other Air Force publications; this memorandum prevails in accordance with AFI 33-360 Publications and Forms Management.

My points of contact for this memorandum are from SAF/AQ, Lt Col Chris Beverly, jon.beverly@pentagon.af.mil, DSN 224-5178 and from AF/A3/5, Lt Col Robert Broady, Robert.Broady@pentagon.af.mil, DSN 224-0768.

Michael B. Donley

Michael B. Donley

- **Do we know what the actual impact of this policy change is?**
- **Will it really improve outcomes?**

Experimental Interventions Completed

- JCIDS Interventions
- PPBE Interventions
- Acquisition Interventions
  - Systems Engineering
  - Acquisition Management
- Combinations of interventions

Model enables testing of different process and policy interventions

- Example intervention:
  - Improve "Funding Instability" by eliminating funding instability module in model
  - Results compared to the baseline:
    - Mean/median reduced by about 4%
- Many other interventions tried—(20 total)
  - Results were similar—no silver bullet solution

"Do Everything" — combination of all separate interventions (13) resulted in schedule reduction of 19% from baseline

What problem are we trying to solve?

- Goal: Reduce total program time to MS C: possible ~10% improvement
  - Multiple interventions most effective
- Goal: Increase program "predictability" (or minimize variances): possible ~20% gain
  - Focus on "quality" initiatives
- Goal: Control process "throughput" or capacity: possible ~10% improvement
  - e.g. Increase termination probability at major reviews

What about Risk?

- **Enterprise Risk is difficult to articulate**
  - **Working definition: Any process, procedure, or policy in the overall enterprise system that influences individual program success outcomes, e.g. cost, schedule, performance, negatively**

Enterprise Risk Influence

- Research suggests it may dominate all other individual contributions of risk to the overall program outcomes
  - The model lends support to the notion that a majority of the variance in program outcomes traces to the emergent behaviors of the Enterprise "system"

Possible Manifestations of Enterprise Risk

- Impact of Rescheduling of Calendar for various reviews
- Early Systems Engineering effort (or lack thereof)
- Impact of changing policies and procedures

Key Qualitative Conclusion

- **The overall Acquisition system incentivizes personnel to not follow existing processes and go around it.**
  - **Some of the evidence in this regard is the proliferation of new programs, prototypes and rapid reaction programs that operate on the fringes of the current system.**

Key Quantitative Conclusions

- The complexity of the system complicates the testing & measurement of proposed interventions.
  - Real world interventions are rarely understood because years must transpire before steady-state results relating to that intervention are seen.
- The most effective interventions are those that address the "quality" of system processes or attack sources of variability in the system.
  - For example: Improving systems engineering processes, reducing technical & funding uncertainties cause programs to execute less randomly

Overarching Conclusion

- The “Enterprise” of Acquisition or the “system” is designed for flexibility, transparency, and performance at the expense of cost and schedule
  - It is not just cost, schedule, & performance. Instead of three major considerations, there are five
    - A good rule of thumb? “Pick three at the expense of two”

Implications for "human requirements"

- Recognize that humans are also part of the "system" of acquisition
  - Some Pathologies
    - Overconfidence, e.g. implausible timelines
    - "Salute smartly" attitude – accepts requirement changes without corresponding resources to implement those changes
    - "Us vs. them" mentality between government program offices & contractors
    - Etc.

Conclusions

- **Human Factors Engineering must extend beyond official program requirements**
  - **It must also recognize and address the impact complex human interactions that occur during the acquisition and development of DoD systems.**
    - **Should be a key consideration from Day 1 of a program**

Conclusions (cont.)

- Human Factors Engineering has the potential to contribute much to the improvement of the Acquisition Enterprise
- An Enterprise perspective on Acquisition yields new insights into individual program execution issues & system improvement strategies

Implications

- **Changing Acquisition System outcomes will require a multi-community effort (i.e., users, requirements, PPBE, acquisition, contractors, etc.)**
- **Model new or changed system processes, procedures, and policies *before* implementation**
  - **Eliminating unnecessary or duplicative processes and decisions will reduce program development time and cost.**
- **Stay the course/accelerate LSS/CPI efforts, especially toward reducing variability in system inputs**
- **Acknowledge system-level issues and set appropriate goals**
  - **Significant effort over many years will be required for system-wide change**

Questions?

Backup

Original Research Contributions

- Model and Methodology shed new insight into overall system
  - Provides a different mechanism to look at the behaviors of the overall system
- Provides an opportunity to:
  - Selectively test different interventions
  - Analyze those outcomes
- Methodology can be applied to other very complex and dynamic socio-technological systems

Key Breakthrough

- Interviewees were only able to articulate job descriptions in generalities
  - "It depends"
- However, every single interviewee WAS able to give me a time "distribution" or probability
  - "between 6 days and 5 weeks"
  - "80% of the time"
  - etc

Verification and Validation

- Modeled by hand; checking for logic errors
- Modeled on paper; sought expert feedback
  - Many improvements received
- Coded in modeling tool; verified coding done correctly
- Compared model outcomes with real data
  - For all ACATs, there is no difference in means between the model data and actual data at the 95% confidence level (from a student t-test)
    - Also for individual ACAT levels
- Validated model structure and results with other acquisition professionals

Complete process of checking model by hand

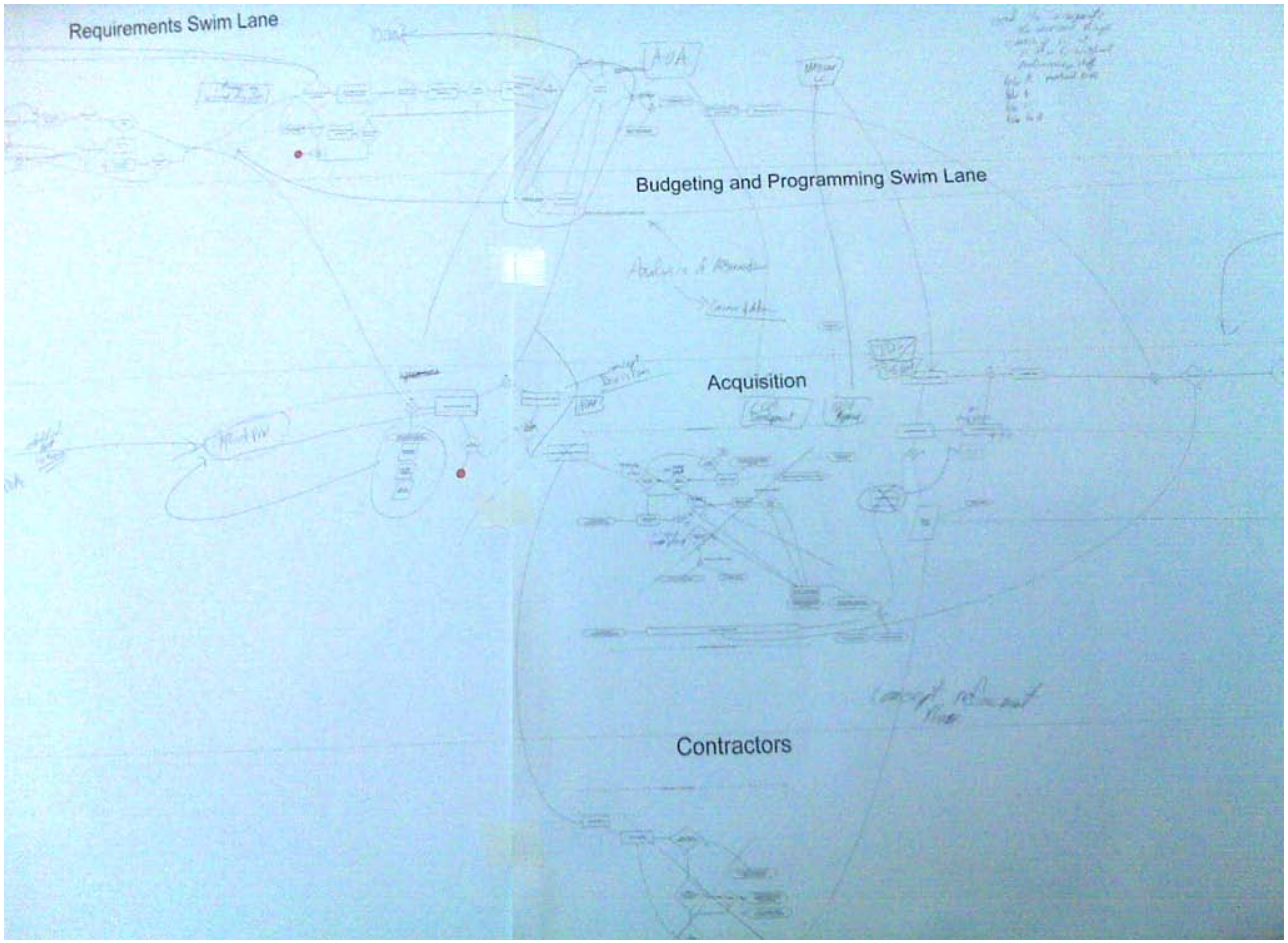
- **Completed**
  - **Many trials by hand**
    - **Example: 4th trial reached Milestone A at 1410 days**
    - **Each hand trial required 15 to 300 individual roles of the dice, plus calculation of time elapsed based on triangular distributions and probabilities of different paths to take**

	Hand model #1	Hand model #2	Hand model #3	Hand model #4
Ending point	Stay in Sustainment system	Stay in sustainment system	Stay in sustainment system	Milestone A
Number of process steps	7	7	7	192
Final days	439	959	785	1222

Expert feedback was helpful

- All agreed the model approach was understandable
- All had inputs on model improvements
  - The majority of inputs were on interactions between the processes that are not well documented
- All task durations and decision probabilities were re-verified and validated

Obtain expert's feedback on model



Data Sources used to obtain verifiable data

- SMART (System Metric and Reporting Tool) data access
  - MAR scores (all programs of record; some since 1990s)
  - PoPS scores (all programs of record since 2006)
- DAMIR (Defense Acquisition Management Information Retrieval) data access
  - SAR data (archives; current; preliminary); APBs, etc
- AF Financial data access
  - PEM assignments; PE to program mapping; P & R docs, archives, etc.
- AF Systems Library access
  - PEO system groupings; ACAT levels for programs; PMs; locations
- OSD Acquisition Management data access
  - All PMDs since 1989
- SACOM data access
  - Acquisition manning data (requested/desired and allocated)

Records of existing programs; past and current

Program Name	Initial ACAT Level	Initial Start Date		Initial Milestone of Entry	Projected Milestone Dates				Actual Milestone Dates				Initial Analysis of Schedule		
			Source		A	B	C	Source	A	B	C	Source	Projected B to C	Actual B to C	% change
B-2 RMP	I	17 Aug 2004	SMART Schedule	B	-	Jul 2004, Sep 2004	Feb 2007, Sep 2008	Jan 2009 APB	-	17 Aug 2004	4 Sep 2008	SMART Schedule	30 months	49 months	63%
C-5 RERP	I	1 Feb 2000	SMART Schedule	B	-	Nov 2001	Dec 2006, Mar 2007, Mar 2008	Jun 2008 APB	-	5 Nov 2001	25 Mar 08	SMART Schedule	61 months	88 months	44%
JDAM	I	11 Sep 2000	SMART Schedule	A	Oct 1993	Oct 1995, Sep 1995	Jul 1999, Apr 1998, Feb 1999, Nov 1999, Nov 2000	Oct 2002 APB	1 Oct 1993	1 Sep 1995	1 Mar 2001	SMART Schedule	34 months	66 months	94%
F-22	I	1 Oct 1986	SMART Schedule	A	Oct 1986	Jun 1991	Dec 1999, Jul 2001, Mar 2002, Sep 2002, Jul 2003, Mar 2004, Sep 2004	May 2007 APB	1 Oct 1986	1 Jun 1991	1 Mar 2005	SMART Schedule	102 months	165 months	62%
JPATS	I	1 Jan 1993	SMART Schedule	A	Jan 1993	Jun 1994, Feb 1995, Aug 1995	Jun 1998, Jan 1999, Sep 1999, Dec 1999, Nov 2000, Nov 2001	Sep 2007 APB	1 Jan 1993	1 Aug 1995	1 Nov 2001	SMART Schedule	34 months	75 months	120%
AMRAAM	I	1 Nov 1978	SMART Schedule	A	Nov 1978	Nov 1982, Sep 1982	Jun 1987	May 2008 APB	1 Nov 1978	1 Sep 1982	1 Jun 1987	SMART Schedule	45 months	45 months	0%
B-2 EHF Increment 1	I	22 Feb 2007	SMART Schedule	B	-	Feb 2007	Jul 2011	May 2007 APB	-	22 Feb 2007	*31 Jul 2011*	SMART Schedule	52 months	52 months	0%
C-130 AMP	I	1 Nov 2005	SMART Schedule	B	-	Jul 2007	Jun 2008	Feb 2008 APB	-	31 Jul 2007	*30 Jun 2009*	SMART Schedule	11 months	23 months	109%

Other Termination points within the formal model

- independent document PreC
- 2nd time requirements path
- independent document preA
- independent document PreB
- joint interest preC
- 1st time requirements path
- 1st time requirements path preC
- joint interest PreB
- joint integration PreC
- joint interest preA
- 2nd time requirements preB
- 1st time requirements PreB
- 2nd time requirements path preC
- kill at MS C
- joint integration preB
- Joint Integration PreA
- end at COA
- no AoA
- kill at CDR
- stop MS B
- pre-MS C begin
- kill at MS B
- kill at PDR
- concept selection
- 2nd try ms A

Other Termination Points account for 5% (2431) of a 48500 sample in model