Modeling Technology/System Readiness Level Impacts on LCC

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ICEAA 2018 PROFESSIONAL DEVELOPMENT & TRAINING WORKSHOP

Agenda – TRL Research

- Overview
- Analysis Framework
- Data Acquisition
- Regression and Model Development
- Proposed Mapping of SRL to DoD acquisition lifecycle

Objectives

Understand how different level of TRL progressions (e.g. TRL 5-7 vs TRL 5-9) influence non-recurring development costs (NRDEV) and schedule

Research Questions

How does TRL inform system maturity?

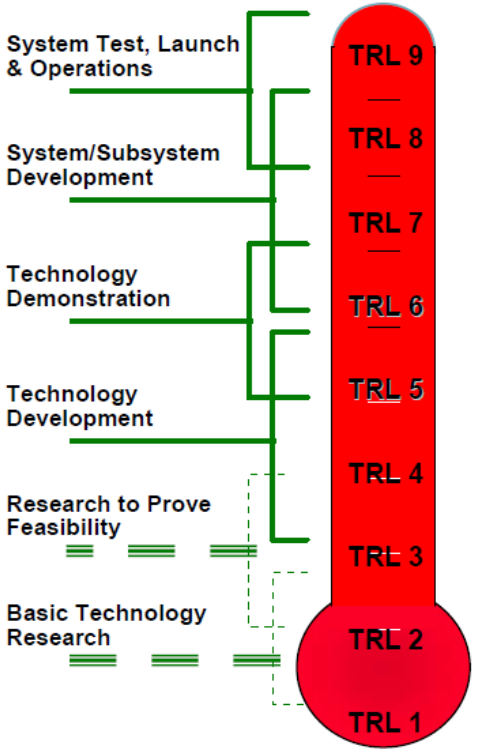
What factors play a role in determining TRL progression timeline? System Complexity, IOC date, Weight, System Type, Unit Production Cost, …

How do DoD 5000.02 milestone definitions correlate to TRL and System Maturity?

MS-A → TRL/SRL 3
MS-B → TRL/SRL 5
MS-C → TRL/SRL 7
IOC → TRL/SRL 9

Definition

Technology Readiness Level (TRL)



- TRL 9: Actual system proven through successful mission operations
- TRL 8: Actual system completed and qualified through test and demonstration
- TRL 7: System prototype demonstration in a relevant environment
- TRL 6: System/subsystem model or prototype demonstration in a relevant environment
- TRL 5: Component and/or breadboard validation in relevant environment
- TRL 4: Component and/or breadboard validation in laboratory environment
- TRL 3: Analytical and experimental critical function and/or characteristic proof-of-concept
- TRL 2: Technology concept and/or application formulated
- TRL 1: Basic principles observed and reported

- Rate of maturity is unique to technology types
- Time is a factor and is dependent on investment

An integrated approach to managing technology maturation costs, NDIA 13th Annual Systems Engineering Conference, October 28, 2010, Dr. R. Smoker, Dr. D. Armon

TruePlanning Inputs affected by TRL

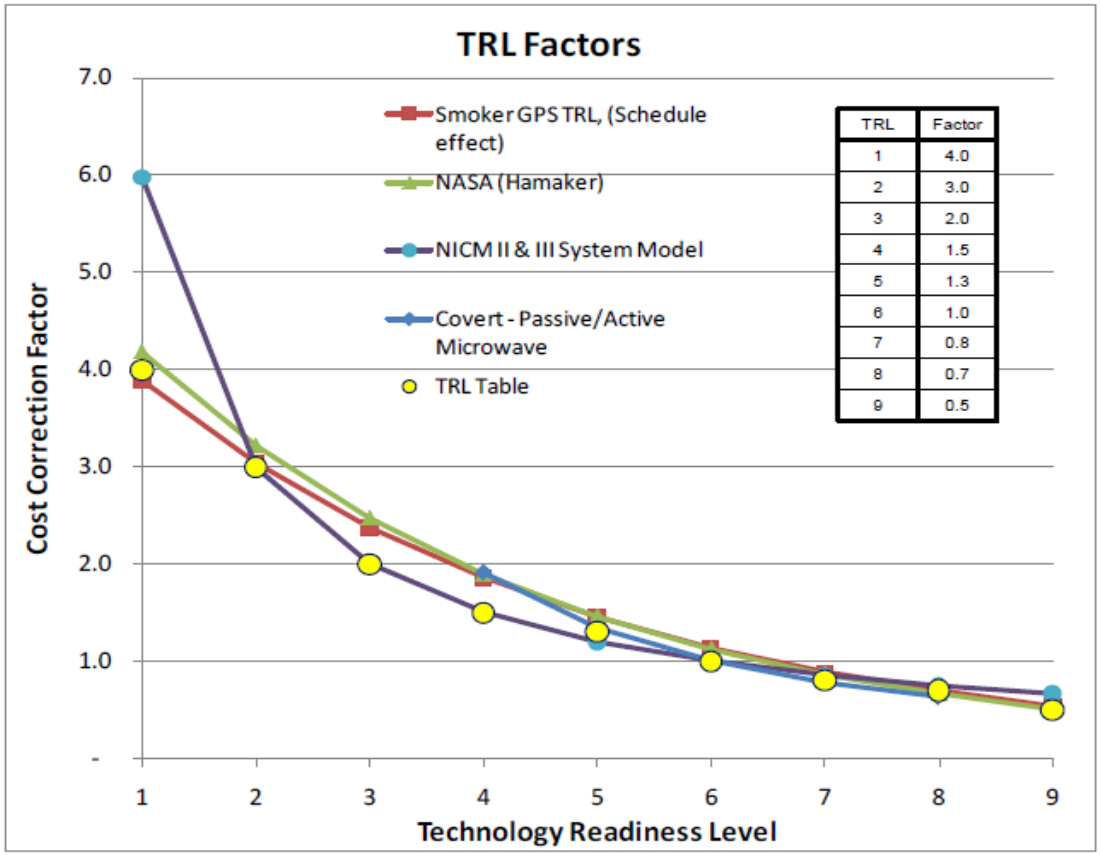
Research by:

Dr. Roy Smoker, MCR LLC

Mr. Joe Hamaker, previous head of NASA Cost

Dr. Hamid Habib-Agahi, JPL NICM II Model

Ray Covert, MCR LLC



TRL	Factor
1	4.0
2	3.0
3	2.0
4	1.5
5	1.3
6	1.0
7	0.8
8	0.7
9	0.5

Figure 1. Cost correction factors based upon historical data.

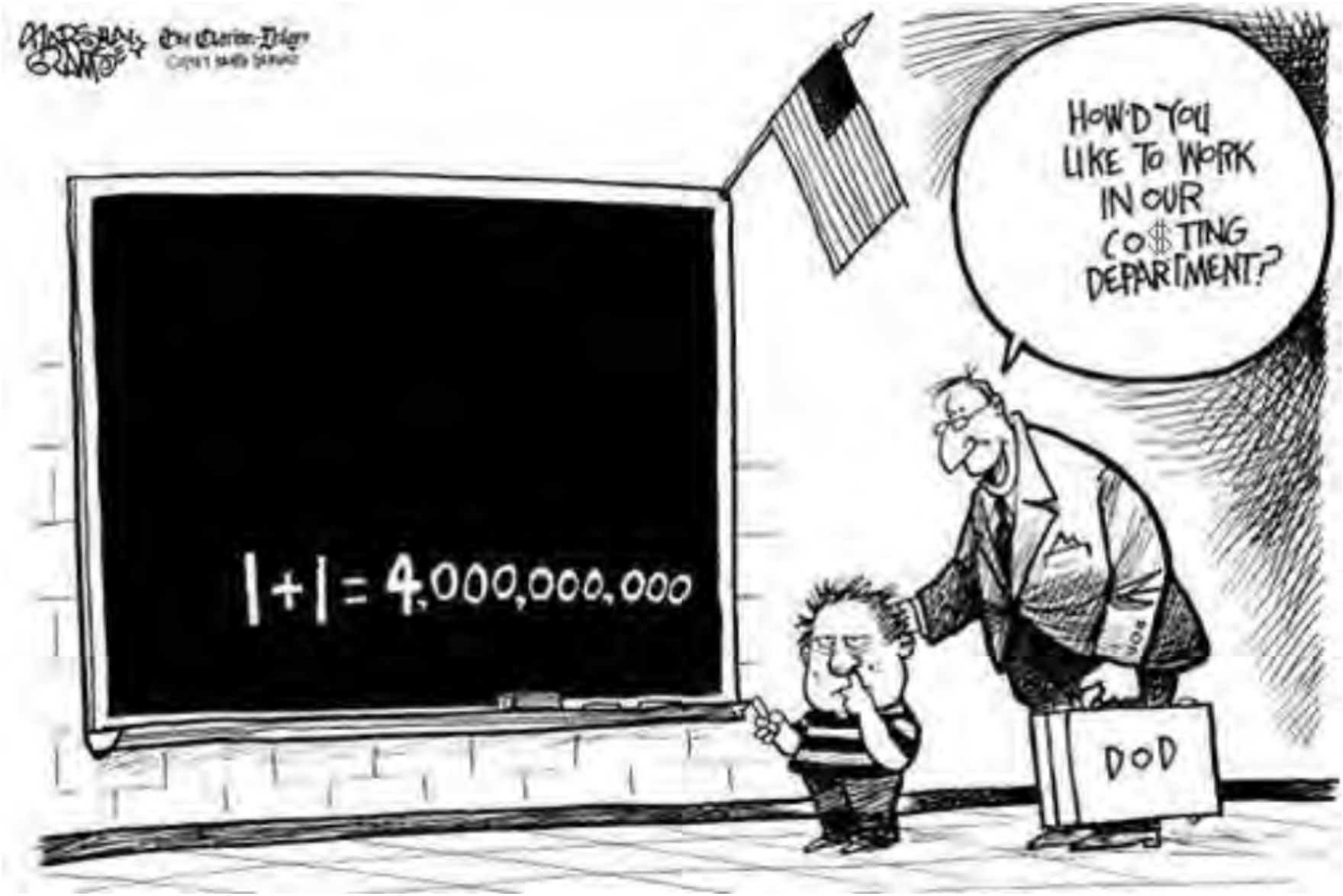
Analysis Framework

TRL Shortcomings

- Application of TRL to systems of technologies is not sufficient to give a holistic picture of complex system of systems readiness
  - TRL is only a measure of an individual technology
- Assessments of several technologies rapidly becomes very complex without a systematic method of comparison
- Multiple TRLs do not provide insight into integrations between technologies nor the maturity of the resulting system
  - Yet most complex systems fail at the integration points

From TRL to SRL: The Concept of Systems Readiness Levels, Conference on Systems Engineering Research, Los Angeles, CA, April 2006

Technologies ≠ System



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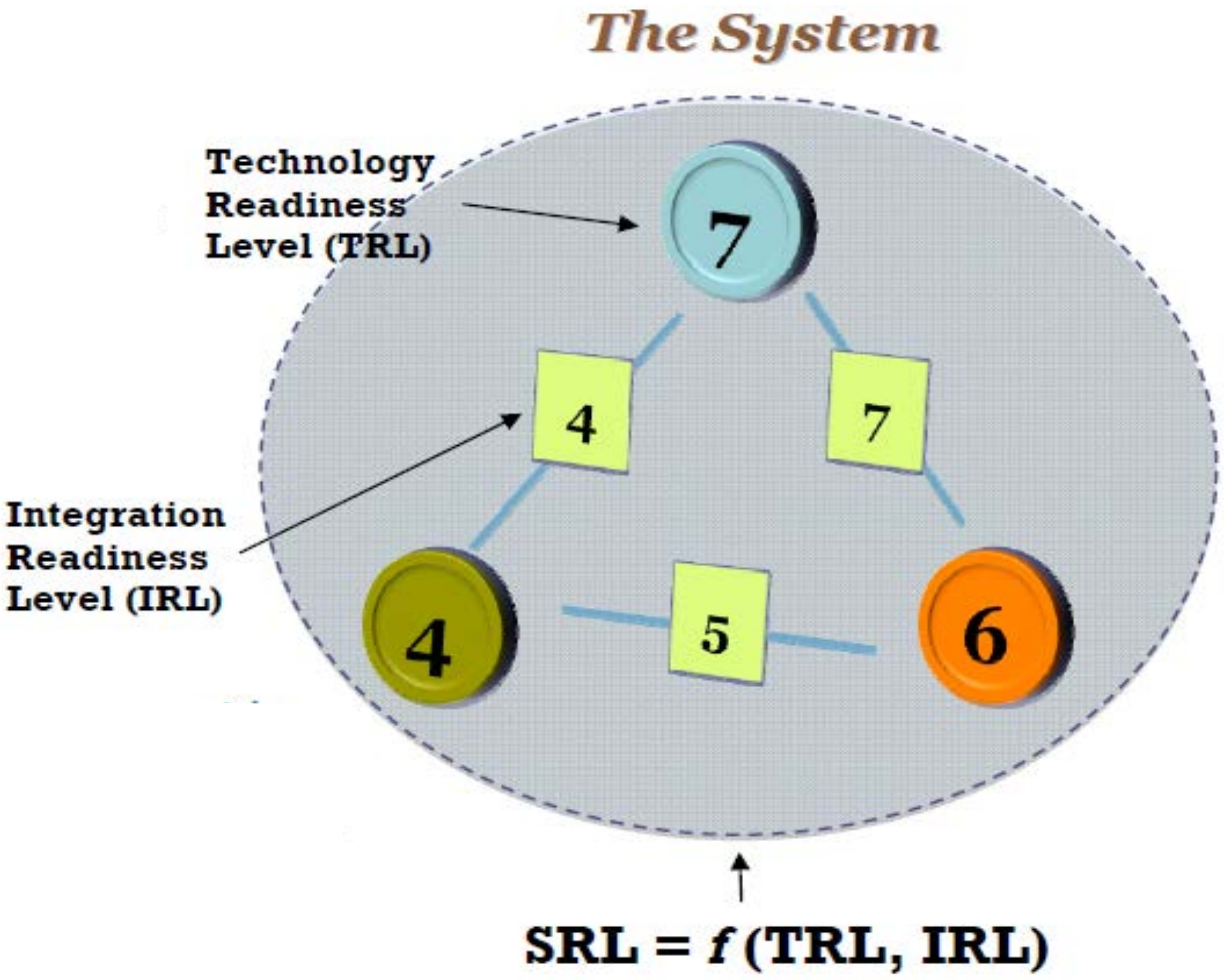
Integration Readiness Level

	IRL	Definition
Pragmatic	9	Integration is **Mission Proven** through successful mission operations.
	8	Actual integration completed and **Mission Qualified** through test and demonstration, in the system environment.
Syntactic	7	The integration of technologies has been **Verified and Validated** with sufficient detail to be actionable.
	6	The integrating technologies can **Accept, Translate, and Structure Information** for its intended application.
	5	There is sufficient **Control** between technologies necessary to establish, manage, and terminate the integration.
	4	There is sufficient detail in the **Quality and Assurance** of the integration between technologies.
Semantic	3	There is **Compatibility** (i.e. common language) between technologies to orderly and efficiently integrate and interact.
	2	There is some level of specificity to characterize the **Interaction** (i.e. ability to influence) between technologies through their interface.
	1	An **Interface** between technologies has been identified with sufficient detail to allow characterization of the relationship.

SRL Calculation



SRL Calculation

- The SRL is not user defined, but is instead based on the outcomes of the documented TRL and IRL evaluations
- Through mathematically combining these two separate readiness levels, a better picture of overall complex system readiness is obtained by examining all technologies in concert with all of their required integrations

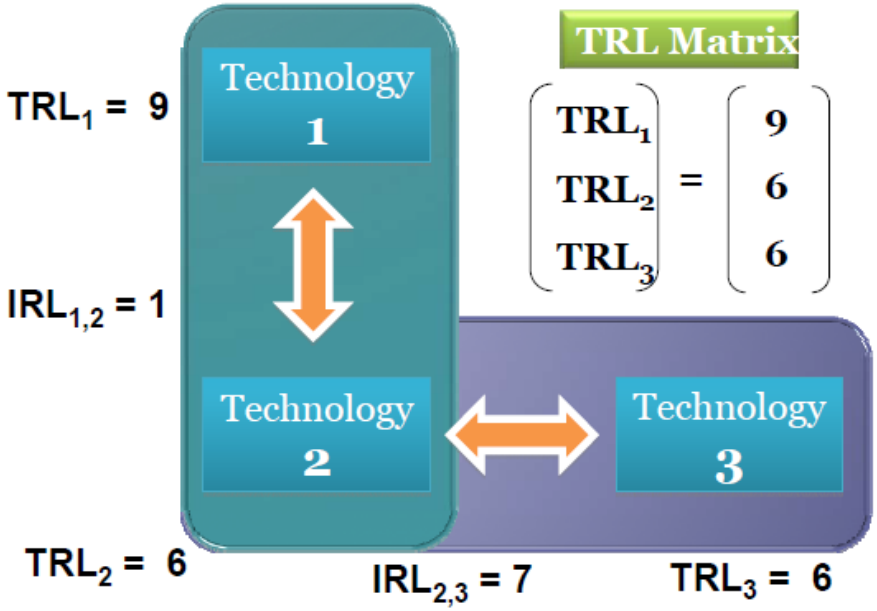
$$\mathbf{SRL = IRL \times TRL}$$

$$\begin{pmatrix} SRL_1 & SRL_2 & SRL_3 \end{pmatrix} = \begin{pmatrix} IRL_{11} & IRL_{12} & IRL_{13} \\ IRL_{12} & IRL_{22} & IRL_{23} \\ IRL_{13} & IRL_{23} & IRL_{33} \end{pmatrix} \times \begin{pmatrix} TRL_1 \\ TRL_2 \\ TRL_3 \end{pmatrix}$$

$$\text{Composite SRL} = 1/n \left(SRL_1/n + SRL_2/n + SRL_3/n \right)$$

$$= 1/n^2 \left(SRL_1 + SRL_2 + SRL_3 \right)$$

SRL Calculation Example



TRL Matrix

$$\begin{pmatrix} TRL_1 \\ TRL_2 \\ TRL_3 \end{pmatrix} = \begin{pmatrix} 9 \\ 6 \\ 6 \end{pmatrix}$$

IRL Matrix

$$\begin{pmatrix} IRL_1 & IRL_{12} & IRL_{13} \\ IRL_{12} & IRL_2 & IRL_{23} \\ IRL_{13} & IRL_{23} & IRL_3 \end{pmatrix} = \begin{pmatrix} 9 & 1 & 0 \\ 1 & 9 & 7 \\ 0 & 7 & 9 \end{pmatrix}$$

SRL = IRL x TRL
(Normalized)

$$\text{Component SRL} = \begin{pmatrix} SRL_1 & SRL_2 & SRL_3 \end{pmatrix} = \begin{pmatrix} 0.54 & 0.43 & 0.59 \end{pmatrix}$$

Component SRL_x represents Technology "X" and its IRLs considered

$$\text{Composite SRL} = 1/3\ (0.54 + 0.43 + 0.59) = 0.52$$

The Composite SRL provides an overall assessment of the system readiness

Sauser, B., J. Ramirez-Marquez, R. Magnaye, and W. Tan. (2008). "A Systems Approach to Expanding the Technology Readiness Level within Defense Acquisition." *International Journal of Defense Acquisition Management.* 1:39-58

Key Assumptions and Limitations

- Ordinal data is given numeric value in order to assess overall progression or performance.
  - Grade Point Average (GPA), Failure Modes and Effects Analysis (FMEA)
- One system cannot be compared to the SRL of another system unless they are the same system.
  - You cannot a student with a 3.2 GPA in physics with a student that has a 3.8 GPA in biology. These students belong to different systems of education, but they are evaluated with the same system of metrics.
- Analysis is limited by the experience of previous assessments and experience of the assessors

Data Acquisition

Milestone Dates

Selected Acquisition Report (SAR)

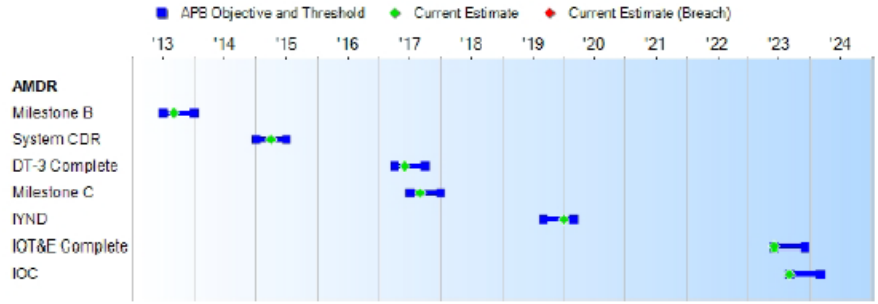
RCS: DD-A&T(Q&A)823-384

Air and Missile Defense Radar (AMDR)

As of FY 2015 President's Budget

Defense Acquisition Management
Information Retrieval
(DAMIR)

Schedule



Milestones	SAR Baseline Dev Est	Current APB Development Objective/Threshold		Current Estimate
Milestone B	JUL 2013	JUL 2013	JAN 2014	SEP 2013
System CDR	JAN 2015	JAN 2015	JUL 2015	APR 2015
DT-3 Complete	APR 2017	APR 2017	OCT 2017	JUN 2017
Milestone C	JUL 2017	JUL 2017	JAN 2018	SEP 2017
IYND	SEP 2019	SEP 2019	MAR 2020	JAN 2020
IOT&E Complete	JUN 2023	JUN 2023	DEC 2023	JUN 2023
IOC	SEP 2023	SEP 2023	MAR 2024	SEP 2023

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Total Cost and Quantity

Selected Acquisition Report (SAR)

RCS: DD-A&T(Q&A)823-384

Air and Missile Defense Radar (AMDR)

As of FY 2015 President's Budget

Defense Acquisition Management
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Cost and Funding

Cost Summary

Total Acquisition Cost and Quantity

Appropriation	BY2013 $M			BY2013 $M	TY $M		
	SAR Baseline Dev Est	Current APB Development Objective/Threshold		Current Estimate	SAR Baseline Dev Est	Current APB Development Objective	Current Estimate
RDT&E	1860.0	1860.0	2046.0	1711.2	1911.1	1911.1	1761.4
Procurement	3846.9	3846.9	4231.6	3290.8	4724.0	4724.0	4043.8
Flyaway	--	--	--	2672.0	--	--	3286.2
Recurring	--	--	--	2654.0	--	--	3266.2
Non Recurring	--	--	--	18.0	--	--	20.0
Support	--	--	--	618.8	--	--	757.6
Other Support	--	--	--	521.9	--	--	638.3
Initial Spares	--	--	--	96.9	--	--	119.3
MILCON	28.8	28.8	31.7	28.6	27.5	27.5	27.5
Acq O&M	0.0	0.0	--	0.0	0.0	0.0	0.0
Total	5735.7	5735.7	N/A	5030.6	6662.6	6662.6	5832.7

Confidence Level for Current APB Cost 50% -

Based on the AMDR Independent Cost Estimate (ICE) prepared for the Milestone B Defense Acquisition Board (DAB) review (memo dated May 29, 2013), it is about equally likely that the estimate will prove too low or too high.

Quantity	SAR Baseline Dev Est	Current APB Development	Current Estimate
RDT&E	0	0	0
Procurement	22	22	22
Total	22	22	22

Annual Funding

Selected Acquisition Report (SAR)

RCS: DD-A&T(Q&A)823-384

Air and Missile Defense Radar (AMDR)
As of FY 2015 President's Budget

Defense Acquisition Management
Information Retrieval
(DAMIR)

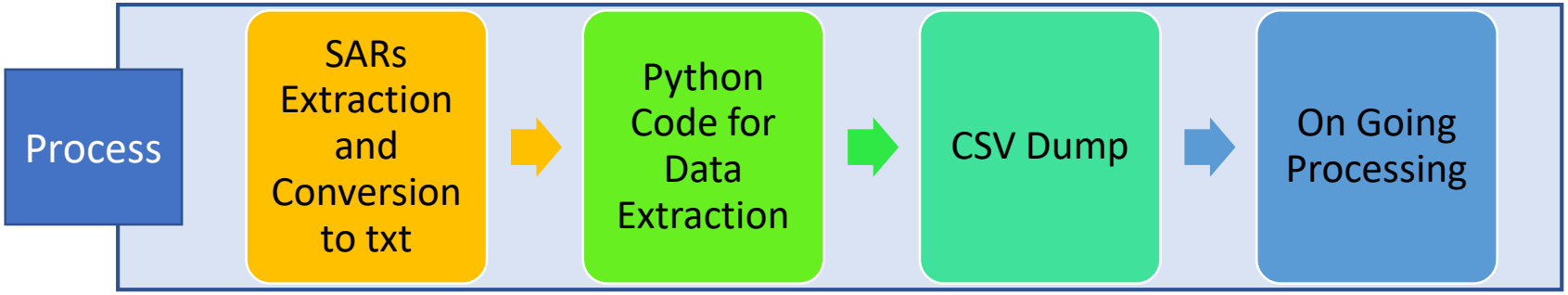
Cost and Funding

Annual Funding By Appropriation

Annual Funding TY$
1319 | RDT&E | Research, Development, Test, and Evaluation, Navy

Fiscal Year	Quantity	End Item Recurring Flyaway TY $M	Non End Item Recurring Flyaway TY $M	Non Recurring Flyaway TY $M	Total Flyaway TY $M	Total Support TY $M	Total Program TY $M
2006	–	--	--	–	--	--	10.9
2007	–	--	--	–	--	--	35.3
2008	–	--	--	–	--	--	92.9
2009	–	--	--	–	--	--	92.5
2010	–	--	--	–	--	--	164.9
2011	–	--	--	–	--	--	204.2
2012	–	--	--	–	--	--	138.8
2013	–	--	--	–	--	--	193.9
2014	–	--	--	–	--	--	125.1
2015	–	--	--	–	--	--	144.7
2016	–	--	--	–	--	--	247.3
2017	–	--	--	–	--	--	100.4
2018	–	--	--	–	--	--	43.1
2019	–	--	--	–	--	--	41.3
2020	–	--	--	–	--	--	32.3
2021	–	--	--	–	--	--	30.5
2022	–	--	--	–	--	--	32.9
2023	–	--	--	–	--	--	30.4
Subtotal	--	--	--	--	--	--	**1761.4**

Process Overview



- 504 SAR Reports for DoD MDAP ACAT-1 programs
- >50% are duplicates since SARs are updated yearly for active programs

createObject.py
inflation.py
main.py
rdteSpendingProfile.py

- Program name
- RDTE and Proc $$
- Base Year
- RDTE units
- Procurement Units
- Unit Flyaway
- MS-B, MS-C, IOC dates
- RDTE yearly spending

+

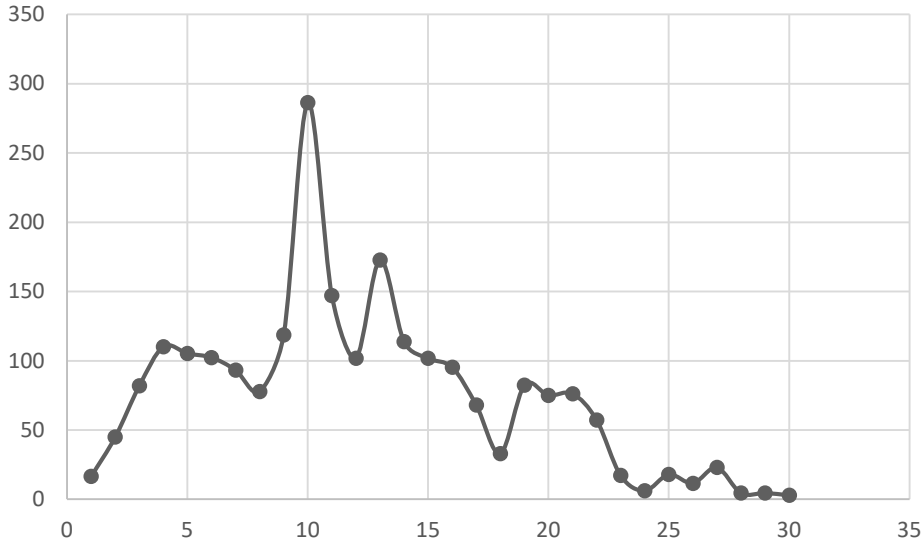
- Milestone Duration (mos)
- Milestone Spending (FY2016)

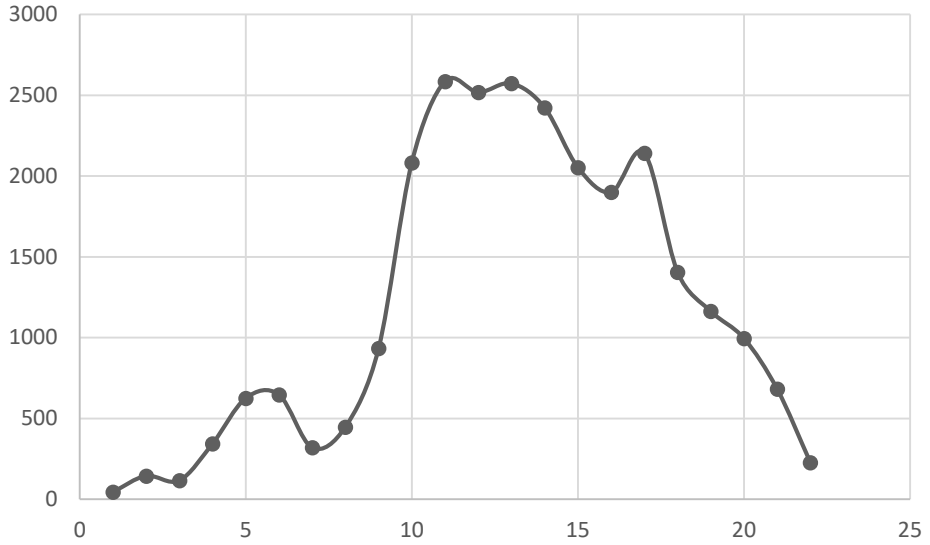
allPrograms_
goodProgra
spendingPro

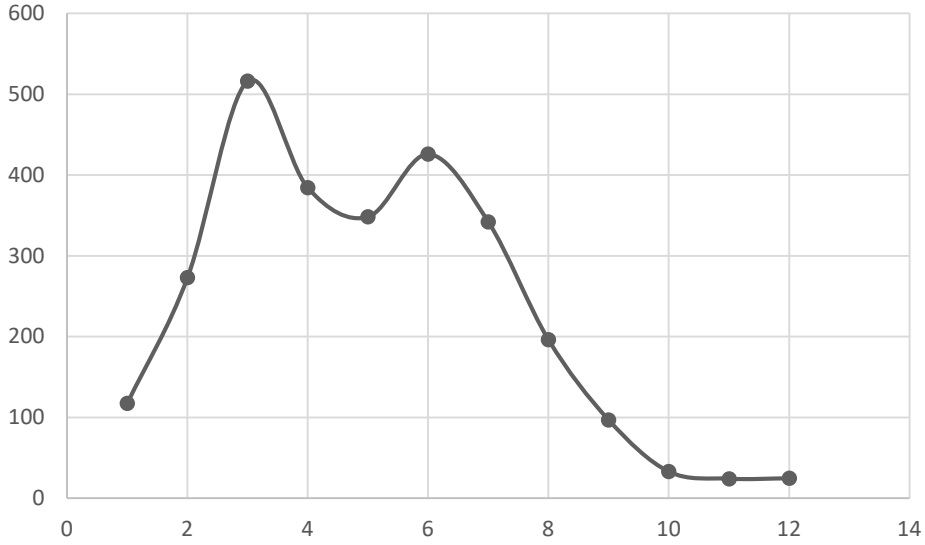
Limitations:

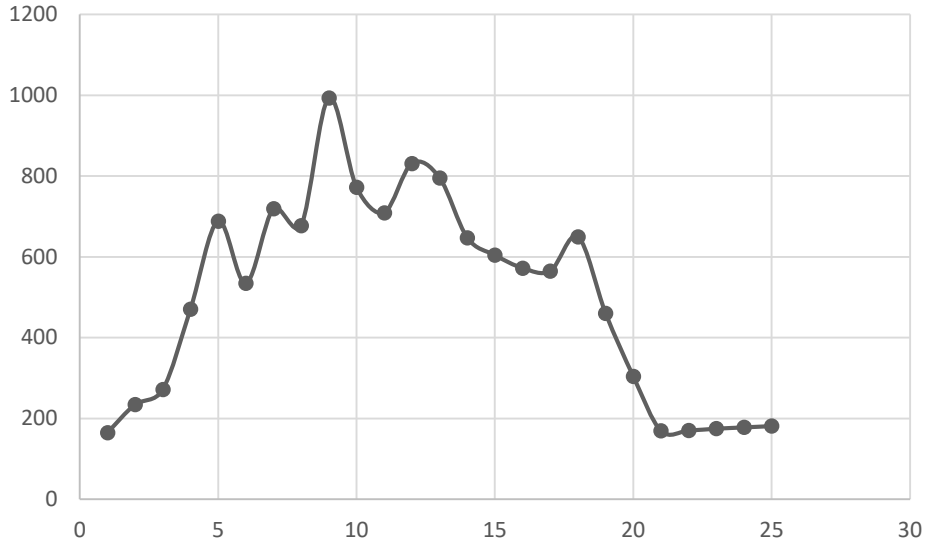
- 10-15% of data is expected to be outlier/inaccurate
- Cannot handle SARs that contain multiple sub-programs, e.g. F-35 airframe and engine programs are reported in the same SAR reports – only the first sub-program is extracted
- Cannot distinguish system type (aircraft, missile, etc.), or program type (new development, major mod., remanufacture, etc.)
- Further improvements to this dataset would likely be done manually

Typical RDT&E Spending Profiles









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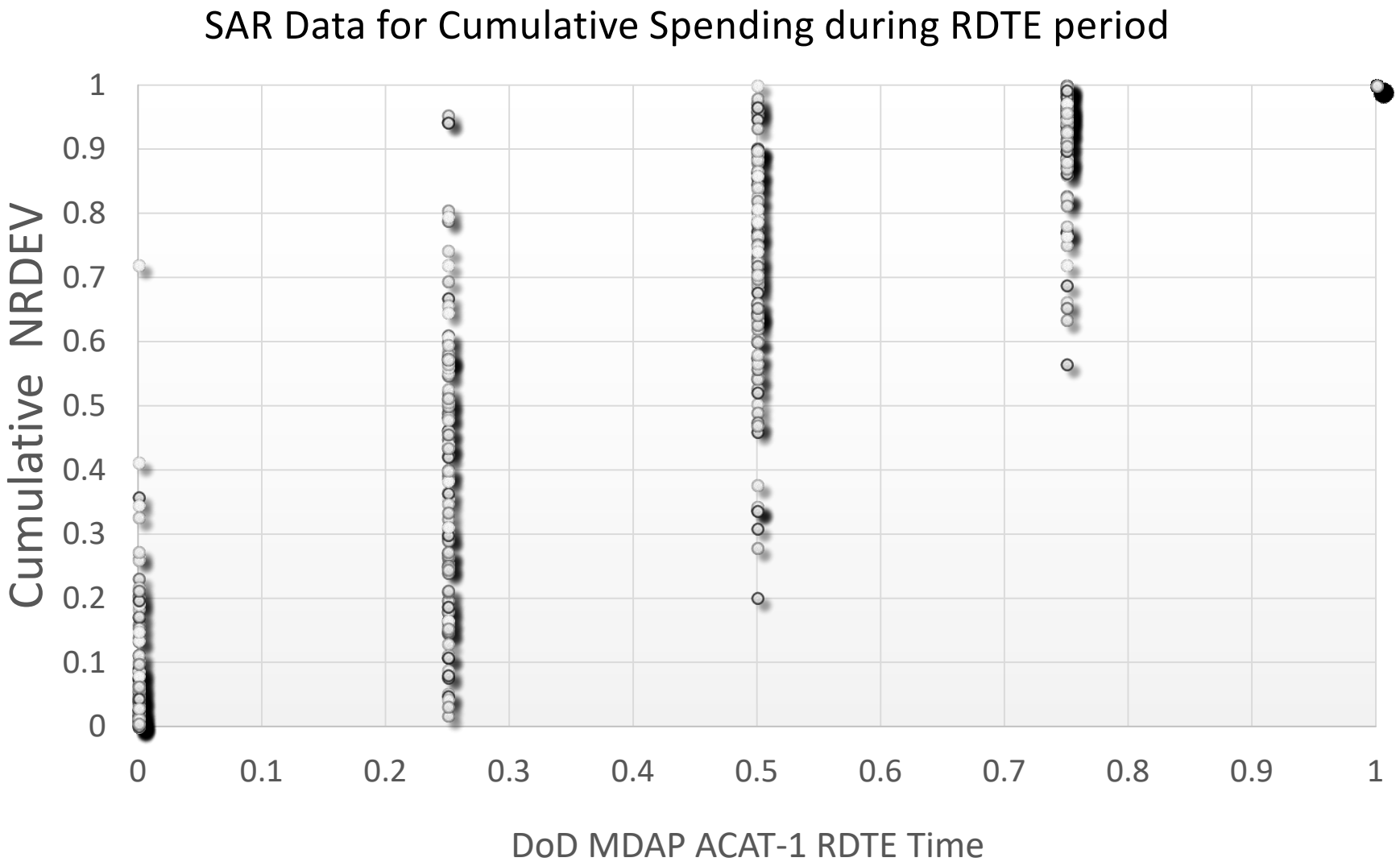
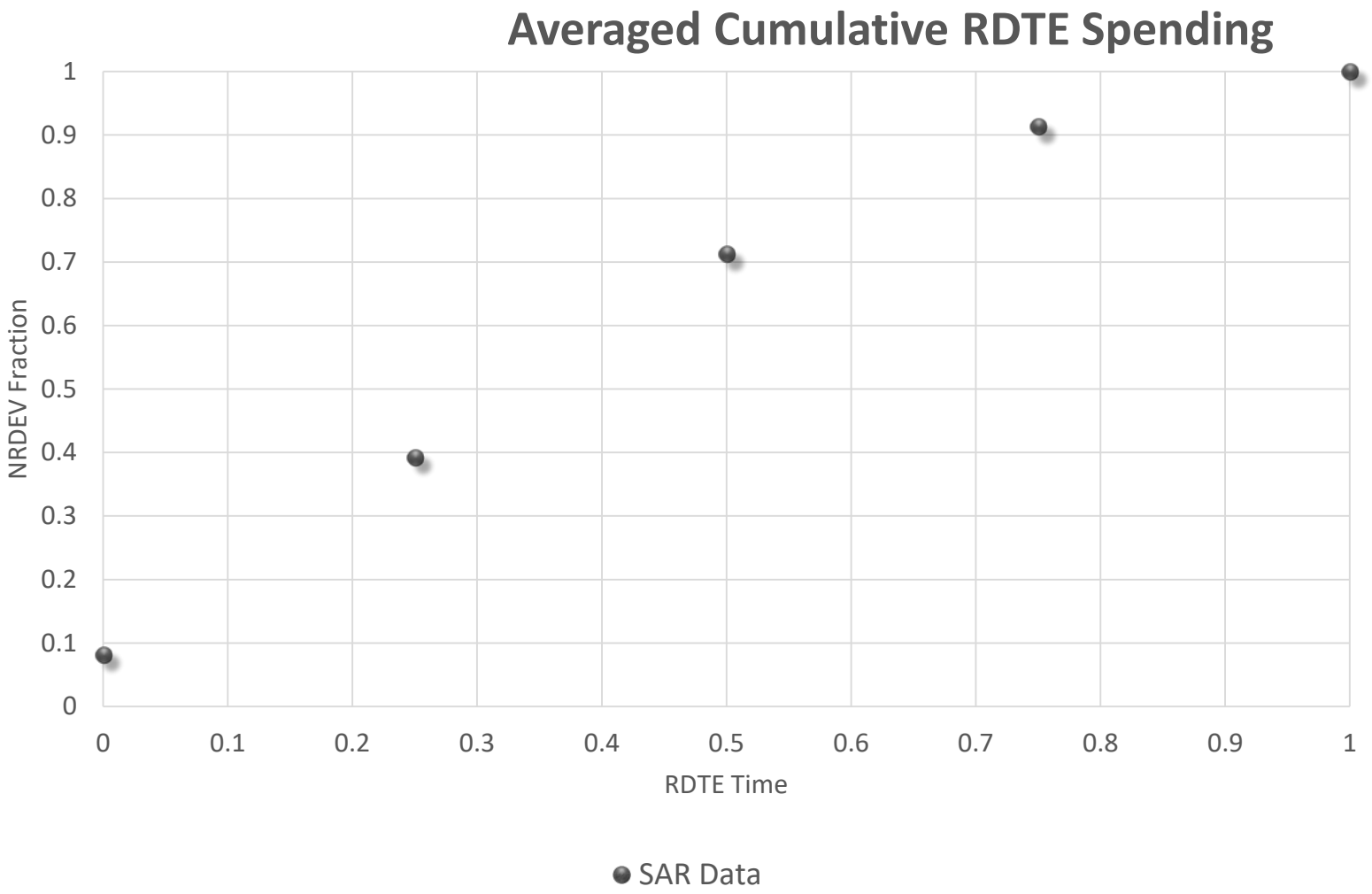
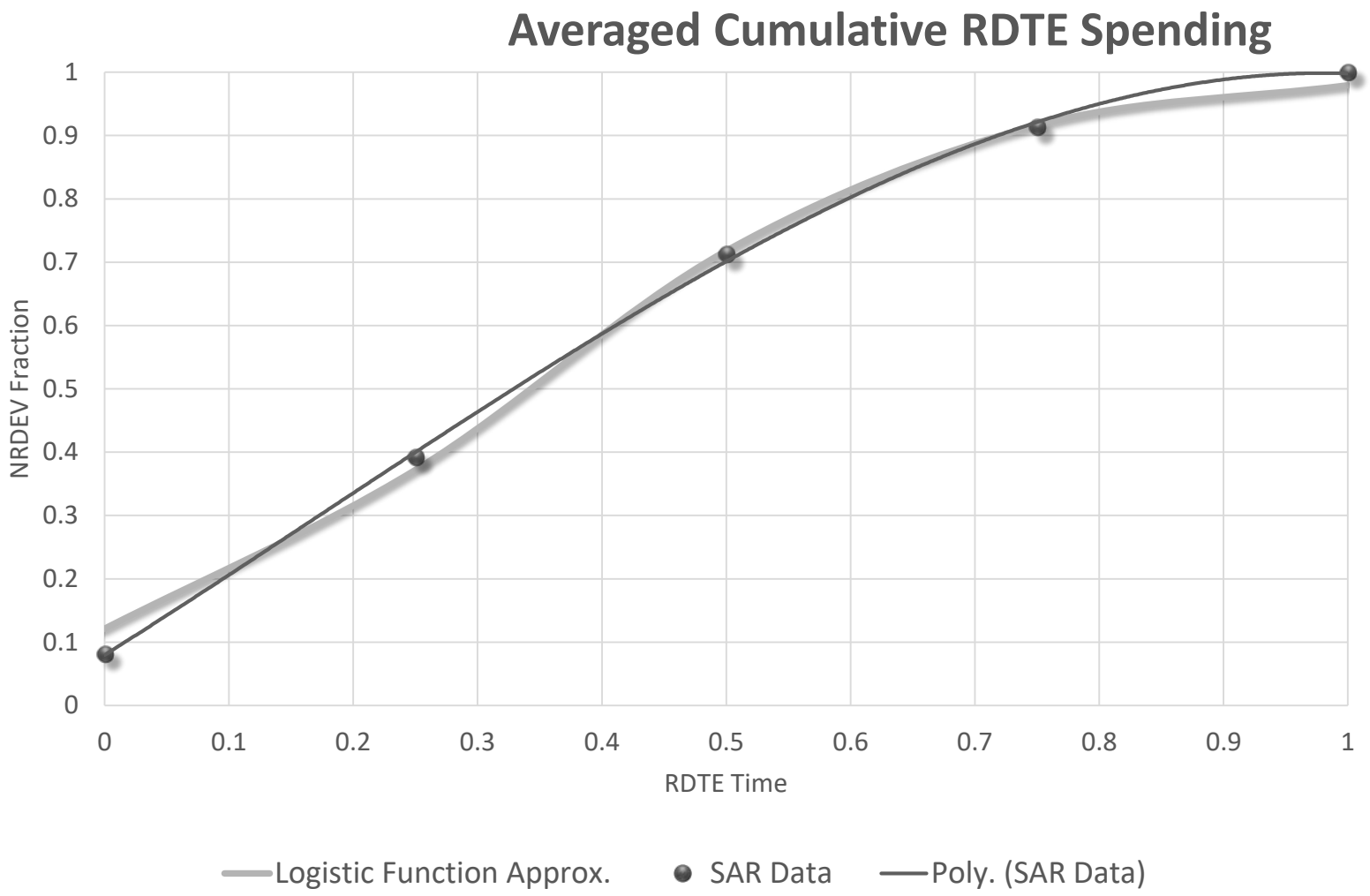
SAR Data Extraction and Normalization



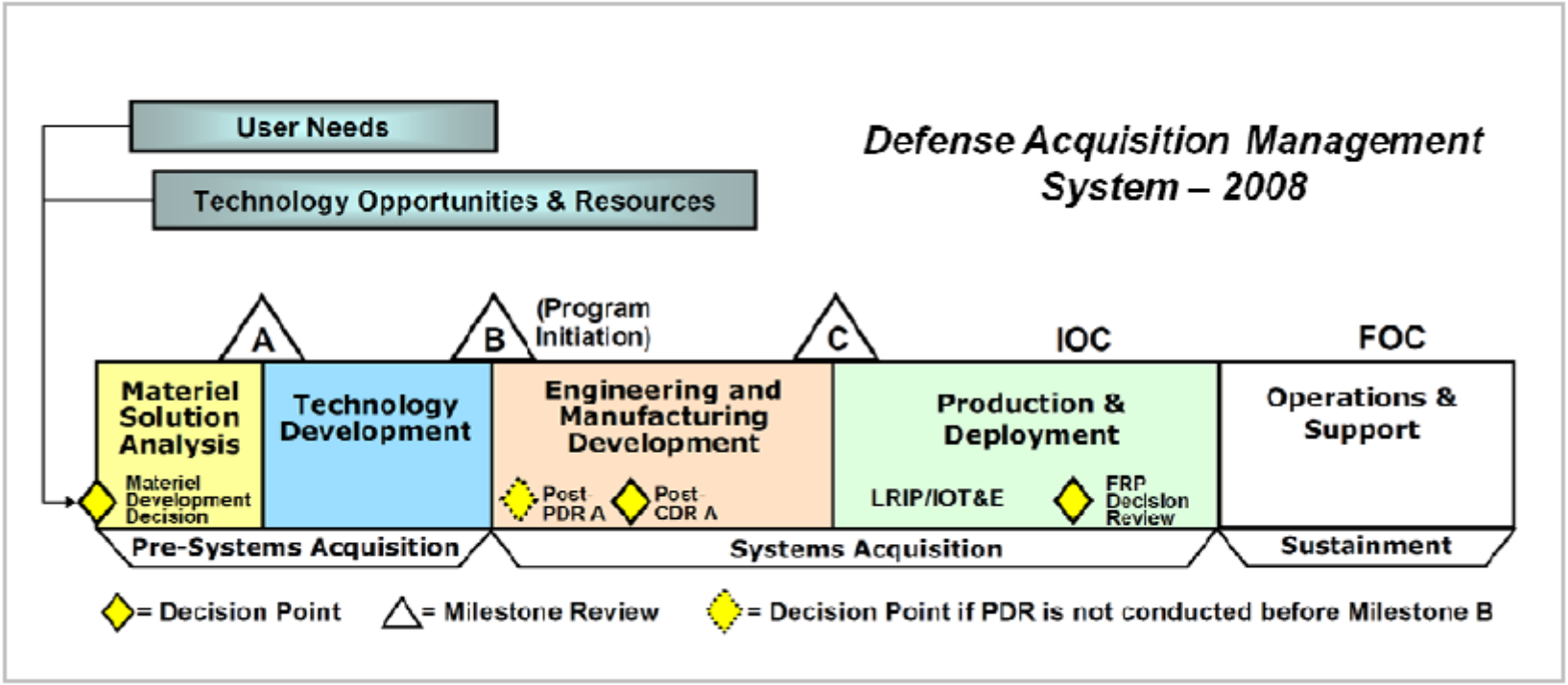
Average RDTE Spending Over Time



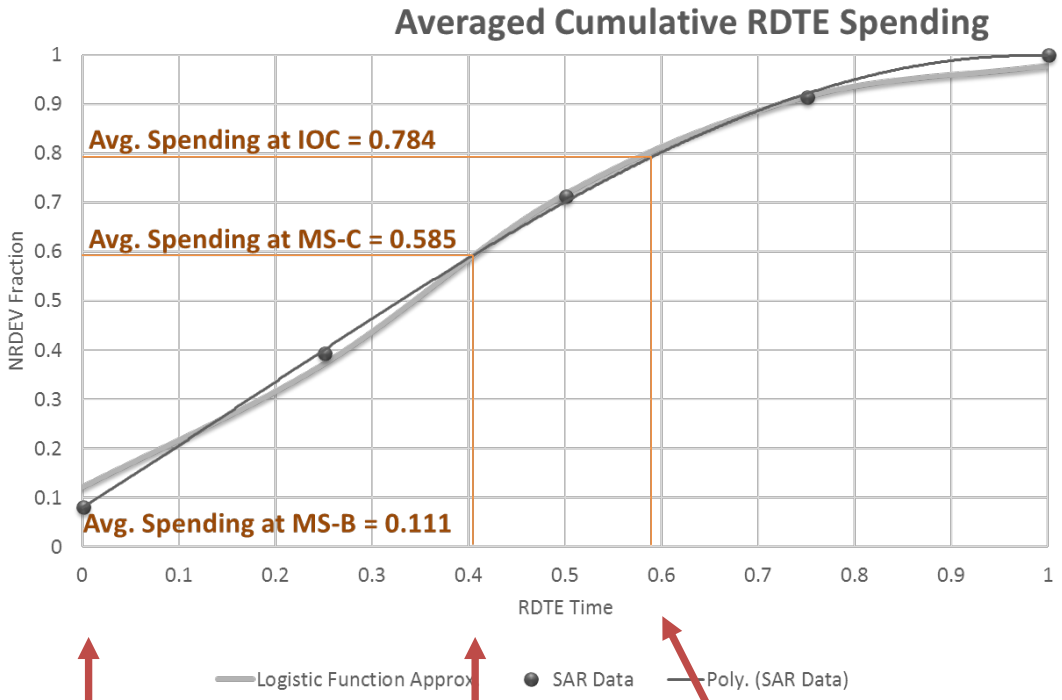
Average RDTE Spending Over Time

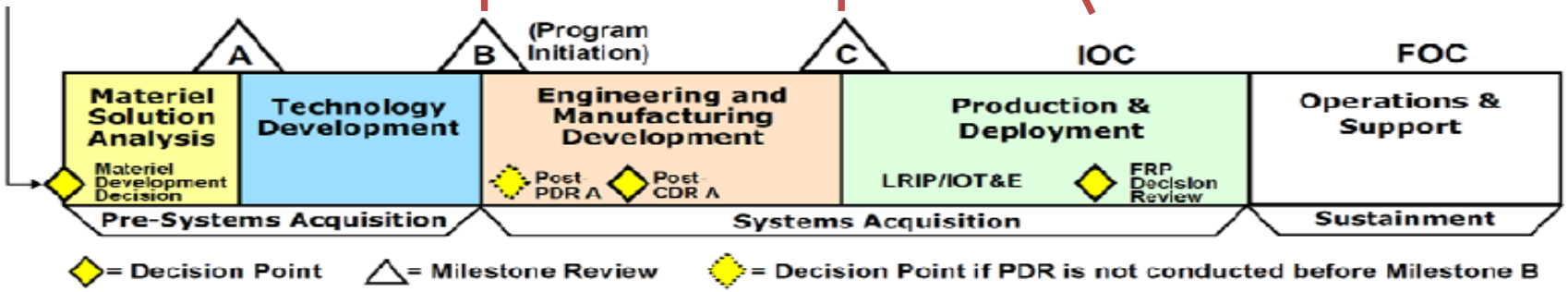


DoD Acquisition Process

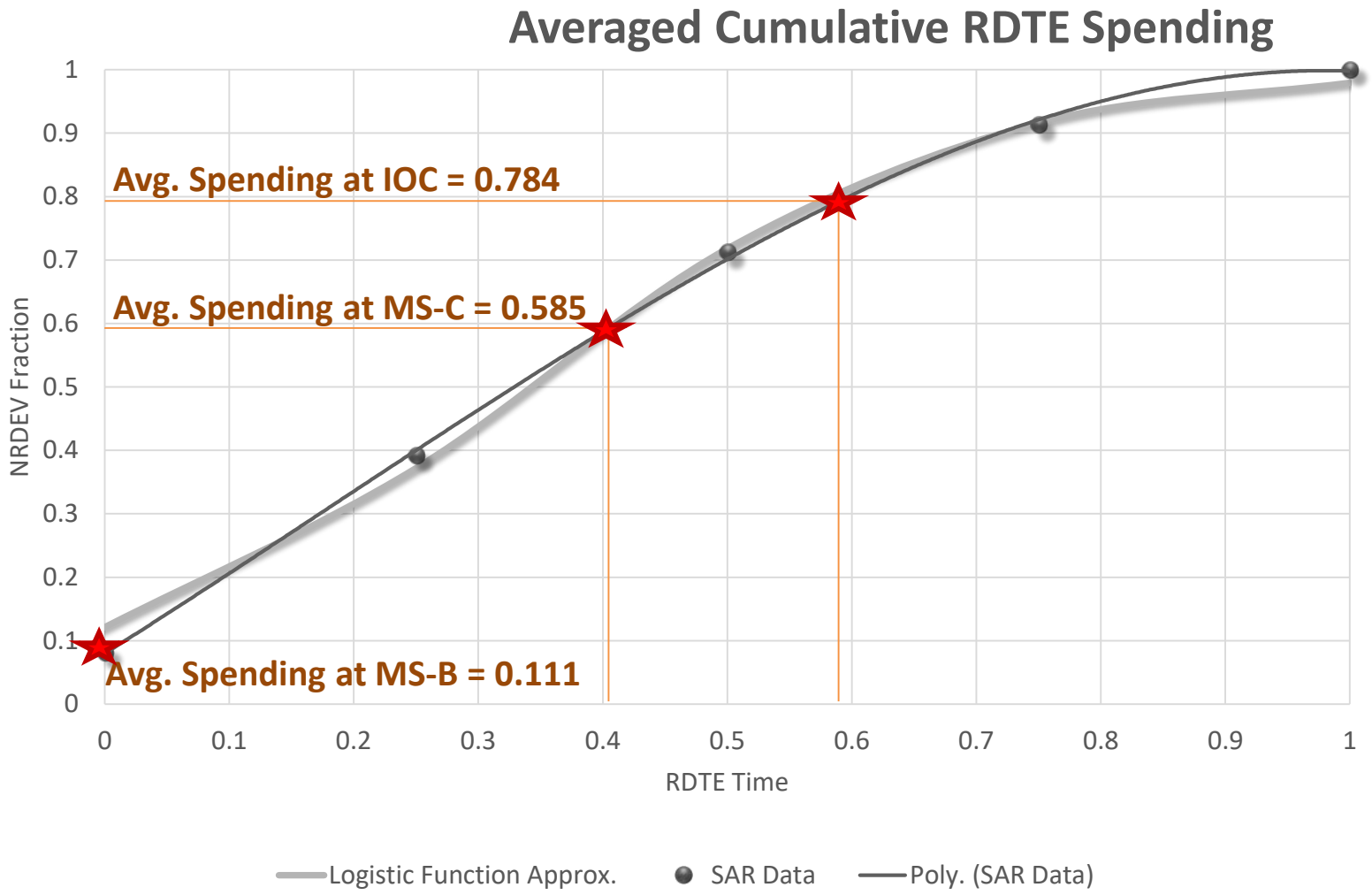


Average RDTE Spending Over Time



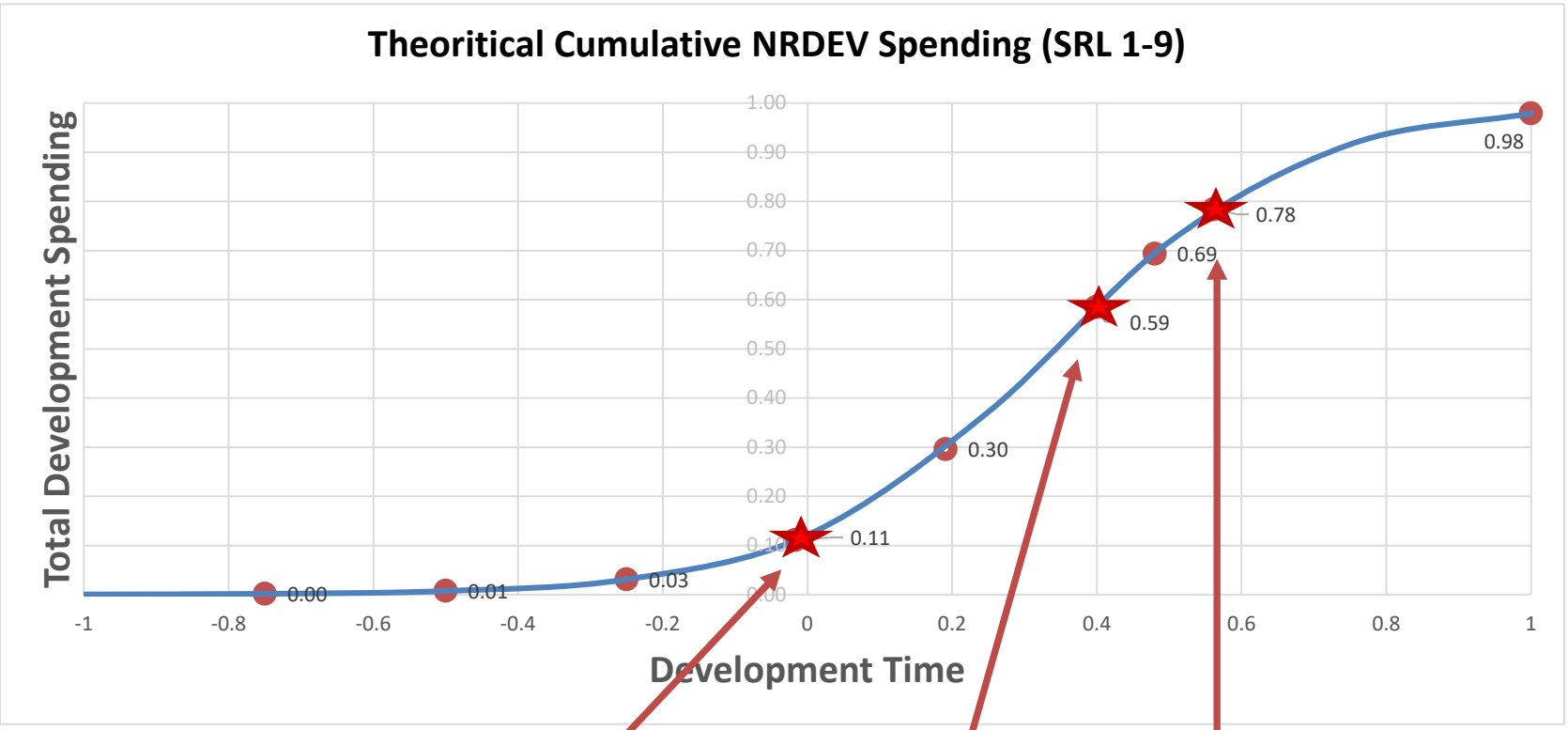


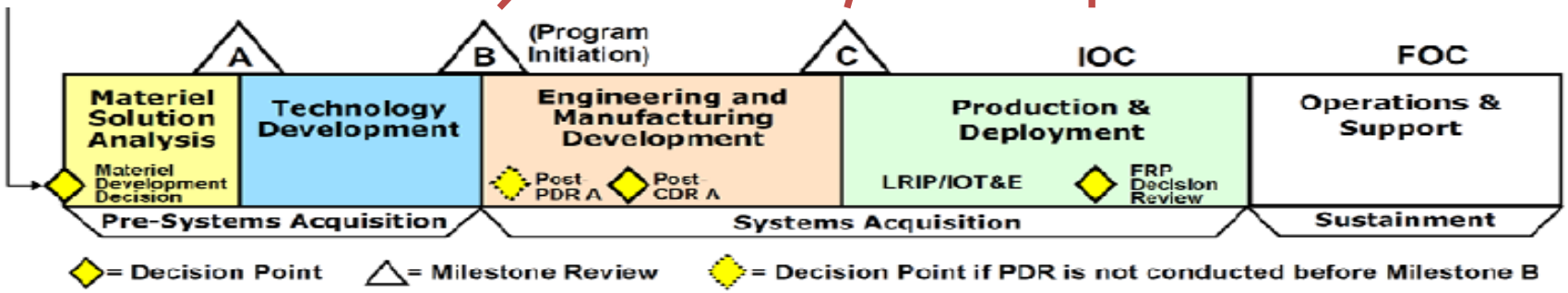
Average RDTE Spending Over Time



Theoretical Correlation

★ = Actual Average





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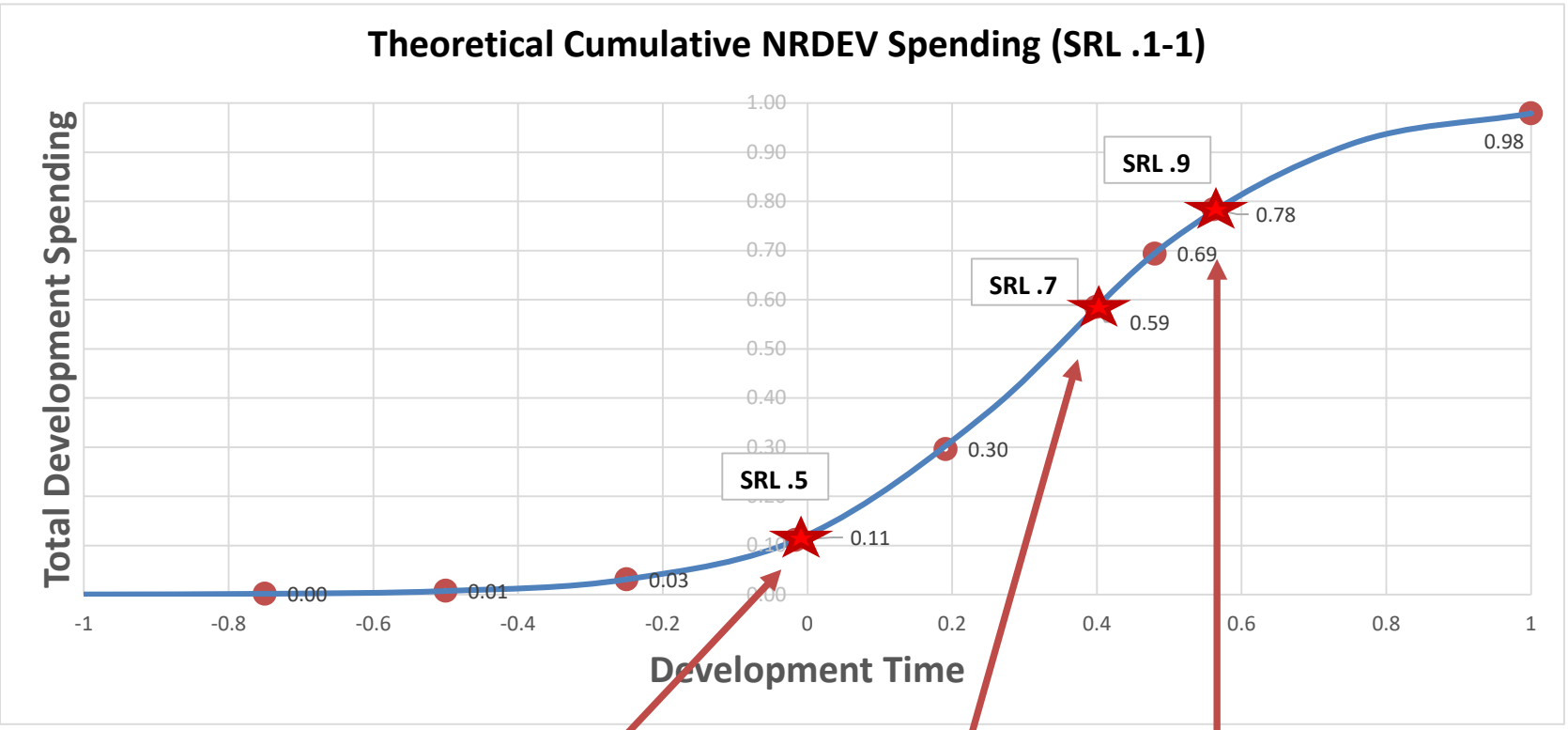

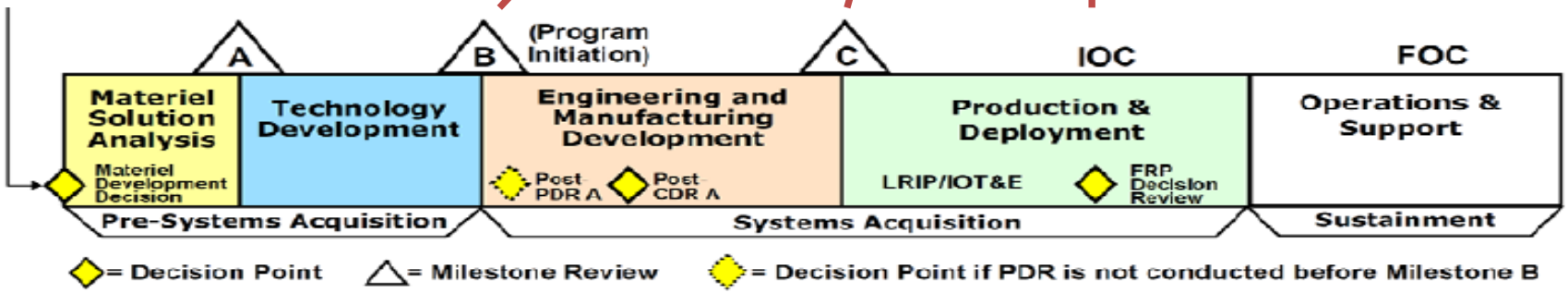

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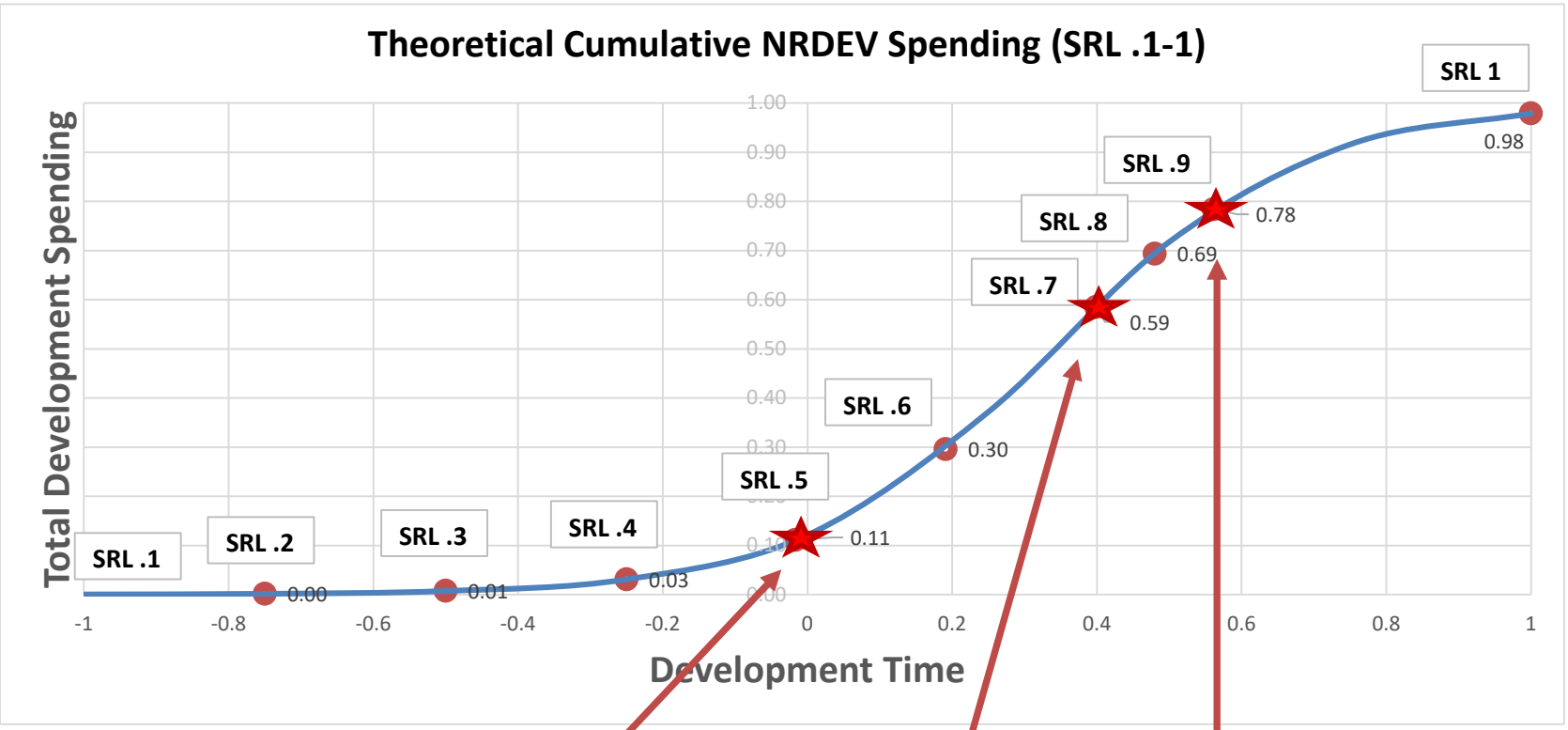

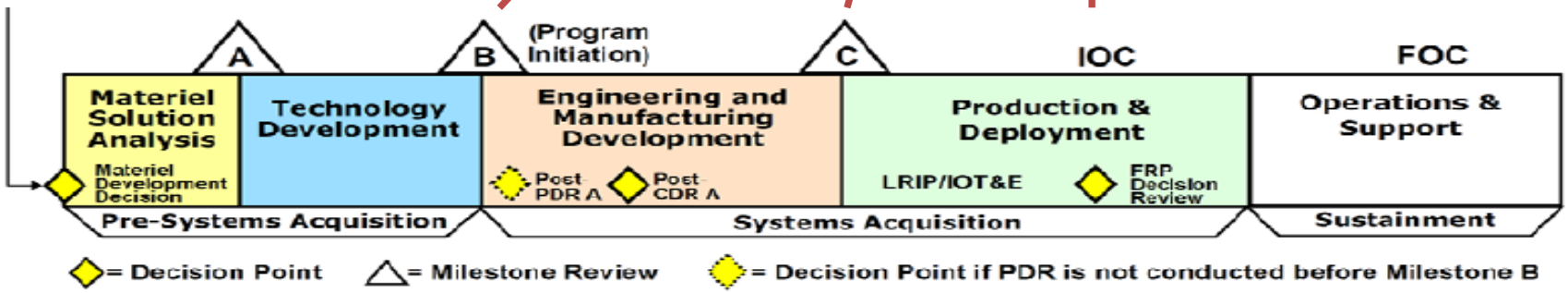

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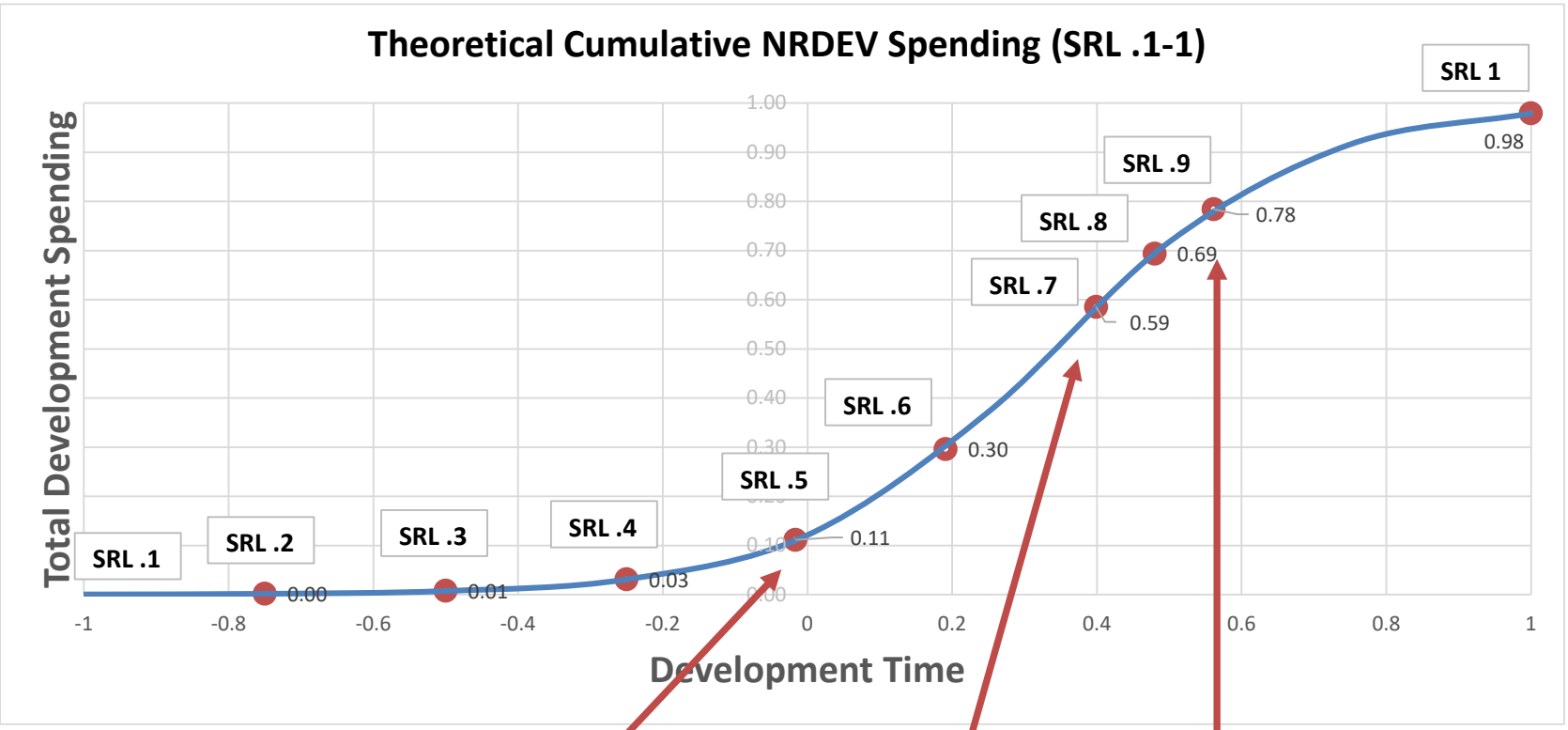
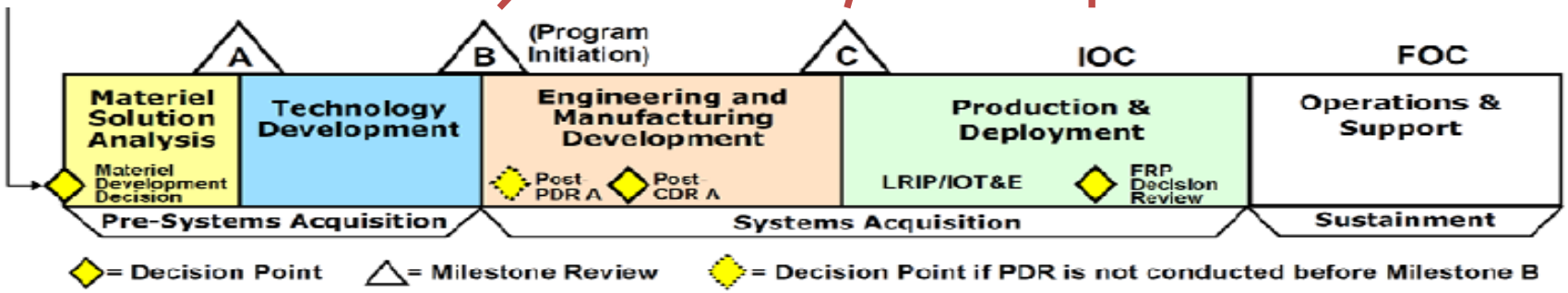
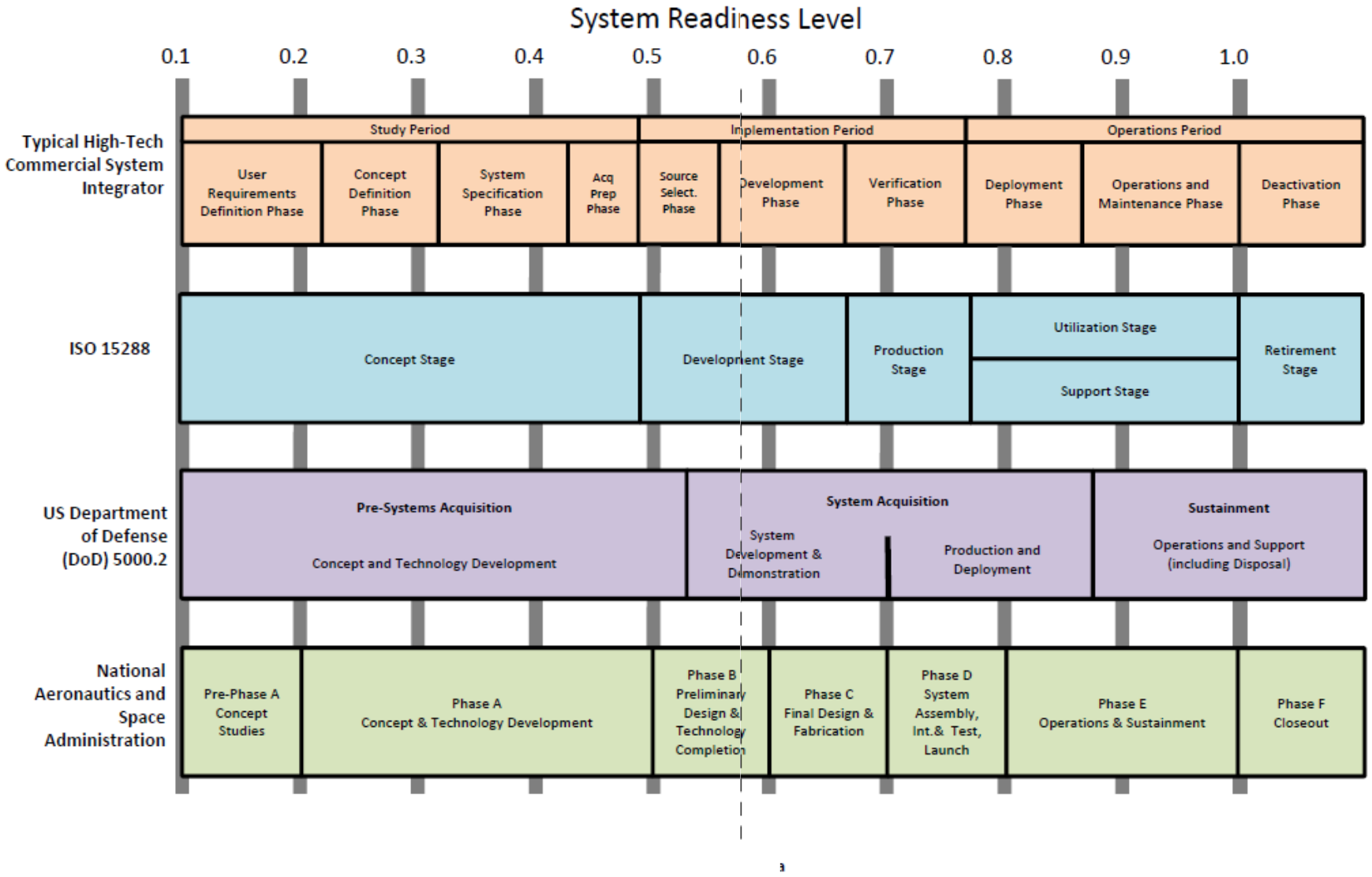




Mapping of SRL to Acquisition Processes



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Conclusion

- SRL calculation framework is proposed to represent system maturity composing of multiple technologies with varying TRLs and IRLs
- Selected Acquisition Report (SARs) data are extracted through mining exercise for RDT&E cost and schedule
- Aggregate level data is used to determine average cost and schedule for each milestone A/B/C and IOC when available
- Generic mapping of MDAP ACAT1 Milestones and SRL is proposed
- Math model representing normalized, non-linear behavior of SRL/TRL progression is proposed
  - Model can be calibrated to any program when at least two data points are known, e.g. cost and schedule at MS B and C,

Future Work

- Improve data quality and segmentation based on
  - System type (aircraft, missile, ship, ground system, space system, etc.) and
  - Program type (new development, modification, remanufacture)
- Consider additional dataset
  - TBD
- Validate model with actual program
  - TBD