Framework for Evaluating ROI of TRA of Major Defense Acquisition Programs Using Real Options

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Presentation Overview

- Introduction
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- Major Defense Acquisition Program (MDAP) Assessments
- Technology Readiness
- Real Options Analysis of MDAPs
- Direction of Future Work
- Conclusions and Recommendations

Return on Investment

"A performance measure used to evaluate the efficiency of an investment or to compare the efficiency of a number of investments." – Investopedia.com

- *U.S. Government mandates ROI analysis of IT investments:*
  - *Clinger-Cohen Act of 1996:* "the head of each executive agency shall design and implement…a process for maximizing the value and assessing and managing the risks of the information technology acquisitions…(3) include minimum criteria to be applied in considering whether to undertake a particular investment in information systems, including criteria related to the quantitatively expressed projected net, risk-adjusted **return on investment** and specific quantitative and qualitative criteria for comparing and prioritizing alternative information systems investment projects"
  - *DoD Directive 8115.01 of 2005*: "IT investments shall be managed as portfolios to: ensure IT investments support the Department's vision, mission, and goals; ensure efficient and effective delivery of capabilities to the warfighter; and maximize **return on investment** to the Enterprise"
- *U.S. GAO recommends DoD model commercial Best Practices to Maximize ROI:*
  - *GAO Report of 2007*[1]: "DoD to implement an integrated portfolio management approach to weapon systems investments…<and seek> to achieve a balanced portfolio that maximizes the **return on investments**"
- *ROI provides a valuable quantitative tool for the decision-maker to gain insight into the business value of an investment*

1- GAO Report, An Integrated Portfolio Management Approach to Weapon System Investments Could Improve DOD's Acquisition Outcomes, Mar 2007, GAO-07-388

Early Real Options Analysis

Thales, regarded as one of the fathers of Greek philosophy, believed next season's olive harvest would be substantial. He contracted with the olive press owners of Miletus and Chios the right, but not the obligation, to rent the presses at an agreed fixed rate during the harvest season. He figured if the harvest was not as he predicted, he would not rent the presses, and he would only lose his original contract fee. If, however, the harvest were as he predicted, he would honor the contract and rent the presses, then rent them out to farmers at a significant margin. His hunch was correct, and he made (or could have made) a fortune![2]

Thales of Miletus, ca 620 B.C.

2 – Barker, Ernest, The Politics of Aristotle, Oxford University Press, 1976

Options Analysis Defined

- Financial Option – the right, but not the obligation, to take action (buy, sell), on an underlying financial asset (i.e. stocks, bonds, etc) at a predetermined price on or before a predetermined date.
- Real Option – the right, but not the obligation, to take action (e.g. defer, expand, contract, etc.), on an underlying non-financial asset (e.g. property, product, etc.) at a predetermined cost on or before a predetermined date.
- European vs. American Option Method – a European option is exercisable only after a specific period of time or upon a specific date, whereas an American option is exercisable anytime up through a specific date.

Problem Statement

Research Question

- What is the effect (value) of Real Options Analysis on the ROI valuation of TRAs for MDAPs?
  - H0: There is no effect or added valuation of ROI of TRA for MDAPs using ROA
  - H1: There is added valuation of ROI of TRA for MDAPs using ROA
    - What is the relationship of program risk and ROI?
    - What is the relationship of program risk and ROA?
    - What is the relationship of ROI and ROA?
    - What is the relationship of TRA and program risk?
    - What is the relationship of TRA and ROI?
    - What is the relationship of TRA and ROA?

Importance of Problem

- Today's national and world economic picture necessitates tighter fiscal policy, and consequently the need and expectation of the DoD to get more done with less. Implicit within this need is the criticality of improving the portfolio performance of MDAPs.

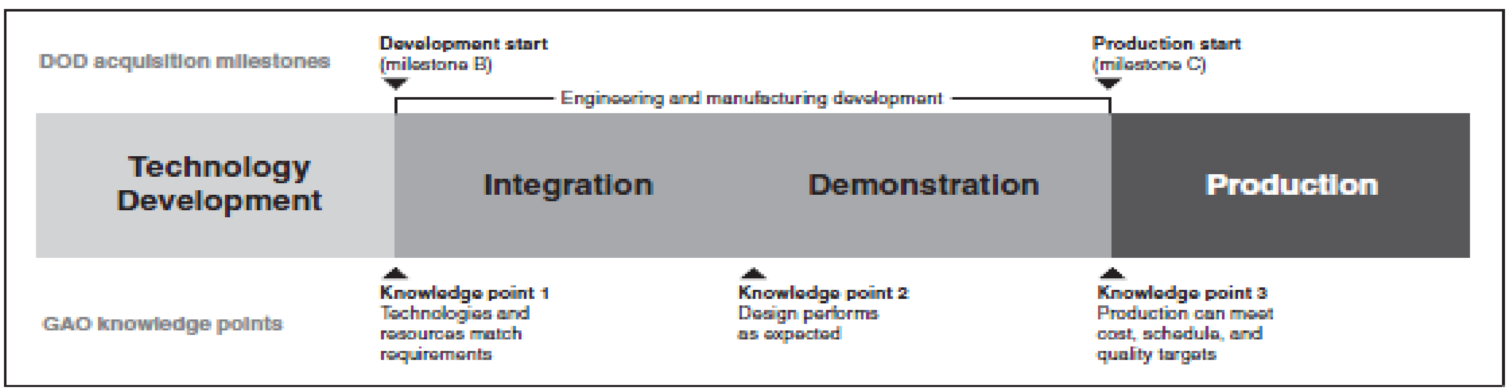
Major Defense Acquisition Program Assessments

- U.S. DoD for decades has had difficulty achieving cost/schedule/performance objectives for Major Defense Acquisition Programs (MDAPs*)
- In a U.S. GAO 2011[3] report
  - 2008-2010 MDAPs have grown from 96 to 98 programs, with estimated total worth $1.68 trillion
  - 2010 MDAP portfolio increased by $135 billion
  - >50% of portfolio didn’t meet cost objectives
  - >80% of portfolio had increased unit costs

** MDAP: Major defense acquisition programs are those determined by the DoD o have RDT&E expenditures of greater than $365 million, or procurement expenditures greater than $2.19 billion.*
3- GAO Report, Defense Acquisitions Assessments of Selected Weapons Programs, Mar 2011, GAO-11-233SP

Major Defense Acquisition Program Assessments

- Substantial portion of MDAP portfolio enter into development/production phase without sufficient knowledge of its critical technologies
  - GAO identified 30% cost benefit associated with having critical technologies mature before starting development[4]
- GAO recommended in a 1999[5] report adoption of disciplined and knowledge-based acquisition processes to improve outcomes



Source: GAO.

4- GAO Report, Defense Acquisitions Assessments of Selected Weapons Programs, Mar 2007, GAO-07-406SP
5- GAO Report, Better Management of Technology Development Can Improve Weapon System Outcome, Jul 1999, GAO/NSIAD-99-162

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Technology Readiness Assessments Defined

- Technology Readiness Assessment (TRA) is a systematic, metrics-based process that assesses the maturity of, and the risk associated with, critical technologies to be used in Major Defense Acquisition Programs (MDAPs)[6].
- DoD requires TRAs of MDAPs at entry of development and production phases (DoD Acquisition Milestones B & C)
- The strategy of delaying a decision to move into development or production to allow critical technology elements (CTEs) to mature sufficiently may be of significant value toward cost/schedule/technical performance of a program.

6- DOD, Technology Readiness Assessment (TRA) Guidance, Apr 2011, ASD(R&E)

Technology Readiness Levels

"A discipline-independent, programmatic figure of merit (FOM), to allow more effective assessment of, and communication regarding the maturity of new technology." – John Mankins

- Technology Readiness Levels[7] defined and used by NASA
  - 1989 – Initial articulation
  - 1995 - Expanded and refined
    - 9 step product/technology maturation process
  - 1999 - Embraced by U.S. GAO
  - 2000 - Instituted by U.S. DoD

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

7 – Mankins, John, Technology Readiness Assessments: A Retrospective, Acta Astronautica 65 (2009), 1216-1223

Options Pricing Valuation

- Black & Scholes Method[9]
  - Developed in early 1970's; awarded Nobel Price
  - Transformed financial options pricing
- Kodukula's formulation[11]
  - $C = N(d_1)S_0 - N(d_2)X\exp^{(-rT)}$
    - C = value of the call option
    - S_0 = current value of the underlying asset
    - X = cost of investment or strike price
    - r = risk-free rate of return
    - T = time to expiration
    - $d_1 = [\ln(S_0/X) + (r + 0.5\sigma^2)T]/\sigma\sqrt{T}$, $d_2 = d_1 - \sigma\sqrt{T}$

9- Black, Fischer, Scholes, Myron. The Pricing of Options and Corporate Liabilities, The Journal of Political Economy, 1973, 637-654

11- Kodukula, Prasad, Papudesu, Chandra. Project Valuation Using Real Options. J. Ross Publishing, Inc, 2006

Metrics for Measuring ROI of TRAs

Metric	Description	Model
Costs	Total amount of money spent on technology readiness	$\sum Cost_i$
Benefits	Total amount of money gained from technology readiness	$\sum Benefits_i$
B/CR	Ratio of technology readiness benefits to costs	Benefits/Costs
ROI%	Ratio of adjusted technology readiness benefits to costs	(Benefits-Costs/Costs)*100%
NPV	Discounted cash flows of technology readiness	$\sum Benefits_i /(1+Discount\ Rate)^{Years}-Costs$
BEP	Point when benefits exceed costs of technology readiness	(Costs/NPV) * Years
ROA	Business value realized from strategic delay due to risk	$N(d_1)*Benefits-N(d_2)*Costs*e^{-Rate*Years}$

Note: d1 = [ln (Benefits/Costs) + (Rate + 0.5*Risk2)*Years]/ Risk*√Years, d2 = d1 – Risk*√Years

13- Rico, David. ROI of Technology Readiness Assessments Using Real Options: An Analysis of GAO Data from 62 U.S. DoD Programs, Unpublished White Paper, 2007

Cost Analysis of Technology Readiness

- The GAO annually provides detailed cost data of MDAPs
  - 2003-2011 reports analyzed (both RDT&E and Total Program)
  - Presentation focuses on 2011 report, then expands to analyze overall trends during the decade
  - Analysis utilized total program cost data

No.	Service	Type	Program	Program	R&D Cost	Total Cost
1	Air Force	Satellite	AEHF	Advanced Extremely High Frequency Satellites	$7,346.3	$12,919.6
2	Navy	Missile	AARGM	AGM-88E Advanced Anti-Radiation Guide Missile	$702.8	$1,838.3
3	Army	Helicopter	AH-64D Block III	Longbow Apache Block III	$1,629.6	$12,742.2
4	Army	C^2	IAMD	Army Integrated Air and Missile Defense	$1,571.4	$4,954.0
⋮						
44	Air Force	Satellite	SBIRS High	Space Based Infrared System High	$10,626.7	$15,938.5
45	Navy	Missile	SM-6	Standard Missile-6 Extended Range Active Missile	$972.0	$6,132.8
46	Navy	UAV	VTUAV	Vertical Take-off and Landing Tactical Unmanned Aerial Vehicle	$664.8	$2,547.2
47	Navy	Sensors	SSN 774	SSN 774 Technology Insertion Program	$7,076.9	$83,569.4

Note: monetary units are in millions of dollars

Benefit Analysis of Technology Readiness

- Three key data points provided by GAO's annual report
  - Total costs
  - Technology maturity (ratio of immature to total critical technologies)
  - Average cost savings from technology stability and maturity (~30%)[4,8,3]
- These data points allow generation of
  - Cost risk = normalized rank of total costs
  - Technology risk = normalized rank of technology maturity
  - Combined risk = composite of cost and moderated technology risk
  - Risk Percentage = is the normalized combined risk
  - Benefits = product of total costs, risk, and a benefit constant

No.	Program	Total Cost	Maturity	Risk Model			Risk Percent	Benefit
				Cost	Tech	Combo		
1	AEHF	$12,919.6	100.0%	0.05	0.00	0.05	4.4%	$3,685.5
2	AARGM	$1,838.3	100.0%	0.01	0.00	0.01	0.6%	$542.9
3	AH-64D Block III	$12,742.2	100.0%	0.04	0.00	0.04	4.3%	$3,637.0
4	IAMD	$4,954.0	0.0%	0.02	1.00	0.12	11.3%	$1,321.4
⋮								
44	SBIRS High	$15,938.5	100.0%	0.06	0.00	0.06	5.4%	$4,503.0
45	SM-6	$6,132.8	100.0%	0.02	0.00	0.02	2.1%	$1,787.3
46	VTUAV	$2,547.2	100.0%	0.01	0.00	0.01	0.9%	$750.6
47	SSN 774	$83,569.4	0.0%	0.29	1.00	0.39	38.0%	$16,324.2

Note: monetary units are in millions of dollars

8- GAO Report, Defense Acquisitions Assessments of Selected Weapons Programs, Mar 2009, GAO-09-326SP

Cost and Benefit Analysis of Technology Readiness

- Return on Investment Percentage: ratio of benefits to costs less the costs
  - Supports determination of near-term benefits
- NPV: net present value includes the time-value of money
  - Supports determination of mid-term benefits
- Real Options Analysis: represents the business value of investment(s) as a strategy of delaying investments due to the presence of risk
  - Supports determination of longer term benefits in the presence of risk
- Our TRA analysis takes advantage of all three vantage points

No.	Program	Cost	Benefit	Benefit/ Cost Ratio	Return on Investment	Net Present Value	Breakeven Point	Real Options
1	AEHF	$1,292.0	$3,685.5	2.9:1	185.3%	$1,899.3	3.4 Years	$2,679.3
2	AARGM	$183.8	$542.9	3.0:1	195.3%	$286.3	3.2 Years	$399.7
3	AH-64D Block III	$1,274.2	$3,637.0	2.9:1	185.4%	$1,875.0	3.4 Years	$2,644.6
4	IAMD	$495.4	$1,321.4	2.7:1	166.7%	$648.8	3.8 Years	$935.6
⋮								
44	SBIRS High	$1,593.9	$4,503.0	2.8:1	182.5%	$2,305.3	3.5 Years	$3,261.7
45	SM-6	$613.3	$1,787.3	2.9:1	191.4%	$934.3	3.3 Years	$1,309.7
46	VTUAV	$254.7	$750.6	2.9:1	194.7%	$395.2	3.2 Years	$552.2
47	SSN 774	$8,356.9	$16,324.2	2.0:1	95.3%	$5,778.1	7.2 Years	$10,404.4

Note: monetary units are in millions of dollars

Government does not have a profit motive, but rather achievement of mission objectives within cost, schedule and technical parameters.

ROI Analysis of Technology Readiness

- Risk, ROI, and ROA are linked;
  - when risk is low, ROA is also low, however ROI is higher due to lack of uncertainty on cost or technical risk. Delay of investment not warranted.
  - when risk is high, ROA is also high, however ROI is lower due to uncertainty on cost or technical risk. Delay of investment may be warranted until risk is lower.

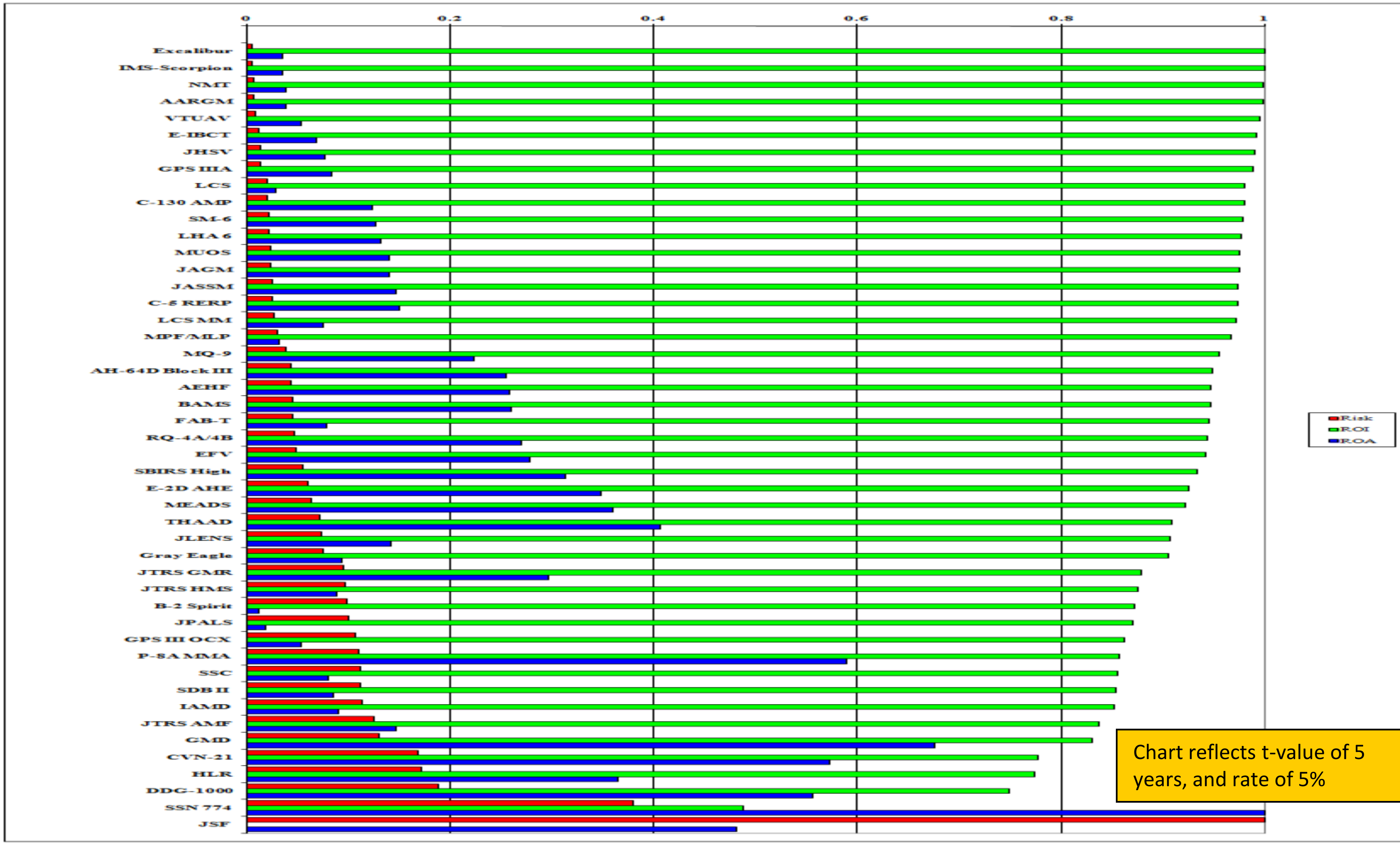
ROI of Technology Readiness Assessments Using Real Options

(Spreadsheet Analysis of GAO Data from 49 U.S. DoD Programs)

No.	Service	Type	Program	Total Program Cost			Critical Technologies			Risk Percent	Cost	Benefit	Benefit/ Cost Ratio	Return on Investment	Net Present Value	Breakeven Point	Real Options	Risk	ROI	ROA
				Estimated	Actual	Change	Immature	Total	Mature											
15	Army	Munition	Excalibur	$4,705.9	$1,670.9	-64.5%	0	3	100.0%	0.6%	$167.1	$493.7	3.0:1	195.5%	$260.4	3.2 Years	$363.6	0.01	1.00	0.03
24	Army	Munition	IMS-Scorpion	$1,685.2	$1,685.2	0.0%	0	4	100.0%	0.6%	$168.5	$497.9	3.0:1	195.5%	$262.6	3.2 Years	$366.7	0.01	1.00	0.04
38	Navy	SATCOM	NMT	$2,286.8	$1,804.7	-21.1%	0	2	100.0%	0.6%	$180.5	$533.0	3.0:1	195.4%	$281.1	3.2 Years	$392.5	0.01	1.00	0.04
2	Navy	Missile	AARGM	$1,577.2	$1,838.3	16.6%	0	2	100.0%	0.6%	$183.8	$542.9	3.0:1	195.3%	$286.3	3.2 Years	$399.7	0.01	1.00	0.04
46	Navy	UAV	VTUAV	$2,576.3	$2,547.2	-1.1%	0	0	100.0%	0.9%	$254.7	$750.6	2.9:1	194.7%	$395.2	3.2 Years	$552.2	0.01	1.00	0.05
23	Army	C^2	E-IBCT	$3,184.2	$3,257.6	2.3%	0	10	100.0%	1.1%	$325.8	$957.9	2.9:1	194.0%	$503.7	3.2 Years	$704.2	0.01	0.99	0.07
27	Army	Ship	JHSV	$3,582.5	$3,669.1	2.4%	0	18	100.0%	1.2%	$366.9	$1,077.5	2.9:1	193.7%	$566.1	3.2 Years	$791.7	0.01	0.99	0.08
20	Air Force	Satellite	GPS IIIA	$3,883.1	$4,024.8	3.6%	0	5	100.0%	1.4%	$402.5	$1,180.7	2.9:1	193.3%	$619.8	3.2 Years	$867.2	0.01	0.99	0.08
33	Navy	Ship	LCS	$1,338.5	$1,338.5	0.0%	3	19	84.2%	2.0%	$133.9	$390.5	2.9:1	191.7%	$204.2	3.3 Years	$286.2	0.02	0.98	0.03
10	Air Force	Avionics	C-130 AMP	$4,071.2	$5,995.6	47.3%	0	3	100.0%	2.0%	$599.6	$1,748.0	2.9:1	191.6%	$914.1	3.3 Years	$1,281.1	0.02	0.98	0.12
6	MDA	Missile	GMD	$38,082.4	$38,082.4	0.0%	0	9	100.0%	12.9%	$3,808.2	$9,993.3	2.6:1	162.4%	$4,844.9	3.9 Years	$7,027.5	0.13	0.83	0.68
12	Navy	Ship	CVN-21	$35,048.5	$34,185.7	-2.5%	7	13	46.2%	16.8%	$3,418.6	$8,617.5	2.5:1	152.1%	$4,043.3	4.2 Years	$5,955.5	0.17	0.78	0.57
11	Marines	Helicopter	HLR	$16,311.5	$21,902.3	34.3%	2	2	0.0%	17.1%	$2,190.2	$5,505.0	2.5:1	151.3%	$2,576.5	4.3 Years	$3,799.6	0.17	0.77	0.37
13	Navy	Ship	DDG-1000	$34,283.9	$34,283.9	0.0%	9	12	25.0%	18.9%	$3,428.4	$8,452.3	2.5:1	146.5%	$3,890.5	4.4 Years	$5,784.2	0.19	0.75	0.56
47	Navy	Sensors	SSN 774	$59,550.2	$83,569.4	40.3%	1	1	0.0%	38.0%	$8,356.9	$16,324.2	2.0:1	95.3%	$5,778.1	7.2 Years	$10,404.4	0.38	0.49	1.00
17	Joint	Airplane	JSF	$210,557.6	$283,674.5	34.7%	3	8	62.5%	100.0%	$28,367.5	$8,425.1	0.3:1	-70.3%	-$21,072.2	-6.7 Years	$5,011.6	1.00	-0.36	0.48
				$660,360.3	**$816,163.7**	**23.6%**	**89**	**336**	**73.5%**	**8.8%**	**$81,616.4**	**$226,490.9**	**2.8:1**	**177.5%**	**$114,501.0**	**3.6 Years**	**$162,928.0**			

Note: monetary units are in millions of dollars

ROI Analysis of Technology Readiness



ROI trends lower as Risk and ROA increase

Data Sensitivity Analysis

- 2011 data sensitivity analysis
  - Shorten/lengthen exercise period (t=1, 3, 10)
    - NPV goes lower as t (delay or decision point) extends, and goes higher as t retracts
    - ROA goes higher as t (delay) extends, and goes lower as t retracts
  - Increase/decrease fixed interest rate (r=1, 2, 3, 4)
    - NPV goes higher as r (rate) goes lower, and goes lower as r goes higher
    - ROA goes lower as r (rate) goes lower, and goes higher as r goes higher

The opportunity to delay investment decisions (development/production) until technologies are sufficiently stable and mature, improves cost and technical outcomes

Trend Analysis

ROI of Technology Readiness Assessments Using Real Options

(Summary Spreadsheet Analysis of GAO Data from 2003 - 2011 U.S. DoD Programs)

Year	No. Programs	Total Program Cost			Critical Technologies			Risk Percent	Cost	Benefit	Benefit/ Cost Ratio	Return on Investment	Net Present Value	Breakeven Point	Real Options
		Estimated	Actual	Change	Immature	Total	Mature								
2011	47	$660,360.3	$816,163.7	23.6%	89	336	73.5%	8.8%	$81,616.4	$226,490.9	2.8:1	177.5%	$114,501.0	3.6 Years	$162,928.0
2010	55	$739,230.4	$879,095.5	18.9%	105	372	71.8%	9.6%	$87,909.6	$242,195.4	2.8:1	175.5%	$121,806.3	3.6 Years	$173,731.3
2009	59	$828,303.3	$974,442.8	17.6%	177	420	57.9%	10.2%	$97,444.3	$267,164.5	2.7:1	174.2%	$133,892.2	3.6 Years	$191,274.9
2008	72	$877,507.2	$1,063,048.3	21.1%	208	466	55.4%	8.7%	$106,304.8	$295,161.2	2.8:1	177.7%	$149,273.9	3.6 Years	$212,370.9
2007	62	$718,829.7	$879,978.4	22.4%	241	451	46.6%	10.0%	$87,997.8	$241,720.7	2.7:1	174.7%	$121,307.0	3.6 Years	$173,187.9
2006	51	$732,174.8	$844,258.0	15.3%	225	428	47.4%	11.2%	$84,425.8	$229,735.5	2.7:1	172.1%	$114,501.1	3.7 Years	$163,984.7
2005	54	$702,006.2	$804,222.7	14.6%	251	443	43.3%	11.3%	$80,422.3	$218,670.8	2.7:1	171.9%	$108,923.7	3.7 Years	$156,037.8
2004	51	$628,544.0	$674,293.0	7.3%	193	391	50.6%	10.9%	$67,429.3	$183,931.0	2.7:1	172.8%	$91,835.7	3.7 Years	$131,417.0
2003	26	$470,459.1	$477,020.3	1.4%	39	117	66.7%	12.0%	$47,702.0	$128,889.7	2.7:1	170.2%	$63,902.9	3.7 Years	$91,739.3

Note: monetary units are in millions of dollars

Incorporation of Knowledge Based Acquisition Processes by DoD Improves Cost/Schedule/Technical Performance of Individual Programs and Integrated MDAP Portfolio

Direction of Future Work

- Monte Carlo Simulation
  - Investigate impact of Monte Carlo simulation upon key attributes
- Leuhrman Analysis[12]
  - Investigate mapping of program(s) within two dimensional option space using two additional metrics (NPV quotient and Volatility)

12- Luehrman, Timothy. Investment Opportunities as Real Options: Getting Started on the Numbers, HBR July-August 1998, 51-67

Conclusions & Recommendations

- Used in conjunction with other traditional discounted cash flow methods, ROA provides additional insight into ROI of TRA for MDAPs highlighting program development risk
  - Valuation of decision to delay, expand, contract, abandon
  - Identification/quantification of risk associated with CTEs
  - Support prioritization of program development, and mitigation of program risks
- Recommend additional research into optimization of key parameters of ROA of ROI for TRA to improve decision process

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