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AN ESTIMATE OF COST SAVINGS FROM USING EMERGING SOFTWARE TECHNOLOGIES ON DoD MIGRATION SYSTEMS

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PREFACE

This document was prepared by the Institute for Defense Analyses (IDA) for the Defense Information Systems Agency (DISA) under a task entitled "Return on Investment for Software Systems Engineering." The objective of the task is to assess the return on investment DISA would realize from investments in new software engineering technologies. In this annotated briefing, IDA explores the issue by estimating the cost savings due to DISA's accelerated adoption and implementation of software engineering technologies to DoD migration systems. The briefing was presented to Dr. Alan Smith of DISA on 2 August 1995.

This work was reviewed within IDA by Bruce N. Angier.

CONTENTS

Outline

- Background
- Approach
- Assumptions
- Results
- Future Research

Background

- **Today, DoD software costs are much higher than industry's best practice**
- **Adoption and implementation of emerging software engineering technologies need to be accelerated with leadership from DISA**
- **What are the potential cost savings of accelerated adoption and implementation on migration systems?**

The Defense Information Systems Agency's (DISA's) Software Infrastructure Initiative states that "Today's software managers and practitioners work without defined processes and with antiquated tools and technologies." These deficiencies cause DoD to have unreliable and error-prone software, as well as increased maintenance costs. For these reasons and others, DoD software costs are much higher than those best practices of the industry.

One way to help reduce DoD software costs is for software-intensive organizations to accelerate the adoption and implementation of software engineering technologies to increase their Software Engineering Capability (SEC). Once their SEC increases, the organizations can develop and maintain software more efficiently and at a lower cost to DoD.

As mentioned in the Software Infrastructure Initiative, DISA needs to lead by promoting and integrating the technologies to the software-intensive organizations. Without DISA's leadership, software-intensive organizations may not adopt these technologies on their own. DISA's goal is to promote the rapid transfer of state-of practice software development and maintenance technologies throughout DoD, thus increasing SEC and promoting cost savings across the board.

Because potential cost savings are an important incentive for using new technologies, the question that needs to be answered is: What cost savings will accrue from DISA's accelerating the adoption and implementation of the software engineering technologies to DoD migration systems?

The question addresses DoD migration systems instead of all of DoD software for the following two main reasons:

1. The software technologies we will discuss are easily applied to migration systems.
2. The cost of all DoD migration systems is easier to estimate than the cost of all DoD software.

Outline

- Background
- → Approach
- Assumptions
- Results
- Future Research

Approach

- **Assess economic effect of DISA's accelerating the use of emerging software technologies**
- **Look at a subset of all DoD software: DoD migration systems**
- **Use the STEIM to assess the cost savings to migration systems**

Our objective was to assign a dollar figure to DISA's accelerating the use of software engineering technologies. Specifically, we calculated two costs: 1) the cost to DoD *without* DISA accelerating the use of the technologies, and 2) the cost to DoD *with* DISA accelerating the use of the technologies. By comparing the two costs, a cost savings from DISA's effect could be determined.

We first gathered and analyzed data on DoD migration systems. Next, we calculated a baseline cost for the migration systems and used it as input to the Software Technology Economic Impact Model (STEIM). The STEIM was used to calculate the cost without DISA and the cost with DISA. Using the results from the STEIM, we were able to determine a specific dollar figure associated with DISA's effect on the acceleration of the software engineering technologies.

The next few pages explain in detail the analysis of the migration systems data and the STEIM calculations.

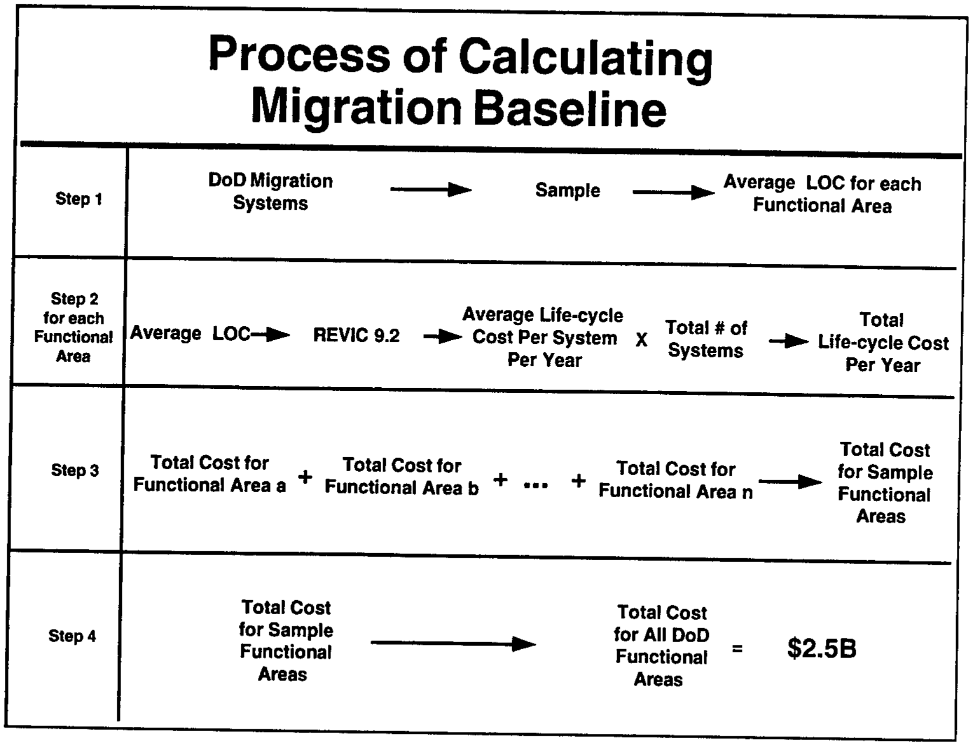
Migration Baseline

- **Estimated the FY94 total cost of migration systems at $2.5 billion**
- **Used data from the October 94 Full Migration Report generated by the DIST**
- **Used REVIC 9.2 to obtain average life-cycle cost estimate for data gathered**

A baseline cost is needed as input to the STEIM. The baseline cost for all DoD migration systems in fiscal year 1994 was estimated to be $2.5 billion. The baseline cost was estimated using:

1) Data on the migration systems. The data were gathered from the October 1994 Full Migration Report generated by the Defense Integration Support Tools (DIST), a set of computer-based tools that are being developed by DISA with the support of Electronic Data Systems (EDS). The DIST contain migration assessment tools as well as migration tracking tools that allow the user to gather information on the migration systems.

2) The Revised Enhanced Version of Intermediate COCOMO (REVIC) 9.2 software cost/schedule model. Once the data were gathered, the software cost/schedule model REVIC 9.2 was used to obtain an annual life-cycle cost for the migration systems. This model estimates the cost and schedule of a software program as a function of the lines of code and other environmental factors of the program. The life-cycle cost includes both development and maintenance costs.



The calculation of the migration baseline of $2.5 billion was a four-step process:

Step One: Calculate average lines of code (LOC) in each functional area

From the October 94 Full Migration Report of all DoD migration systems, a sample of 19 systems was taken. For each system in the sample, the LOC in the system and the programming language of the system were gathered. The sample systems were then categorized by their functional area. DoD categorizes migration systems into 19 different functional areas. From the sample of 19 systems, only 5 functional areas were represented: Command and Control, Finance, Logistics, Procurement, and Health. Once the systems were categorized by their functional area, the average LOC for each functional area were determined.

Step Two: Calculate annual life-cycle cost for each functional area

For each functional area, the average LOC were entered into REVIC 9.2, which generated an average life-cycle cost per system per year. This cost per system per year was then multiplied by the total number of systems in the relative functional area to obtain the average life-cycle cost per year for the functional area.

Step Three: Calculate annual life-cycle cost for all sampled areas

After an average life-cycle cost per year for each functional area was determined in the previous step, all of the costs were summed to obtain an annual life-cycle cost for the five functional areas represented in the sample.

Step Four: Project annual cost for all functional areas

The annual life-cycle cost of the five functional areas determined in Step Three was then inflated to include all 19 functional areas. Since the systems in the five functional areas were estimated to represent 74% of all systems in all functional areas, we assumed that the five functional areas also represent 74% of the cost. The inflated cost of $2.5 billion was used as the baseline for all DoD migration systems.

STEIM Model

- **Calculates cost savings resulting from three major types of technologies**
  - **Software Reuse Improvements**
  - **Process Improvements**
  - **Tools and Software Engineering Environments (SEEs)**
- **Cost savings are calculated for both development and maintenance**

Once the migration baseline cost had been calculated, it was used as input for the STEIM. The STEIM calculates savings based on implementing three major types of software engineering technologies:

1. Software Reuse Improvements: Considered as work avoidance by using commercial off-the-shelf (COTS) software and code libraries.
2. Process Improvements: Considered as working smarter by using a process such as peer review.
3. Tools and Software Engineering Environments (SEEs): Considered as working faster by partially automating software development and maintenance.

The STEIM also calculates separate savings for development and maintenance. Development is considered to be 30% of the total life-cycle cost, and maintenance is considered to be 70% of the total life-cycle cost.

The next page explains how the STEIM calculates the development savings from using the three technologies listed above.

Development Savings

- **Each technology and year have two parameters**
  - FS represents savings from use
  - FT represents fraction of projects on which the given technology is used
- **1- (FS x FT) yields the RCF**
  - RCF represents the fraction of cost left after the technology improvements have been applied
  - FS x FT alone represents the proportion of cost savings in a given year for a given technology
- **RCF x Annual Baseline Cost for development yields an annual development cost under a software technology improvement program**

STEIM calculates the savings for development and maintenance separately. We will first discuss how STEIM calculates the savings for development.

For each technology (i.e., reuse, process, and SEEs) and each year (i.e., 1994 through 2008), the model contains two parameters:

1. Fraction of Savings (FS) represents savings from use.

2. Fraction of Time (FT) represents the fraction of projects on which the given technology is used.

These parameters were calculated specifically for this study. The assumptions used for the calculations will be explained later.

Once the model has the FS and FT parameters, it calculates the Residual Cost Fraction (RCF). The RCF represents the fraction of cost remaining after the technology improvements have been applied.

The RCF is then multiplied by the annual baseline cost for development to yield an estimate of the total cost that would occur with the use of the software engineering technologies. Subtracting this annual baseline cost from the original annual baseline cost yields a development savings.

Development Savings Example

Baseline Cost for 1995: $1.0 Billion

	Reuse		Process		SEEs	
Year	FT	FS	FT	FS	FT	FS
1995	3.3%	6.8%	3.3%	4.8%	3.3%	8.9%

Technology Improvements	RCF	Annual Cost
Reuse	1 – (0.033 x 0.068) = 0.998	0.998 x $1.0B = $0.998B
+ Process	1 – (0.033 x 0.048) = 0.998	0.998 x $0.998B = $0.996B
+ SEEs	1 – (0.033 x 0.089) = 0.997	0.997 x $0.996B = $0.993B

The chart above is an example of how the STEIM calculates development savings from the use of the software engineering technologies.

Maintenance Savings

- **Calculated in the same way as development savings**
- **FT and FS are different from those used in development calculations**

The STEIM calculates maintenance savings in the same way as the development savings. However, the FS and FT parameters are different for maintenance. How and why the maintenance parameters are different will be explained later in the assumptions.

Outline

- Background
- Approach
- → Assumptions
- Results
- Future Research

Assumptions

- **DoD baseline software development productivity increases 7% each year**
- **DoD baseline software demand increases 9% each year**
- **Contributions from the three technologies will become the largest portion of the standard 7%**
- **Fraction of time increases more from year to year than fraction of savings**
- **Fraction of time is the same for all three technologies in any given year**

We must first calculate the values of several parameters in order to use the STEIM to generate savings estimates for the adoption of new software development and maintenance technologies. To calculate these parameters, we surveyed past studies and chose from them the results that characterize the effects of these new technologies on the migration systems. This and the next two pages discuss how these parameter values were calculated.

The Software Life Cycle Model (SLIM) database from Quantitative Software Management, Inc. in McLean, Virginia, revealed that the productivity index of the average user of the model has increased four fold since 1975. This implies an average annual increase in productivity of 7% over the past 20 years. We assumed that this rate of progress is the norm in the industry and will continue throughout the period modeled by this study.

The STEIM, developed by the Institute for Defense Analyses, uses a default demand increase of 9% each year.

Reuse, process, and SEEs will together dominate software technology advances over the next 18 years. Other contributors, such as high-level languages or interactive development, have either already made their greatest impact or will be subsumed under the definitions of reuse, process, and SEEs.

We assumed that the savings available from the technologies will increase as the technologies mature; however, we also assumed that this maturation will not account for as much of the increase in savings as will the increase in the number of users of the technologies.

Because it is difficult to differentiate and isolate the effect of the use of one technology from the others, we make the simplifying assumption that all three are being adopted at the same rate by software developers. However, we allow a different fraction of savings for each technology.

Assumptions (Continued)

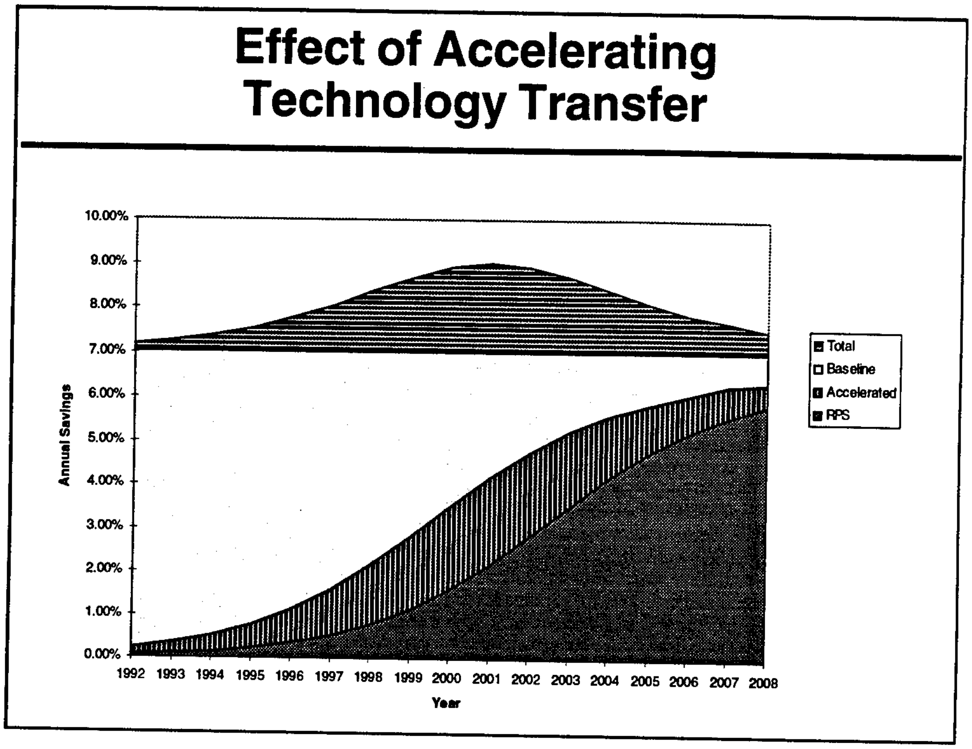
- **Effects on savings from the technologies are estimated independently**
- **Independent productivity contribution from SEEs will be greater than that from reuse, and reuse greater than that from process**
- **Maintenance FT and FS parameters follow the development parameters by three years**
- **Savings are derived from the accelerated adoption (FT) of the technologies promoted by DISA**
- **Contributions to savings from reuse, process, and SEEs will follow an idealized 18-year S-curve**

Because we are working from the total net 7% annual improvement, the relative savings between the technologies, which together constitute the total savings, have been chosen mainly for illustration and do not change the net result.

We assumed that the technology used to develop a system will follow that system throughout its maintenance life. We further assumed that the average system takes three years to develop. Therefore, the savings realized during development will begin to be observed in maintenance three years later.

The savings from this initiative will accrue when the technologies are adopted more rapidly as a result of DISA's efforts to identify, select, promote, train, and mandate them. We measured the point in time where there is a 50% saturation of the marketplace to discuss the effects of DISA efforts. For example, we examined both the situation where DISA's efforts advance the 50% adoption point by one year and also by three years.

A study IDA conducted in 1984 for the Advanced Research Projects Agency's Software Technology for Adaptable, Reliable Systems (STARS) program studied several technology insertion efforts and observed an average 18-year adoption cycle between the time a technology is first demonstrated to be beneficial and the time it is in commonplace use. An S-curve approximates the popularity of an emerging technology that starts with few users, spreads throughout a market, and gradually approaches universal use.



This graph shows the annual savings from accelerating technology transfer. It is not the actual S-curve used to calculate the annual savings. This S-curve illustrates a one-time investment in accelerating technology adoption and an increase in productivity to 9% that slowly returns to the normal 7%. The actual S-curve used to calculate the annual savings illustrates the effect of continuous investment in accelerating technology adoption in order to maintain a 9% annual productivity improvement. The following paragraphs explain the S-curve in more detail.

The lower S-curve (represented by RPS on the legend) shows the estimated baseline rate of the adoption of reuse, process, and SEE technologies over the next 17 years. The flat line at 7% (represented by Baseline on the legend) shows the total productivity improvement baseline for each year. In other words, if in year 1999, the reuse, process, SEE technologies account for a 1% annual productivity improvement, then other technologies must make up the remaining 6%. Later in the adoption cycle, the reuse, process, and SEE technologies account for a greater portion of the 7% total annual improvement.

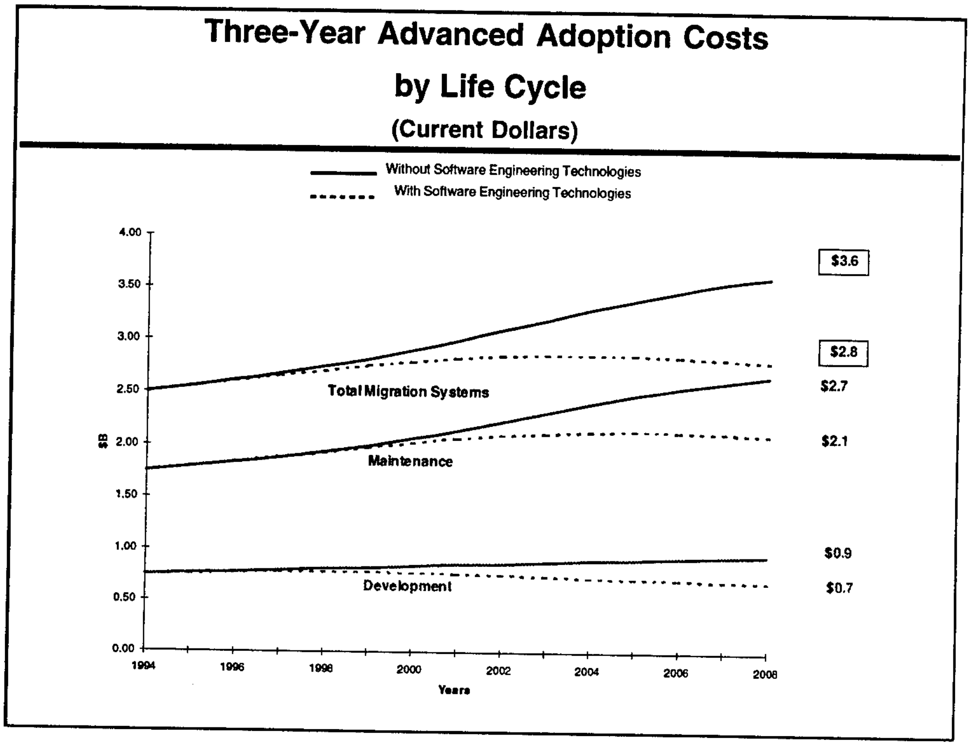
The higher S-curve (represented by Accelerated on the legend) shows the rate of adoption if the 50% adoption point is moved three years earlier. For example, if 50% of the software-intensive organizations have adopted these technologies by the year 2002, then we have accelerated the adoption point by three years to 1999. The additional annual productivity improvement is measured by the difference between the Accelerated curve and the RPS curve. The uppermost curve (represented by Total on the legend) shows the net effect of adding this difference to the 7% baseline improvement, giving a boost to the total annual productivity improvement, particularly during the middle years. This higher annual productivity gives rise to the savings realized from accelerating the technology adoption.

Outline

- Background
- Approach
- Assumptions
- → Results
- Future Research

After developing the STEIM parameters, we used them to calculate two savings estimates based upon DISA accelerating the spread of reuse, process, and SEE technologies. In the first case, we assumed DISA accelerates the date to the point where 50% of the users have adopted the technologies by three years. In the second case, we assume a one-year acceleration. These results are presented in current, constant 1994, and discounted dollars.

Three-Year Advanced Adoption

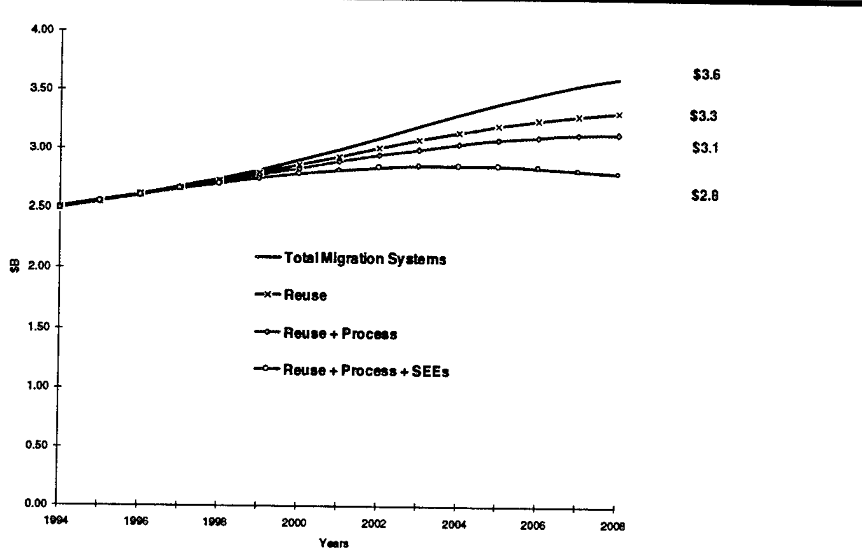


The solid lines show the expected cost of the migration systems assuming a 9% annual demand growth partially offset by a baseline 7% annual productivity improvement. In other words, the solid lines show the cost of the migration systems with no technology acceleration. The lower two solid lines show the computed costs of development and maintenance under the assumption that development costs account for 30% of the total life-cycle costs of a system and maintenance the other 70%. Therefore, the upper solid line, the Total Migration Systems line, shows the sum of these costs.

The dashed lines show the effect of the increased productivity that would be achieved by accelerating the 50% adoption point of reuse, process, and SEE technologies by three years. This results in a net annual improvement that slightly outweighs the 9% demand growth. This results in a leveling effect on the cost curves around the year 2000.

For this study, we maintained the improved productivity rate through the rest of the time period instead of allowing it to decrease as illustrated on the graph on page 17. We did this to show the effect of continued funding for technology acceleration. The continued funding will cause continued cost savings on the technologies as they evolve. If there were to be no additional funding for technology acceleration after the peak effect of the reuse, process, and SEE acceleration, then the dashed lines in the graph above would begin to rise again after about 2003, remaining below the solid lines and rising nearly parallel to them.

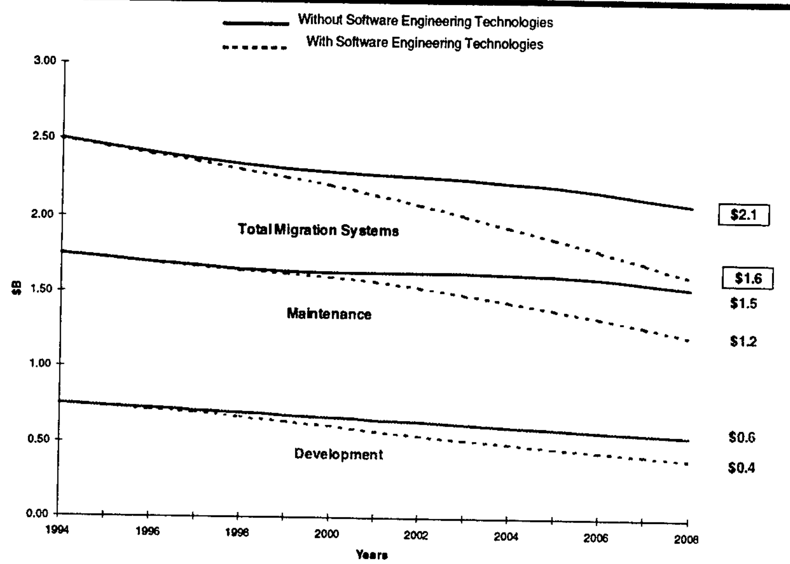
Three-Year Advanced Adoption Costs by Source
(Current Dollars)



This graph shows the computed individual effects of the cost savings for each of the three technologies. The top line is the same as the top line in the previous graph, showing the total expected costs of the migration systems over the 14-year period. The second line down shows the effect of only accelerating the adoption of reuse technologies, the third line shows the effect of accelerating reuse and process, and the bottom line shows the savings from accelerating all three (the same as the top dashed line on the graph on page 21).

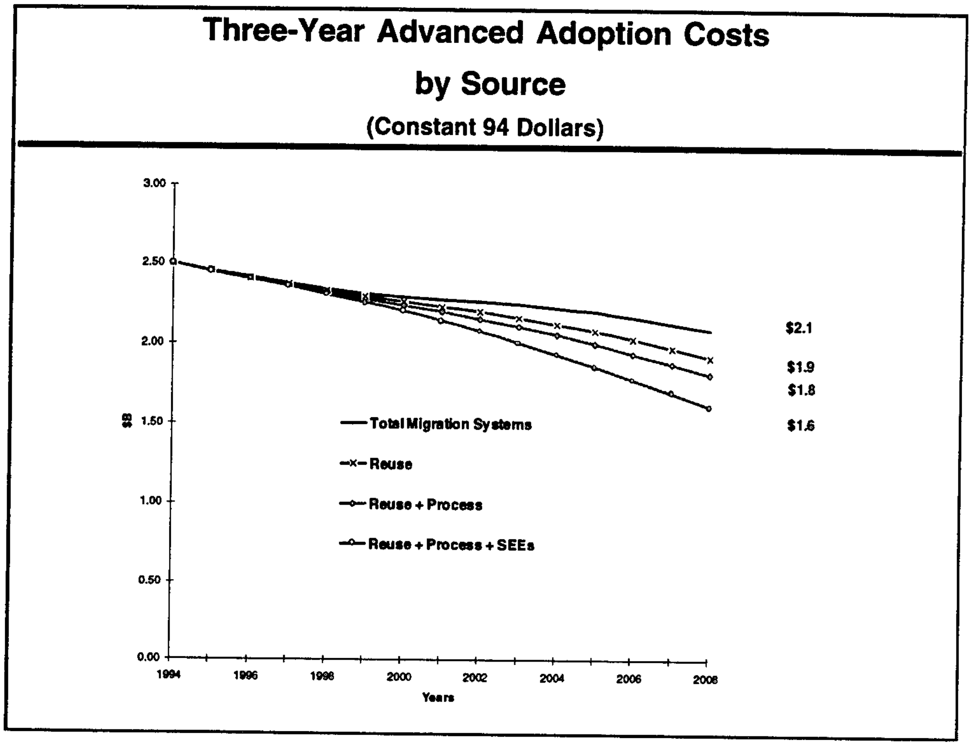
The savings shown are a notional representation more than a true picture of the individual effects since there is considerable synergy among these technologies and it is difficult to determine the effect of each alone. Nevertheless, for illustration, we have shown how each of the technologies contributes a portion of the total savings. They relative contributions shown are not all equal (i.e., the distance between the pairs of lines varies). They have been chosen to reflect our knowledge of the results of studies into the benefits of reuse, process, and SEE tools (see page 16).

Three-Year Advanced Adoption Costs by Life Cycle
(Constant 94 Dollars)



Presenting these results in constant dollars involves removing inflation from the growth of demand. In our example, we assumed a 9% demand growth, 4% of which was inflation. Since the inflation factor used is greater than the difference between the 9% annual demand growth and the 7% annual productivity increase, even the baseline costs appear to fall from year to year. When the savings from the technology acceleration is added to this, however, the net result is an even more substantial decrease in annual expenditures. This is again shown by the lower two dashed lines.

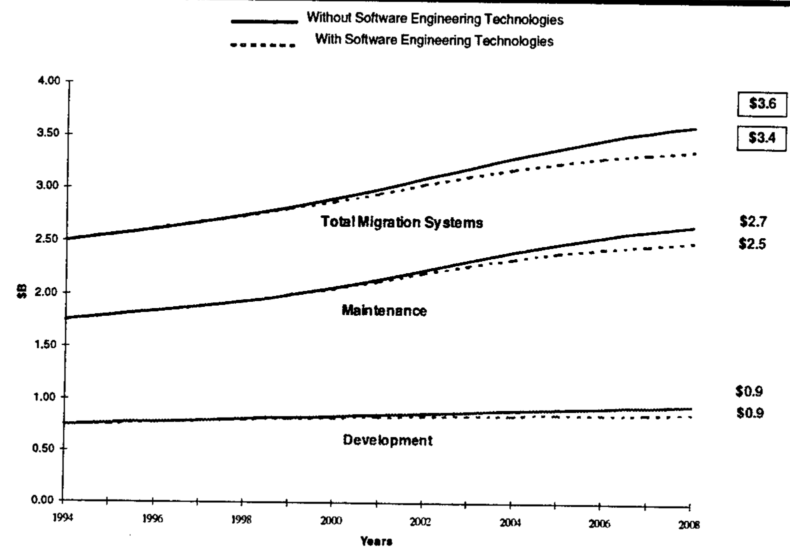
By the year 2008, the annual savings is $0.5 billion in constant 1994 dollars, and over the total time span, the cumulative net present value of the savings is $1.0 billion.



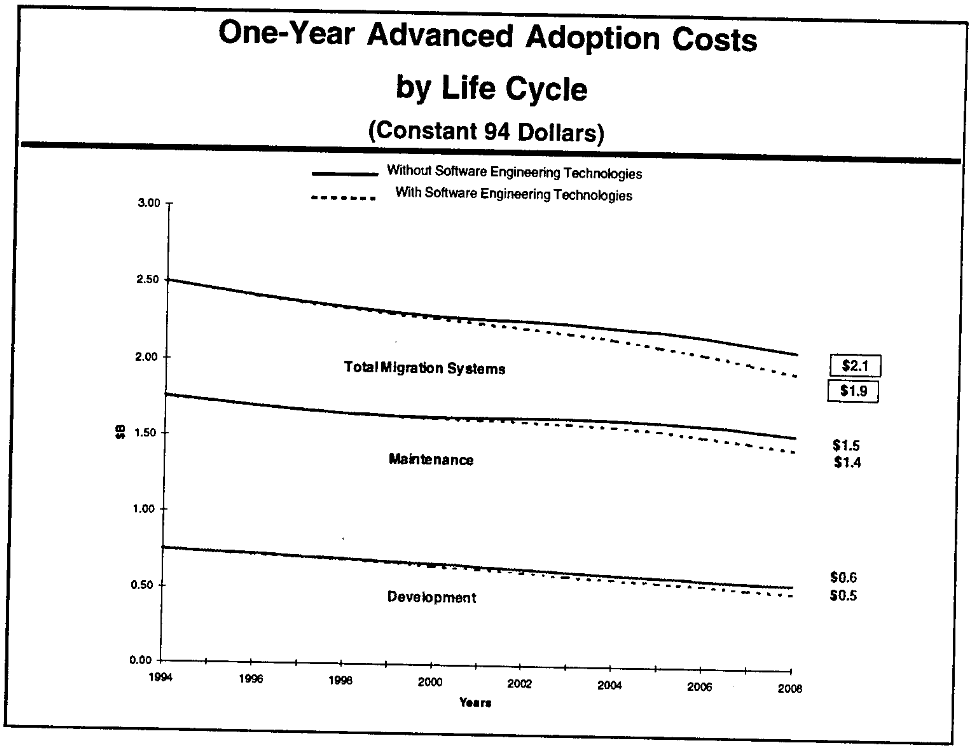
This graph shows the notional view of the individual savings from each of the three technologies in constant 1994 dollars.

One-Year Advanced Adoption

One-Year Advanced Adoption Costs
by Life Cycle
(Current Dollars)

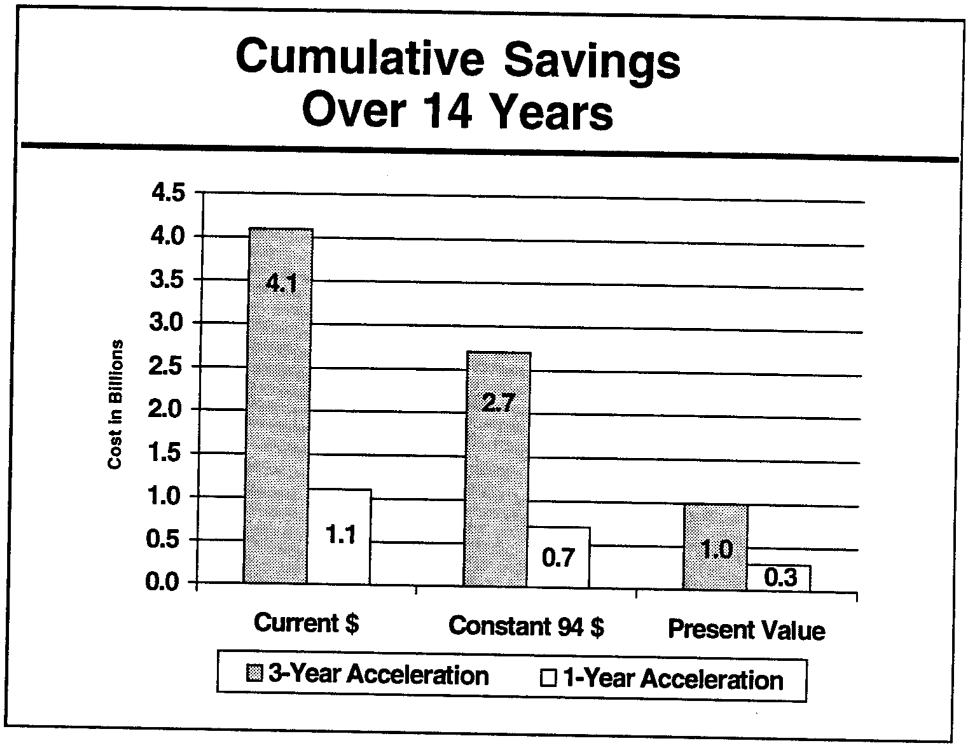


This graph shows the lesser savings that would occur if the 50% adoption point of the technologies were advanced by only one year instead of the three years assumed in the preceding graphs. Again, the top solid line shows the increasing annual costs in current dollars for the migration systems without technology acceleration, and the lower solid lines again show the constituent costs of development and maintenance. The lower dashed lines show, in each case, the smaller but measurable savings that result from adopting the technologies one year sooner than the baseline rate.



This graph shows the same information as the previous graph but includes the normalization to constant 1994 dollars. In the year 2008, the annual savings reach $0.2 billion in constant 1994 dollars. Over the 14-year period, the cumulative net present value of the one-year acceleration is approximately $0.3 billion.

Cumulative Savings



The question to be answered by this analysis is: What are the cost savings? In order to see the total effect of DISA's acceleration of the software engineering technologies, it is necessary to look at the cumulative savings over the entire 14-year period. In *current year dollars*, the savings using a three-year acceleration schedule are approximately $4 billion. Using only a one-year acceleration schedule, the savings are a little more than $1 billion. In *constant 1994 dollars*, the savings for three-year acceleration are a little more than $2.5 billion, whereas the one-year acceleration savings are estimated at $700 million. The cumulative *net present value* of savings for the three year acceleration is estimated to be one billion dollars, where as the net present value for the one-year acceleration is approximately $300 million.

Outline

- Background
- Approach
- Assumptions
- Results
- → Future Research

Future Research

- Apply the STEIM model to a cost estimate of all DoD Software
- How can DISA effectively promote technology transfer?

The analysis reported on in this briefing shows that accelerating the adoption of reuse, process, and SEEs technologies on migration systems alone can save DoD large amounts of funds and result in the faster provision of software capability. This conclusion leads immediately to two further research topics. First, what are the potential savings for all DoD software, not just migration systems? Second, how can DISA efficiently promote this technology transfer? That is, if we know how much we can save in the software life cycle, what approaches can we use to generate those savings, and how much would they cost?

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13. ABSTRACT ***(Maximum 200 words)***

The Defense Information Systems Agency (DISA) is considering ways to accelerate its adoption and implementation of new software engineering technologies for DoD migration systems. This document presents estimates of the cost savings that could be derived from such an action. IDA collected data on DoD migration systems, calculated a baseline cost for the systems, and used the Software Technology Economic Impact Model (STEIM) to estimate costs. The results indicate that by speeding adoption of technologies such as software reuse, process improvements, and software engineering environments by one year, the DoD could save $700 million in constant 1994 dollars. The estimated cost savings for a three-year acceleration are about $2.5 billion.

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