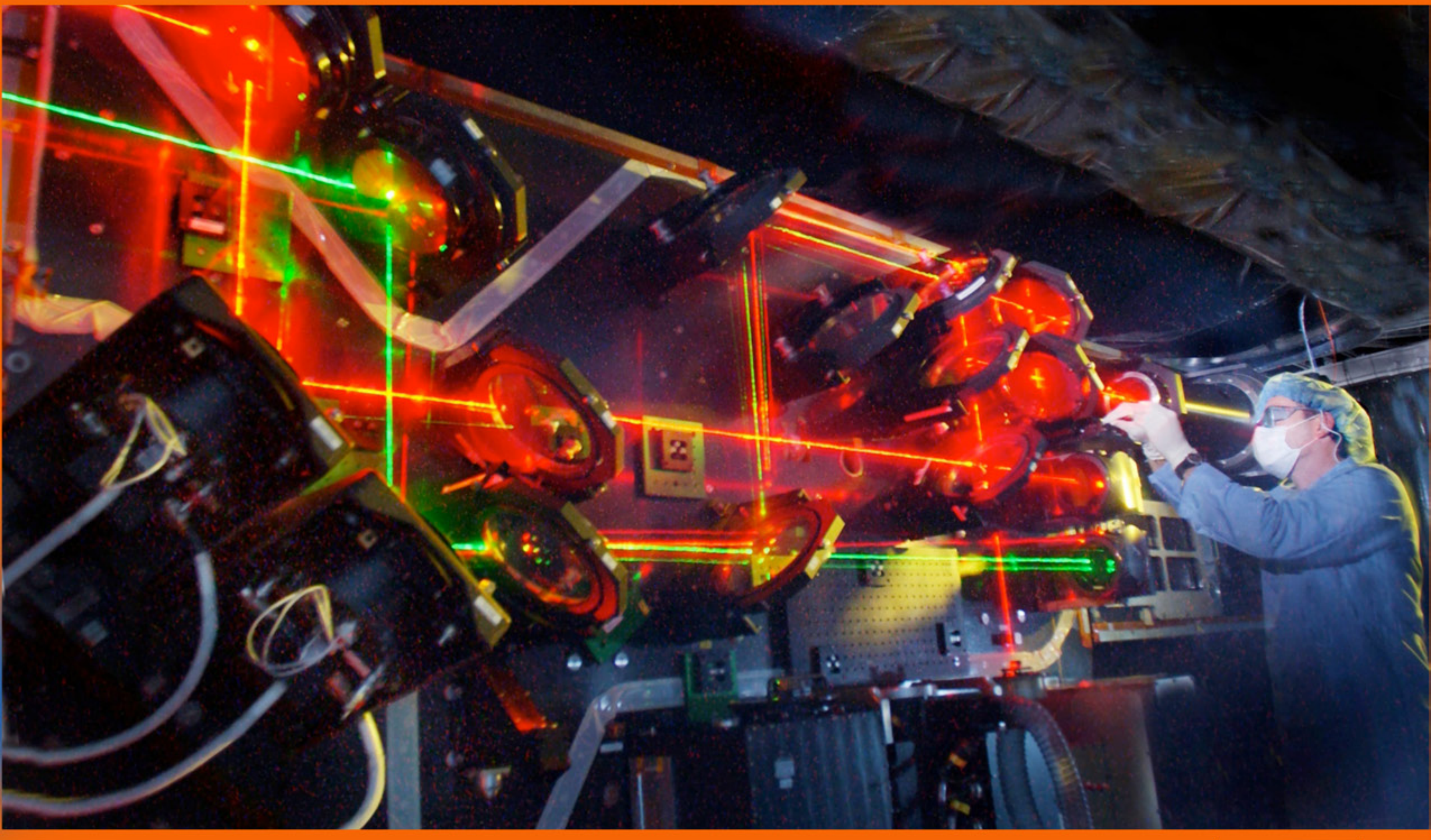
SAND2009-1844P

Technology Review & Assessment Model (TRAM)

R&D 100 ENTRY



Sandia National Laboratories

2009

2009 R&D 100 AWARDS ENTRY FORM
TECHNOLOGY REVIEW & ASSESSMENT MODEL (TRAM)

SUBMITTING ORGANIZATION

Sandia National Laboratories
PO Box 5800, MS 1188
Albuquerque, New Mexico 87185
USA
Craig Lawton
Phone: (505) 844-4895
Fax: (505) 844-3321
crlawto@sandia.gov

AFFIRMATION: I affirm that all information submitted as a part of, or supplemental to, this entry is a fair and accurate representation of this product.

(Signature) ______________________________

JOINT ENTRY

Lockheed Martin Aeronautics Company
PO Box 748
Fort Worth, Texas 76101
USA
Daniel C. Brown
Phone: (817) 935-4574
Fax: (866) 238-6803
Email: daniel.c.brown@lmco.com

PRODUCT NAME

The Technology Review & Assessment Model (TRAM).

About the cover: Optimizing technology management for high value, technologically sophisticated systems into the future.

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BRIEF DESCRIPTIONOF ENTRY

TRAM is a decision-support software application that performs technology management optimization of technologically sophisticated systems, from military combat systems to energy futures road-mapping.

PRODUCT FIRST MARKETED OR AVAILABLE FOR ORDER

TRAM became available for license in 2008.

INVENTORS OR PRINCIPAL DEVELOPERS

Principal Developer:

Craig Lawton
Principal Member of Technical Staff
Sandia National Laboratories
PO Box 5800
Albuquerque, New Mexico 87185
USA
Phone: (505) 844-4895
Fax: (505) 844-3321
crlawto@sandia.gov

Jack Gauthier
Principal Member of Technical Staff
Sandia National Laboratories
PO Box 5800
Albuquerque, New Mexico 87185
USA
Phone: (505) 284-3944
Fax: (505) 844-3321
jhgauth@sandia.gov

Developers:

John Eddy
Senior Member of Technical Staff
Sandia National Laboratories
PO Box 5800
Albuquerque, New Mexico 87185
USA
Phone: (505) 284-1642
Fax: (505) 844-3321
jpeddy@sandia.gov

Daniel C. Brown
Systems Engineer Principal
Lockheed Martin Aeronautics Company
PO Box 748
Fort Worth, Texas 76101
USA
Phone: (817) 935-4574
Fax: (866) 773-5946
daniel.c.brown@lmco.com

Kerry Batts
Embedded Software Senior Staff
Lockheed Martin Aeronautics Company
PO Box 748
Fort Worth, Texas 76101
USA
Phone: (817) 935-4574
Fax: (866) 773-5946
kerry.g.batts@lmco.com

Kevin Abshire
Systems Engineer Senior Staff
Lockheed Martin Aeronautics Company
PO Box 748
Fort Worth, Texas 76101
USA
Phone: (817) 935-4440
Fax: (866) 773-5946
kevin.j.abshire@lmco.com

PRODUCT PRICE

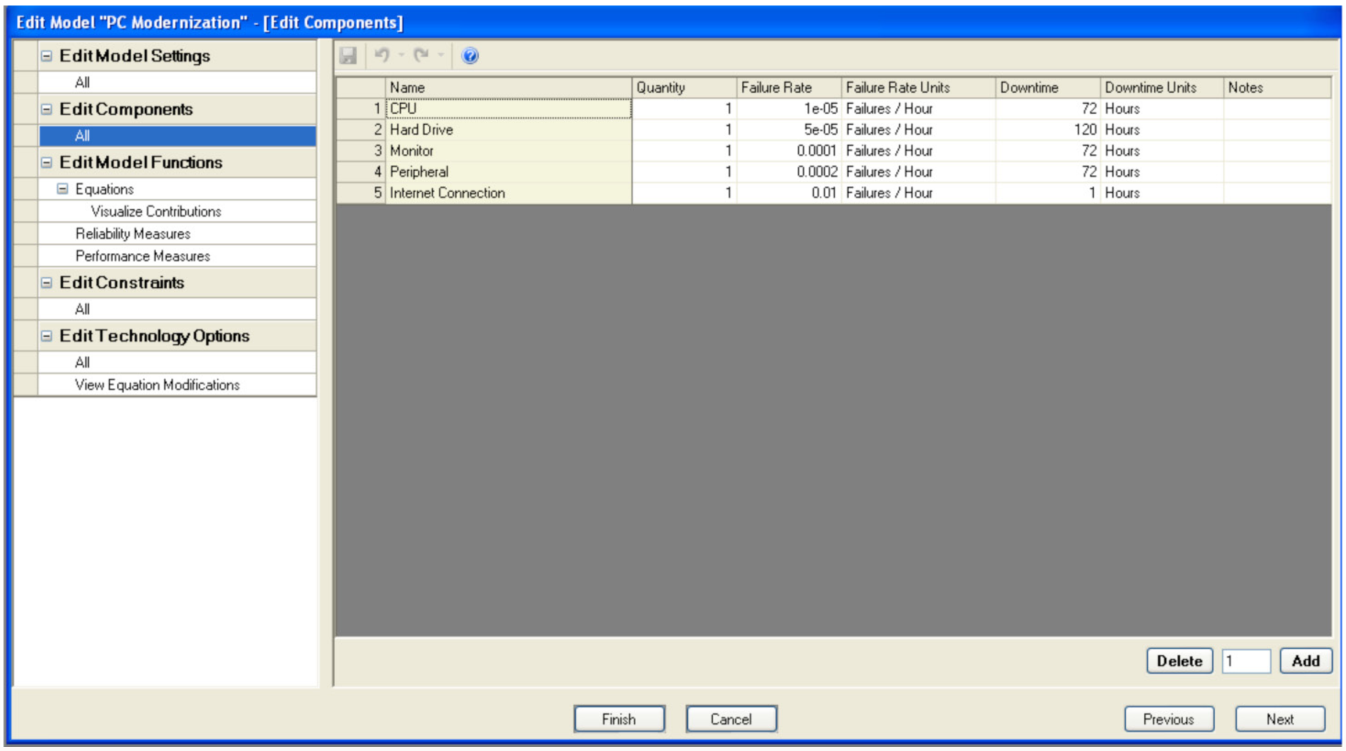
Sandia National Laboratories and Lockheed Martin Aeronautics co-developed TRAM and Lockheed Martin has use rights to the technology during the period of performance of the collaborative agreement. Additional licensing opportunities are available and subject to negotiation.

PATENTS HELD/PENDING

None.

PRODUCT'S PRIMARY FUNCTION

The Technology Review & Assessment Model (TRAM) is a computer software application that provides analysts and executives with the ability to perform analyses that result in optimal technology management decisions over the life cycle of a technologically sophisticated, high-value system or system-of-systems. The tool enables the development of optimal technology management strategies and technology roadmaps over long-term time horizons while factoring in performance, cost, schedule and risk.



Technology management optimization input data can include reliability measures (such as availability and mean time between failures), performance measures (such as targeting accuracy and range), and system constraints (such as cost, weight, power consumption, and size).

The software provides a sophisticated user interface for constructing a model of a system, allowing the analyst to define system and subsystem components and functionally decompose systems. An analyst charged with (for example) defining the subsystems of an aircraft system has complete flexibility in defining those subsystems and functions. He or she might break down the aircraft system into "avionics subsystems" and "hardware" (such as integrated computer systems and displays). The analyst might further define one area of system functions as "targeting" (specific) and another as "operability" (general), depending on the desired granularity of subsystem/function definition. The analyst could then assign each of the defined functions one or more performance measures; for example, in the case of a "targeting" function, the analyst could define a performance measure of "accuracy" or "precision" (or both).

Analysts define system constraints through TRAM to establish feasible boundaries for cost and other limiting factors (such as size, weight, power consumption, and time). TRAM factors in the impact of those system constraints plus the technology enhancement options defined by the analyst to provide alternatives for improving system performance through improving system functions. For example, two technology enhancement options might be two new targeting systems. One may be more costly but weigh less while the other may cost less but weigh more, and each option may perform differently with respect to the performance measures that have been defined.

TRAM uses all of this information when it determines the set of optimal technology enhancement options over the timeframe of analysis....

After developing the baseline model (as described above), the analyst determines the importance (or weighting) of the objectives (function performance measures) and constraints. TRAM's optimization engine selects the best set of technology options over a time horizon based on a user-defined set of time periods (such as number of days, months, or years). The model's optimization method draws on the theory of single- and multi-objective genetic optimization (MOGA). The TRAM application utilizes cutting-edge, evolutionary algorithms – genetic algorithms similar to second-generation, non-dominated genetic sorting algorithms (NGSA II) – to develop possible solutions. The user currently has the option of selecting from several genetic algorithm-based optimization engines and has control over many algorithm parameters. Although TRAM's algorithms and parameter settings are highly customizable, the default settings perform well in most cases so relatively inexperienced personnel as well as highly experienced technology management analysts can utilize the power of TRAM's analytical capability. Furthermore, TRAM is highly scalable, providing solutions to problems with 10200 or more possible solutions in a matter of minutes on today's laptops. While such problems sound unimaginably large, they are in fact commonplace in some of today's high-tech systems.

TRAM displays the optimized solution as a Gantt-style chart (a schedule) together with a variety of other results that enable the user to evaluate how the system would improve over time as well as impacts on other factors like cost, risk, and other system constraints. TRAM can directly utilize the schedule and additional results (such as amount of expected improvement and expected impact on cost/budget and other system constraints) when developing system life cycle technology roadmaps; in fact, future versions of TRAM will feed results directly into traditional roadmapping software. Thus, by automating what has previously been a manual process, TRAM reduces errors, increases efficiency, and allows for easy "what-if" scenarios.

PRODUCT'S COMPETITORS

10A. TRAM COMPETITORS

Although there are numerous optimization products available, only a few products address technology management or large, system-level trade studies (which are sometimes used for technology management problems).

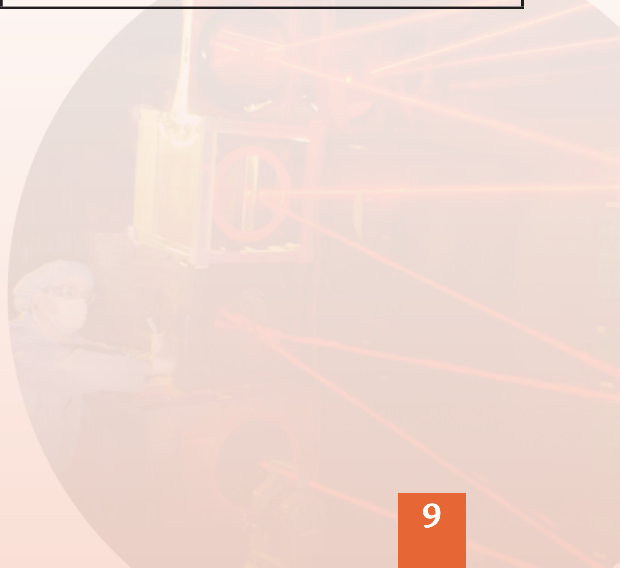
Software Product: **The Advanced Collaborative System Optimization Model (ACSOM)**
Contact: Doug Rogers, General Dynamics Land Systems, 38500 Mound Rd., Sterling Heights, MI 48310, rogersd@gdls.com.
Reference: D. Rogers, J. Czerniak, M. Donnell, G. Hartman, S. Rapp, *The Advanced Collaborative System Optimization Model (ACSOM)*, INFORMS Seattle, 2007.

Software Product: **Mitigation of Obsolescence Cost Analysis (MOCA)**
Contact: P. Sandborn and P. Singh, Department of Mechanical Engineering University of Maryland, College Park, Maryland 20742, Sandborn@eng.umd.edu, (310) 405-3167.
Reference: Sandborn, P., *Electronic Part Obsolescence Driven Product Redesign Optimization*, 6th Joint FAA/DoD/NASA Aging Aircraft Conference – Sept.16-19, 2002.

Software Product: **SeaQuest**
Contact: Chris J. Dafis, NAVSEA-Philadelphia Advanced Machinery Systems Integration Branch, Code 986.
Reference: B.J. Brady, C.J. Dafis, S.M. Gallagher, M.C. Robinson, D.C. Woodward, *Early Stage Evaluation of Navy Ship Machinery Systems using SeaQuest*, www.phoenix-int.com/GTsymposium/April29/NAVSEA.pdf.

COMPARISON MATRIX

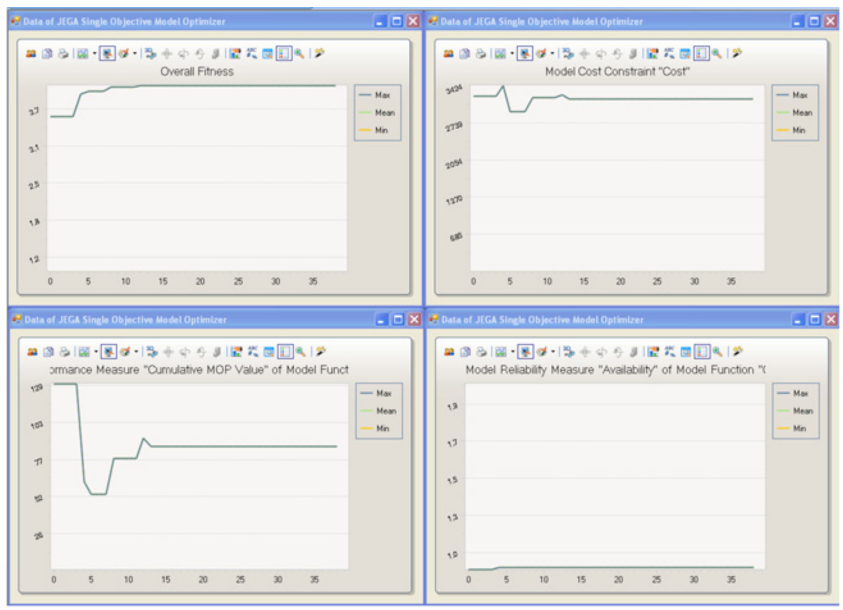
Product Feature	TRAM	ACSOM	MOCA	SeaQuest	TRAM's Competitive Advantage
Tool Flexibility and Generality	YES	no	no	no	TRAM is both a framework for approaching the development of optimal technology roadmaps and a software application that supports this framework
Multiple user-defined objectives and constraints	YES	YES	no	YES	Provides in-depth analysis of single solutions (set of optimal technology enhancement options) and exploration of Pareto (effectively equivalent) optimal solution set
Time-based specification of user-defined objectives and constraints	YES	no	no	no	Handles time-based (scheduling) technology management optimization, including constraints and resource requirements (e.g., load-leveling of costs)
Time-based optimization	YES	no	YES	no	Produces an optimal roadmap
Dependencies among technologies	YES	YES	no	no	Handles cases where one technology option either requires or obviates another option
Factors in scheduling risk	YES	no	YES	no	Addresses a primary driver of uncertainty in technology management



HOW PRODUCT IMPROVES UPON COMPETITION

Technology management is a challenging problem that requires the ability to "see" into the future while balancing the requirements of many competing objectives and constraints. TRAM's technical advance and uniqueness is in formulating the components of technology management problems in a single analytical framework that facilitates system optimization. The framework supports the unified analysis of disparate, complex processes and constraining factors that impact system performance.

Several products have been developed to address aspects of technology management. All of these competing products, however, deal with a restricted view of the problem: they either determine optimal technologies for a specific system (products like ACSOM and SeaQuest) or determine an optimal timeline dealing with diverse technology management events (products like MOCA). The uniqueness of TRAM, and the key to its success, is that it does both.



TRAM uses a robust suite of genetic algorithms to solve the optimization problem.

With its ability to identify optimal technologies and determine an optimal roadmap for when these technologies should be in place, TRAM brings cutting-edge optimization to technology management. The model's optimization method draws on the theory of single- and multi-objective genetic optimization (MOGA), and it utilizes evolutionary algorithms to develop its solutions. No known competing product allows time-based specification of user-defined objectives and constraints. This unique capability allows TRAM to accommodate changing budgets and performance demands over time. One competing product (MOCA) addresses scheduling risk based on uncertainty in future costs; TRAM treats scheduling risk as a problem constraint, and thus, the risk of planning for future technologies is directly included in TRAM's calculation of the solution. Another competing product (ACSOM) disallows infeasible solutions that do not contain technologies that require one another; TRAM considers technologies that require each other and technologies that obviate each other.

No known competing product allows time-based specification of user-defined objectives and constraints.

A single application that addresses both optimal technology solutions and optimal timing to enable a complete technology management solution may seem like an unreachable goal. However, TRAM's ground-breaking technology, encapsulated in an easy-to-use Windows application that can handle even very large problems common in today's increasingly complex systems, means that the goal has been reached.

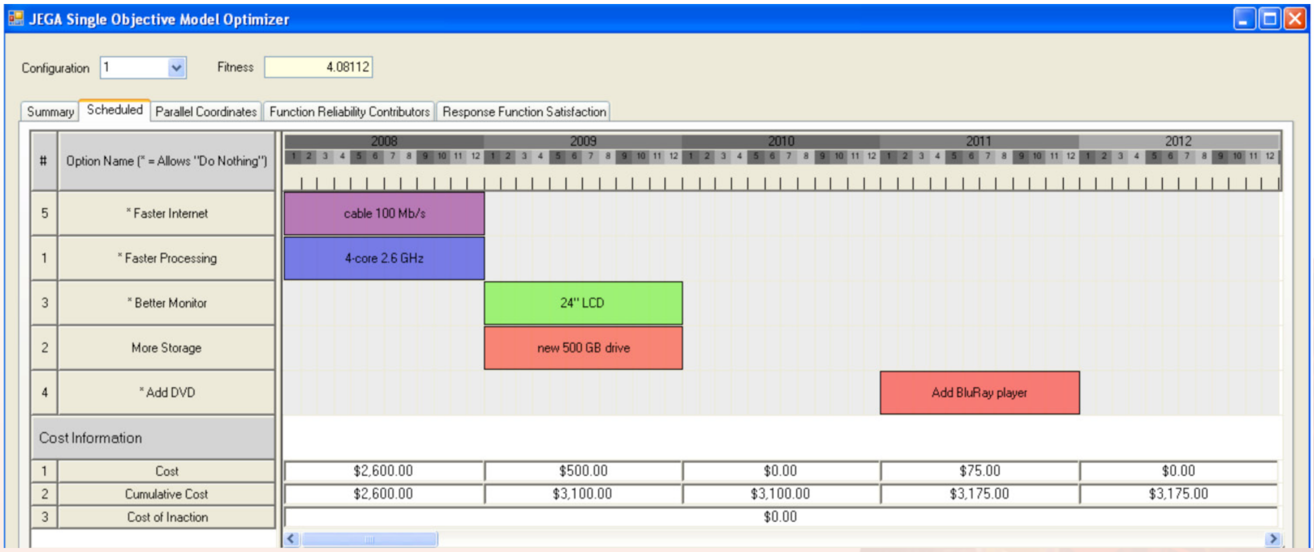
PRODUCT'S PRINCIPAL APPLICATIONS

The primary practical application of TRAM is in evaluating technology improvement strategies (such as developing optimal technology roadmaps) for high-value, technologically sophisticated systems. The software has broad applicability across many fields of use within the government and industry. TRAM is currently being applied in areas as diverse as identifying optimal technology solutions for upgrading military combat systems to roadmapping energy futures.

OTHER APPLICATIONS

TRAM can be applied to any technologically sophisticated system for which technology management decisions are important to consider over its life cycle. Example applications are as diverse as the U.S. military's Joint Strike Fighter aircraft program and road-mapping for the development of future energy sources.

TRAM also excels in the area of pricing for performance-based logistics (PBL) contracts for large defense stakeholders, where the tool can help predict system sustainment costs versus performance. This will lead to more efficient, proactive, and accurate management of such PBL contracts.



Optimal technology management allows efficient, proactive, and accurate decision-making.

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SUMMARY

Technology management is the process of managing the life cycle of large-scale, architecturally complex systems with multiple interdependent subsystems. TRAM can handle proactive technology management both in the near-term – where issues tend to occur with very little lead time and can have dramatic effect on a system in terms of cost and performance – and over the life cycle of complex systems.

TRAM is a game-changing decision-support tool that enables analysts and executives to factor in, and understand the impact of, complex technology management decisions over the life cycle of technologically sophisticated, high-value systems or systems-of-systems. It also displays the results in an easily understandable format to aid in presentations. No other tool is known to exist that produces optimal roadmaps and identifies optimal technology management strategies over a time-based planning horizon to include performance, cost, feasibility constraints, schedule risk, and system and subsystem interdependencies.

> ***No other tool is known to exist that produces optimal roadmaps and identifies optimal technology management strategies over a time-based planning horizon…***

Using the TRAM decision-support model, optimal technology management planning can lead to significant cost savings through reduced system redesign by using an automated versus manual process – for example, obviating the need for a potential significant subsystem redesign would realize a significant cost savings over the life of the system. The tool's ability to predict system sustainment costs versus performance will also have a dramatic impact on the ability to cost out PBL contracts for large defense industry contractors and, therefore, provide much more proactive, efficient, and accurate management of PBL contracts. More generally, TRAM can help lower costs for sustainment overall – critical cost savings that have never been more important in these challenging economic times. Such savings will benefit all stakeholders – the government, industry, and contractors.

With its current capabilities, flexibility for the user, and virtually unlimited application to a wide variety of technology areas, TRAM is a game-changing application that provides the ability to develop robust, optimal technology roadmaps for sophisticated systems and systems-of-systems.

CONTACT PERSON

Robert W. Carling, Director
Sandia National Laboratories
PO Box 969
Mail Stop 9405
Livermore, CA 94551-0969, USA
Phone: (925) 294-2206
Fax: (925) 294-3403
rwcarli@sandia.gov

APPENDICES ITEMS

APPENDIX ITEM A

TRAM's Role in the Stryker Light Armored Vehicle Modernization Program

APPENDIX ITEM B

Letters of Support/Testimonials

APPENDIX ITEM A

TRAM's Role in the Stryker Light Armored Vehicle Modernization Program

Note: All data is notional (sample rather than actual) and non-sensitive. The data presented in the screen captures is only for example purposes.

The Stryker Light Armored Vehicle III [LAV III] is at the center of the Army's Interim Brigade Combat Teams (IBCTs). The mission of the Stryker is to be deployable anywhere in the world as part of a brigade combat team within 96 hours and provide highly mobile, light armor and peacekeeping combat engagements. The IBCTs are lighter, more mobile, and more deployable than Heavy Brigades, yet offer firepower no enemy can hope to match. Strykers are being deployed to units at Fort Lewis, WA. In all, six brigades will receive the vehicles. Each brigade will have more than 300 Strykers apiece.

In 2008, the Army embarked on the Stryker Modernization program known as Stryker S-MOD. The goal of S-MOD is to upgrade the vehicle with respect to weight, power management, data and information management, survivability, lethality, and mobility all within the traditional contraints of cost and schedule. This will be done through subsystem redesign and technology management.

Figure A-1. A Stryker LAV III being loaded for deployment

Figure A-2. A Stryker LAV III unit supporting US Army ground troops in the Middle East

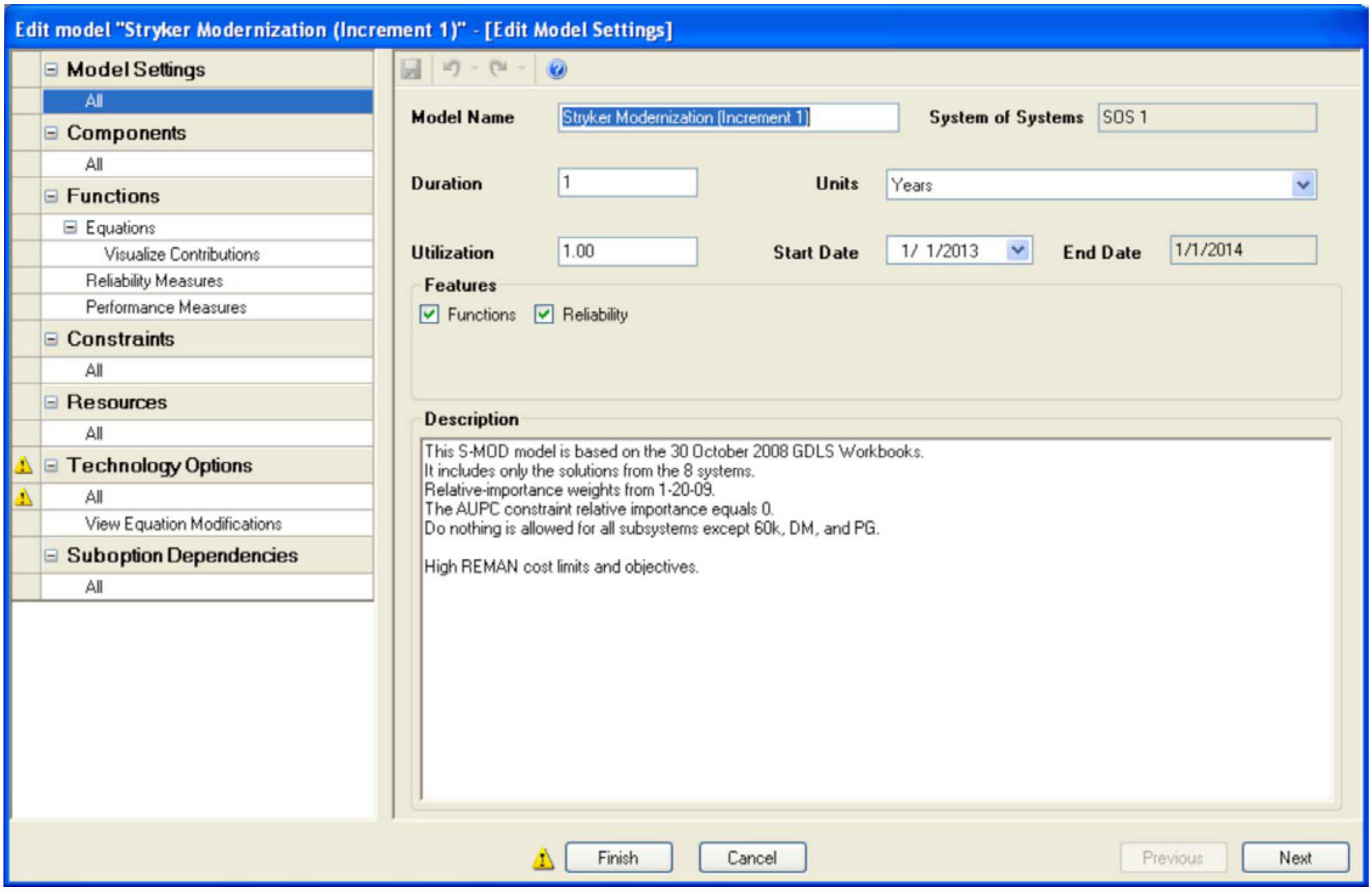

Figure A-3. TRAM provides an easy but powerful interface for setting up and editing models

TRAM was used to assist the Army with making technology management decisions regarding the Stryker S-MOD. This will have a direct impact on the soldiers in the field as the Stryker is one of the primary ground combat systems deployed in Iraq and Afghanistan (Figure A-2). The following examples depict some of TRAM's powerful capabilities available for planning and costing technology management.

TRAM has an elegant, clean interface that offers extreme flexibility in modeling and performing analysis. Users can assign general settings before starting a new model. These settings can be modified while working with the model, but such changes can affect several factors in TRAM as well as model results.

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Once the Army developed a Stryker model in TRAM, they were able to understand quantitatively and within constraint boundaries what the pros and cons were relative to certain technology improvements or system improvement configurations.
After the user sets up a model, TRAM identifies optimal technology management options based on the use of either a single-objective or multi-objective genetic algorithm optimizer.

The optimization process iteratively improves an objective function expressed as the "fitness" of the current best solution (that is, the best set of technology options). During the solution development process TRAM provides the user real time feedback on the fitness as well as the related values of constraints and individual objectives. Figures A-4 and A-5 show an example of this real-time output.

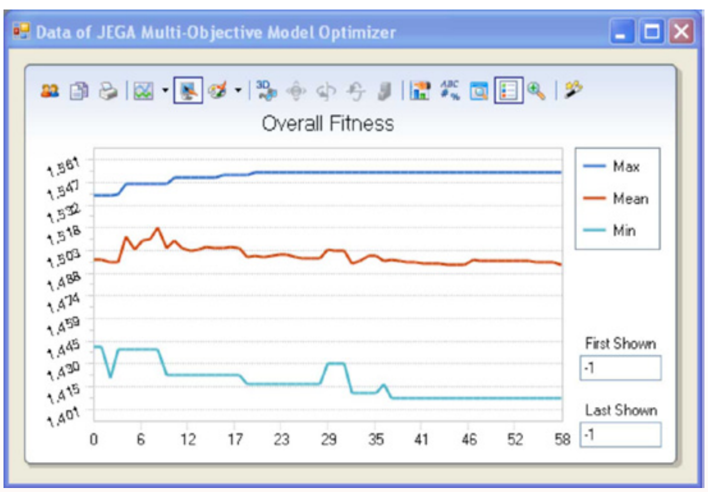


Figure A-4. TRAM's multi-objective optimizer results for "overall fitness" of the identified solution

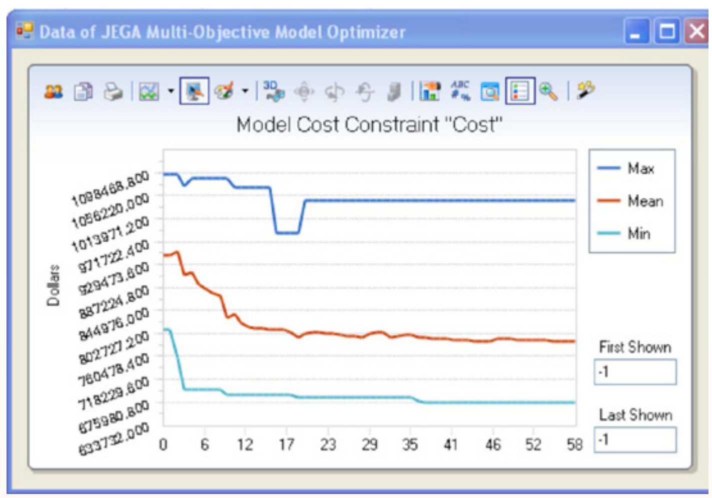
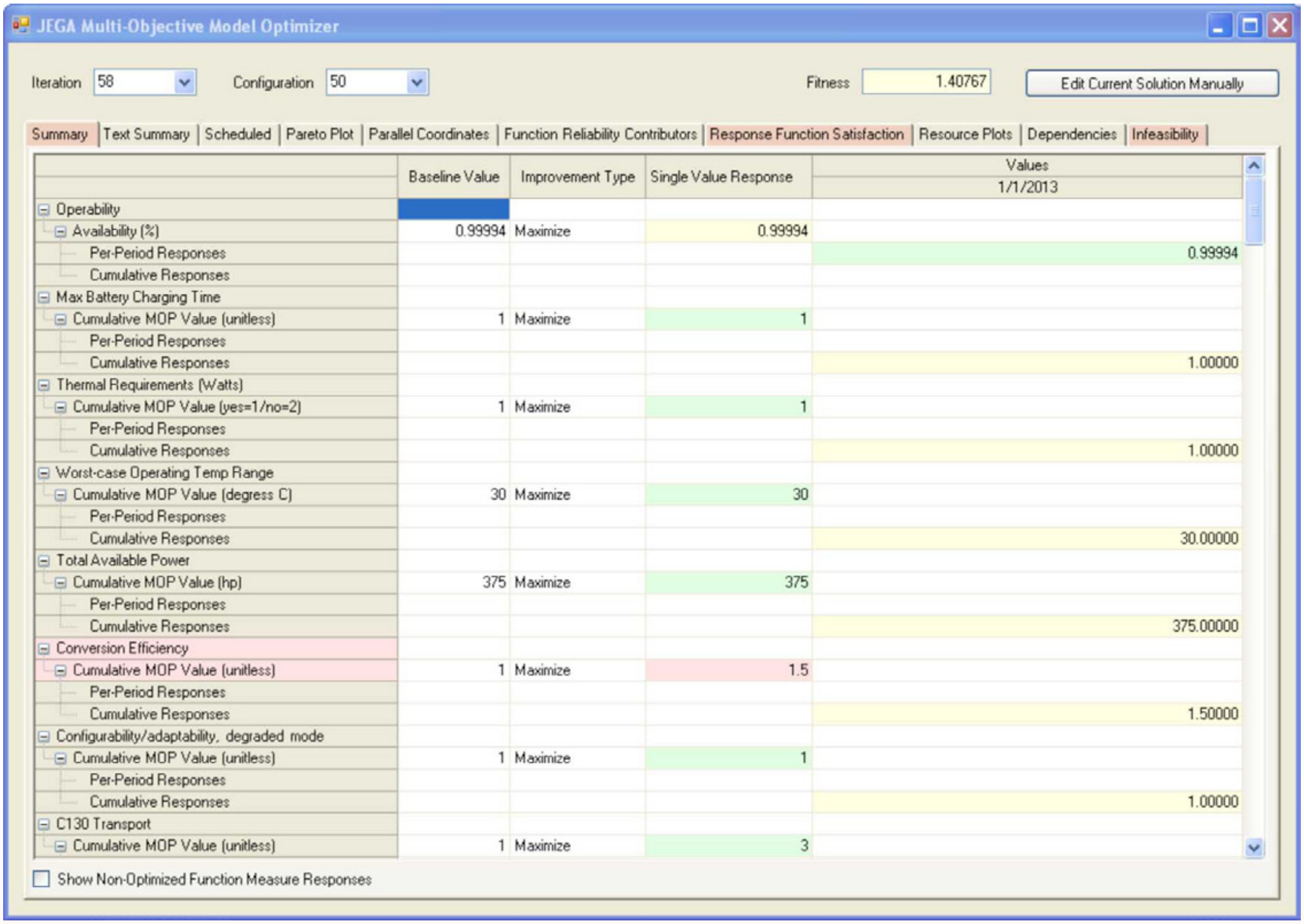


Figure A-5. TRAM's multi-objective optimizer results for the model's "cost" constraint

Real-time output provides the user with a status of the progress TRAM has made in finding the optimal solution. When the solution process is complete, TRAM provides a summary table (Figure A-6) that compiles the details of the identified solutions (constraint impacts, objective value performance, and so on).

The multi-objective optimizer evaluates the fitness of many solutions relative to one another and compiles a set of "non-dominated" solutions. Each of these non-dominated solutions is equivalently optimal to the others, but may differ relative to specific individual objectives. This approach provides the user a set of soultions that can be evaluated with sophisticated visualization tools and interfaces so that specific solutions that display greater



	Baseline Value	Improvement Type	Single Value Response	Values 1/1/2013
Operability				
Availability (%)	0.99994	Maximize	0.99994	
Per-Period Responses				0.99994
Cumulative Responses				
Max Battery Charging Time				
Cumulative MOP Value (unitless)	1	Maximize	1	
Per-Period Responses				
Cumulative Responses				1.00000
Thermal Requirements (Watts)				
Cumulative MOP Value (yes=1/no=2)	1	Maximize	1	
Per-Period Responses				
Cumulative Responses				1.00000
Worst-case Operating Temp Range				
Cumulative MOP Value (degress C)	30	Maximize	30	
Per-Period Responses				
Cumulative Responses				30.00000
Total Available Power				
Cumulative MOP Value (hp)	375	Maximize	375	
Per-Period Responses				
Cumulative Responses				375.00000
Conversion Efficiency				
Cumulative MOP Value (unitless)	1	Maximize	1.5	
Per-Period Responses				
Cumulative Responses				1.50000
Configurability/adaptability, degraded mode				
Cumulative MOP Value (unitless)	1	Maximize	1	
Per-Period Responses				
Cumulative Responses				1.00000
C130 Transport				
Cumulative MOP Value (unitless)	1	Maximize	3	

Figure A-6. Summary table for TRAM's optimal solution

performance relative to specific objectives and constraints (for example, from a particular set of equivalently optimal solutions, the user wants a solution high in survivability and low in cost, but doesn't care about weight, lethality, or mobility).

One such visualization interface unique to TRAM is the Parallel Coordinates interface (Figure A-7). This interface provides a very intuitive mechanism for identifying specific solutions that contain desired performance characteristics. TRAM displays the objectives and constraints side-by-side as "parallel coordinates;" as the user moves slider bars up and down to indicate a certain value for a certain objective or constraint, TRAM filters the solutions based on the value indicated by the slider.

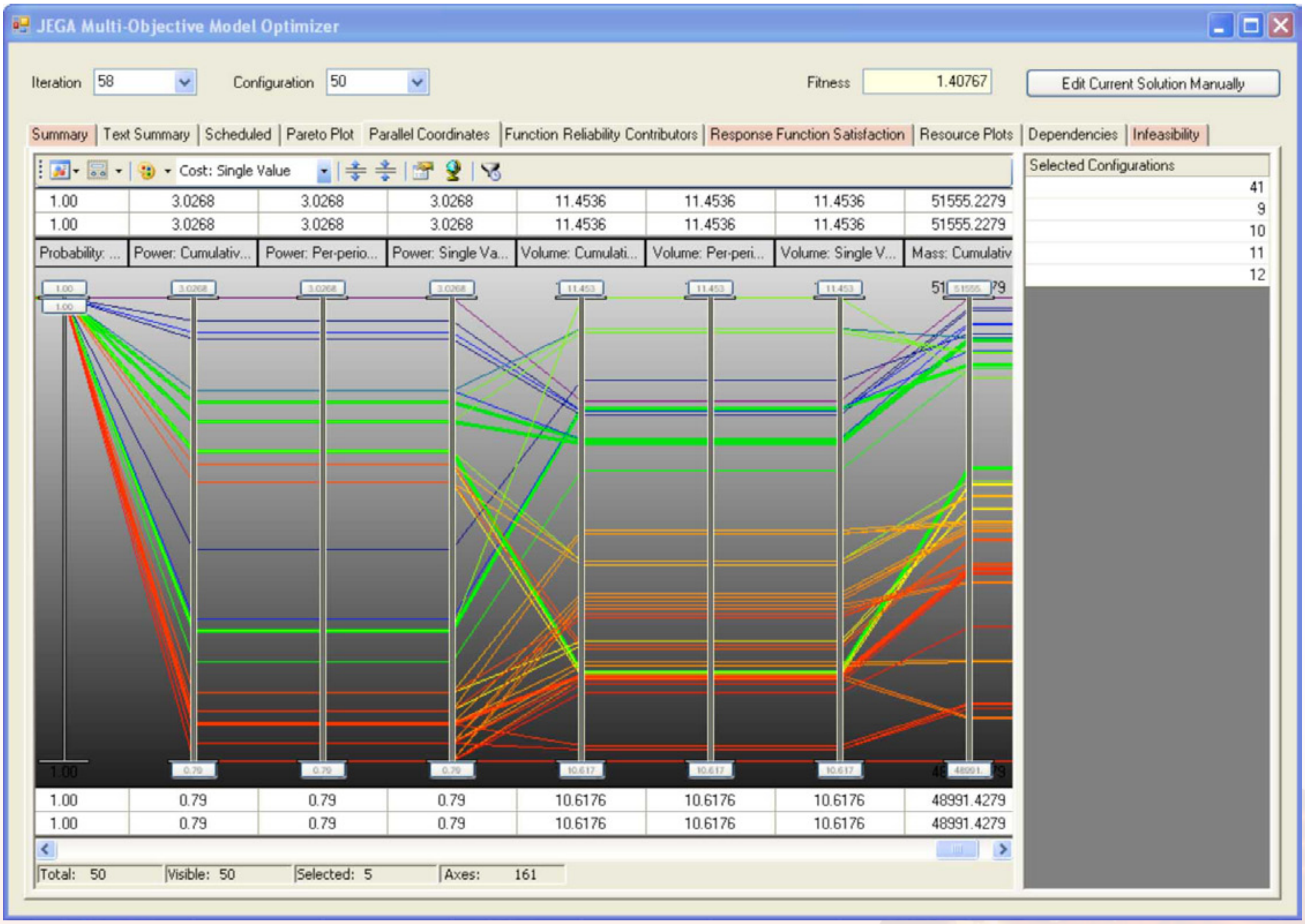


Figure A-7. The "Parallel Coordinates" visualization interface in TRAM

Another unique and powerful visualization interfaces for identifying optimal solutions is the Pareto Frontier (Figure A-8). For this type of output, TRAM plots solutions relative to two objectives and the user selects solutions that perform better relative to both objectives (the solutions in red are not feasible).

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Figure A-8. Results of the Pareto Frontier visualization plot for identifying a model's optimal solutions

In summary, the Army used TRAM's advanced, unique, multi-objective visualization features to quickly identify valuable, high-performing modernization strategies for the Stryker S-MOD program. TRAM enabled the Army to identify the optimal set of technology enhancements from a wide set of alternatives. This will lead to improved performance within budget and system constraints and will help the Army choose the most cost-effective modernization program for the Stryker. This is a complex process that is not achievable without TRAM, regardless of the amount of analysis performed.

APPENDIX ITEM B

Vince Walcek Testimonial

Note: This testimonial has been edited for style and proprietary information.

Tell the background story of TRAM — was there a core development team? Were you a part of that effort?

I have been involved as the technology management subject matter expert at Lockheed Martin (LM) since the inception of TRAM. I knew right away that the concepts being researched and developed by the team were very innovative in my field and potentially very useful in my work.

Explain how TRAM works and why it's a great technology.

I believe TRAM to be a game-changing technology. Technology management of complex systems has traditionally been an ad hoc, reactive activity. That is, analysts in our field typically deal with events as they present themselves.

When an engineering change issue arises, we deal with it in the moment, and then we move on to the next issue. This is inherently not the most efficient way of dealing with engineering challenges because all the while, decisions about alternatives are being considered independently.

TRAM allows for proactive planning for globally optimal technology management and significant cost savings. TRAM allows all of this to be considered at once and performs the complex analysis that leads to an optimal, most cost beneficial technology roadmap. Realized savings could be in the tens of millions of dollars. Beyond that, TRAM is a great technology because, due to its flexibility and generic treatment of technology management, it allows for the unification of many analyses required for complex system planning.

Talk about its core genetic algorithms and how a user gets defensible results.

One important, extremely valuable feature of TRAM is that the results of products that handle problems of this complexity are typically difficult to validate. Normally, I'm wary of "Black Box" tools that spit out an answer. My first question is, "Why is this necessarily the answer? What makes this the right answer?" In the case of TRAM significant thought and innovation have gone into the capability to explore the problem space and drill into why a particular solution has been evaluated as optimal. In TRAM, solutions can be evaluated relative to one another and the analyst can develop a credible understanding of why a solution has been chosen as optimal. This is one of the key innovations of TRAM: the ability to explore the problem space through some very innovative interfaces.

Explain the need for this product – why complex systems and problems need this tool.

The need for TRAM is quite simple. That is, it is tedious, complicated and, in the end, expensive, to make good (let alone optimal) design decisions regarding the technology management and roadmapping of complex, technologically sophisticated systems manually or even with spreadsheets or databases.

Talk about its advantages over competing products in the marketplace.

Over my career as a decision support analyst providing alternatives for the management of many large, complex systems, I have not seen anything approaching the capabilities of TRAM. If it existed, I would already be using it. That is one of the reasons TRAM is so game-changing.

How do you view your relationship with SNL? Is it a good way to innovate by partnering in this fashion?

The technical collaboration between Lockheed Martin Aeronautics and Sandia National Laboratories has been great. We have both learned a great deal from the experience. We bring very diverse experience bases and come from different areas of technical expertise. Bringing all of this diversity together has definitely led to a product of significantly higher quality and capability.

Talk about why this software deserves an R&D 100 award – what is exciting and "wow" about it?

TRAM is a methodology for approaching a problem. In addition, it provides a framework and a software application for implementing this methodology. This methodology is not limited to technology management: It could be applied to any complex system that requires planning and decision making. This is why it is deserving of an R&D 100 award – in a sense it is like the invention of the spreadsheet back in the VisiCalc days.

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NNSA National Nuclear Security Administration