A Roadmap of Risk Diagnostic Methods: Developing an Integrated View of Risk Identification and Analysis Techniques

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September 2004

Acquisition Support Program

Technical Note
CMU/SEI-2004-TN-002

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Executive Summary

This report illustrates the concept and value of the Risk Diagnostic Roadmap (RDR), a compendium of risk identification and analysis (RI&A) techniques for programs that acquire and/or develop software intensive systems. The RDR is conceived as a comprehensive reference tool that not only would provide insight into various risk identification and analysis techniques, but also would enable users to easily compare and contrast these techniques. As such, it would be a powerful resource for anyone who needs to assess the health of programs in the Department of Defense, other government organizations, or in private industry. This audience includes program executive officers, acquisition program managers (PMs), program staff, the chief engineers at the Carnegie Mellon® Software Engineering Institute, as well as the larger risk management community.

Using the Risk Diagnostic Roadmap would provide immediate benefits by optimizing the process of choosing, recommending, and employing RI&A techniques. Currently, choosing among so many RI&A techniques can be challenging for anyone trying to select or use such diagnostic methods. This is true even for experts in risk management; experts whose extensive experience with select RI&A methods may make them less likely to investigate, recommend, or use unfamiliar techniques. The RDR could address this problem and advance risk management practice by opening the full range of RI&A techniques up to the entire user community.

Beyond these immediate benefits, framers of the RDR envision two exciting advances that could occur with its creation and maintenance. First, the RDR will inevitably highlight areas where existing diagnostic methods do not fully address the needs and emerging trends. Thus, the Risk Diagnostic Roadmap would become an invaluable resource for those seeking to address those needs and trends, either by performing research or by strengthening implementation processes.

Second, the effort to organize the Risk Diagnostic Roadmap will reveal commonalities among the diagnostic methods that could lead to a way of translating the output ("leave-behind data") of such methods into a standardized format such as risk statements.

Currently, the output ("leave-behind data") of one technique cannot be compared effectively with the outputs produced by alternative methods. With standardized output, PMs as well as the larger risk management community could better evaluate competing risk diagnostics.

®   Carnegie Mellon, Architecture Tradeoff Analysis Method, ATAM, Capability Maturity Model, CMM, and CMMI are registered in the U.S. Patent and Trademark Office.

This, in turn would improve PMs' ability to accurately measure the status of their programs, while also improving senior acquisition executives' ability to view of program risks service-wide and across services.

At this point, it should be re-emphasized that the Risk Diagnostic Roadmap is not a new diagnostic method or tool. It is a framework for comparing the benefits, strengths, and advantages of existing methods. It is also a means of identifying areas for future RI&A research.

To that end, staff members at the SEI have begun discussing the basis for including or excluding existing methods in the RDR. Moreover, we have begun preparing the roadmap using three risk-based diagnostic tools developed at the institute: the Architecture Tradeoff Analysis Method® (ATAM®), and Commercial Off-the-Shelf (COTS) Usage Risk Evaluation (CURE [SM]), and the Software Risk Evaluation (SRE). The RDR team invites critical comment and seeks collaborators willing to help develop version 1.

[SM] CURE and SCAMPI are services marks of Carnegie Mellon University.

Abstract

This technical note illustrates the concept and value of the Risk Diagnostic Roadmap (RDR), which is envisioned to be a comprehensive reference tool for risk identification and analysis (RI&A) techniques. Program Managers (PMs) responsible for developing or acquiring software-intensive systems typically identify risks in different ways. Some PMs and consultants rely on free-form brainstorming or volunteered statements. Others select risk diagnostic methods based on convenience and familiarity. Both approaches are focused more on the experience and knowledge of the PM and/or consultant than on the requirements of the program.

Researchers at the Carnegie Mellon® Software Engineering Institute are developing an alternative approach in the form of the RDR. The RDR is populated with an "appropriate" set of risk diagnostic methods. The roadmap enables PMs to compare risk diagnostic methods and choose the best method(s) for their particular situations.

This technical note describes the evolution of the Risk Diagnostic Roadmap and presents the attributes that qualify risk diagnostic tools as "appropriate" for the roadmap. SEI researchers then use these attributes to select three candidate risk diagnostic methodologies for inclusion in the RDR.

1 Introduction: What is a Roadmap?

The concept of a roadmap is not new, but it has seen increased use in recent years. The idea of capturing the current understanding of an industry area or product, providing a retrospective of "how we got here," and forecasting the future of the field has piqued the interest of professionals in various industries associated with manufacturing, science, and technology. Roadmaps and similar documents have been produced in the semi-conductor industry, the cyber-infrastructure, the wireless domain, and the Internet (semantic Web) to name a few.

In reviewing the possibilities of presenting a technology roadmap, two specific concepts emerge. The first is the process involved in capturing a current understanding of an industry area or product. Doing so can provide a retrospective of "how we got here," a forecast of "where we are going" or a hybrid of both.

The other is an image of a literal roadmap, with graphical depictions of destinations, rural routes, highways, toll roads, national parks and points of interest. Robert Schaller, professor of in the Department of Business Economics and Legal Studies at the College of Southern Maryland, offers one definition of roadmaps as follows:

> Generically, a "road map" is a layout of paths or routes that exist (or could exist) in some particular geographical space. In everyday life, road maps are used by travelers to decide among alternative routes toward a physical destination. Thus, a road map serves as a traveler's tool that provides essential understanding, proximity, direction, and some degree of certainty in travel planning.[1]

The Risk Diagnostic Roadmap is envisioned to be just such a representation with "cities" categorized as entry points and "destinations" as exit criteria. Traveling between the cities are the various routes prescribed by the PM or general practitioner that will be the most appropriate for the RI&A needs of the organization. After reviewing the RDR, programs can choose the direction among the various possible routes. They will be able to select a route that will take them though a series of diagnostics to get them to their final destination of improved health.

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[1] Schaller, Robert R. 2004. Technological Innovation in the Semiconductor Industry: A Case Study of *the International Technology Roadmap for Semiconductors (ITRS),* PhD Dissertation, George Mason University.

In any case, the creation of a roadmap requires review of current technology and technology trends, as well as real and envisioned business needs. Doing so provides a context for future technological development in a particular field. The Risk Focus Team has opted to focus effort on producing the broad context in exploring and advancing RI&A application.

Based on the combined experiences of the Risk Focus Team, the following initial five exit criteria or recommended destinations were identified:

Come Back Next Year. If the application of one diagnostic yields results that indicate no further diagnostics are needed, the program can "come back next year."

Lifestyle Changes Needed. If results show the program isn't in immediate danger, but could be on the road to future problems then "lifestyle changes are needed."

Extreme Measures Needed. If results of a diagnostic show that the program may be in trouble, but urgent action can save it, "extreme measures are needed."

Out of Immediate Danger. If one or a series of RI&A techniques rescues the program, it is then "out of immediate danger," but should probably continue to monitor health through the general practitioner or a chief engineer.

Terminal Condition. In the most unfortunate circumstances, if results provide the final evidence that recovery is not possible; a "terminal condition" is present. The program should be terminated.

These "exit points" are analogous to the kinds of outcomes patients would expect after a period of exploratory medical diagnostics. With the inclusion of other RI&A techniques into the future Risk Diagnostic Roadmap, other valid end points may also be identified.

To fill in the terrain between entry and exit points, the three risk-based diagnostics selected for initial analysis will be used to depict realistic criteria for visiting one or more of these destinations. All diagnostics that find a place on the roadmap will also be of value to programs at some point in their life cycle. It is likely that once the first RDR is created, gaps will be identified where there will be an obvious area of need that lacks a diagnostic. In some cases, the diagnostic will exist and will be added; in other cases, a known diagnostic will not exist, and framers of the roadmap will recommend development to fill the hole.

1.1 Why a Risk Diagnostic Roadmap?

As in the examples provided above, the Risk Diagnostic Roadmap will allow existing RI&A techniques, current program needs, and technology trends to converge in a coherent and logical framework.

Practitioners and consumers of these diagnostics will have a clear understanding of the range of possibilities in applying specific diagnostics to meet their particular program need. For PMs outside this area of expertise, the RDR will help define the value of existing techniques and the course of exploration that may benefit their programs. For developers of diagnostics, the RDR will either validate their chosen technical direction or will redirect their efforts to ensure more relevance and applicability. In this way, the RDR will help shape future research and development to meet emerging needs, thereby advancing the field of risk.

As part of this effort, the Risk Diagnostic Roadmap will promote the use of a standard format for representing risk items all RI&A methods. Once in the standard format, the risk items can then be entered into a program's risk repository. All program risks, whether derived from a functional architecture or elicited from program staff can be identified, assigned an impact and probability, and monitored, not uniquely, but systemically.

1.2   Why the Carnegie Mellon Software Engineering Institute (SEI)?

Generally, SEI work could be described as sharing the core element of finding ways to identify and mitigate risk. SEI work has either helped members of the software community discover and understand the risks they run, or given them specific approaches for dealing with those risks. For example, process management and improvement is a risk mitigation strategy for a whole constellation of risks that may not be explicitly articulated. Our commercial off-the-shelf software (COTS) and product line efforts have yielded strategies to deal with risks that researchers have perceived in specific technical areas. The network systems survivability work has been to identify risks in information systems and mitigate them as soon and completely as possible. Therefore, developing the RDR can be viewed as a natural extension of our efforts to further the state of the practice.

2 Improving Risk Management Practice through the RDR: An Analogy between Risk Management and Medical Care

Although the state of health care is an oft-debated issue, many of us take for granted that a certain level of sophistication—professional licensure, organizational accreditation, medical research, treatment protocols, standards of care, procedural checks, and so on—is inherent in the health care system. Examining risk identification and analysis from the perspective of medical care might point the way for acquisition to take a few steps toward an analogous care system.

At some point everyone has sought help from doctors and hospitals for illness or injury, so the world of medical care is a familiar one. People seeking health care are not expected to diagnose and treat themselves; instead they seek the help of medical professionals. Likewise, people seeking to improve the health of their programs should be able to draw upon the expertise of a community of risk professionals.

To take the analogy further, consider acquisition support as if it were "medical care for programs." Managers who wanted to check the health of their programs could consult an easy-to-use self-diagnostic tool—a "thermometer."

If the thermometer indicated a problem, the PM could then schedule a "checkup"—consult an RI&A expert—to identify any potential risk areas for preemptive treatment and/or to address small problems before they become big ones.

Programs with clear, urgent, mission-threatening problems could seek "emergency room" care—immediate, expert triage and intervention to preserve the life of the program. In any of these scenarios, programmers could be called "specialists"—experts in treating particular risks or dysfunctions. The following sections describe these three interventions in greater detail.

2.1 The Thermometer

The "thermometer" is conceived as a self-diagnostic tool for PMs or other personnel. The thermometer would provide a snapshot measuring current risk indicators based on a generally accepted picture of program health. Users would have the option to mitigate risks on their

own or seek the help of an expert. Developing such a "thermometer" could represent a project for near-term research.

2.2 The Checkup

If necessary, programs consult an expert analogous to a general practitioner for a regularly scheduled "checkup." The expert applies simple diagnostics—perhaps in the form of surveys or checklists. Depending on the results, the expert might prescribe more costly diagnostics or additional modes of action. As with the thermometer, PMs could use the expert ("check-up" intervention) on a regular basis to track program risks over time.

2.3 The Emergency Room

"Emergency room" diagnostics are implemented for programs requiring immediate attention (critical care). If serious problems threaten the life of the program, the PM can call in experts—perhaps even a team of specialists—to diagnose the immediate/critical issues and determine the appropriate "treatments."

For the "health care" model of acquisition support to work, all diagnostic techniques should have their entry points expressed as one of these modes of intervention— "thermometer," "checkup," or "emergency room." The diagnostics should also identify exit points that either would indicate the need for further testing or suggest the use of other diagnostic methods. In the medical field, these results and recommendations could come in the form of treatments, referrals to other specialists, etc. In the RI&A domain they might include tiger teams, independent technical assessments, and so on.

This structure would enable PMs to take advantage of the range of RI&A techniques. However before this model could be implemented, RI&A practitioners need to know what techniques are available, when and in what situations they are best applied, and how to apply them effectively in combination or in sequence. In short, they need the roadmap.

3 Organizing the RDR

SEI technical staff members initiated the road mapping activity by reviewing a discrete set of diagnostic techniques. To be included, each diagnostic had to satisfy three criteria. First, it had to be risk based (as opposed to model based, see the following section for differentiation). Second, it must include a method to elicit risk items (risk statements). And third, it must be familiar to those staffing this project. These three points allowed us to test assumptions and to gain a better understanding of the diagnostics selected for review.

3.1 Risk Based and Model Based Diagonistics

Risk based Diagnostic
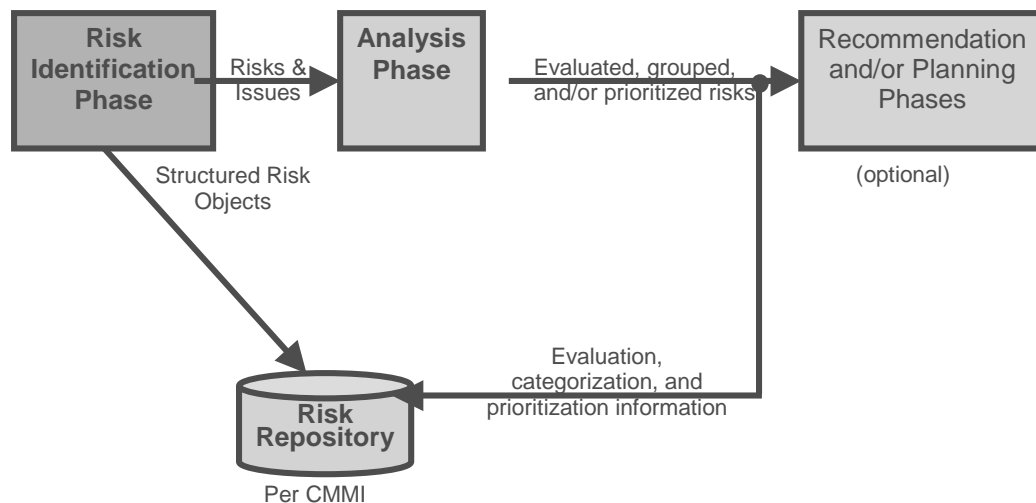
Figure 1:   Risk Diagnostics Roadmap

Diagnostics appear to fall into two broad categories: model based diagnostics and risk-based diagnostics. Model based diagnostics compare real programs to a model and present areas of deviation in the form of findings. Standard CMMI Appraisal Method for Process Improvement (SCAMPI[SM]) [Hays 93], Capability Maturity Model® (CMM®)-Based Appraisals for Internal Process Improvement (CBA-IPI) [Dunaway 01], and Software Capability Evaluations (SCE) are such diagnostics. Risk-based diagnostics focus on a program's current practices and identify risks associated with them. The Software Risk Evaluation (SRE), Architecture Tradeoff Analysis Method® (ATAM®) [Kazman 00], and the Commercial Off-the-Shelf (COTS) Usage Risk Evaluation (CURE[SM]) [Alberts 01], exemplify risk-based diagnostics.

Returning to the medical analogy, model-based diagnostics can be compared to certain blood tests like lipids tests, in which subjects are compared to a historically determined profile for a healthy individual. If individuals deviate from that profile, they face specific risks, e.g., increased risk of heart attack. Risk-based diagnostics can be compared to magnetic resolution images (MRIs) or X-rays, in which specialists look for causes of a patient's reported ailments.

Because the risk-based diagnostics identified above were developed in relative isolation, they can be more confusing to novice users. For that reason, they were appropriate for initial consideration in the roadmap. However, model-based diagnostics certainly have a place in the roadmap, and will be added once the initial structure has been developed and refined.

3.2 The Importance of Risk Items

With the advent of the Capability Maturity Model Integrated (CMMI®) in the software community, programs and organizations have begun instituting continuous process improvement to achieve Level 3 in the CMMI staged representation CMMI [SEI 01, SEI 02]. Level 3 contains three specific goals and seven specific practices in the Risk Management Process Area. These goals and practices form a logical, single-pass process for continuously identifying, analyzing, and mitigating risks.

The existence of at least one risk repository is implicit. Every risk identified for the program or its contractors—regardless of the method used for identification—should find its way to the risk repository. Otherwise, there would be little point in having such a repository.

But what are "risks?" Risk items could be descriptions of potential calamities that could occur to a program, like being late, burning too much money, or building something that the customer doesn't want. Risks could also be "if-then" constructs. The definition and format of risk items is open, and for the most part, it is simply left to the discretion of the user.

Differences among risk items aside, whatever focus the various risk-based diagnostics have, RDR participants, including researchers, PMs, and other interested parties) will need to feed the risk repository, and they need to do it in a consistent, mutually supportive way.

The definition and format of risk items is discussed further in the technical note, *Risk-Based Diagnostics.[2]*

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[2]   Williams, R.; Ambrose, K.; Merendino, T:; & Bentrem, L. *Risk Based Diagnostics*, (CMU/SEI-2004-TN-013). Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University, 2004.

4 Selecting Initial Diagnostics for Inclusion in the Roadmap

Maturing the arena of RI&A is about defining its parts and determining where the software community needs to focus more research. Therefore, we want to cast as large a net as possible for risk-based diagnostics. In our journey toward understanding the RI&A landscape, we began with diagnostics that are reasonably familiar to technical staff at the SEI. We have discerned three different patterns among these diagnostics in terms of how they go about eliciting the risk items and what source they tend to lean on most heavily: (1) mining the knowledge of the people in the program and structuring that knowledge into risk items; (2) bringing outside expertise to bear, and using that expertise to structure the risk items; and (3) providing an "expert system"—a tool that can be applied consistently, independent of the ability of the program's personnel or that of the outside team.

The SRE is an example of the first; the ATAM is an example of the second; and CURE is an example of the third. In addition, we have classed the Software Quality Assessment Exercise (SQAE[3]), Operationally Critical Threat, Asset, and Vulnerability Evaluation (OCTAVE®), and most Independent Technical Assessments (ITAs) as you see here.

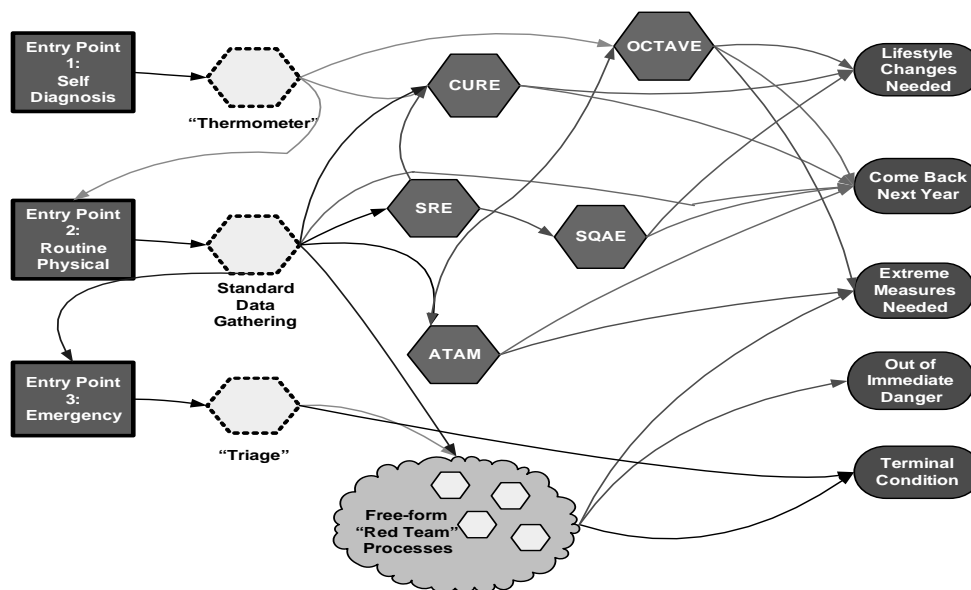*Figure 2:   Notational Roadmap*

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[3]   The SQAE methodology and Framework was developed by and can be licensed through the
        MITRE Corporation.

®   Octave is registered in the U.S. Patent and Trademark Office by Carnegie Mellon University.

By defining the characteristics that make these methods suitable for inclusion in the RDR, it would then be possible to identify others like them. The framers of the roadmap started with the methods most familiar. If an explanation of the characteristics that qualified them for the list could be defined, other diagnostics could be added and analyzed. The following characteristics quickly emerged as the key qualifiers:

- Risk identification phase

- Analysis phase

- Potential risk statement "leave-behind"

We emphasize that this is a notional roadmap. The team has given only the most preliminary thought to the connections between the methods shown. The colors of these connections are likewise only suggestive, and will probably gain meaning and utility as we expand and refine the RDR.

The hexagons with solid line borders represent the methods we are already studying or considering for inclusion. The hexagons with dotted-line borders represent areas that we think should contain a method, but where team members did not know of any risk-based diagnostics that fulfilled the identified function. In these areas, collaborators could identify existing diagnostics that fulfill the identified functions or choose to do development in that area to fill the gap in the Risk Diagnostics Roadmap.

The "cloud" at the bottom of the drawing represents a class of methods that will be necessary for the foreseeable future until more structured diagnostics can be developed. These are the expert-based inquiries—so called "red teams" or "graybeard panels" that include perhaps most of the independent technical assessments that the SEI has conducted over the years. They, too, have a place on the RDR, and their results should also be entered into the risk repository as structured risk items.

5 Next Steps

Since the team investigating risk diagnostics initially focused initial on a small sampling of diagnostics, an obvious next step is to include techniques from outside the SEI. Early candidates include the SQAE developed by MITRE, and the OCTAVE approach developed by the SEI. Once the RDR is populated, it will be possible to construct both retrospective and prospective reviews, ensuring that the roadmap becomes a comprehensive reference of all available RI&A techniques. Another long term goal of this effort will be a) developing standardized descriptions for risk items identified by the various diagnostic techniques and b) ensuring that those standardized risk items are referenced in the RDR.

For the Risk Diagnostics Roadmap to be useful and relevant in any industry area, it must be continually tested and revised based on the current capabilities, the latest technology trends, and the pressing business drivers. A critical mass of professionals in risk, perhaps a panel of both practitioners and consumers, must challenge the roadmap's assumptions and conclusions. Ideally, some body of knowledgeable professionals should review and update the Risk Diagnostic Roadmap at regular intervals.

We would like other stakeholders in the acquisition community to share our sense that the RDR is a synergizing vision that will benefit us all—acquisition programs, the organizations that serve them (e.g., federally funded research and development institutions, consultants), and developers.

We are looking for potential collaborators and funding to help us identify additional risk identification and analysis techniques for possible inclusion in the roadmap.

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/99tr029abstract.html

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE September 2004	3. REPORT TYPE AND DATES COVERED Final

4. TITLE AND SUBTITLE A Roadmap of Risk Diagnostic Methods: Developing an Integrated View of Risk Identification and Analysis Techniques	5. FUNDING NUMBERS F19628-00-C-0003

6. AUTHOR(S)

Ray Williams, Kate Ambrose, Laura Bentrem

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Software Engineering Institute Carnegie Mellon University Pittsburgh, PA 15213	8. PERFORMING ORGANIZATION REPORT NUMBER CMU/SEI-2004-TN-002

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) HQ ESC/XPK 5 Eglin Street Hanscom AFB, MA 01731-2116	10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12A DISTRIBUTION/AVAILABILITY STATEMENT Unclassified/Unlimited, DTIC, NTIS	12B DISTRIBUTION CODE

13. ABSTRACT (MAXIMUM 200 WORDS)

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14. SUBJECT TERMS Risk Diagnostic Methods, Risk Identification and Analysis (RI&A) techniques, Risk-based and Model-based diagnostics, acquisition of software intensive systems	15. NUMBER OF PAGES 25

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL