

6-2015

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### Recommended Citation

Poston, Robin S. and Dhaliwal, Jasbir (2015) "IS Human Capital: Assessing Gaps to Strengthen Skill and Competency Sourcing," *Communications of the Association for Information Systems*: Vol. 36 , Article 34.

DOI: 10.17705/1CAIS.03634

Available at: <https://aisel.aisnet.org/cais/vol36/iss1/34>

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# Communications of the Association for Information Systems

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## IS Human Capital: Assessing Gaps to Strengthen Skill and Competency Sourcing

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### Abstract:

Past research has mainly focused on defining information systems (IS) skills and competencies at the industry or global level; it has offered little guidance on best practices for managing IS at the organization level. And yet, a resource-based view indicates that failure to properly manage skills and competencies could lead to suboptimal outcomes such as a loss of IS process knowledge and innovation, an inability to adequately evaluate vendor performance, and a lack of critical skills and competencies needed to meet future demands. In this paper, we examine how one government agency managed its systems for testing personnel. We describe the need for a process to assess IS skills and competencies in order to analyze the gaps and ensure they are filled. A concrete understanding of existing gaps guides sourcing of skills and competencies through hiring, training, internal transfers, and work allocation. This paper presents an effective methodology for this purpose.

**Keywords:** IS Skills and Competencies, IS Management and Sourcing, Human Capital Management, Case Study.

Volume 36, Article 34, pp. 669-695, May 2015

The manuscript was received 11/02/2014 and was with the authors 7 months for 3 revisions.

## I. HUMAN CAPITAL IN INFORMATION SYSTEMS SOURCING

Executive leadership teams in competitive firms understand the important relationship of human capital (as it relates to information systems (IS), especially to employees' skills and competencies) to firm performance. Human capital includes employees and their knowledge, skills, attitudes, values, and needs in the work environment. Human capital is one of the key resources needed for IS-based innovation that allows organizations to transform assets and services into strategic applications and outcomes (Bharadwaj, Sambamurthy, & Zmud, 1999; Sambamurthy, Bharadwaj, & Grover, 2003). Human resources use technical systems (i.e., devices, tools, and techniques) to deliver strategic actions and financial returns (Bostrom & Heinen, 1977; Kling, 1980; Markus, 1983).

However, many chief information officers (CIOs) focus primarily on technical subsystems. They complain about persistent shortages of IS skill sets in industries (Goulart, 2006; Levinson, 2012), and they would benefit from a better understanding of the human resource skills and competencies they do have (Curran, 2010; Sumastre, 2011). The ability to assess and analyze existing IS skills and competencies is the first step in nurturing and growing those skills and competencies to meet long-term strategic goals. Once a leadership team understands what individual skills and competencies it can draw on, it can staff IS projects optimally because it knows what each member will bring to the team. CIO executives and their management teams need a strategic understanding of their skills and competencies profile of their organization not only for current projects, but also to plan for the organization's long-term needs.

Historically, IS human resources research has focused on IS skills, on how to manage IS personnel (Bartol, 1982; Crepeau, Crook, Goslar, & McMurty, 1992; Lee, Trauth, & Farwell, 1995), and on how IS skills align with the business (Duncan, 1995; Roepke, Agarwal, & Ferratt, 2000; Todd, McKeen, & Galuppe, 1995). More recently, IS human resources research has examined global sourcing to understand what skills are required globally and how to distribute the workforce to meet these needs (Tambe & Hitt, 2012). Findings show companies in low-wage, developing regions value technical skills and global, virtual teamwork more than those in high-wage, developed regions but that they both value project management skills the same (Kaiser, Goles, Hawk, Simon, & Frampton, 2011). Client organizations maintain similar internal skills as the provider firms they hire (Hawk et al., 2012). IS executives tend to regard technical (e.g., programming) and non-technical (e.g., project management) skills as equally important for success (Gallagher, Kaiser, Simon, Beath, & Goles, 2010), although the former are needed for entry-level positions while the latter are needed for advancement (McKeen, Smith, & Jin, 2009). While prior research guides executive leadership in how to manage their IS organizations, it fails to provide a pragmatic methodology for achieving appropriate IS sourcing. This paper complements prior work by offering guidance in this area.

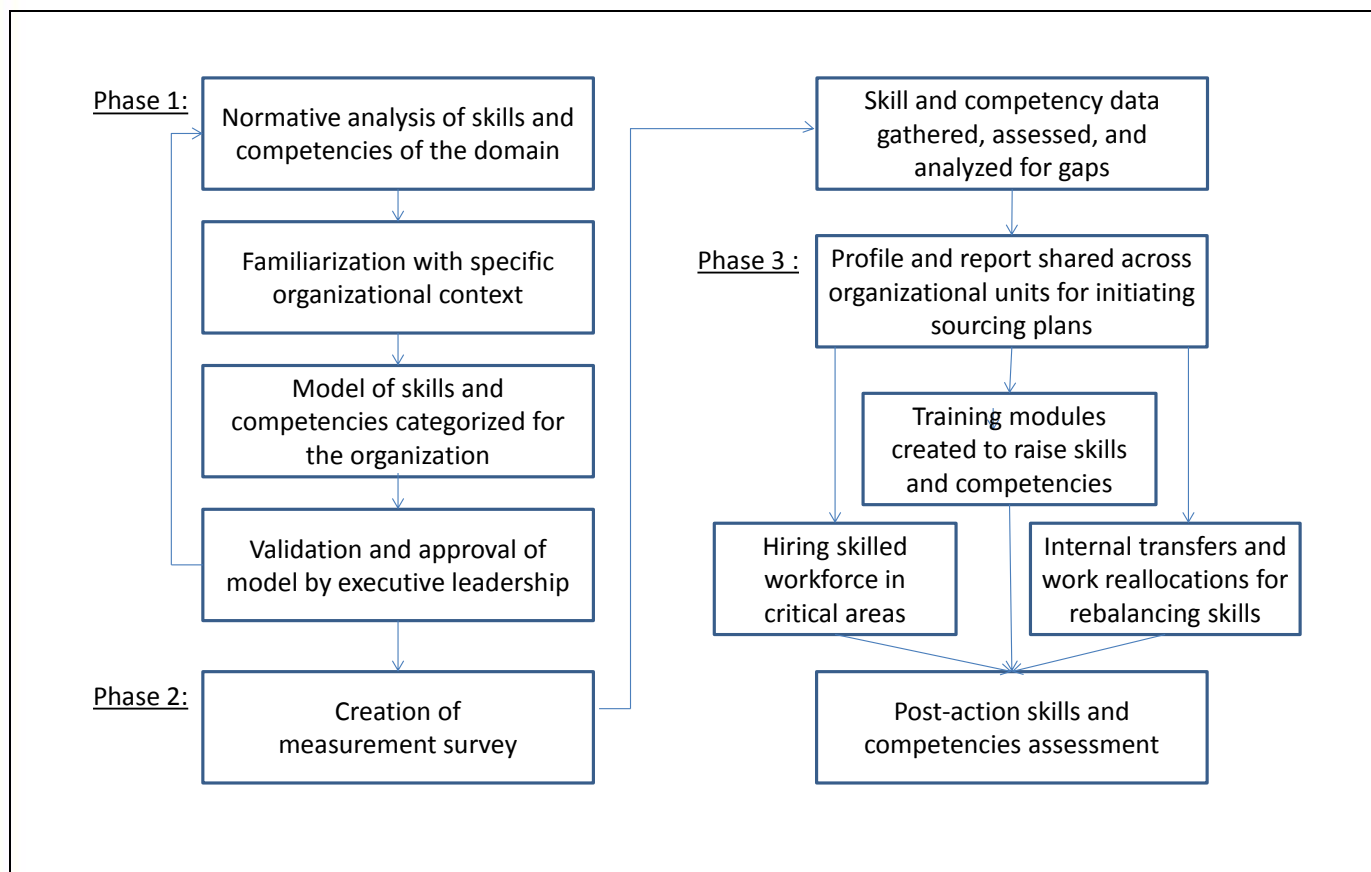
With the help of academic researchers, the U.S. Defense Information Systems Agency (DISA) measured its IS skills and competencies to create a strategic profile. The research team and DISA analyzed and compared the profile with strategic priorities to determine gaps that needed to be filled. The analysis provided a basis for DISA to (1) fund customized training programs to raise overall capabilities for the future, (2) target the hiring of talent in critical areas, and (3) make skills-based internal transfer and work allocation decisions to optimize performance. This paper describes a case study of academic researchers working with DISA to perform a skills-based assessment of DISA's human capital.

## II. SKILLS AND COMPETENCIES ASSESSMENT AND GAP ANALYSIS

Resource-based theories propose that an organization's strategic value and success depend on how well the organization manages its unique valuable resources, including resources related to human knowledge and skills (Rumelt, 1991; Wernerfelt, 1984). Resource-based studies suggest management teams will benefit from assessing and strengthening the skills and competencies of their workforce (Coff, 1997; Ployhart & Moliterno, 2011) by first identifying the organization's existing capabilities and determining which are valuable, rare, inimitable, and non-substitutable and second enabling reinforcing actions to fill the gaps (Barney, 1986, 2001; Sirmon, Hitt, & Ireland, 2007). Skills and competencies are measurable elements of an organization's human capital, but resource-based scholarship has offered little concrete guidance on how to conduct the actual measuring. This study provides one possible methodology.

Faced with the lack of process guidance, a team of research scholars created the skills and competencies assessment and gap analysis process (SACAGAP) by using best practices found in the training and management

literature focused on assessing student and employee capabilities (Davis, Misra, & van Auken, 2002; Hakatie & Rynnänen, 2007; Van Auken, Chrysler, Wells, & Simkin, 2011; Lee et al., 1995). For example, typically, field studies, focus groups, or interview input from IS professionals are used to develop capabilities measures (Havelka & Merhout, 2008; Lee et al., 1995; Tesch, Jiang, & Klein, 2003). The SACAGAP process follows similar approaches to gather input from management teams to update normative models of skills that are outlined in the literature. Drawing on assessment processes used in prior studies (Davis et al., 2002; Hakatie & Rynnänen, 2007; McKeen et al., 2009), SACAGAP offers a methodology for defining customized knowledge areas and associated skill and competency items that make it possible to develop and assess an organization's profile, analyze the organization's skills gaps, and then fill them (see Figure 1). To follow this methodology, organizations must first determine the areas and items that are relevant for their specific context (phase 1) and then measure and assess their current skills and competencies in those areas (phase 2). This is the assessment of the organization's current profile. The organization then projects what future skills and competencies it will need and, based on that projection, creates a plan for improvement that may include customized training, targeted hiring, internal transfers, work allocations, and so on (Phase 3).

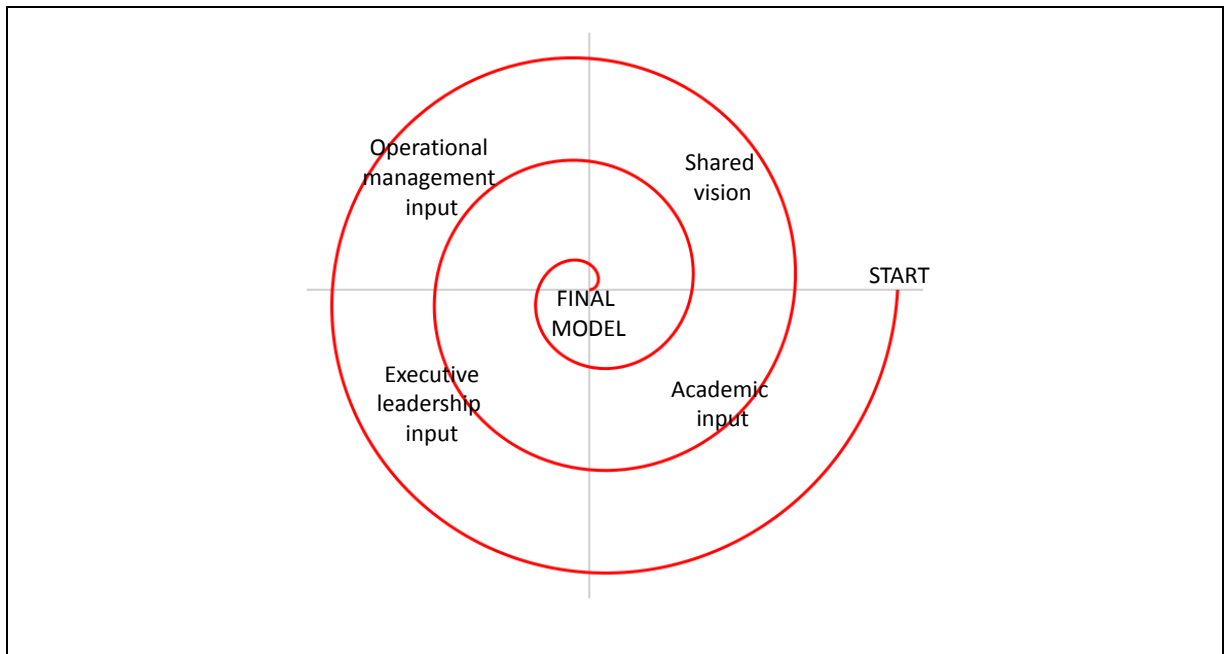


**Figure 1. Skills and Competencies Assessment and Gap Analysis Process (SACAGAP)**

### Phase 1: Contextualizing Knowledge Areas and Skill and Competency Assessment Items

The process begins with the creation of a normative model that brings together knowledge areas and skill and competency items from practitioner and scholarly sources such as published papers, certification programs, textbooks, and so on and from analyses of job advertisement content (e.g., see Lee et al., 1995; Todd et al., 1995; Wade & Parent, 2002). The literature on IS workforce skills suggests several important knowledge areas, including organizational skills, IS knowledge, technical abilities, IS product expertise, etc. (Benbasat, Dexter, & Mantha, 1980; Gallagher et al., 2010; Ives & Olson, 1981; Lee et al., 1995; Nelson, 1991). Knowledge areas are high-level categories that may include multiple skill and competency items. The areas and items are contextualized to the specific operations and needs of the particular organization being examined. For example, in the IS domain, outsourcing of development projects is prevalent (Kern, Willcocks, & Lacity, 2002; Ross & Beath, 2006; Rottman & Lacity, 2004), which means that a normative model that includes detailed development skills and competencies may not be a relevant starting place in some IS organizational settings. With an understanding of an organization's contextual characteristics, one can decide what to include and exclude from the normative model.

To understand the specific context involved, researchers update the normative model iteratively, with executive leaders providing input about strategic, critical areas, and operational management offering input about daily operational needs (see Figure 2). As a result, a shared understanding begins to form about the appropriate bundle of knowledge areas and specific skill and competency items in each area. Each iteration leads to tighter specifications and helps communicate the strategic model of skills and competencies across the organization, which creates a shared vision among the executive leadership team and operational management about the current and future needs of the organization.



**Figure 2. Iterative Development of Knowledge Areas and Skill and Competency Items**

**Phase 2: Measuring and Assessing the Skills and Competencies**

Having created a model of knowledge areas and specific skill and competency items in each area, the next step is to create survey items. For each skill and competency item, multiple survey questions are generated using a five-level measurement scale with the rankings “none”, “basic”, “competent”, “advanced”, and “expert” to quantify an employee’s capability. The training and management literature examining skills gaps offers examples of customized survey instruments: some rely on employee self-assessment of job performance, and others that rely on managers’ or customers’ assessments (Tesch et al., 2003; Tesch, Miller, Jiang, & Klein, 2005; Wade & Parent, 2002). In this phase of SACAGAP, executive leadership and operational management also consider what demographic data to collect for cross-group comparisons. For example, an organization may want to know whether employees at certain organizational levels and with certain types of college degrees exhibit greater capabilities for a specific skill or competency item. Knowing what employee levels and types of degrees correspond with desired skills and competencies helps the organization make better hiring and organizational placement decisions. Executive leadership bases its decision regarding which employees to target with the survey on what needs it predicts will be critical for the organization’s current and future success. For example, if an organization will need a workforce with cloud computing skills, then the survey will go to IS units where those skills are needed. Executive leadership then endorses and drives participation.

Once survey responses are collected, the data provide information that can be used to identify skills gaps and to balance competencies across the organization’s workforce. In each knowledge area, graphs of skill and competency items highlight weaknesses (e.g., a workforce with no employees who are experts in certain vital area), and demographic data analyses can highlight trends (e.g., a workforce with skill differences across seniority levels). The survey results provide the IS leadership team with a profile of current skills and competencies that can be used to make sourcing decisions in units or per individuals. Leadership can see where units lack needed skills and where individuals with strong technical skills but underdeveloped soft skills are currently assigned to managerial positions that require greater leadership competencies. SACAGAP’s insight-from-inside approach gives it an advantage over consulting firms, which can advise an organization on industry best practices but which lack a contextual understanding of an organization. For best results, SACAGAP should draw on a multidisciplinary team of research advisers, executive leadership, and operational management.

### Phase 3: Taking Action to Address Gaps in Skills and Competencies

In the literature, three major approaches exist to address shortfalls in a unit's or an employee's vital skills and competencies: creating customized training programs, hiring workers in critical areas, and reallocating workers or tasks to match skills with needs (Davis et al., 2002; Hakatie & Ryyänen, 2007; Van Auken et al., 2011; Lee et al., 1995). Phases 1 and 2 provide the input and survey data needed for assessing and analyzing a profile of skills and competencies to determine the gaps and create an improvement plan. The profile offers a pictorial representation of current and desired levels of skills and competencies and highlights areas where there is low employee expertise and/or low overall average scores.

Customized training programs are one of the most effective ways to address shortfalls and gaps in workforce skills and competencies. Focusing on the areas with the largest gaps or the most critical strategic needs, researchers create customized training modules to improve employees' skills and competencies. The modules can be pilot tested, updated to maximize their value, and then delivered to a wider audience of employees based on the survey results. Targeted hiring, another common way of addressing shortfalls, brings in skilled workers from outside, while reallocation involves sending talented staff to locations where their skills are needed most or reorganizing work allocations to fit with employee skills.

The SACAGAP profile not only allows CIOs and their management teams to make informed strategic hiring and reorganization decisions, it also creates a baseline against which measurements taken after remediation can be compared. In the following years, the leadership team can repeat phase 1 to update the model of skills and competencies based on evolving strategic and operational requirements. By performing an annual assessment and gap analysis, CIOs can strategically measure, manage, and source their organization's bundle of IS skills and competencies.

### III. MANAGING IS SOURCING: CASE STUDY OF A GOVERNMENT AGENCY'S SUCCESS

In 2011, DISA adopted SACAGAP to examine its systems-testing workforce in partnership with researchers from the Systems Testing Excellence Program (STEP). DISA is a combat support organization in the U.S. Department of Defense (DoD) composed of about 6,000 civilians, 1,500 employees from the armed forces, and 7,500 contractors. DISA is charged with providing, operating, and assuring DoD information sharing through a globally accessible, interoperable enterprise infrastructure that supports the military, government leaders, and coalition partners. DISA's workforce provides strategic value by implementing advanced ultra-contemporary technical solutions and systems connectivity that enables joint warfighter capabilities to gain an advantage over their adversaries.

The U.S. Government's CIOs have committed to adopting internal skill and competency assessments to manage the DoD's IS organizations, which presents an opportunity for corporate CIOs to learn from their efforts. Recently, the U.S. CIO Council announced a 25-point information technology (IT) reform plan that included designing a management career path and developing specialized units of systems development and testing employee assessments (Miller, 2011). The Federal CIO Council also committed itself to surveying its workforce to (1) identify the available supply of IS expertise, (2) determine where resources should be focused to improve or sustain competencies and skills, and (3) assess progress in closing competency and skill gaps (Miller, 2010). According to the CIO Council, the survey would provide "the necessary information to make informed decisions on the capabilities, skills, and resources that every agency's IS workforce will need to achieve its vision" and would inform "strategies to recruit, retain, develop, and manage a fully trained and qualified IS workforce to meet current and future mission requirements" (Miller, 2011, p. 1).

DISA worked with the STEP team to assess the skills and competencies of its software-testing organizations, analyze the gaps between present and needed skills and competencies, and establish a plan for remediation. Next, we describe the lessons DISA learned from its engagement with STEP, which show the importance of using a structured methodology such as SACAGAP to assess capabilities and manage strategic IS sourcing decisions. Based on the process followed and outcomes achieved, we identified six primary management actions for successfully managing IS sourcing.

#### Action 1: Define Contextualized Knowledge Areas with Skill and Competency Items

The process of defining contextualized knowledge areas began with the STEP research team organizing the creation of a normative model of skills and competencies at DISA testing facilities. The STEP research team began by creating a comprehensive list of 258 detailed subcomponents of software testing skills by drawing on textbooks, training certification programs, published articles categorized by knowledge areas (Black, van Veenendaal, & Graham, 2012; Crispin & Gregory 2009; Kaner, Falk, & Nguyen, 1999; Wang, Jia, Sugumaran, Ran, & Liao, 2011; Weyuker & Ostrand, 2000), and studies found among the growing body of software testing literature (Dhaliwal, Onita, Poston, & Zhang, 2011; Jain, Poston, & Simon, 2011; Jain, Simon, & Poston, 2011; Onita & Dhaliwal, 2011;

Meservy, Zhang, Lee, & Dhaliwal, 2012; Poston, Simon, & Jain, 2010; Zhang, Stafford, Dhaliwal, Gillenson, & Moeller, 2014; Zhang, Dhaliwal, Gillenson, & Stafford, 2013). Next, the STEP research team interviewed multiple levels of personnel to gain a deeper understanding of the organizational context. The team visited sites at DISA's major systems testing sites in Indian Head and Fort Meade in Maryland and Fort Huachuca in Arizona (see Table 1). The STEP research team emphasized the need for breadth and depth in interview participation, and DISA executives selected who would be interviewed to ensure all major testing groups were represented. During these visits, STEP researchers met with executives and operational managers to gain an understanding of the testing environment specific to DISA, including activities and types of testing performed, testing techniques used, improvement models followed, Agile approaches used, and skills that were deemed important or missing (see Appendix for the interview script). Two members of the STEP team visited each site, held one-on-one hour-long interviews with key members of executive leadership and operational management, and toured the testing labs and training facilities. At the end of each site visit, the STEP team codified their notes based on the original comprehensive list of subcomponents of skills, discussed the findings and resolved any coding differences, and updated an evolving model of knowledge areas and associated skills and competencies.

<b>Table 1: Site Visits and Interviewees</b>			
	<b>DISA Headquarters, Fort Meade, MD</b>	<b>DISA Testing Site, Indian Head, MD</b>	<b>DISA Testing Site, Fort Huachuca, AZ</b>
<b>Interviewees</b>			
<b>Executive leadership</b>	chief technology officer, component acquisition executive, test and evaluation executive, rear admiral vice director, director of manpower, personnel, and security		testing and evaluation executive
<b>Operational management</b>	five testing and evaluation leads	information assurance and homeland security manager, messaging systems manager, coalition testing and evaluation manager, enterprise services manager, eight logistics and business systems testing leads	senior technical director and chief scientist, operational testing manager, test engineering division manager, six testing and evaluation leads
<b>2001</b>			
<b>Lab tour</b>	no	yes	yes
<b>Number of testing employees</b>	50	85	350

Contextualization is key to the assessment and analysis process. In the case study, for example, scholarly norms suggested that the STEP research team should assess the software application knowledge of testing personnel, but DISA executive leadership determined this knowledge was more aligned with the skills and competencies of project management personnel than of the testing workforce (Lee et al., 1995; Todd et al., 1995; Wade & Parent, 2002). In addition, DISA executive leadership emphasized that Agile testing and statistical-operations research methods for testing were strategically critical knowledge areas for the IS organization, which prompted STEP researchers to include these skill and competency items. The final model of customized knowledge areas and related skill and competency items that DISA executive leadership approved took into account DISA's unique context (see Table 2). The knowledge areas represent both organizational skills (testing overview and professionalism in testing), technical testing skills (developmental testing, operational testing, security testing, and interoperability testing), and testing areas that are strategically important to DISA (Agile testing and operations research in testing). This model, built with input from leadership team members, operational managers, and others, represents a shared vision for making IS sourcing decisions based on identified gaps in knowledge and skills.

<b>Table 2: Customized Model of Knowledge Areas and Skill and Competency Items for DISA's Testing Organization</b>							
<b>Knowledge Areas</b>							
<b>Testing overview</b>	<b>Developmental testing</b>	<b>Operational testing</b>	<b>Security testing</b>	<b>Inter-operability testing</b>	<b>Agile Testing</b>	<b>Operations research in testing</b>	<b>Professionalism in testing</b>



**Skill and competency items**

Evolution of systems testing	Knowledge of testing frameworks	Testing documentation	Factors impacting software security	Inter-operability testing	Agile principles	Test automation and tools	Contractor management
Reasons for testing	Test cycle activities	Evaluation criteria for inter-operability	Differentiating functional from security testing	Network testing	Agile methods	Testing tool integration	Project management
Testing as a science	Types of testing	Configuration management	Security terminology for testing		Agile techniques	Quality methods for testing	Professional competency
Scientific basis of testing	Defect management		Secure development life cycle		Agile Management practices	Test process models and standards	Relationship competency in testing
	Test Techniques and Test coverage		Open source security or information assurance process			Statistical and operational Methods for testing	

The team used the approved list of knowledge areas and skill and competency items to create and administer an online survey. The team converted each skill and competency item into multiple questions to increase their reliability and they assessed them using the following scale:

- 1.0 = **None:** possesses only an awareness of the skill area.
- 2.0 = **Basic:** possesses a theoretical understanding of the skill area.
- 3.0 = **Competent:** possesses a working understanding and is able to apply skill to achieve tangible results.
- 4.0 = **Advanced:** possesses a high level of proficiency and competence.
- 5.0 = **Expert:** possesses broad knowledge of skill area, is capable of resolving highly complex problems, and is acknowledged as an authority.

To ensure ample participation, the executive leader of DISA issued a letter of endorsement strongly advocating employees complete the survey in a two-week time frame. DISA employed 485 people in the testing organization. The STEP research team sent a request for participation to 300 testing staff members identified by DISA executive leadership, of whom 203 responded (see Table 3 for respondent demographics). In DISA, no one had a comprehensive understanding of each individual's capabilities because the organization had never kept such records in the past. Optimally, survey responses should be corroborated by employee performance data or direct manager assessments, but this was not possible because DISA had no data or assessments of this sort. To partially validate the survey responses, the STEP research team reviewed the responses with operational management, who confirmed that individual data points were consistent with their expectations, which suggests that employees scored themselves honestly. Survey data then became the basis for documenting the testing workforce skills and competencies and making recommendations for improvements based on current needs and long-term goals.

**Table 3: DISA Skill and Competency Survey Respondent Demographics**

**Demographics of respondents (N = 203)**

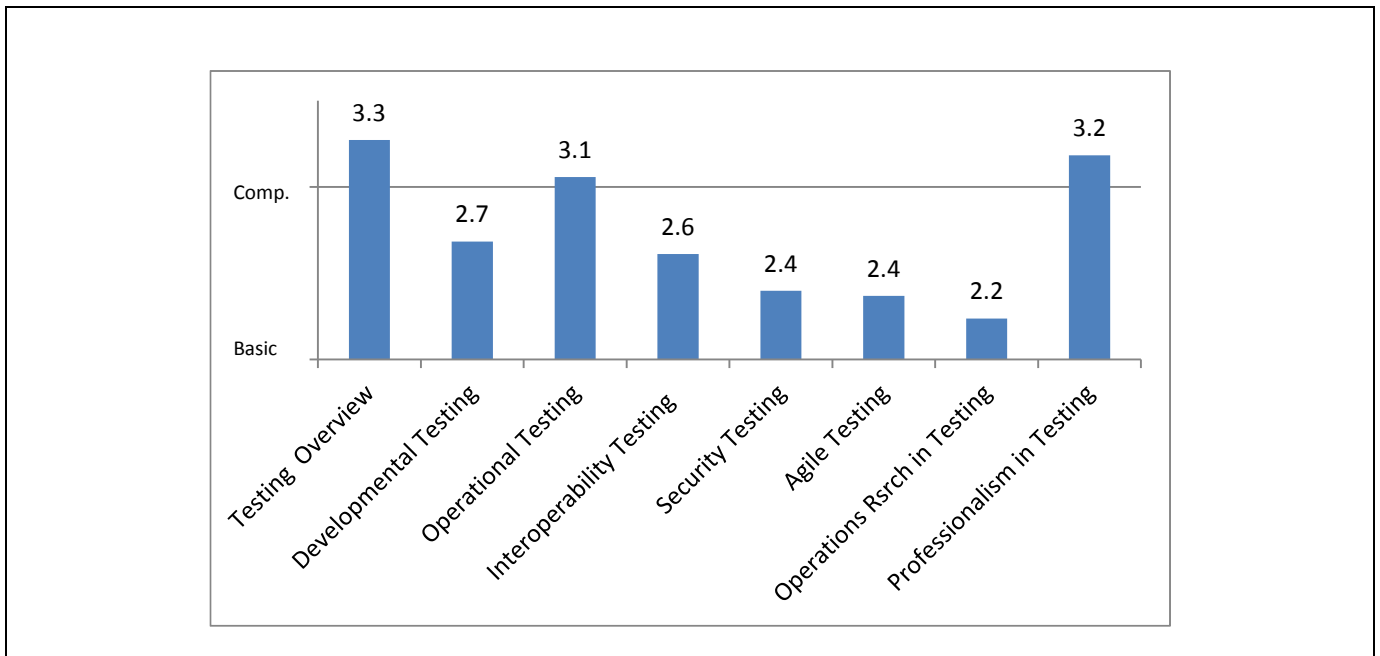
Category	Value	Frequency	Percentage
Job area	Interdisciplinary	78	38.4%
	Information technology	116	57.7%
	Military (Army, Air Force, Navy, Marine Corps)	9	4.4%
Seniority	11 & 12 (most junior)	20	9.8%
	13	101	50.0%
	14	51	25.0%
	15 (most senior)	20	9.8%
	Other	11	5.4%
Job classification	Developmental and standards conformance testing	27	13.3%
	Security testing	21	10.3%
	Operational testing	15	7.4%
	Interoperability testing	102	50.2%
	Testing oversight and management	21	10.3%



	Other	17	8.4%
Years in testing (N = 163)	< = 5	70	43.2%
	6–10	31	19.1%
	11–15	27	16.7%
	16–20	16	9.9%
	> = 21	18	11.1%
	Not provided	41	-----

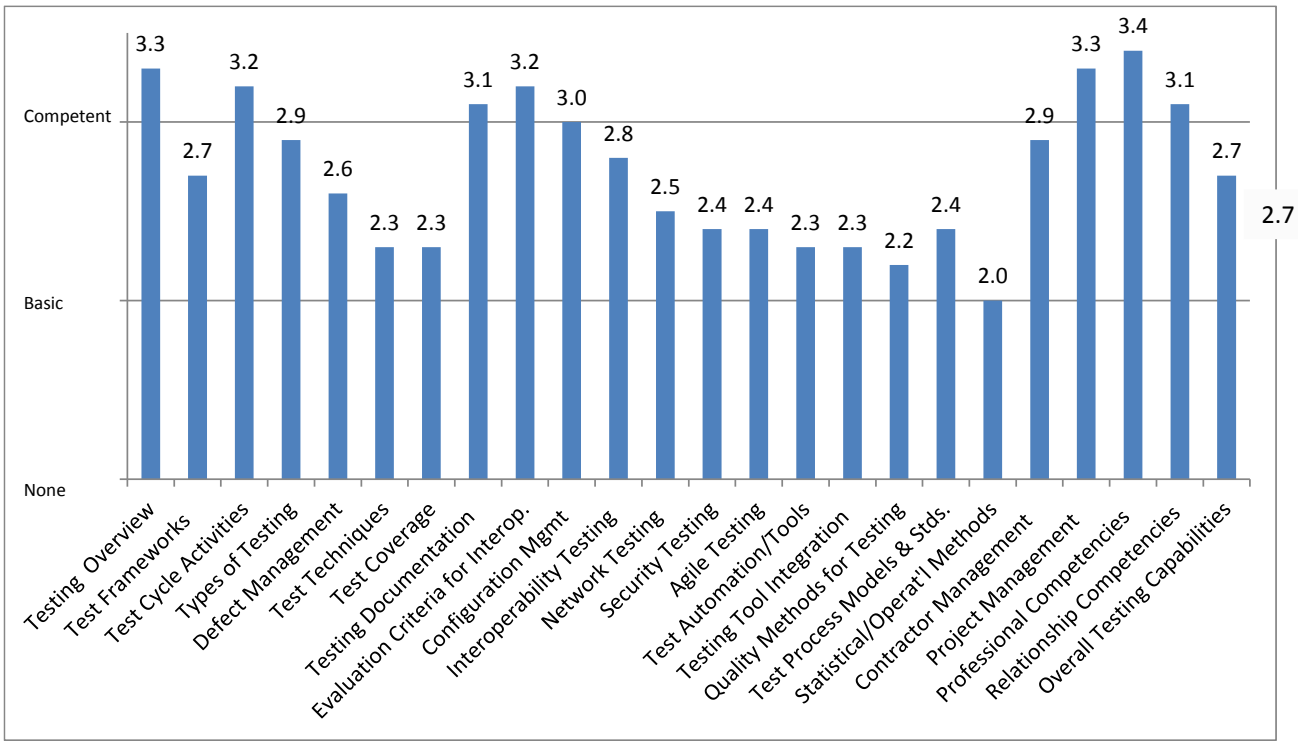
### Action 2: Understand and Share the Skills and Competencies Profile

The data revealed that, across all the testing knowledge areas, the DISA workforce averaged 2.7 on a 5.0 scale—between Basic (2.0) and Competent (3.0). Figure 3 shows the profile of DISA’s testing skills and competencies across knowledge areas. When these profile results were shared across the organization, senior management gained valuable insight needed to make improvements, especially with respect to reaching competent in the short term and moving to advanced or expert in the longer term. The areas of lowest skills and competencies were in operations research in testing, security testing, and Agile testing, which were considered strategically critical knowledge areas, and the highest were in testing overview, operational testing, and professionalism in testing.



**Figure 3. DISA Testing Skills and Competencies Profile by Knowledge Area**

To provide more in-depth insights into DISA testing skills and competencies, the data provided a more detailed profile highlighting specific areas of focus for improvement (see Figure 4). This revealed that statistical and operational methods and quality methods for testing needed greater focus because they both demonstrated a low level of performance, yet were in the strategically critical knowledge area of operations research. Using the profile results, DISA executive leadership determined several immediate and long-term actions to address areas where knowledge levels were below competent. The skills and competencies profile and improvement action plans were shared across organizational units to gain cooperation and reinforce a shared vision of the organization’s current and strategic IS sourcing plans. The profile results provided leadership with the data to emphasize and facilitate dialogues and changes in its IS sourcing practices.

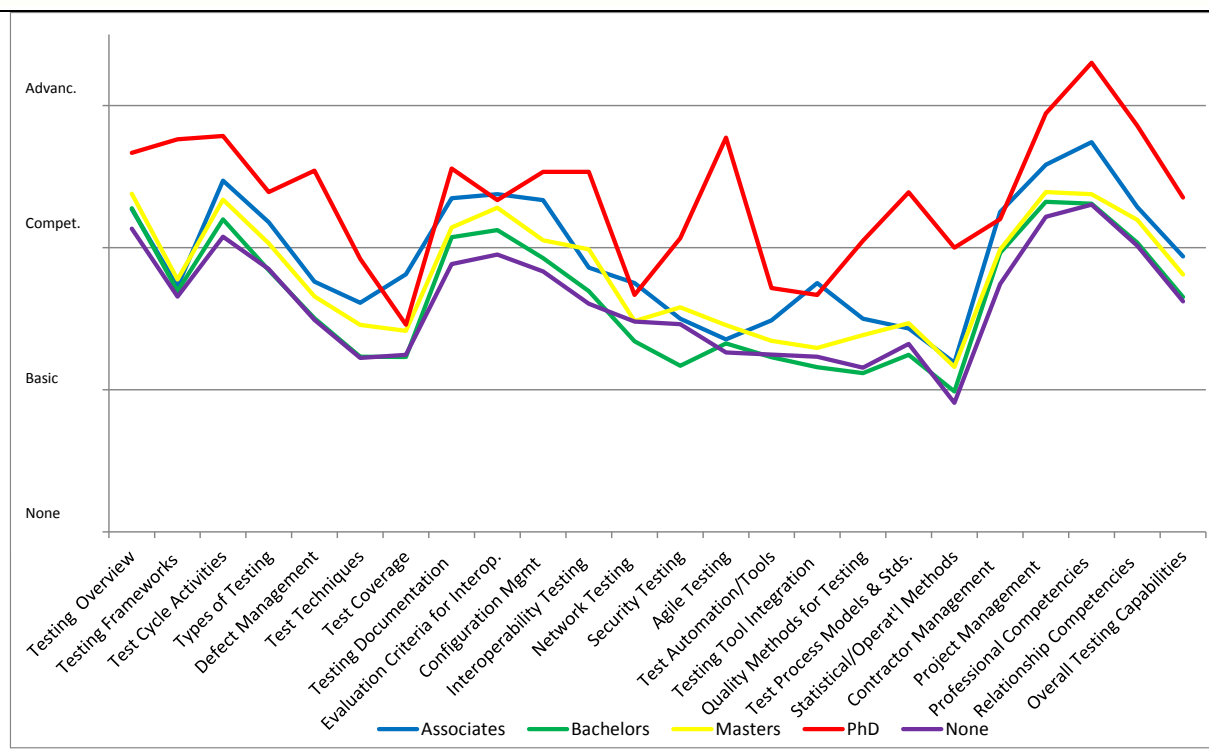


**Figure 4. DISA Testing Skills and Competencies Profile by Skill and Competency Items**

### Action 3: Take Sourcing Actions Using the Skills and Competencies Profile

To raise overall skills and competencies to the competent level, DISA’s executive leadership adopted a customized training and certification curriculum. The customized plan involved on-site delivery of a five-day training certification program at all three testing sites. The training modules contained a balanced mix of theory, research, and practical application-based examples translated to the DISA environment. Training delivery comprised classes with DISA and contractor employees. The first class was designated as a pilot, and DISA executive leadership and operational management attended and provided feedback. The modules were updated prior to subsequent classes to ensure targeted and useful training occurred. To reinforce learning, at the end of each module, training participants were asked to list the three key points that were learned from the module and three key ideas the organization should follow up on for improvement.

In addition to customized training, DISA also adopted hiring and work allocation decisions to manage sourcing. To make these decisions, the research team analyzed skill and competency levels across education qualifications, occupational areas, locations, and years of experience. Figure 5 illustrates how data for the testing workforce compares across employee degree level. Overall, testing skill and competency averages for those with a higher education degree (associates, bachelors, masters, PhD) were consistently equivalent or greater than those with only a high-school degree, which suggests that continuing education correlates with higher skills. Based on this knowledge, DISA management made possessing a degree a base requirement for future hiring.

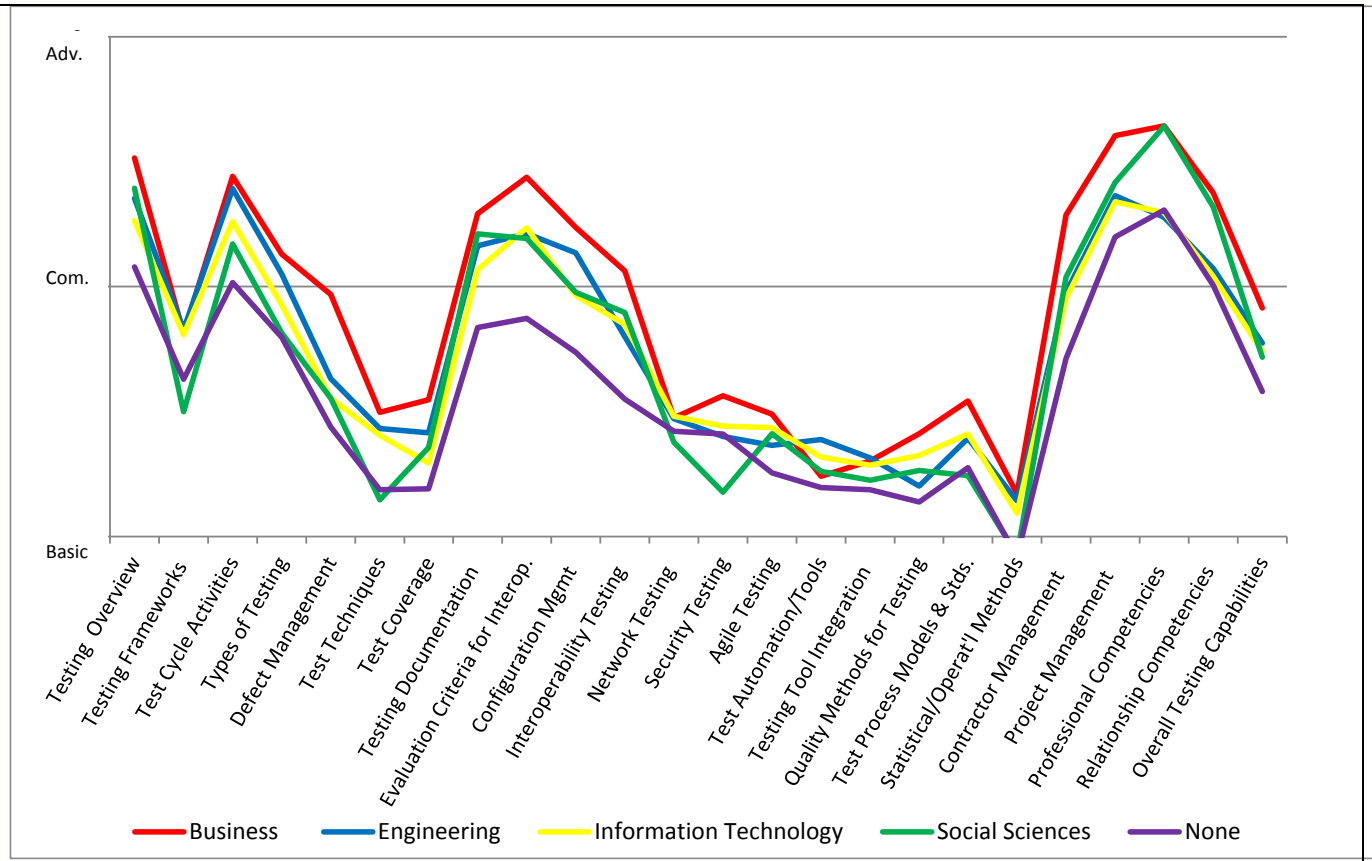


NOTE: When a respondent had multiple degrees, the highest degree level is reported.

Degree	Frequency	Percentage
Associates (AA)	12	5.9%
Bachelors (BA/BS)	75	36.8%
Masters (MA/MS)	58	28.4%
PhD	3	1.5%
None	55	27.5%

**Figure 5. DISA Testing Skills and Competencies Profile by Higher Education Degree Level**

To make reallocation decisions, the research team analyzed skill and competency levels across degree areas (business, engineering, IT, and social sciences) (see Figure 6). DISA considered a degree to be a business degree if it was in the areas of accounting, marketing, management, finance, or general business. Engineering degrees in specific areas (e.g., computer, electrical, mechanical, civil, computer science, systems, mining) were all considered simply engineering degrees. Degrees in computer or management information systems or in information assurance were considered IT degrees, and degrees in anthropology, economics, political science, psychology, philosophy, criminal justice, or sociology were considered social sciences degrees. The overall testing skills and competencies average for those with a business degree were almost always greater than those with other types of degrees, though the comparison has the drawback that business degree holders represented the smallest number of respondents. Those with social sciences degrees had higher skills in project management, professional competencies, and relationship competencies in testing. Contrary to expectations, employees with an engineering degree did not have stronger technical skills (i.e., network, security, Agile testing, testing automation, and testing quality methods) than those with other types of degrees.



NOTE: When a respondent had multiple degrees, their highest degree area is reported.

Degree type	Frequency	Percentage	Avg. years in testing
Business	16	8%	6.8
Engineering	53	26%	8.7
Information technology	52	25%	8.2
Social sciences	26	13%	

**Figure 6. DISA Testing Skills and Competencies Profile by Educational Degree Type**

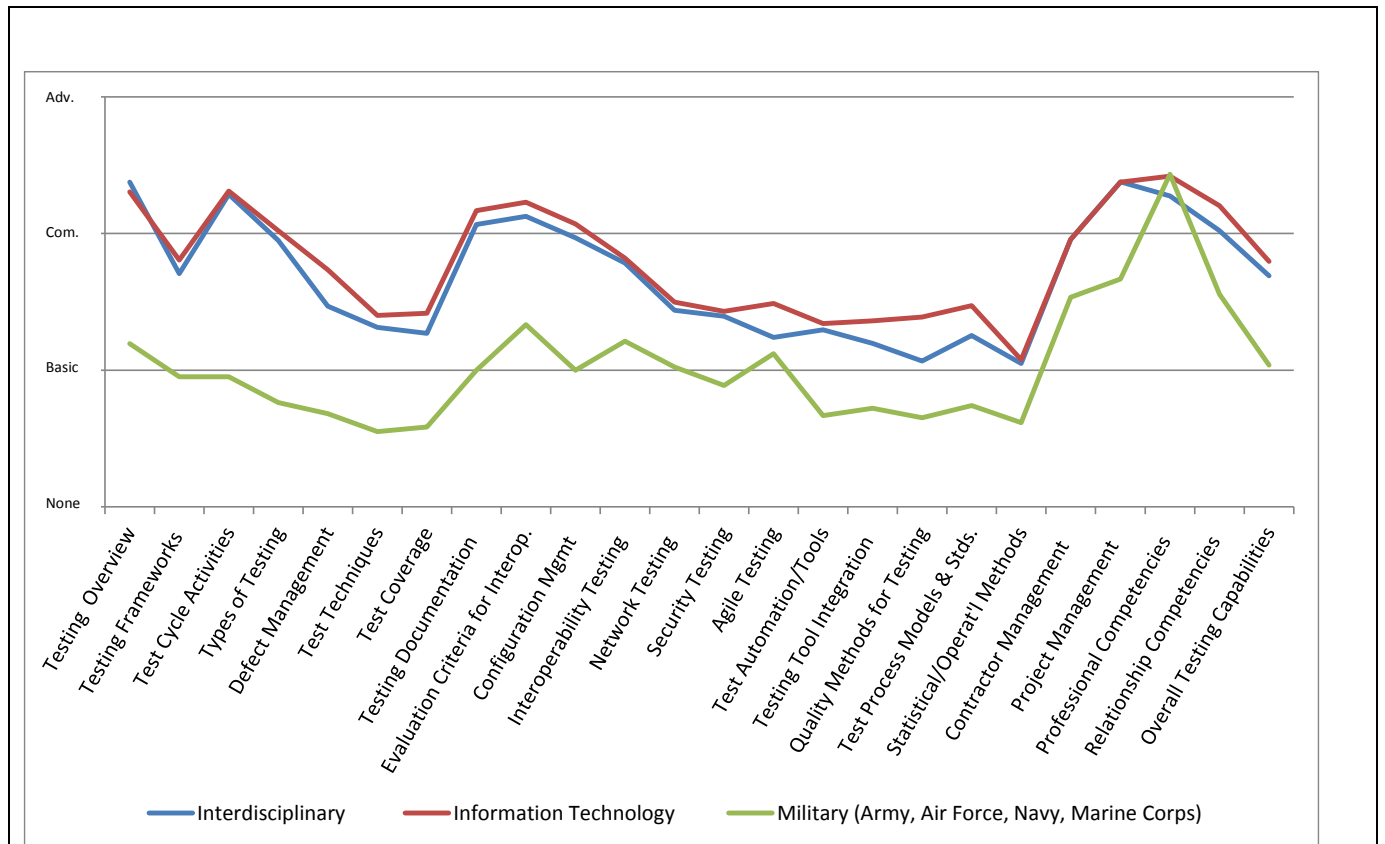
Using the skills and competencies profile, DISA's executive leadership determined that units, especially those in critical areas, should be sourced with employees with business degrees. It also realized the comparative lack of importance of an engineering degree and, by contrast, the importance of individual-based, skills-focused decisions when it comes to internal transfers and reallocations. Furthermore, to keep the skills of those with engineering degrees sharp, management realized that those employees should be assigned to technical roles pertaining to test execution rather than to areas such as contractor management. Skills-focused work allocation decisions simultaneously optimize an organization's use of much-needed skills and strengthen those skills.

**Action 4: Investigate Concerns Regarding the Organization's Human Capital**

To understand the strengths and weaknesses of the organization's human capital, the skills and competencies analysis can be directed at several strategic areas that are of concern to executive management. During site visit interviews, DISA executive leadership expressed certain expectations of their workforce characteristics, and the skills and competencies profile data can be used to evaluate the specific areas of concern. For DISA, these concerns included whether (1) field personnel were appropriate testers, (2) junior employees were more technically competent than senior employees, (3) skills were atrophying in particular categories, and (4) outsourcing systems development to defense contractors was impacting the testing organization's technical skills.

To examine the first concern, the research team analyzed the testing workforce skills and competencies data across occupational areas (see Figure 7). The analysis showed that the testing skills and competency average for those

performing work in interdisciplinary job areas was similar to those in IT jobs, with many skill and competency items scoring below the overall profile average (2.7).



**Figure 7. DISA Testing Skills and Competencies Profile by Occupational Area**

Contrary to DISA executive leadership’s expectations, the testing skills and competency average for those in military positions (Army, Air Force, Navy, Marine Corps) was below the overall average (2.7) in all categories except professional competencies. The DISA testing organization employs military personnel on a rotating basis in an attempt to augment IS capabilities and to ensure systems are released that are suitable and viable for warfighter use on the field of battle. The interdisciplinary and IT workforces, having similar skills profiles, demonstrated higher skills and competencies than those in the military. Based on these data, management realized it needed to change how it used military personnel in testing activities: it needed to focus on using military personnel’s practical field-based knowledge. DISA leadership also realized it needed to enhance its professional testing workforce to guard against inappropriate overreliance on military personnel for test execution.

Regarding the second and third concerns, DISA executive leadership anticipated junior employees would have more up-to-date skills and knowledge than senior employees, yet that was not the case (see Figure 8). Those at senior levels dominated in virtually every knowledge category in the overall profile. Junior employees (< = five years in testing) consistently underperformed those with more years in testing in all skill and competency items. Given the rapid changes in testing knowledge in a technology field, new entrants to the workforce will need senior guidance and continuous on-the-job and classroom training to build and maintain the knowledge needed. However, those with over 16 years of testing experience did not consistently outperform those immediately junior to them, suggesting the senior workforce’s growth in skills and competencies may be stagnating, which may require a special focus. DISA executive leadership realized that it needs to plan not only for junior-level training but also for continuous education to keep senior personnel’s knowledge current.

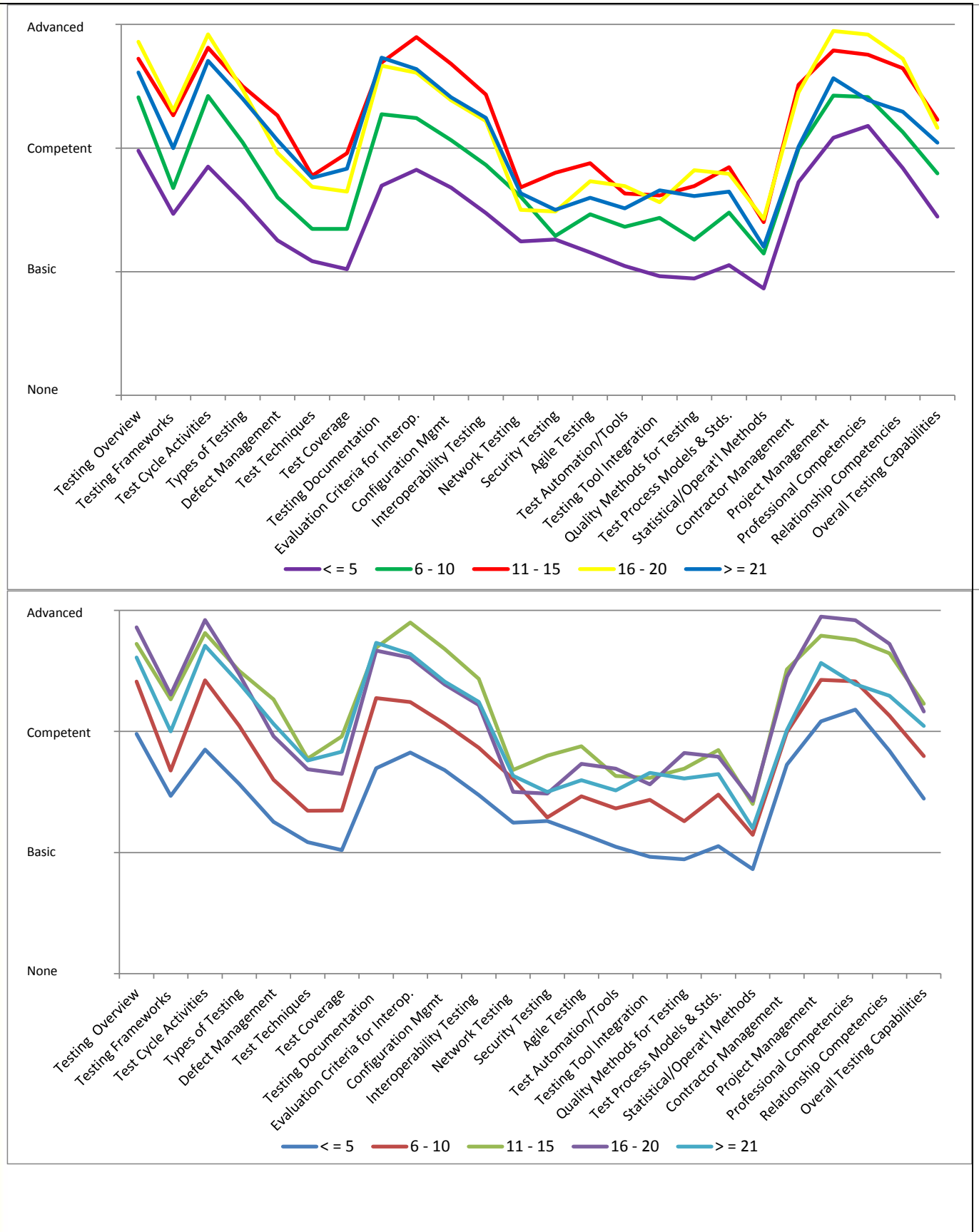
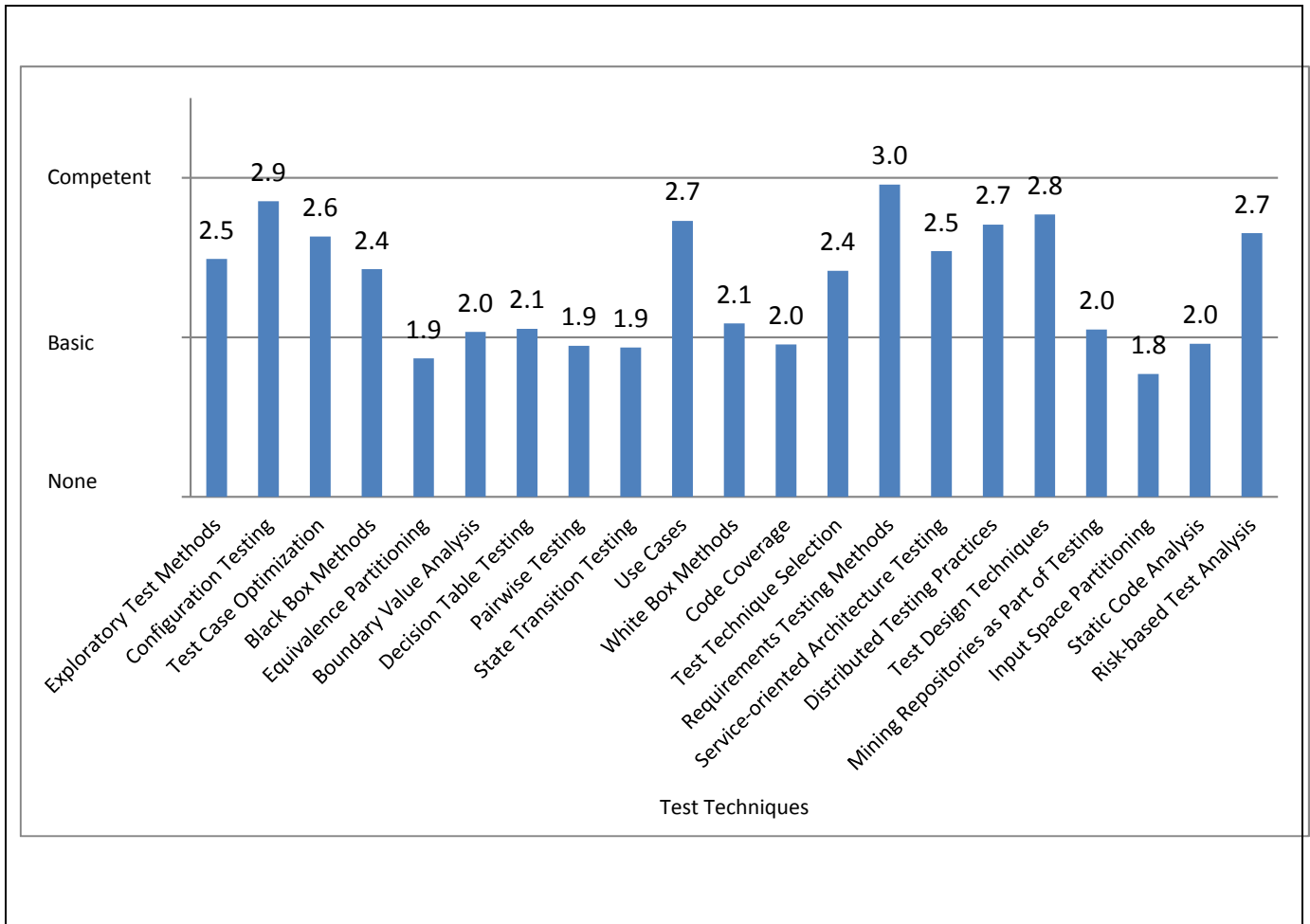


Figure 8. DISA Testing Skills and Competencies Profile by Years in Testing

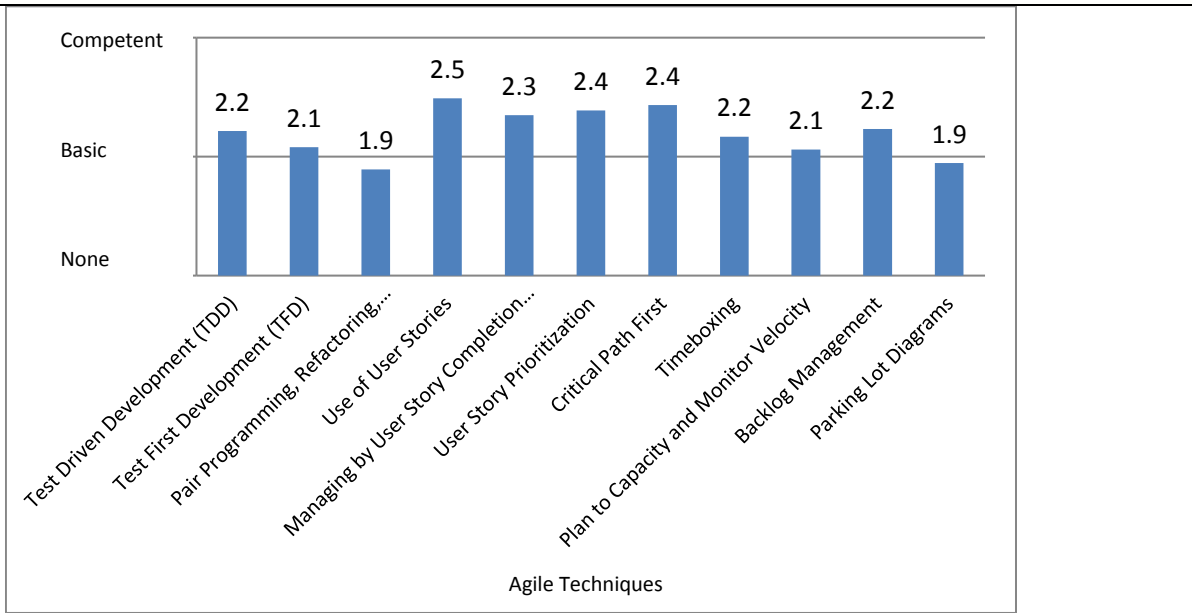
To examine the fourth concern, regarding outsourcing, the research team analysed the testing techniques data at the lowest levels of measurement. Testing techniques overall exhibited an average of 2.3—below the 3.0 competent level—with variation among skills ranging from 1.8 to 3.0 and with 15 of the 21 skill and competency items below the average 2.7 level (see Figure 9). Once tested, problems and defects must be identified and fixed prior to a system’s release to the end user (e.g., the warfighter). Because DISA is a professional testing organization, the expectation is that its testing technique skills will be high. The surprising finding of low testing technique skills was attributed to gaps resulting from much of the development and unit testing work being outsourced to vendors. DISA leadership realized that the testing workforce needed to require vendors to follow state-of-the-art processes and to create reliable systems, especially in combination with the strategic move to Agile development and testing approaches. As DISA makes the strategic move to more Agile processes, the testing workforce will need to engage with vendor developers in iterative development and testing sprint cycles, which means both the vendors and DISA’s own workforce must fully understand the testing techniques topics.



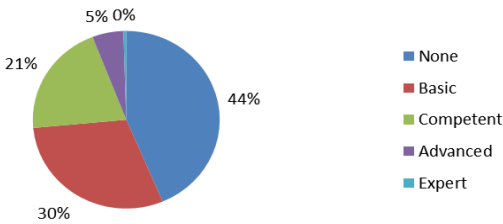
**Figure 9. DISA Testing Skills and Competencies Profile for Testing Techniques**

**Action 5: Analyze Weaknesses and Strengths in Strategic Areas**

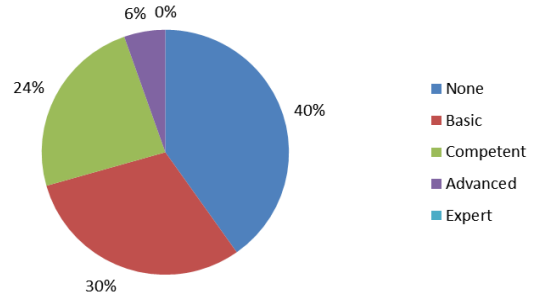
To gain insight into specific testing skills, the research team drilled down into each of the skill and competency items by knowledge area to assess workforce weaknesses. As an example, Figure 10 provides the average scores for the skill and competency item for Agile techniques. Agile techniques are part of the strategically important Agile-testing knowledge area identified by the DISA management team. Figure 10 also provides pie charts showing the percentages of respondents at each of the five competency levels for the items with the poorest results.



**Pair Programming, Refactoring, Continuous Integration, and Sustainable Pace**



**Parking Lot Diagrams**

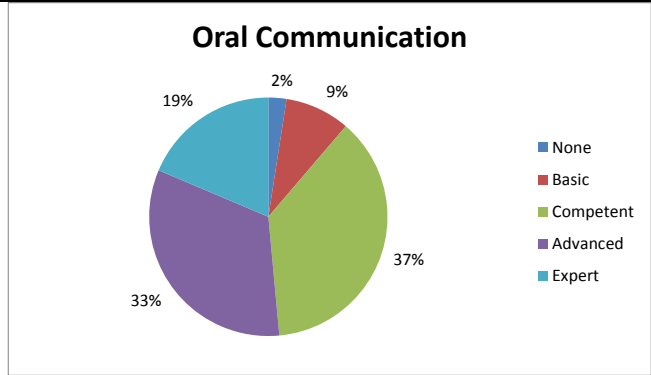
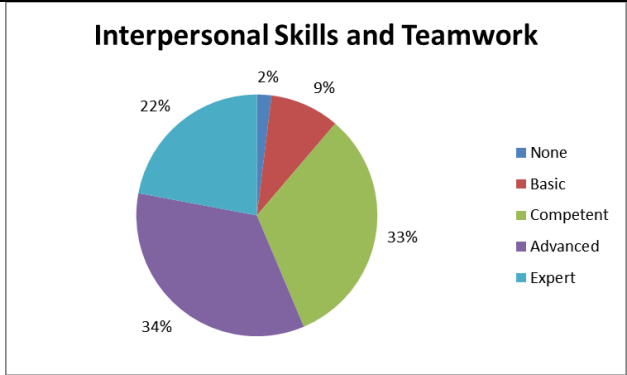
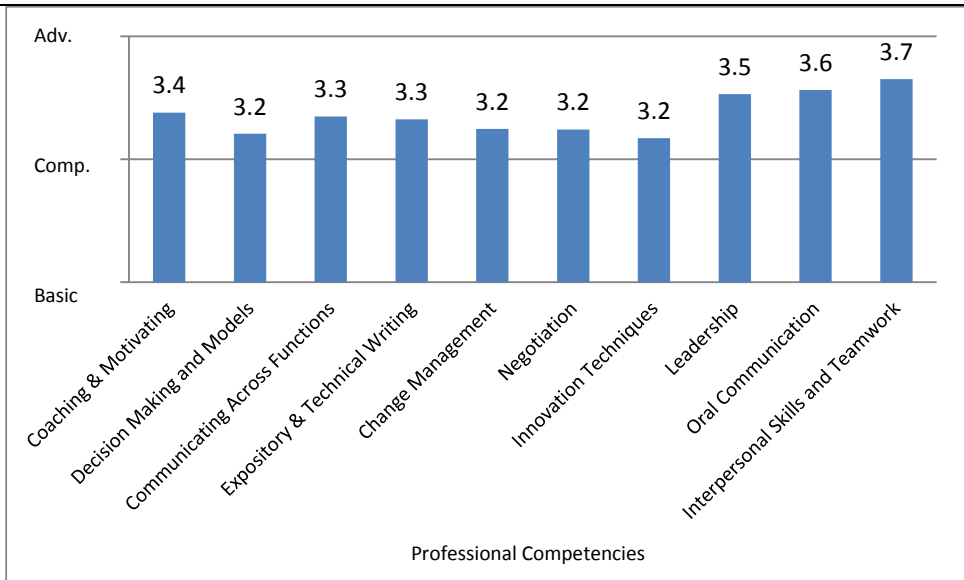


**Figure 10. DISA Testing Skills and Competencies Profile for Agile Techniques**

Agile development requires programmers to be able to work together in pairs and to be able to use parking lot diagrams as a way to illustrate development progress with percentage-complete summaries. In DISA, the average for the Agile-techniques skill and competency item was 2.2, and all skills were below the overall testing profile average of 2.7. As the pie diagrams show, for pair programming and for parking lot diagrams, only 5 percent and 6 percent of employees, respectively, reported having advanced knowledge, and no one was considered an expert, meaning the level of capability for these skill items was extremely low at DISA. DISA leadership realized it needed to act immediately to build up skills and competencies in the strategically important area of Agile techniques.

Equally important were the insights gained from drilling down into the data to review workforce strengths. As an example, Figure 11 provides data on professional competencies skills from the professionalism-in-testing knowledge area. In this example, interpersonal skills and teamwork and oral communication scored highest. Figure 11 also includes pie charts showing the percentages of participants at each of the five competency levels for these items. Professional competencies involve an employee’s ability to work with others and manage people on their team. In DISA, the professional-competencies average was 3.4, and the component skills were above the overall profile average of 2.7. Demonstrated in the pie diagrams, for interpersonal skills and teamwork and oral communication 34% and 33% of employees, respectively, report advanced competency, with 22% and 19% self-reporting as experts, meaning DISA’s personnel are extremely capable in these areas. With customized profile data and the ability to drill down to specific skill and competency items, DISA executive leadership gained a stronger understanding of the workforce’s strengths and weaknesses and of how each individual contributes to the organization’s overall bundle of skills and competencies.

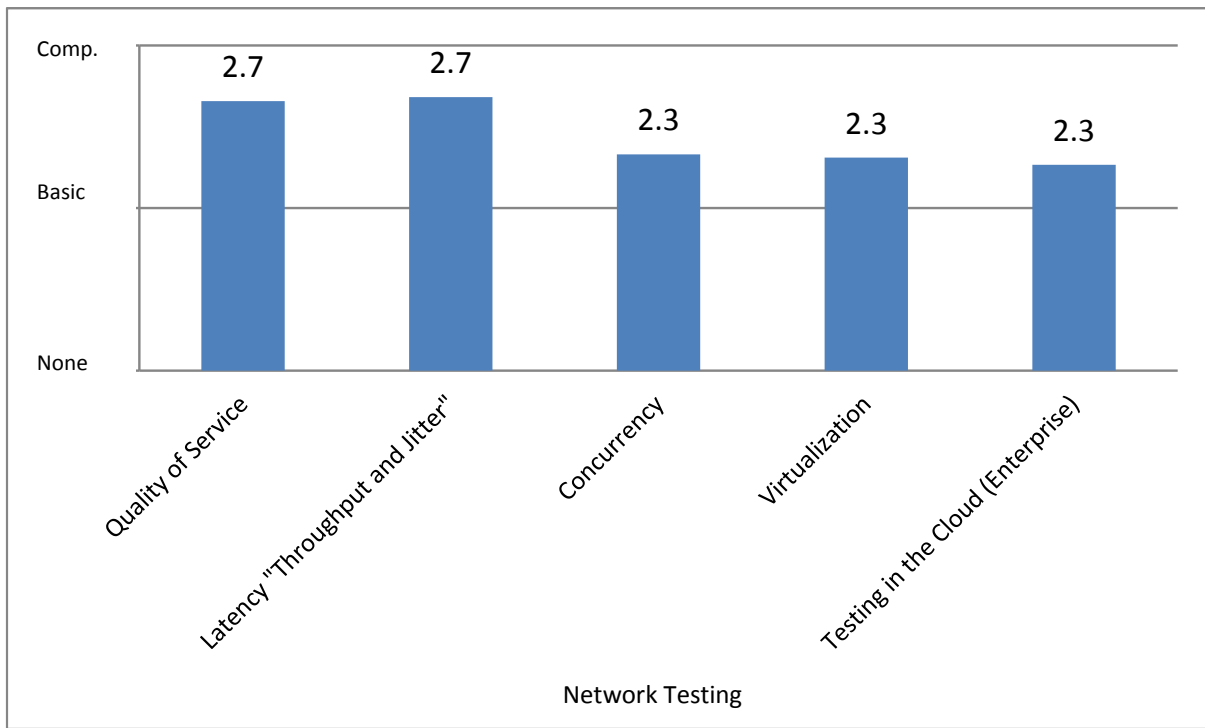
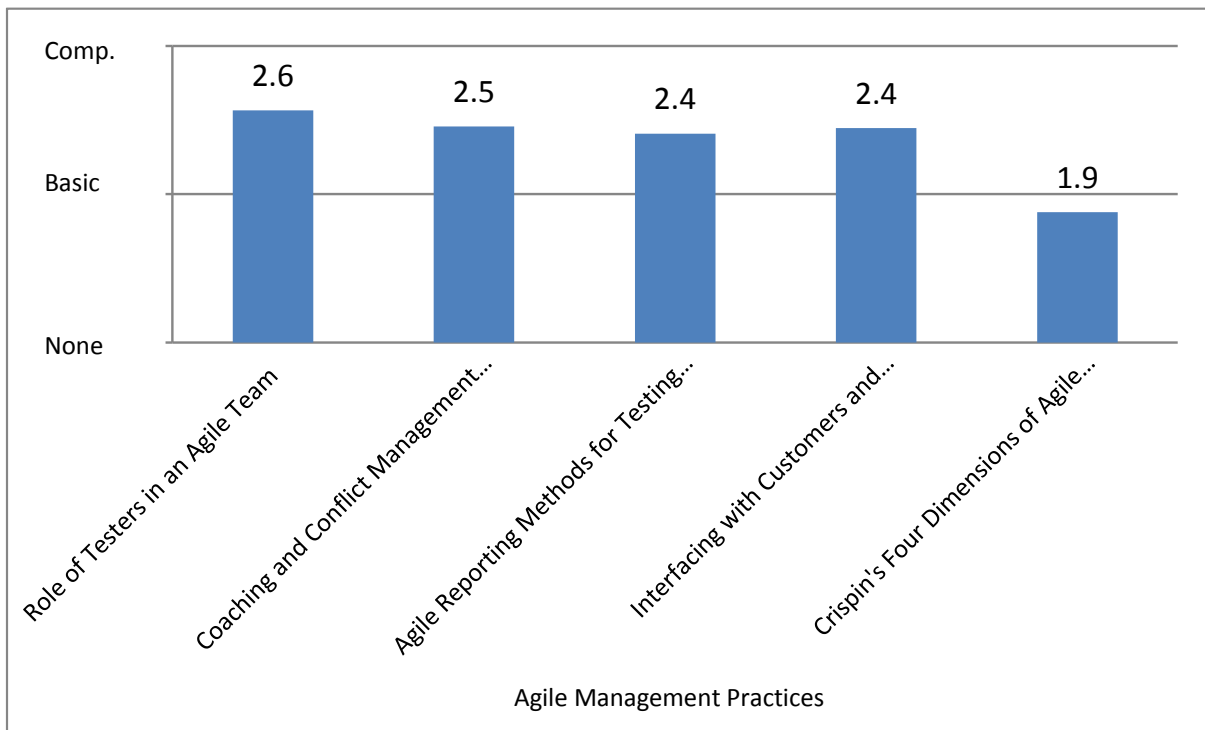




**Figure 11. DISA Testing Skills and Competencies Profile for Professional Competencies**

**Action 6: Link Skills and Competencies to Strategic Priorities**

Data from the survey allowed executive leadership to link skills and competencies to specific strategic priorities. At DISA, these priorities included a shift to Agile methods and network testing. Many organizational skills in these areas were below the 2.7 average, making it clear to management that progress on these fronts was going to be impeded unless the pertinent skill sets were developed and acquired while better using the expertise that was available. Figure 12 illustrates that Agile-management practices fared poorly, with a category average of 2.4 and all skills below the overall average 2.7 level. The skill set pertaining to Crispin’s four dimensions of Agile testing was the lowest. Figure 12 also illustrates that the network-testing category, which is also a strategic area, also yielded poor results, with an overall average of 2.4 and all skills at or below the average 2.7 level. The lowest skills were concurrency, virtualization, and testing in the cloud (enterprise). DISA leadership realized it needed to bolster skills for exploiting virtualization opportunities, managing concurrency issues in complex networks, and testing in both private and public clouds.



**Figure 12. DISA Testing Skills and Competencies Profile for Agile Management and Network Testing**

Profile data also helped to identify individuals who had higher expertise in specific strategic areas. The systematic process for measuring skills and competencies ensured that valued, available skills would not be hidden in “dark” corners of the organization. Identifying skills and competencies linked to strategic priorities is just as important as identifying gaps or skills shortages in strategic areas. Using the skills and competencies profile, DISA executive leadership educated its managers and built consensus on the need to manage system-testing personnel more rigorously. A clearer, more precise understanding of skills and competencies spurred discourse about where the

organization needed to go for future success. This provided a sound basis for action to ensure the organization had the right set of skills and competencies to support its strategic priorities. In essence, SACAGAP offered DISA's executive leadership a systematic approach to measuring and managing skill and competency assessments in IS management. All too often such a focus on skills and competencies gets sidelined in the rush to acquire new technologies whose potential is then not fully realized because the internal skills to take full advantage of them are lacking.

#### **IV. LESSONS LEARNED FOR IS SKILLS SOURCING**

It is imperative that CIOs use a skills-and-competencies measurement approach to explicitly manage their human capital from a sourcing perspective. As we note above, resource-based theories say that executives should measure their organization's skills and competencies because that approach will let them identify strengths and weaknesses among their personnel, which then can be managed and addressed to build the organization's strategic value and success. Prior resource-based studies suggest that management teams will benefit from assessing and strengthening the skills and competencies of their workforce (Coff, 1997; Crook, Combs, Todd, Woehr, & Ketchen, 2011; Fulmer & Ployhart, 2014; Ployhart & Moliterno, 2011), and this paper provides guidance on using a methodology to do this. Using the six management actions discussed above as a guide, CIOs can use SACAGAP to gain insightful benefits for IS sourcing (see Table 4 for a summary of the actions and associated benefits of this approach).





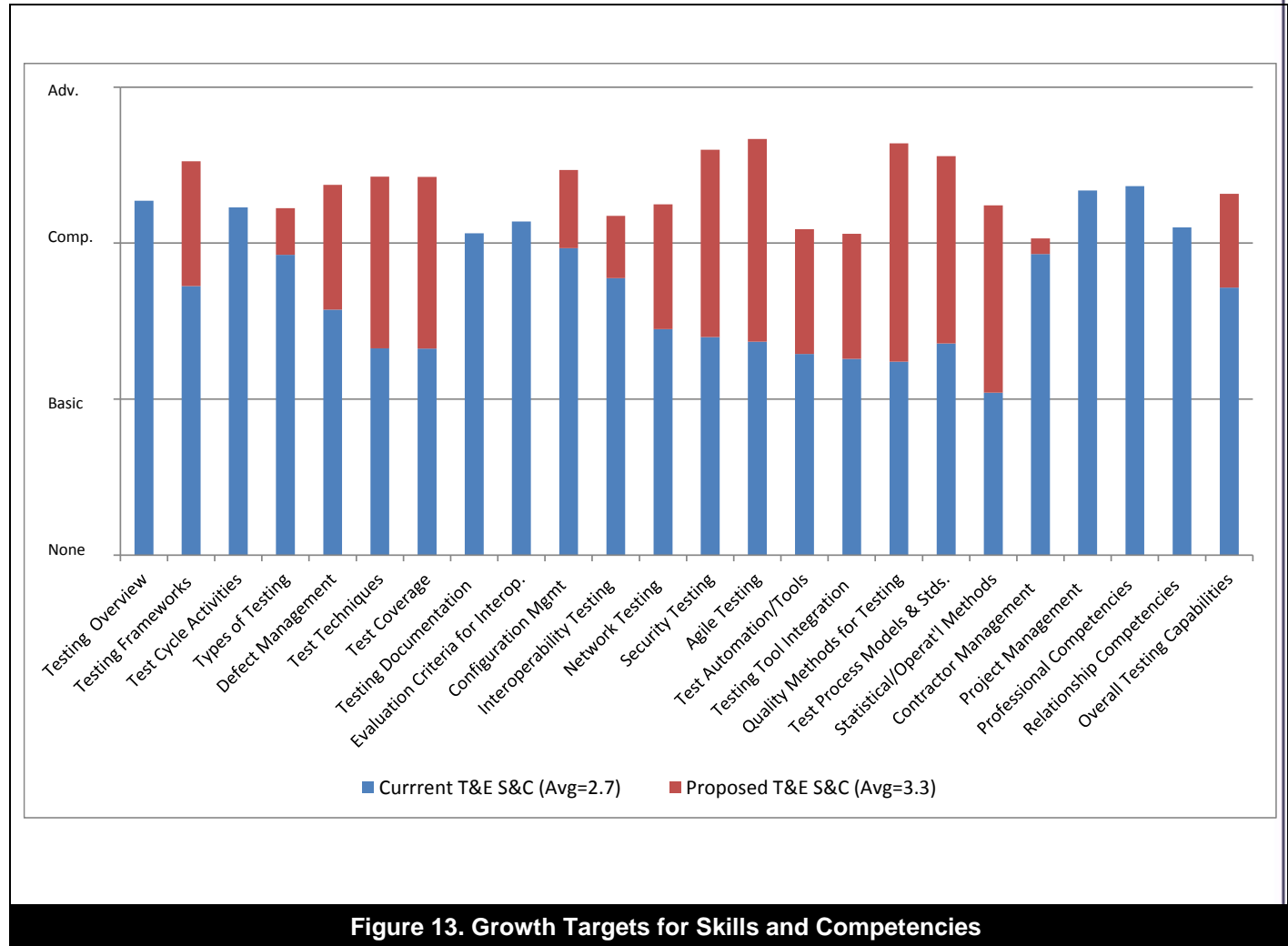
**Table 4: Principles for Gaining Benefits from Assessing and Managing IS Sourcing**

Action	DISA's approach	Benefits realized
Action 1: define contextualized knowledge areas with skill and competency items	Came together with operational managers and others to create an evolving model of knowledge areas and skill and competency items.	Developed a contextualized assessment and analysis process that emphasizes strategic skills and competencies. Established foundations for a shared vision of sourcing. Created a customized organizational model of knowledge areas and skill and competency items. Gained the ability to survey and assess workforce.
Action 2: understand and share the skills and competencies profile	Widely shared the skills and competencies profile, containing the DISA workforce's scores, across organizational units.	Achieved awareness and insights needed to improve skills and competencies in both the short and long term. Identified high and low skills and competencies. Gained the ability to review detailed-level skills and competencies. Gained support for action plans for changes in IS sourcing practices.
Action 3: take sourcing actions using the skills and competencies profile	Initiated actions to bring the organization's overall skills and competencies up to Competent in all areas through the adoption of a customized curriculum plan in the short term and dialogues on changes in future hiring and work allocation decisions in the longer term.	Gained the ability to capitalize on knowledge of organizational environment to tailor training modules. Gained the ability to address key shortfalls and maintain knowledge in critical areas through customized training modules. Opened discussions regarding requiring an advanced educational degree as a prerequisite for hiring. Opened discussions of assigning those with engineering qualifications to technical roles to help prevent knowledge and skills atrophy.
Action 4: investigate concerns regarding the organization's human capital	Analyzed data on workforce weaknesses to support or falsify claims.	Found field personnel were inappropriate testers and would be better utilized in a function that capitalized on their applied field knowledge in testing events. Disproved certain assumptions (e.g., that junior employees were more technically competent than senior employees). Found support for certain assumptions (e.g., that skills atrophy was a problem in certain areas). Discovered that outsourcing of systems development appeared to be impacting the testing organization's technical skills.
Action 5: analyze weaknesses and strengths in strategic areas	Examined the breakdown in each of the weakest and strongest knowledge areas, comparing testing workforce skills and competencies across demographics and knowledge areas.	Gained a more complete understanding of workforce strengths (professional competencies) and weaknesses (Agile testing).
Action 6: link skills and competencies to strategic priorities	Included strategic areas such as Agile methods, virtualization, and cloud testing in the skills and competency assessment.	Understood skill requirements for success in strategic areas. Identified experts who could be mobilized for success. Exposed skills gaps impeding achievement of strategic goals.

**Lesson 1: Set Short-term and Long-term Skills Targets for IS Sourcing**

The profile can provide valuable information for organization-wide discussions on short-term and long-term skills targets and is consistent with resource-based theoretical approaches to human resource management (Nyberg, Moliterno, Hale, & Lepak, 2014; Ployhart, Van Iddekinge, & Mackenzie, 2011; Ployhart, Weekley, & Ramsey, 2009). At DISA, each skill and competency item was reviewed to determine which knowledge areas needed more

resources to boost overall skills level from 2.7 to 3.3 over a short term of three years (see Figure 13). The blue portion of the bars represents the initial level of DISA's skills and competencies, and the red portion shows where growth in skills were needed through training, hiring, and internal transfers or work reallocation. DISA executive leadership then set goals for where the organization would like to be in the long term. It emphasized adding newer skills areas for future growth (i.e., Agile and network testing) that are particularly pertinent to the success of the organization in serving the warfighter of the future. Prior to adopting SACAGAP, DISA's leadership had lacked this focus on future IS skills and competencies. SACAGAP provided a benchmark of skills and competencies that facilitates future analysis and goal setting.



**Figure 13. Growth Targets for Skills and Competencies**

### Lesson 2: Use Customized Training for IS Sourcing

Earlier studies in the resource-based literature have shown that organizations that aim both to hire expert human resource talent and also grow skills internally through training realize better outcomes than those employing only one approach (Neirotti, 2013; Youngsang & Ployhart, 2014). Thus, along with the benefit of hiring needed skills, organizations also benefit from instituting customized employee training that can be created and performed by expert instructional teams based on highlighted weaknesses in knowledge areas and skill and competency items. In DISA's case, the overall profile suggests that the organization was strong in skills and competencies related to managing test projects and relationships, which, in turn, suggests that these areas needed to be de-emphasized in training. The profile analysis also highlighted training areas which were not priorities, such as requirements testing, where the workforce had relatively stronger skills and competencies.

The profile also identified the weakest areas where training was essential: core testing techniques, test coverage factors, technical areas focusing on test automation and processes, and strategic imperatives like Agile testing, network testing, and operational analysis. These were the areas of focus for the customized curriculum plan. Besides addressing requisite skills gaps, the training program also focused on (1) providing testing knowledge informed by best practices drawn from the business systems industry, (2) providing testing knowledge informed by

research, and (3) providing testing knowledge emphasizing a big-picture perspective that facilitated innovation absorption.

### Lesson 3: Make Hiring and Job Allocation Decisions Specific to IS Sourcing

Profile data can also be used to locate personnel with expertise who may be moved to areas in need of their skills and to identify areas that will require new hires. This accords with resource-based theories regarding aligning resources with needs to optimize strategic value (Brymer, Molloy, & Gilbert, 2014; Youngsang & Ployhart, 2014). DISA's profile led its leadership to consider adopting specific actions:

1. Integrating the skills and competencies survey into annual personnel evaluations (i.e., addressing each employee's skills gap analysis with an individualized plan).
2. Incorporating select skill and competency items into a strategic scorecard by using the initial overall average as a baseline for efforts to improve the testing organization's effectiveness and setting target dates to reach higher overall average levels.
3. Establishing hiring approaches to seek out and add needed skills.
4. Setting a target of maintaining at least 20 percent of the workforce at the 4.0 expert level for each strategically critical skills area.
5. Using the skills and competencies profile as the basis for leadership discourse about the appropriate target profile over a three-to-five-year time horizon to drive hiring, internal transfers, and organizational development decisions.
6. Using the profile to clarify the skills breakdown of each testing employee and to recognize in-house experts in each category of skills and competencies.
7. Employing the profile as the basis for assigning testers to Agile or networking projects and other work assignments.

Thanks to the profile data, DISA's senior leaders realized that having a degree correlated strongly with organizational testing skills and competencies, which caused them to make it a requirement for all future hires. They also learned that those with primarily engineering qualifications possess a skills profile similar to those with primarily IT qualifications. This close alignment suggests that there need not be any difference in the duties assigned to those with technical engineering qualifications and those with IT qualifications. DISA testing management was considering a new focus on the division of labor in work assignments to match with employee backgrounds (e.g., deploying engineering-based personnel in more technical testing roles and the IS-based personnel in test management roles).

In addition, DISA leadership learned that the interdisciplinary and IS workforce, which have similar skills profiles, demonstrated higher skills and competencies than the military workforce. DISA leadership was considering expanding the professional testing workforce to avoid an overreliance on military personnel. Contrary to expectations, DISA leadership found that younger workers did not have an advantage in terms of skills and competencies or currency of knowledge, but, at the same time, there was some indication that the capabilities of those with more than 15 years of testing experience may be stagnating. Therefore, DISA leadership was considering addressing these points in future training and skills development programs. Finally, the leadership learned that irrespective of testing background, all groups had knowledge gaps in technology testing skills.

## V. CONCLUSION

This paper illustrates how a resource-based perspective can help CIOs understand and manage the skills and competencies in their organization. This paper also provides a useful methodology in SACAGAP and practical lessons learned for taking a resource-based approach to managing skills and competencies as an explicit resource. Contemporary business management requires direct focus on the strategic management of an organization's bundle of skills and competencies as opposed to a traditional focus on an individual's qualifications and work performance. A first step is to understand the organization's underlying skills and competency profile. DISA's experience shows how a skills and competency analysis of the workforce can lead to raising the benchmark in the short term and moving toward overall excellence in the long term.

While every approach has its limitations, SACAGAP as implemented in this case study with DISA was limited by its use of self-reported perception-based performance data. STEP researchers attempted to validate survey responses with operational management assessments and found them consistent with expectations. However, future implementations of SACAGAP should explore its application in other types of organizational settings and mitigate the use of self-report data further. For example, those using SACAGAP could measure skills and competencies by receiving performance input from a wider variety of stakeholders, such as managers, human resources, other technology staff members, and end users (Joshi, Kuhn, & Niederman, 2010). While SACAGAP focuses on a static set of tester-specific skills and competencies and contributes to the body of relevant research on software testing



(see Dhaliwal et al., 2011; Jain et al., 2011; among others), future implementations could explore using different types of measures across organizational hierarchical levels or between organizational units. The additional input could be gathered via survey or focus group formats. Gathering data from an expanded set of evaluators may serve to increase the multidimensionality of characteristics considered in related to that person's job role (Joshi et al., 2010).

CIOs must assess what type of skills and competencies exist and are needed to support the long-term strategic directions and initiatives of their IS organization. One member of the DISA executive leadership team stated: "The reports bring up what we thought were issues, but seeing it in the data confirms it". Our case study suggests that IS leaders should think beyond particular personnel qualifications to how each individual's skills and competencies play a role in the overall bundle of skills and competencies of the organization—which should be dynamically managed. As a tangential benefit, the skills profile also made employees feel upper management was concerned about their needs for improved skills and competencies. The skills profile also established a baseline for measuring the effectiveness of future training, hiring, and work allocation efforts at macro-levels and provided measures for making project allocation decisions at micro levels.

The DISA case study suggests that a skills profile is a practical mechanism for handling the knowledge creation and maintenance aspects of human capital management in the IS field. The six management actions and three lessons learned set out in this paper outline how CIOs can improve the assessment and management of their IS sourcing. The SACAGAP approach has several important applications, including (1) strengthening discourse about each employee's skills and competencies in the annual review process; (2) understanding what capability bundles currently exist, where missing skills and competencies are an issue, and where weaknesses need to be strengthened; (3) using strategic sourcing in hiring decisions to address skills shortages; (4) providing a skills-and-competencies baseline for discussions of where the organization needs to be in the long term; and (5) performing skills-based work allocations to optimize employee contributions to organizational units and individual projects.

## ACKNOWLEDGMENTS

The authors appreciate and acknowledge the research funding support of the Systems Testing Excellence Program, research access support provided by the Defense Information Systems Agency (DISA), and feedback provided by attendees at the 29th Annual International Test and Evaluation Symposium, September 17–20, 2012, Huntington Beach, California.

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## APPENDIX

### Interview Script for DISA Site Visits

#### Testing Stakeholder Meetings

##### Meeting goals:

To achieve a more comprehensive understanding of the DISA testing environments at Ft. Huachuca, Az., Ft. Meade, Md., and Indian Head, Md. in order to update the Competency Assessment survey. Also, to tour the facility to understand the testing work environment.

##### Background information about interviewees:

1. Name
2. Position
3. Years with DISA or the DoD
4. Position description (major testing activities responsible for)
5. Share the PowerPoint slides with attendees as general overview of objectives

##### Interview guide

###### Overview

1. Please name all the organizations that you and your group support, such as Service Operational Test Agencies (OTA), information assurance/security test organizations, DISA, Joint Staff, and other federal and non-federal agencies.
2. Please name the main applications or systems that you and your group support.
3. Overall, what is your impression or general thoughts regarding the testing environment?

###### Testing specifics

4. What are all the testing activities that you and your group perform (i.e., planning and management, scope and coverage, scripting, test plans, etc.)?
5. What are all the types of tests that you and your group perform (i.e., requirements, risk-based, defect analysis, functional, acceptance, regulatory, etc.)?
6. What are the test techniques that you perform (i.e., exploratory, black/white box, interface, requirements, service-oriented architecture, configuration, graph coverage, modeling defect prediction, mining repositories, input space partitioning, etc.)?
7. Are you following any improvement models for testing (i.e., test process improvement, critical test process, capability maturity model, systematic test and evaluation, etc.)?

###### Testing agility

8. What do you think about a structured vs. Agile testing approach within DISA? What are the pros and cons?
9. If you follow an Agile approach, do you use scrum interactions, feature driven testing, collaborative testing, etc.)?

Would you provide an example of when you used an Agile approach and how it worked out?

10. How are you using automation for testing (i.e., automated test products, ROI on automation, implementing now, standalone testing tools, etc.)?

###### Environment

11. What skills and competencies can help improve the speed and quality of testing at DISA?
12. Where resources or skills are lacking within your group?
13. What are the key messages about interoperability that should be included in any base testing knowledge base (standards, interfaces, data structure and format, etc.)?
14. What is the most critical argument or message that a base testing curriculum should convey?

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# Communications of the Association for Information Systems

ISSN: 1529-3181

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