Policy and Technology Readiness: Engaging the User and Developer Community to Develop a Research Roadmap

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ABSTRACT

A key challenge for research roadmapping in the crisis response and management domain is articulation of a shared vision that describes what the future can and should include. Visioning allows for far-reaching stakeholder engagement that can properly align research with stakeholders' needs. Engagement includes feedback from researchers, policy makers, general public, and end-users on technical and non-technical factors. This work articulates a process and framework for the construction and maintenance of a stakeholder-centric research vision and roadmap in the emergency management domain. This novel roadmapping process integrates three pieces: analysis of the research and technology landscape, visioning, and stakeholder engagement. Our structured engagement process elicits research foci for the roadmap based on relevance to stakeholder mission, identifies collaborators, and builds consensus around the roadmap priorities. We find that the vision process and vision storyboard helps SMEs conceptualize and discuss a technology's strengths, weaknesses, and alignment with needs.

Keywords

Technology readiness, policy readiness, R&D roadmap, workshops, user needs

INTRODUCTION

Challenges in equipment, voice, and data interoperability, as well as governance, reliability, access rights, and security, are obstacles to achieving effective emergency communications. Both government and private industry have ongoing research that will impact this space, but it may not be well aligned, may duplicate efforts, and will not necessarily contribute to a shared vision held by potential future users.

The U.S. Department of Homeland Security (DHS) is funding the Next Generation Communications Interoperability (NGCI) project to bring the different communities of researchers, engineers, users, and policymakers together. The goal

is to build both a strong, interactive community, and to develop a research agenda that is aligned, leverages existing and parallel work, and works to meet U.S. national security needs.

Stakeholder engagement to develop a technology roadmap is not new. However, an estimated 50% of roadmapping projects fail to "stay alive" (Phaal, Farrukh & Probert, 2001) and developing a credible, sustainable process is both difficult and novel. NGCI has developed a systematic approach for Technology Roadmapping (TRM) that works through the process of visioning with stakeholders, identifies high priority technologies, evaluates them for both technical and policy readiness, and then produces a technology roadmap. Novel aspects include the integration of visioning and roadmap development, the methodology for assessing "non-technical factors" (i.e. policy readiness), and the vision. We believe that this approach meets the recommendations in the literature and is likely to "stay alive" over a long time horizon and evolve to address new needs. In this paper we describe the literature on TRM, NGCI's systematic approach for TRM, and the process and results to date.

Background

TRM is a process to improve the alignment between technology planning and business drivers (Amer & Daim, 2010; Daim & Oliver, 2008; Dissel, Phaal, Farrukh, & Probert, 2009). It dates most prominently to the 1980s when Motorola popularized the approach (Carvalho, Fleury & Lopes, 2013). It has been adopted in industry, government and other institutions, and there is general recognition that the process itself is just as important as (if not more important than) the final product (Carvalho et al., 2013). There is a clear delineation between a technology roadmap, which is a product describing the development plan and market environment of a specific technology, and TRM, which is the process to create the technology roadmap. The literature on TRM primarily focuses on private business roadmaps, which are often business sensitive and narrowly distributed. Alternatively, sector-specific roadmaps are broadly disseminated and include a wide range of stakeholders during the development process (Phaal, Farrukh & Probert, 2009). In this paper, we focus on the process of creating a sector-specific roadmap more than the end product.

Recently, authors on TRM have aimed to understand the dynamic of engaging with experts and stakeholders (e.g. Lee, Kim & Phaal, 2012) and expanded the scope of experts engaged to include non-technical constraints and challenges (e.g. Dissel et al., 2009; Daim and Oliver, 2008). Carvalho et al. (2013) reviews critical factors for a successful TRM process and finds a focus on stakeholders/communication, vision/leadership, and the importance of non-technical factors ("the market" and potential policy constraints). NGCI addresses these areas for R&D TRM by explicitly focusing on stakeholders and communication by building a virtual community of participants that is broad and inclusive. NGCI's stakeholders include participants in the "market" like first responders, community members, industry, and experts on policy concerns (e.g. privacy advocates).

Stakeholder Engagement

"Communication… is the essence of technology roadmapping," (Kostoff and Schaller 2001, pg. 265-266). A long-running challenge with TRM is keeping the process "alive" (Phaal, 2004; Lee, Kim & Phaal, 2012). Waning interest in TRM is often attributed to a lack of credibility for the process. Lee et al. (2012) found that continuous communication with users of the roadmap is critical to its perceived credibility. Additionally, Dissel et al. (2009) have noted that TRM can be focused more broadly and exploratory (looking for new connections and opportunities) than a single widget. Simply participating in the process has value for communication and dialogue.

Determining the participants for TRM is a critical source of success noted by many authors (e.g. Kostoff, Boylan & Simons, 2004). They note that committed senior level participants are necessary (Kostoff et al., 2004), that competent people should be involved (Kostoff et al., 2004), and the group should be multi-disciplinary (McMillan, 2003). There is a dispute as to whether customers are an important participant. Some argue that it is important for understanding the market (McMillan, 2003), while others have noted that customer requirements can stifle radical innovation by focusing on the tools at hand (O'Conner and Veryzer, 2001). In the case where customers are included, a dedicated team must understand potential market availability. Ultimately, O'Conner and Veryzer note that customers and marketing teams can be critical once a product has a prototype

available, but not before.

The NGCI model was designed with these principles in mind. Communication is addressed through multiple modes and is both bottoms-up and top-down. Bottom-up communication takes place through an online presence with a socially-focused website that allows stakeholders to interact without the constraints of face-to-face meetings like scheduling and geography (http://www.ngcicommunity.org). For a top-down communication structure, NGCI hosts moderated workshops with stakeholders that can be attended in person or via video-conference. These workshops are structured to drive conversation around specific scenarios for TRM to elicit information from the stakeholders and answer questions.

Stakeholder selection is inclusive and focuses on both targeted and word-of-mouth recruitment. While the roadmapping team invites a specific list of participants, they also take recommendations in a snowball approach. The online presence has no membership requirements, but content is moderated to maintain quality control. Stakeholders are grouped based on their function (e.g. industry, researchers, privacy advocates, etc.). Customers (i.e., users) are invited to participate in scenario-based discussions as their own group.

Vision Development

O'Conner and Veryzer (2001) note that that people have a difficult time imagining innovative technologies in use. They describe a process for "visioning," or leading product development based on a long-term vision of development, which is different from TRM. Roadmapping would be used to identify a development path for a vision, but visions are not always a part of roadmapping. Lin and Luh (2009) articulate a series of steps. First, organizers define the project, and incorporate stakeholders. Next, organizers research challenges, opportunities and other topics within the scope of the project definition to help prompt stakeholders to identify specific challenge areas. Then, stakeholders develop a set of alternative visions, and negotiate those alternatives into a consensus-based single vision. Finally, organizers develop a long-range scenario from the consensus vision. Both background information from the process and discussion of vision should be incorporated to create a rich scenario.

The NGCI model incorporates visioning as described by Lin and Luh (2009) to create an initial "prototype" (i.e. scenario) for users and other designers to see during discussion of the roadmap. The scenario used to develop the roadmap is drawn from earlier workshops where the roadmapping team identified a set of potential issues and stakeholders came together to articulate critical issue areas. Iterating with stakeholders, the team developed a consensus vision and scenario. The scenario has been developed into a storyboard for participants. This serves the objective of communication and also helps stakeholders put the concepts into context. This outcome is detailed in the results section.

Analysis of Non-Technical Factors

Several authors noted the need for analysis of "non-technical" factors, and the systems engineering approach (INCOSE, 2011) calls for a review of constraints to development. Both are referring to policy issues that may help or hinder a technical project. In the context of national technology roadmaps, Daim and Oliver (2008) identify the need to consider social impacts and policy in determining the readiness of a given technology. Work in this area has traditionally resided in the area of Technology Assessment (TA), which aims to forecast the full societal impact of a technology (Palm and Hansson, 2006). TA is criticized for being too expensive, for trying to capture every aspect of technology impact, and for inaccurate forecasts (e.g. Palm and Hansson, 2006).

We developed an index-based model that complements the Technology Readiness Levels (TRL) called the Policy Readiness Index (PRI). It rates a technology based on existing literature along 6 dimensions of readiness that map to traditional areas of policy analysis: Policy Plausibility; Legal/Regulatory; Social Acceptability; Political Acceptability; Cost-Effectiveness; and Alignment (Figure1). The PRI is an evidence marshalling framework, allowing an analyst to make a qualitative judgment (on a 1-3 scale) about the readiness of a technology in a policy context. For example, in the legal analysis category, a technology could be either a 1 (not legal), a 2 (ambiguously legal), or a 3 (legal). We believe that using the PRI framework will allow for production of consistent analytical results that can be used to compare technologies. The final roadmap will use PRI to identify respond to policy barriers and opportunities that could impact development. Mitigation could include design features, or modifying the policy environment. We are evaluating and refining the approach as a part of the NGCI process.

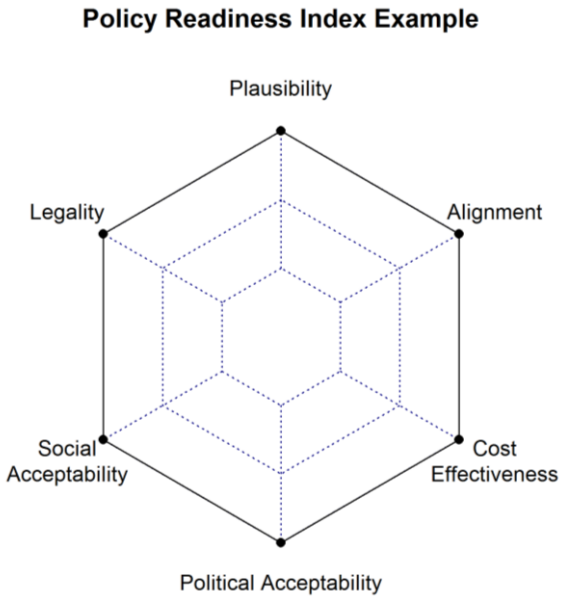

Figure 1 - PRI Radar Chart

APPROACH

Drawing on the literature, the NGCI approach is highly integrated with stakeholders, improves communication of concepts through a visioning process, and employs PRI to assess non-technical issues. Figure 2 shows the NGCI approach visually. The first 4 phases align with Lin and Luh (2009) for visioning. The final steps employ TRL and the PRI to assess technologies in the vision for their readiness and develop a TRM for their deployment. Input from stakeholders is transcribed and coded using NVivo™. NVivo helps turn qualitative information into a more quantitative form (e.g. cross-referenced counts of occurrence) for analysis. Additionally, conversation flow analysis was performed using R (R Core Team, 2008)

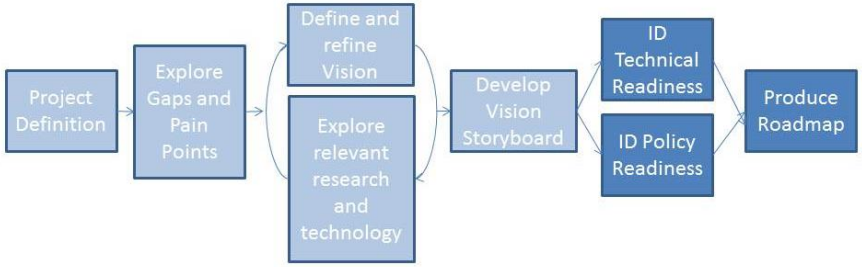

Figure 2 - NGCI Model (remaining tasks in dark blue)

RESULTS

Consistent with Carvalho et al.'s (2013) argument that the process is as important as the final product, we present initial results for this project based on the outcomes of each step in the process depicted by Figure 2 To date, the project has completed its vision storyboard, and is undergoing the process of assessing readiness through SME elicitation and analysis.

Project Definition

This project grew out of earlier work for DHS on the Precision Information Environment (PIE) and draws on those findings (PNNL, 2011). SMEs, the researchers, and DHS collaborated to identify project objectives, which included the development of a technology roadmap that is supported by a community of stakeholders.

Explore Gaps and Pain Points

In early 2014, PNNL hosted a workshop using both a physical presence (in a conference room) and a virtual presence (using Microsoft Lync) for any participants unable to travel and participate. Participants included law enforcement (LE), firefighters, emergency management, military, and the private communications and technology sector. This meeting explored gaps and pain points in communications and interoperability. The research team presented topic

areas of interest, and then moderated discussion around two specific, participant-selected topic areas (intuitive collaboration and predictive modeling) to vet concepts in the emergency response context. The conversation was transcribed and coded using NVivo qualitative analysis software to track themes and identify areas of agreement.

Figure 3 shows the flow of conversation by topic area and concern articulated by the stakeholder. Topic area and concern were coded using NVivo and then plotted in time series. Training/Learning, Filtering of data, and Reliability were critical in the context of intuitive collaboration. Alternatively, stakeholders highlighted a wide array of concerns for Prediction and Forecasting. There was some focus on data inputs, but also usefulness and use cases. The questions about context (usefulness and use cases) and the variation of concerns suggest that participants lacked context to discuss the technologies completely and needed a more concrete vision of its application. The need to more clearly demonstrate the potential use cases shows the need for a vision storyboard to provide context. Most participants were familiar with collaboration and could clearly articulate pain points for implementation, but prediction and forecasting was newer and more difficult.

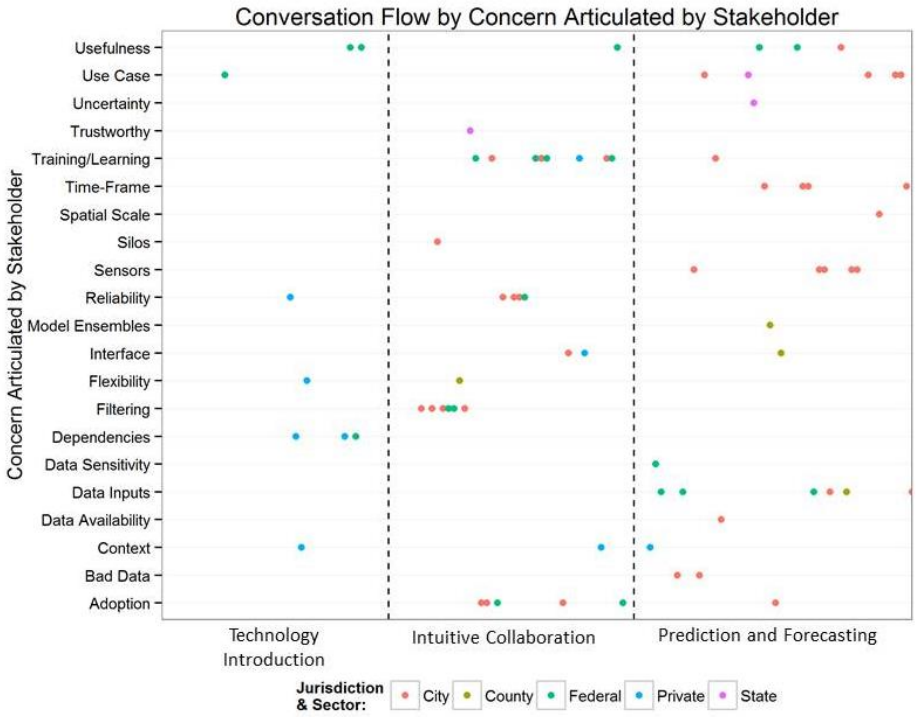

Figure 3 - Conversation by concern stakeholder concern

Define and Refine Vision / Explore Relevant Research and Technology

Taking the feedback from the workshop, the research team developed a vision storyboard outline, which was based on an event identified by stakeholders as relevant and the tasks required to respond to the event by the stakeholder group. Technologies were mapped to tasks where they were best suited to meet the gaps articulated by participants in our workshop. The outline was vetted with stakeholders who volunteered.

Develop Vision Storyboard

The final vision was translated into a storyboard and used for conversations during the second phase of interviews (underway). The vision storyboard addresses a LE scenario of communication, collaboration, and response during a large-scale event. Drawing from the results of the conversation analysis, we highlight forecasting and prediction to support planning, response, and recovery. In the scenario the local professional sports team just won a championship and there is a parade to celebrate the victory with a massive expected influx of people. LE is charged with maintaining order, but several actors are looking to disrupt the event and damage the city. The storyboard shows LE preventing and responding to different events, including an attack on a Supervisory Control and Data Acquisition (SCADA) system. They utilize technologies that are either not yet developed, or used in a different context.

The storyboard consists of six scenes, each addressing a different topic and consisting of several boards selected for alignment of technologies related to the identified stakeholder pain points which utilized:

- Scene 1: Situation awareness, communication, resource tracking, wearable computing, distributed sensor network
- Scene 2: Planning, risk mitigation, needs assessment, collaboration, internet of things, information access rights
- Scene 3: Briefing, resource and task management, distributed work, geospatial awareness and information sharing
- Scene 4: Field operations, observation, social media, citizen as a sensor and response
- Scene 5: Cyber awareness, assessment, modeling, sequestration, network quarantine and mitigation
- Scene 6: Debrief, security and privacy control

In Figure 4, a bicycle officer is checking the route and receiving information from a heads up display integrating sensor information. Meanwhile, the command center has a common operating picture showing their team members with access to detailed information on their readiness and position. Each storyboard is accompanied with a vision statement

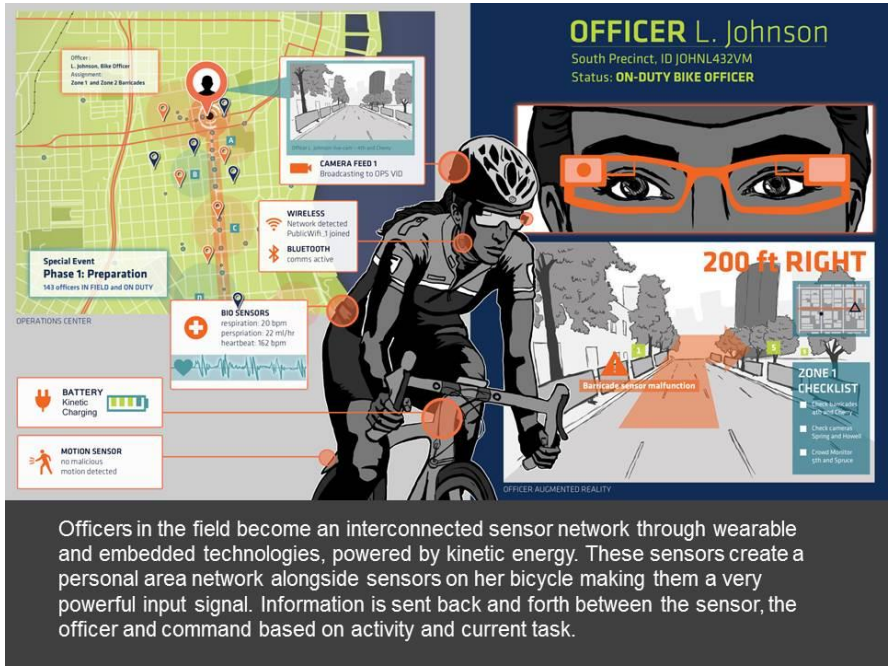

Figure 4 - A board from scene 1 of the vision storyboard

DISCUSSION AND CONCLUSION

Work is ongoing to perform the analysis of the technical and policy readiness of the technology concepts from the vision storyboard that were identified as priorities by participants in workshops. The technical readiness evaluation has drawn from a variety of R&D roadmaps to identify existing and future technologies to evaluate its readiness for use (Marron & Minder, 2006; Rush, Ramos, Deutsch, Dennehy & Seibert, 2012; Wainwright & Papanikolaou, 2011).

The analysis aims to identify potential areas of overlap and critical bottlenecks. The policy readiness evaluation is employing PRI, as described above, along with targeted interviews and workshops with SMEs. Additionally, literature will be consulted to triangulate with results from the qualitative analysis of SME perspectives and judgments will be made regarding each technology concept's readiness. Concepts will be scored for both technical and policy readiness, and research opportunities will be identified based on those scores.

The results of the readiness evaluations will be used to construct R&D TRMs for each concept. While the final deliverable of this project is a roadmap, we expect that roadmap to be owned by the NGCI community and undergo frequent re-analysis by members of that community as it evolves and additional vision scenarios are explored and created. Participation in that community will take place through the NGCI website.

Many lessons have been learned during this process. First and foremost, stakeholder engagement is a challenging proposition, but a consistent, robust methodology can be used to marshal the information provided by those meetings so that the analysis is robust. Incorporating multiple modes for participation in the workshops helped to add geographic and disciplinary diversity. By including a video conference option, we were able to include additional participants. Moreover, video conference provides a convenient means of capturing data for analysis of the engagement process and outcomes.

Additionally, based on early feedback, SMEs find the visual storyboard to be an effective way of translating difficult concepts into forms that are easy to understand and provide feedback on. The factors influencing policy readiness can be more easily discussed and SMEs find it easier to prioritize technology concepts. With the prioritization and policy readiness, a complete picture of the research gaps is more apparent.

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REFERENCES

1. Amer, M., & Daim, T. U. (2010). Application of technology roadmaps for renewable energy sector. *Technological Forecasting and Social Change*, 77, 8, 1355–1370. doi:10.1016/j.techfore.2010.05.002
2. Carvalho, M. M., Fleury, A., & Lopes, A. P. (2013). An overview of the literature on technology roadmapping (TRM): Contributions and trends. *Technological Forecasting and Social Change*, 80, 7, 1418–1437. doi:10.1016/j.techfore.2012.11.008
3. Daim, T. U., & Oliver, T. (2008). Implementing technology roadmap process in the energy services sector: A case study of a government agency. *Technological Forecasting and Social Change*, 75, 5, 687–720. doi:10.1016/j.techfore.2007.04.006
4. Dissel, M. C., Phaal, R., Farrukh, C. J., & Probert, D. R. (2009). Value Roadmapping. *Research-Technology Management*, 52, 6, 45–53.
5. INCOSE. (2011). INCOSE systems engineering handbook v. 3.2. 2. INCOSE-TP-2003-002-03.2.2.
6. Kostoff, R. N., Boylan, R., & Simons, G. R. (2004). Disruptive technology roadmaps. *Technological Forecasting and Social Change*, 71, 1–2, 141–159. doi:10.1016/S0040-1625(03)00048-9
7. Kostoff, R. N., & Schaller, R. R. (2001). Science and technology roadmaps. *IEEE Transactions on Engineering Management*, 48, 2, 132–143. doi:10.1109/17.922473
8. Lee, J. H., Kim, H., & Phaal, R. (2012). An analysis of factors improving technology roadmap credibility: A communications theory assessment of roadmapping processes. *Technological Forecasting and Social Change*, 79, 2, 263–280. doi:10.1016/j.techfore.2011.05.003
9. Lin, C.-C., & Luh, D.-B. (2009). A vision-oriented approach for innovative product design. *Advanced Engineering Informatics*, 23, 2, 191–200. doi:10.1016/j.aei.2008.10.005
10. Marron, P. J., & Minder, D. (2006). Embedded WiSeNts Research Roadmap.

Information Society Technologies. Retrieved from ftp://ftp.informatik.uni-stuttgart.de/pub/library/ncstrl.ustuttgart_fi/BOOK-2006-03/BOOK-2006-03.pdf

11. McMillan, A. (2003). Roadmapping - agent of change. *IEEE Engineering Management Review*, 31, 3, 42–42. doi:10.1109/EMR.2003.24904
12. O'Connor, G. C., & Veryzer, R. W. (2001). The nature of market visioning for technology-based radical innovation. *Journal of Product Innovation Management*, 18, 4, 231–246. doi:10.1111/1540-5885.1840231
13. Palm, E., & Hansson, S. O. (2006). The case for ethical technology assessment (eTA). *Technological Forecasting and Social Change*, 73, 5, 543–558. doi:10.1016/j.techfore.2005.06.002
14. Phaal, R., Farrukh, C. J. P., & Probert, D. R. (2004). Technology roadmapping—A planning framework for evolution and revolution. *Technological Forecasting and Social Change*, 71, 1–2, 5–26. doi:10.1016/S0040-1625(03)00072-6
15. Phaal, R., Farrukh, C. J. P., & Probert, D. R. (2009). Visualising strategy: a classification of graphical roadmap forms. *International Journal of Technology Management*, 47, 4, 286–305. doi:10.1504/IJTM.2009.024431
16. Phaal, R., Farrukh, C., & Probert, D. (2001). T-plan: The Fast Start to Technology Roadmapping. Planning Your Route to Success. Cambridge: University of Cambridge, Institute for Manufacturing.
17. PNNL. (2011). Gap Assessment in the Emergency Response Community. Technical Report: Pacific Northwest National Laboratory. Retrieved from http://precisioninformation.org/?p=24
18. R Development Core Team. (2008). R: A Language and Environment for Statistical Computing. Vienna: R Foundation for Statistical Computing. Retrieved from http://www.R-project.org.
19. Rush, J., Israel, D., Ramos, C., Deutsch, L., Dennehy, N., & Seibert, M. (2012). Communication and Navigation Systems Roadmap - Technology Area 05. NASA. Retrieved from http://www.nasa.gov/sites/default/files/501623main_TA05-ID_rev6_NRC_wTASR.pdf
20. Wainwright, N., & Papanikolaou, N. (2011). Trust and Security Research Roadmap: An Analysis of Discussions at EFFECTSPLUS Clustering and Roadmapping Events. EffectsPlus. Retrieved from http://www.effectsplus.eu/files/2011/04/Trust-and-Security-Research-Roadmap-Draft-1.pdf