

*“Strong reasons make strong actions.”*

—William Shakespeare (1564-1616), *The Life and Death of King John*

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## Positioning for Enduring Success

The research and development (R&D) agenda for visual analytics constitutes a grand challenge for the scientific enterprise, but achieving this agenda is vital to the mission to protect our homeland. The scale, diversity, and complexity of available information pose both challenges and opportunities throughout the analytical process. To address this complexity and its associated uncertainty will require advances in the science of analytical reasoning. The mind must be enabled to provide better judgment through new visual representations and interaction techniques. These techniques must be supported by advanced data transformations and representations. Diverse data must be brought together, or synthesized, to enable the detection of the expected and discovery of the unexpected. Often forgotten is the requirement for new methods to effectively communicate analytical understandings to a wide variety of users to enable further action. The combination of all of these requirements constitutes a grand scientific challenge.

This agenda is likely to take 5 to 10 years to fully address. Its achievement requires the establishment and continual enhancement of tool suites that are evaluated to prove effectiveness and utility. These tools must be engineered to support security and privacy policies. They must be developed with an understanding that they will be deployed in a wide variety of environments.

Achievement of this agenda also requires the development of educational foundations to stimulate a new generation of scientists and engineers. Although rapid incremental advancements can be made by delivering interim software suites, significant investments are necessary to establish educational partnerships and programs that engage the best talents possible in building the capability to fully achieve this mission. These investments are essential to positioning the science for enduring success.

The recommendations presented in Chapters 2–6 will enable researchers to make major breakthroughs in discovering and creating new technologies that enable profound insights from massive and dynamic data. These technologies will facilitate new understanding that can be used to protect against terrorist attacks, secure our borders, and assist in timely response in the event of an attack or other major emergency. The urgency of protecting our homeland demands strong leadership to achieve this science and technology mission and to develop an enduring multidisciplinary community of practice to meet these needs. The resulting capabilities will

also have a broad impact on other disciplines where data-intensive analytics are required, such as biology and medicine.

This chapter addresses the critical foundational elements that are necessary to achieve the R&D agenda described in this book. It discusses the urgency of accomplishing this agenda; it addresses the need for partnerships and collaboration; and it outlines the need for funding and coordination. It concludes with our recommendations and a call to action.

## Urgency of the Visual Analytics Mission

It is fair to ask: Why now? For the family members of those lost to terrorism, we are already late. Examinations of the events leading to terrorist attacks have produced calls for new processes, methods, and technologies to prevent, protect, and respond to future threats. We cannot delay.

This agenda must be accomplished expeditiously. This agenda calls for *accelerated creation of new capabilities* and streamlining their evaluation and implementation so that they may have a direct and transforming impact on the day-to-day activities of protecting the country. If new research is conducted and papers are published but no new tools are placed in users' hands, our goals will not be met. To achieve success, we must adopt a *science-to-solutions* approach to address the entire research, development, and deployment process. We must create a close partnership between the researchers discovering new approaches and the engineers who are putting those methods into practice. New and important research challenges come to light when putting technology into practice. To ensure that these emerging challenges are identified and addressed rapidly, a strong connection among research, engineering, and technology insertion is essential.

Technical success will require experts in many sciences working together to understand the challenges, develop high-impact technologies, and learn from evaluations to rapidly develop and deploy the required capabilities. We must engage experts in mathematics, statistics, cognitive and perceptual sciences, knowledge discovery and engineering, visualization, and many other sub-disciplines within computer science, as well as experts in reasoning and decision sciences, communications, graphics design, and other related disciplines. Multidisciplinary teams must work together to jointly understand the technical challenges and develop common taxonomies with which they can communicate. These shared foundations must be put in place to allow teams to invent, develop, and evaluate technology that is quickly adopted within targeted mission areas. We recommend that users, to the extent possible, be involved from the start in order to provide insight and grounding to the teams.

An important goal is to provide an enduring capability in which growing teams of experts throughout the research and engineering communities remain focused on the creation of new, high-impact technologies for visual analytics. With the overwhelming volume of data rapidly increasing, we will continue, for the foreseeable future, to collect more data than we can effectively analyze within time and mission

constraints. While we grow in our abilities to detect, prevent, and respond to terrorist attacks, the potential attackers will become increasingly sophisticated. This means that we must continue to advance our technologies to meet ever-growing needs.

To create this enduring capability, our educational enterprise must be engaged from the start. We need a new multidisciplinary curriculum to prepare new researchers for careers in visual analytics R&D. Students must have opportunities to augment their education with internships at national laboratories and other applied research locations to see the context of the technical challenges firsthand. Faculty should have opportunities to spend extended periods of time in national laboratories or industry supporting this mission. One example of an existing program to address this need is the US Department of Homeland Security (DHS) Scholars and Fellows Program. We must assist universities in understanding user needs through access to speakers and training, and we must provide support for transforming innovative technology demonstrations into robust software tools that can be deployed in the homeland security user community.

In summary, successfully accomplishing this agenda will demand more than the achievement of individual technical recommendations. It requires the involvement of the users and an understanding of their analytical processes. It requires the formation of multidisciplinary teams that can rapidly translate this understanding into innovative software suites. It demands a continuous cycle of research, engineering, evaluation, and technology insertion. It requires a concerted effort on the part of a diverse group of scientists and engineers working in partnership, and it can be sustained over the long term only through an active focus on education.

## **Meeting the Challenges through Partnerships and Collaborations**

Accomplishing this R&D agenda will require the efforts of teams of researchers throughout academia, industry, and the national laboratory system. However, it will not be sufficient to have these research teams working in isolation on parts of this grand challenge.

Instead, we must establish a community of practice for visual analytics research and engineering. This community of practice will be an important source of information for the researchers and engineers about user needs. The community of practice must foster appropriate collaborations with user organizations both to inform new research directions and to evaluate promising research. It must bring together the entire research community to support information sharing and collaboration. In addition, it must support collaboration among funding agencies to enable the most efficient use of investments.

While DHS will provide initial leadership establishing these partnerships and collaborations, it will ultimately be up to the R&D institutions to work in concert to build an enduring community of practice in visual analytics.

## Funding and Coordination

Visual analytics R&D efforts must be coordinated to achieve the highest possible return on research investments. Elements of the R&D agenda are being funded at varying levels by several government agencies. Researchers and engineers must be made aware of the technical advances being made in these areas, and government agencies must be able to stay abreast of what others are funding.

Technical forums should be held to share advancing technologies. These should leverage existing technical meetings such as those sponsored by the Institute of Electrical and Electronics Engineers, Inc. (IEEE) and Association of Computing Machinery (ACM) to the extent possible to maximize the information sharing while minimizing the number of schedule disruptions that the researchers must accommodate. Special-purpose conferences and workshops will also be needed to allow focused attention to areas of particular interest.

The challenge of funding this R&D agenda must be addressed. This agenda will not be accomplished through small, isolated investment programs. The necessary investments will not likely be developed through one agency, one company, or one national laboratory but through a coordinated, or at least confederated, suite of investments. The investments must address a full suite of needs including basic research, applied research, testing and evaluation, product engineering, and technology insertion and training. In one possible model, individual government agencies choose to invest in portions of the R&D agenda that have the most direct impact on their work. Industry researchers can focus on portions of the agenda for which they see the most potential commercial applications. The National Visualization and Analytics Center™ (NVAC™) can serve as the focal point for awareness about the R&D agenda. NVAC can identify areas in which substantial new research is needed and communicate this to potential funders of R&D effort. In addition, NVAC can provide a forum for the visual analytics research community, the funding sponsors, and other stakeholders to share breakthroughs, emerging requirements, and plans.

Although the final model chosen may differ from the one we describe here, we believe that a successful model can be established. We are encouraged by the strong interest from academia, industry, and the national laboratories to help bring solutions to the analytic community.

A critical requirement for the success of this agenda is the government's role in stimulating this agenda, the investment programs, and the *science-to-solutions* culture for the protection of our homeland. The government must remain dedicated in its support for funding this grand challenge. The success of its investments can be measured via peer reviews, technology insertion and, most of all, the utility of these technologies to the end users. Congressional commitments are needed to fund research in visual analytics. Although the cost of this research will be substantial, the cost of failure to achieve this agenda is far greater, as it is measured in lives lost and major economic impact.

## Recommendations

Achieving the agenda outlined here will require the sustained efforts of a multi-disciplinary community of researchers. Educational efforts and partnerships are necessary to establish and sustain an enduring visual analytics R&D community capable of meeting these challenges.

### *Recommendation 7.1*

**Develop programs to support education of the research community about the drivers for visual analytics research.**

Two major educational efforts are required. First, we must work in conjunction with universities to influence university curricula to provide formal education about visual analytics needs and challenges. Second, we must provide an active continuing education program through workshops, tutorials, and conferences to provide a broad understanding of analytic needs, technical challenges, and state-of-the-art R&D. These forums will be open to practitioners from academia, industry, and the national laboratory system.

### *Recommendation 7.2*

**Form university-led centers of excellence and partnerships with industry, national laboratories, and selected international research entities to bring together the best talents to accomplish the visual analytics R&D agenda.**

NVAC should be the coordinating point for the achievement of the visual analytics R&D agenda. University-led centers of excellence should be established to focus on advancement of specific high-priority portions of the agenda.

In addition, opportunities must be provided so that experts outside academia can contribute to advancement of this agenda. Avenues must be provided for partnerships with researchers, both individually and organizationally, in industry, in government, and in the national laboratory system. Selected international collaborations and partnerships should also be established to accomplish portions of the research mission.

### *Recommendation 7.3*

**Establish special partnerships with user organizations and the Corporate Information Office (CIO) organizations that support them to facilitate technology insertion within their operational environments.**

Transitioning technology into operation is a complex challenge and requires intimate knowledge of the domain into which the technology will be deployed. Partnerships with user organizations and their supporting CIO offices can supply the necessary insight to understand the analytical needs and the operational constraints for software being deployed. These insights are essential to accelerating the process of transitioning research into operation.

### *Recommendation 7.4*

**Provide ongoing support for collaborations, internships, staff exchanges, educational material development, and other efforts that foster interest in R&D that addresses the missions of homeland security.**

This support is a critical need to meet DHS's mission of enduring security for the homeland. This educational outreach effort should be coordinated with the DHS Educational Programs Office and stimulated by coordinated learning and training investments.

## **Call to Action**

The agenda described herein is only a beginning. As the new discipline of visual analytics matures during the next few years, our understanding of the research challenges and priorities will grow rapidly.

To remain on target for accomplishing this agenda, we will periodically evaluate its progress. While success may be measured in many ways, we choose to focus on two specific areas for evaluation. This effort will be a success if:

- New visual analytic techniques are being successfully transitioned into practice
- A vibrant and growing community of practice has been established for visual analytics researchers and engineers.

This R&D agenda constitutes a grand challenge. While DHS is providing the foundational support for this effort, its success must be realized through the coordinated support and efforts of multiple government agencies, industry, academia, and the national laboratories. As we mobilize to address this challenge, we are mindful of the role we play in helping to safeguard our nation.