THE NATIONAL ACADEMIES

DIVISION ON EARTH AND LIFE STUDIES

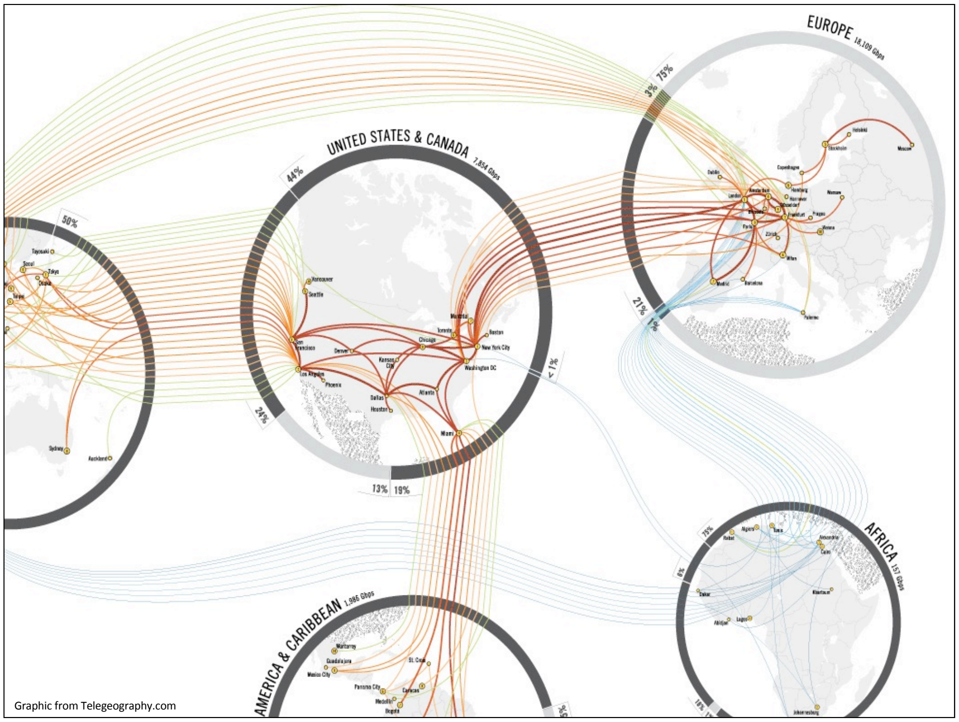
Leveraging Technological Change for the Betterment of Society

From *Understanding the Changing Planet: Strategic Directions for the Geographical Sciences,* National Academies Press, 2010, http://www.nap.edu/catalog.php?record_id=12860

Dawn Wright
Oregon State University
Mike Goodchild
UCSB

THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

National Academy of Sciences
National Academy of Engineering
Institute of Medicine
National Research Council



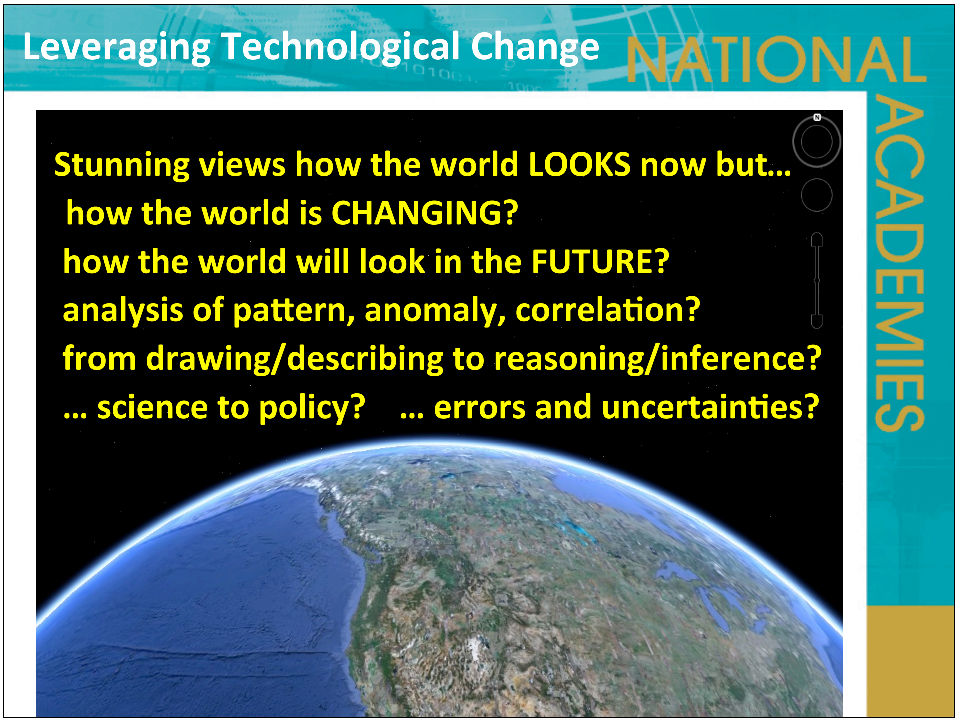
This map shows key intercontinental and regional internet routes and their bandwidth. Disparities in available internet bandwidth contribute to the differences in access to information and communication technologies that have come to be known as the "digital divide." SOURCE: TeleGeography.

Because of its multidisciplinary character, research in the geographical sciences lends itself to multi-investigator projects, which are becoming increasingly common. The explosive growth in geographical data and technologies can facilitate collaborative projects across vast distances, as researchers tap into shared data banks and make use of virtual systems. The diffusion of information and communication technology has also led to a democratization of science that puts anyone with access to a computer terminal and the internet in the position of being able to collect and disseminate information. Geographical platforms such as Microsoft Virtual Earth and Google Earth are at the forefront of this development. These developments heighten the importance of geographical investigation—both to harness the flood of new geographical information in 540 productive ways and to explore the possibilities and limitations of the information and ideas coming from the rapidly expanding community of "neogeographers" (non542

specialists involved in the collection and assessment of locational data using geographical platforms and technologies). Moreover, when geographical techniques that allow for the precise, systematic monitoring of phenomena are used to collect information on people's activities, complex issues of privacy arise that demand careful consideration by researchers who possess a significant understanding of the nature and power of the geographical technologies involved.

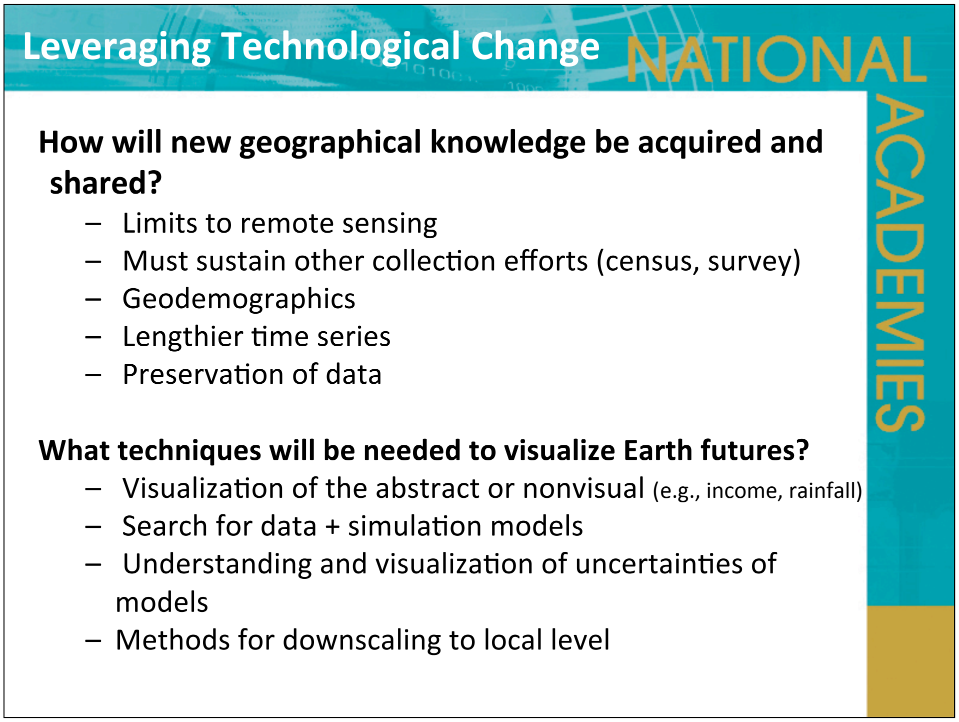
Leveraging Technological Change

NATIONAL ACADEMIES



Web-based virtual globes display stunningly detailed images of how the geographical world looks, they provide little sense of how the world is changing, how it will look in the future, how certain or uncertain we may be about future states, and how the world works as an interconnected system. The general public makes use of these technologies to obtain driving directions and to look at recent events around the world, but gains very little understanding of the many problems that humanity faces, and the options available for dealing with them that have been discussed in previous chapters. The methods of analysis that search for pattern, anomaly, and correlation in geographical information reflect the needs of an earlier, slowly changing world and its somewhat leisurely pace of investigation, rather than the rapidly changing planet of the new century, and its need for quick, science-based response.

None of these developments, has in any way reduced the importance of expertise in reasoning and inference, and it is clearly in this area that the role of the geographical scientist is most critical (Longley et al., 2005). No one would suggest, for example, that technology has in any way reduced the need for expert pedologists--both as creators of knowledge about soils and as interpreters of that knowledge--to users, even though that knowledge may be expressed through the simple medium of a map.

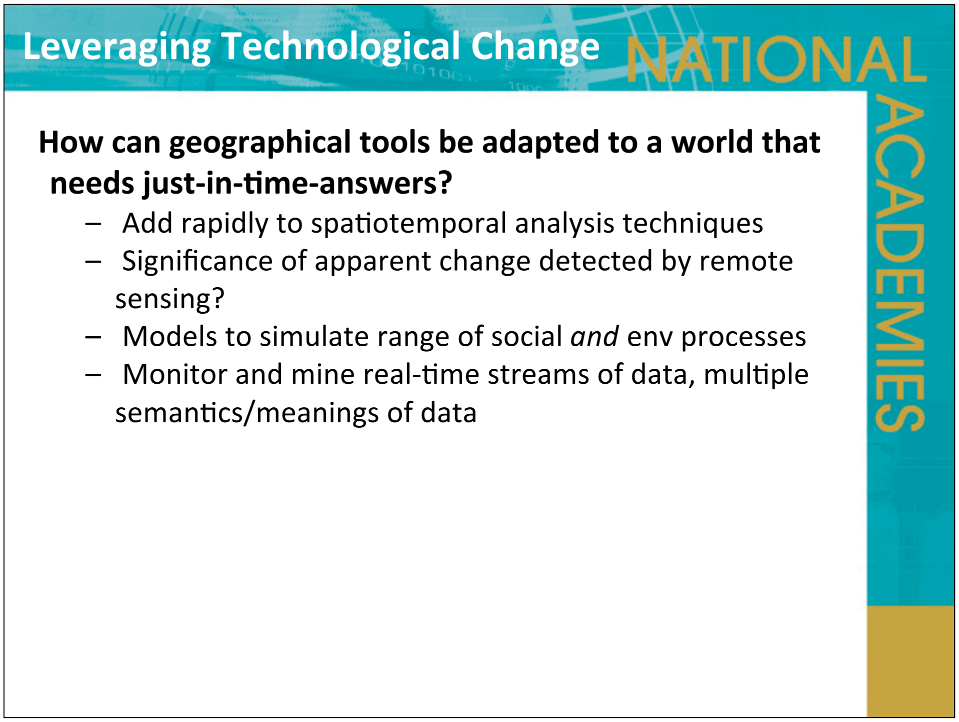


How will new geographical knowledge be acquired and shared?

Satellite remote sensing, ground-based sensors, acoustic remote sensing continue to be critically important. However, there are obvious limits to what can be observed, identified, and measured from remote sensors, whether in space, on the ground, or in the ocean. People use place names, distinctive landmarks, and addresses to describe locations, but maps of these are created by humans on the ground. Data on demographics, socioeconomic status, and all of the wealth of information created by censuses, surveys, and other mechanisms for gathering social data are available only from people, and only by expensive processes of official data gathering. It is important that researchers find ways of sustaining these processes despite their cost and what appears to be an increasing unwillingness of some members of the public to participate.

Underlying all of these approaches to data acquisition is the problem of sustaining long-term programs that can yield useful longitudinal data. All too often geographical data sets are no more than snapshots, obtained at a few times over a short interval. Changing technology, lack of interest, and the short-sighted nature of many programs present a major obstacle to any concerted effort to build lengthy time series that can support analysis of change. We run a real danger that, in the not too distant future, much of what we now know about the planet through our current programs of remote sensing will be lost because of a lack of both the resources and the organizations needed for long-term preservation. Research is needed to identify robust approaches to preservation, to ensure easy and reliable access by the researchers of the future.

What techniques will be needed to visualize Earth futures?



Because of the legacy of mapping relatively static phenomena, our methods of analysis are similarly geared to so-called cross-sectional data, or data of spatial distributions at one point in time. This limitation is exacerbated by the tendency for many social data-gathering exercises, such as the U.S. Census, to take place at fixed intervals. Remotely sensed images have also provided timed snapshots, although the effective frequency of overpasses has been improving recently as more satellites are launched, allowing the recovery effort following the Wenchuan earthquake in China in May 2008, for example, to make use of images collected from dozens of satellite sensors. Another reason for the paucity of lengthy time series has been the difficulty of maintaining the flow of public resources needed to keep large-scale, expensive government data-gathering programs in operation decade after decade.

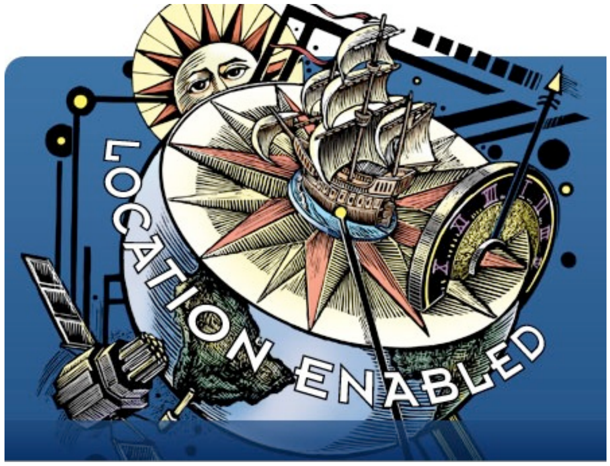
As change accelerates and as sensor networks begin to provide densely sampled data in both space and time, we will need to add rapidly to our collection of spatio-temporal techniques of analysis. At this time, we know little about how to analyze and mine the increasing supply of data resulting from the tracking of vehicles, people, and animals (Miller and Han, 2001). We know little about how to assess the significance of an apparent change on Earth's surface detected by remote sensing. We need a comprehensive battery of easy-to-use models to simulate a range of social and environmental processes, and to investigate the footprints they leave on Earth's surface.

Even more urgent is the need for methods that can continuously monitor the stream of data coming from our acquisition systems, searching constantly for anomalies and novel patterns, and initiating appropriate investigations. Such real-time analysis of medical diagnoses by primary-care physicians, for example, could provide early warning of disease outbreaks and health hazards. Data coming from individuals could be used to provide early assessments of the damage from disasters, and could speed the initiation of response. Spatial decision-support systems based on real-time streams of data could provide new levels of effectiveness in the management of numerous social and environmental problems.

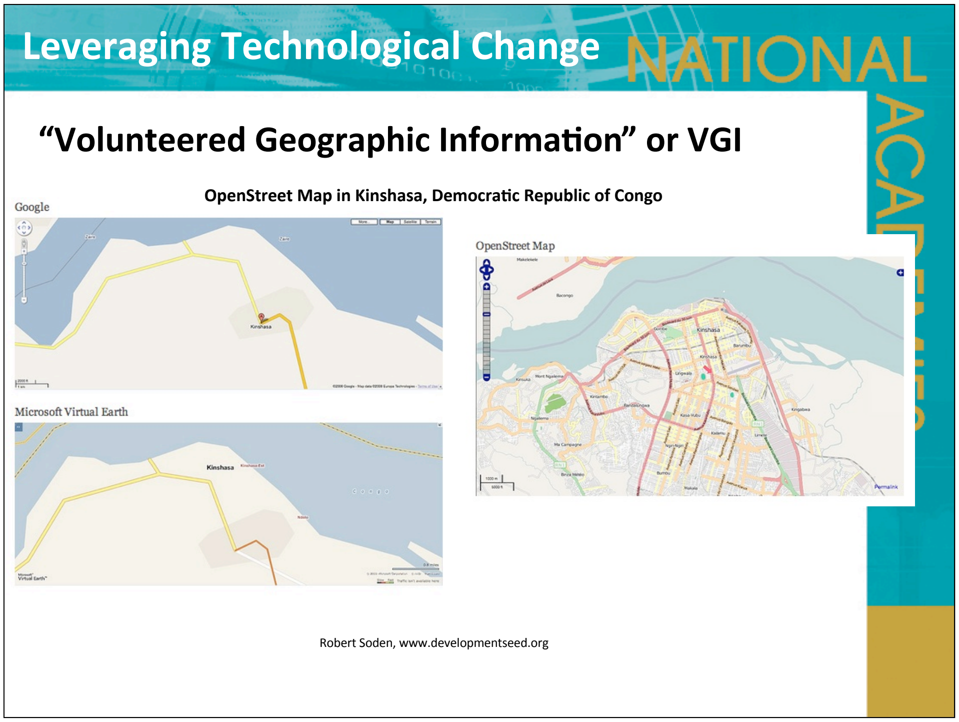
Leveraging Technological Change

NATIONAL ACADEMIES

What are the societal implications of *citizen mapping* and *mapping citizens*?



Graphic from O'Reilly Media, Inc., Where 2.0

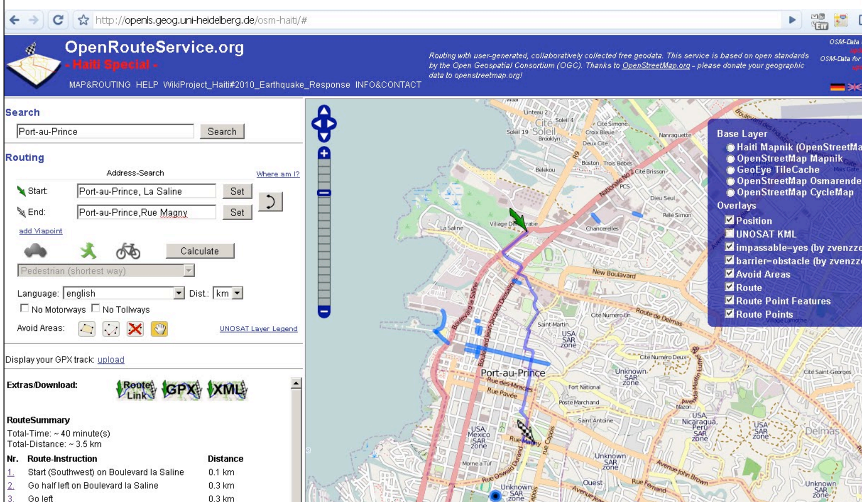


The map on the left shows part of the street network in Mogadishu, Somalia available in Google Earth (top) and Microsoft Virtual Earth (bottom). The map on the right showing the same region, but with streets supplied by VGI in OpenStreetMap.org, provides information of considerable use to international development and humanitarian relief organizations. SOURCE: www.developmentseed.org/tags/mapping (accessed January 20, 2010).

Leveraging Technological Change

NATIONAL ACADEMIES

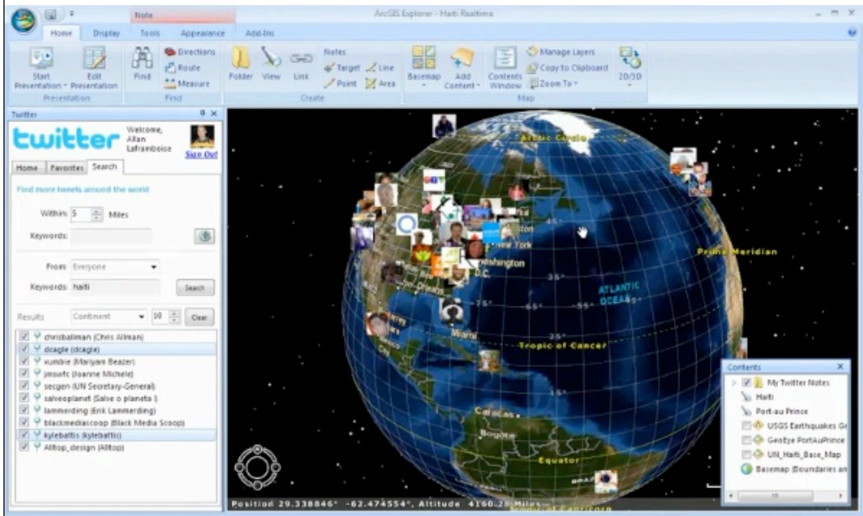
Haiti Disaster, MapAction.org



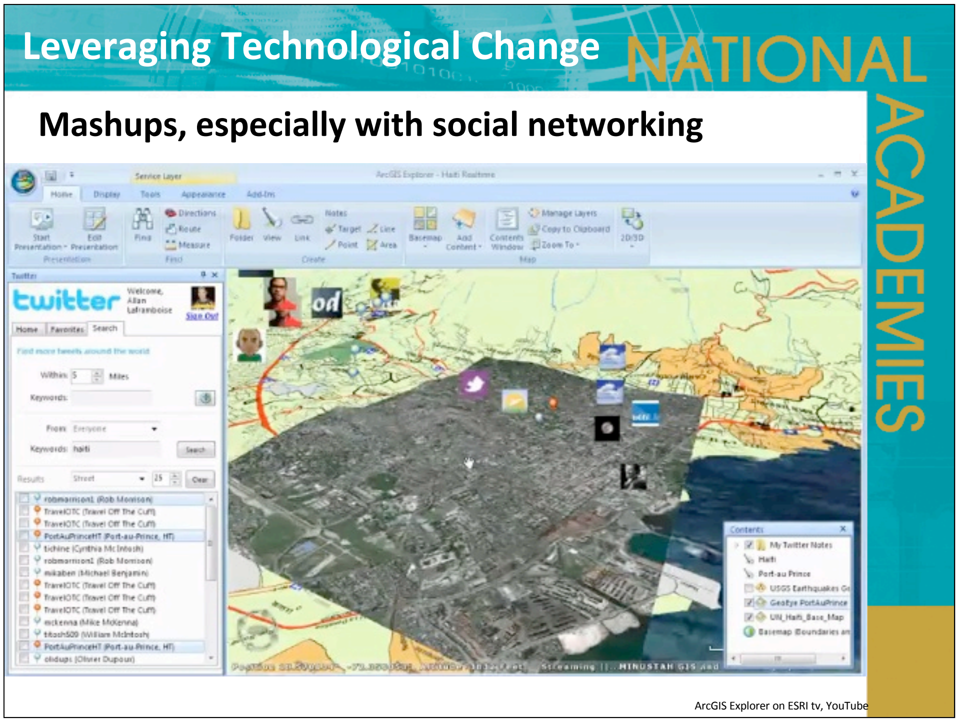
Leveraging Technological Change

NATIONAL ACADEMIES

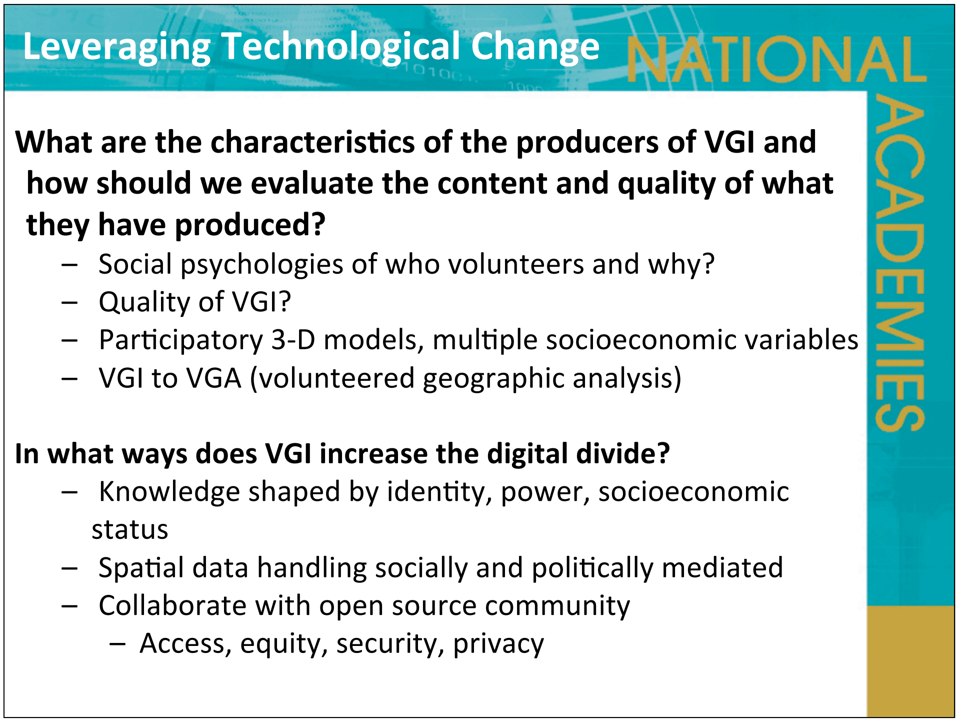
Mashups, especially with social networking



ArcGIS Explorer on ESRI tv, YouTube

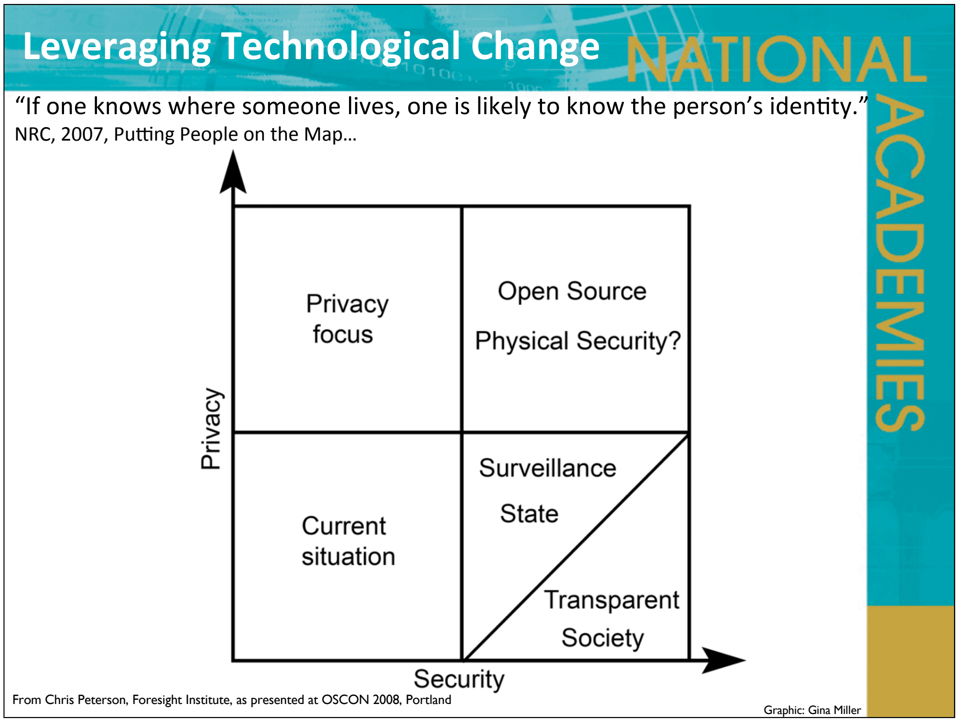


Port-au-Prince, Haiti after the earthquake – mashup of Twitter feeds, high rez aerial photograph, USGS aftershock RSS feeds



Producers of VGI are themselves subjects of much needed research (e.g., who volunteers and why, what are their geographical and social characteristics, what kind of locational information are they interested in volunteering?). Initial studies have shown that people volunteer information in the belief that it will be open, accessible, and free, and may even be of significant help. Some are also motivated by self-promotion, the desire to fill in gaps in data, or merely to connect easily to friends, relatives, and colleagues (Goodchild, 2008). Geographical methods for exploration, analysis, synthesis and classification of spatial data (e.g., multiple criteria evaluation methods in the context of decision support systems as developed by Jankowski et al. (2008), as well as various landscape visualization techniques and participatory 3D models) are needed to shed light on who is involved in VGI and what they are doing. A study that mapped participation and correlated it with multiple socioeconomic variables might, for example, reveal that most VGI in a certain region comes from upscale residential neighborhoods, and could further understanding of the social, political, and technological factors that affect how geographical data are developed, accessed, and interpreted (Elwood, 2007). Research is needed to define the limits of VGI in this context and to shed light on the social psychology of the producers of VGI.

Institutional review boards (IRBs) have emerged in recent years to protect the rights of human subjects in research projects, and yet there is wide variability in their capacity to apply and disseminate confidential research (Lane, 2003). Many IRBs are quite conservative vis-à-vis locational privacy, making it difficult for researchers to work with tracking data. This orientation could be a major impediment to useful research. Seiber (2004) has suggested some innovative ways in which IRBs could improve researchers' understanding of confidentiality issues, including how best to interpret, adapt and apply nondisclosure techniques, but the challenge of developing ways to contront locational privacy issues remains (NRC, 2007b).

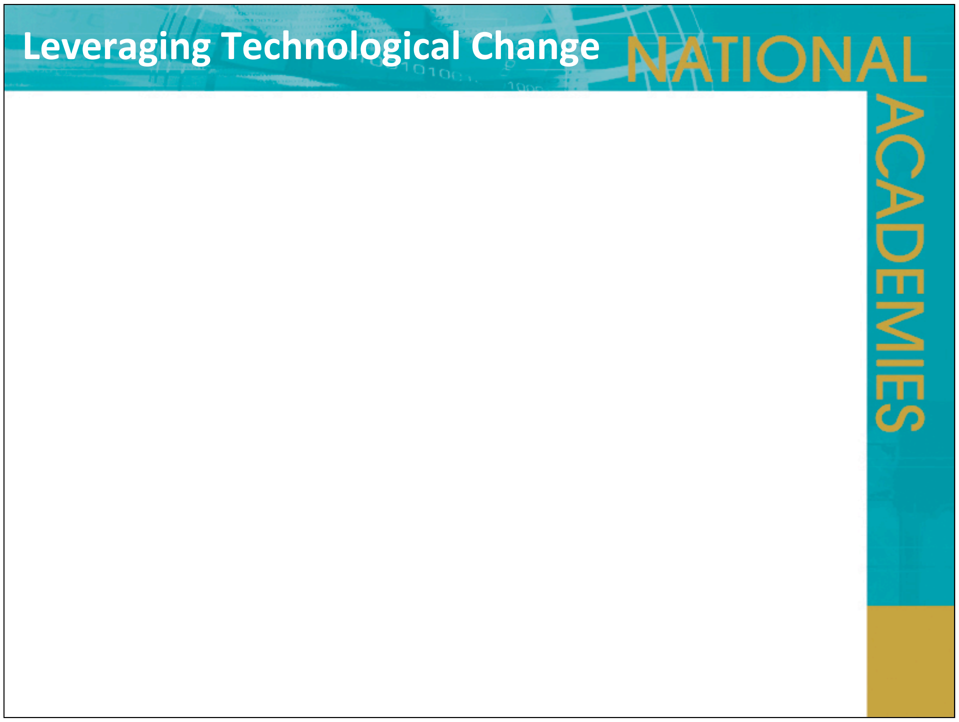


The power of such web sites to increase the efficiency, pleasure, and safety of our lives is becoming increasingly apparent. However, the issue of individual privacy has arisen just as quickly as the technologies themselves. Privacy is about limiting access to facts about an individual, including gender, marital status, income, and social security number, in order to protect against intrusion, appropriation, or breach of confidence. The issue of privacy is heightened when locational information is involved. Most people do not expect ultimate privacy while at their places of work, but they expect it in their homes. Location can also present privacy concerns in a dynamic sense, both directly ("I don't want people to know my current location in space and time"), and indirectly ("I don't want certain things associated with me *because* of my current location in space and time, such as my presence at an adult video store") (Curry, 1998; Armstrong and Ruggles, 2005; Bertino et al., 2008).

There is growing concern that the proliferation of technologies and the production of detailed, micro-level spatial data are outpacing our ability to protect information about individuals. The same techniques that allow Web users to create mashups by linking information around common geographical locations also allow government agencies to build massive databases on individuals and their behaviors (e.g., NRC, 2008a) and make it possible for the private sector to keep track of a wealth of personal information. The practitioners of the emerging field of "collective intelligence" acknowledge that, if misused, locational information on individuals "could create an Orwellian future on a level Big Brother could only dream of" (Markoff, 2008). The geographical sciences are of central importance to this challenge because, as noted by the NRC Committee on Confidentiality Issues Arising from the Integration of Remotely Sensed and Self-Identifying Data (NRC, 2007b): "precise information about spatial location is almost perfectly identifying: if one knows where someone lives, one is likely to know the person's identity." The social issues raised by these tools are more urgent today than two decades ago, and there is every indication that the urgency will grow in the future.

Collaborations between academics and industry scientists can lead to the development of effective algorithms for "geographic encryption," also known as "geographic masking" (Kwan et al., 2004). There is a need for different ways of suppressing, re-sampling, or multiplying by random noise certain records in a geographical database (e.g., Armstrong et al., 1999), perturbing the underlying micro-data rather than perturbing the database cells themselves (Lane, 2003), and developing other geo-masking techniques for both continuous and categorical variables that can be applied locally (to a subset of records with a high disclosure risk) rather than globally (e.g., VanWey et al., 2005; Zimmerman et al., 2007). These approaches are supported by the NRC (2007b), which recommends that data stewards should develop licensing agreements to provide increased access to linked social-spatial datasets that include confidential information. Bertino et al. (2008) recommend further that standards for geographical data security and advanced geographical data protection are now critical to develop. In addition, the work of Zandbergen (2008), which characterizes the capabilities of reverse geocoding (i.e., deriving an address from a position, rather than vice versa) using a range of different network analysis methods, offers a promising example of how research on this topic could make advances over the ten years.

The urgent need for work on privacy protections for locational data becomes clear when one considers that, despite efforts to ensure the privacy of personal information (e.g., protection of social security, credit card, driver's license numbers, etc.), no explicit regulation currently protects locational privacy in the U.S. It is important to note that data availability and concerns about privacy vary by culture. For example, in the U.S. Google has responded to privacy concerns by testing and gradually implementing a face-blurring algorithm for its Street View service (Figure 11.3), but Canada has enacted an identity protection law, requiring Google to blur not only faces, but also license plates. Bitouk et al. (2008) have developed software that goes beyond the simple blurring of a face in a photograph to "swapping" the features in a face with random features from a library of faces (such as a



Remote sensing, ground-based sensors, acoustic remote sensing

Title

NATIONAL ACADEMIES

Discrete global grids of Sahr, Kimerling, et al.