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First Responder Big Data Analytics: Roadmap Recommendations

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This report presents the results of research conducted under task #43134233-AA, FRG Big Data Analytics of SEDI's Fiscal Year 2013. The task presents a high-level environmental scan of multiple data and tool categories in use or requested by the first responder community. The categorization of data sources include: (1) news, blog, and website content; (2) social media (e.g., Twitter, Facebook); (3) tagging systems (e.g., radio frequency identification, bar codes); (4) consumer devices; (5) remote sensing and geo-sensor systems; and (6) sensor web and mesh networks. Emergency response teams, realizing the power and immediacy of these non-traditional data sources and near real-time communication, see the potential in leveraging these tools to improve disaster detection, rapid response, public awareness and communication, and disaster survivability and recovery. This report examines gaps in capabilities as well as ongoing industry and academic efforts to fill them. A clear gap is integrating data from the types identified using a "big data" architecture to show proof-of-concept utility.

The results presented in this report do not necessarily reflect official DHS opinion or policy.

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Abstract

The Department of Homeland Security (DHS) mission, as well as the hands-on work of the first responder community, presents unique challenges. One unique aspect of the first responder mission is its need to respond at the local level in an ongoing manner with the occasional need to respond to large scale crises that involve state, regional, and national resources. This requirement requires response capabilities to analyze and process big data at the local level and feed it up to agencies at a national level, if necessary. To gain awareness of current forward leaning practices, this report includes case studies of the New York City Office of Emergency Management and the American Red Cross Digital Operations Center to see how these two organizations currently leverage online and social media sources and big data analytics to manage response efforts and communicate with the public during events. It also includes an evaluation of key research and publications that address the emergence, use, and future of big data analytics as it applies to first responder missions, and a survey of the technical landscape to achieve big data analytics in support of those missions. Finally, this report identifies critical gaps in data, industry access, standards, and research, and makes recommendations for DHS Science and Technology leadership that would provide impetus for progress. These recommendations include:

(1) funding research on the Social Internet of Things relevant to healthcare, energy, and transportation;
(2) engaging on standards development for first responder-related big data;
(3) providing researchers access to various big data sets and industry tools, and requiring researcher engagement with first responders through exercises; and
(4) prototyping industry local to national first responder-related big data systems for daily and crisis-use cases.

Key Words

- Bar codes
- Big data analytics
- Disaster response
- Emergency response
- Internet of Things
- Online and social media sources
- Radio Frequency Identification (RFID)
- Smart consumer devices
- Social Internet of Things

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Executive Summary

This report intends to provide Department of Homeland Security (DHS) Science and Technology Directorate (S&T) decision-makers with an understanding of the utility and use of big data in support of first responder missions. The information and recommendations provided will support the selection of research programs directed at providing actionable information to emergency managers and first responders in a timeframe that enables them to be proactive. This report includes an evaluation of key research and publications that address the emergence, use, and future of big data analytics as it applies to first responder missions, as well as a survey of the technical landscape to achieve big data analytics in support of those missions.

1. What are the areas where DHS S&T can break new ground, not just incrementally improve on the work of others?

Prototyping tools that address local to national response to disasters would greatly help identify current gaps in industry tools for the first responder mission. Existing industry gaps include:

- Multisource, sentiment analysis including aliasing, opinion holder, and sentiment target in multiple languages;
- Twitter, language agnostic demographic analyses, especially analysis of location, native language, and deception;
- Multisource narrative analysis in multiple languages;
- Multisource, language agnostic meme detection;
- Multisource, language agnostic social network analysis;
- Multisource, tunable methodologies for alerting users (e.g., phase change, event detection);
- Integration of analytic results in near real time with the ability to explore the data; and
- Course of action analyses.

The above gaps are being addressed by research programs, however, the following recommendations represent a place to break new ground.

Recommendation: It would be valuable if DHS S&T funded research on the Social Internet of Things, which is relevant to DHS' healthcare, energy, and transportation missions. DHS-related missions in this space fall under Presidential Policy Directive 21 (PPD-21), which advances a national policy to strengthen and maintain 16 secure, functioning, and resilient critical infrastructure sectors. These sectors include emergency services, transportation, healthcare, and public health. Falling within these domains are traffic control, monitoring and controlling the spread of infectious disease, and disaster response. Social Internet of Things can, for example, help determine the crisis impact area spatially, and address victim needs, resource and victim tracking, public sentiment, and communications with the public. How can DHS S&T contribute to the improvement of interoperability through introduction of practices or standards?

Recommendation: It would be valuable if DHS S&T engaged in standards development for first responder-related big data by requiring research and development efforts to be cognizant of standards efforts and join relevant groups. This would allow researchers to prototype capabilities

that would help with standards development and could more easily be transitioned. The World Wide Web Consortium (W3C) is one group focused on social media standards.

2. What "amazing outcome" should DHS S&T strive to achieve in the near future?

These recommendations may sound modest, but connecting researchers, industry, and first responders ensures the usefulness of research contributions and the ability to transition to industry, providing first responders with rapid access to the best tools to support their missions.

Recommendation: It would be valuable if DHS S&T provided researchers access to various big data sets and industry tools, and required engagement with first responders through exercises and partnerships as part of the grant process. This would allow researchers to work with data at scale, understand existing industry solutions, fill industry gaps, and test their research in relevant environments—all while engaging with first responders. As an example, Innovaccer appears to be addressing researcher data and standard analytic needs.

Recommendation: It would be valuable if DHS S&T prototyped local to national first responder-related big data systems for daily and crisis use cases. During daily operations, the local level would use big data analytic tools and push very limited information to the regional and national level, but during a crisis, the flow of information would increase to support the additional agencies responding. HootSuite, Marketwired's Sysomos, and Salesforce's Radian6 maintain such capabilities today, as illustrated by the New York City Office of Emergency Management (NYC OEM) using HootSuite and the American Red Cross Digital Operations Center (DigiDOC) using Radian6. NYC OEM and Red Cross are not using them to support a local to national capability, however. Big data management requires end-to-end solutions so that information can be rapidly provided to first responders at all levels in near real time to support decisions, especially during a crisis.

Of utmost importance is the notion that if the first responder community is to use big data in the management of crisis scenarios, both at the command and control level and "on the ground," it needs technological solutions that make sense of the vast amounts of data collected online and by sensors from disparate sources.

The big data analytics approaches reviewed included: 1) Relational databases, 2) Massively Parallel Processing (MPP) databases, 3) NoSQL (not only Structured Query Language) Databases, 4) Semantic Databases, and 5) Analytic Cloud Computing. Analytic Cloud Computing meets many of the criteria needed to bring these data sources together. Analytic Cloud Computing is scalable (nearly linear), agile (easy to add new types of data and new analytics), affordable (there are many open source options using commodity hardware with built-in fault tolerance), able to work on all data, features row or cell level security, and provides some access to support. The challenges include a limited number of supporting vendors and limited experience base, latency in starting up a new job, and ensuring that the solution addresses the problem at hand.

1. First Responder Data Needs: Online and Social Media Sources

The Federal Emergency Management Agency (FEMA) wrote in its 2013 National Preparedness report that during and immediately following Hurricane Sandy, "users sent more than 20 million Sandy-related "tweets," despite the loss of cell phone service during the peak of the storm."1

Ellison and Boyd (2013), define social media as a "communication platform in which participants 1) have uniquely identifiable profiles that consist of user-supplied content, content provided by other users, and/or system-level data; 2) can publicly articulate connections that can be viewed and traversed by others; and 3) can consume, produce, and/or interact with streams of user-generated content provided by their connections on the site."[2] As shown in Figure 1, online and social media sources can be categorized into groups that include: microblogs, social networking sites, content communities, commenting sites, chat, and collaborative projects.

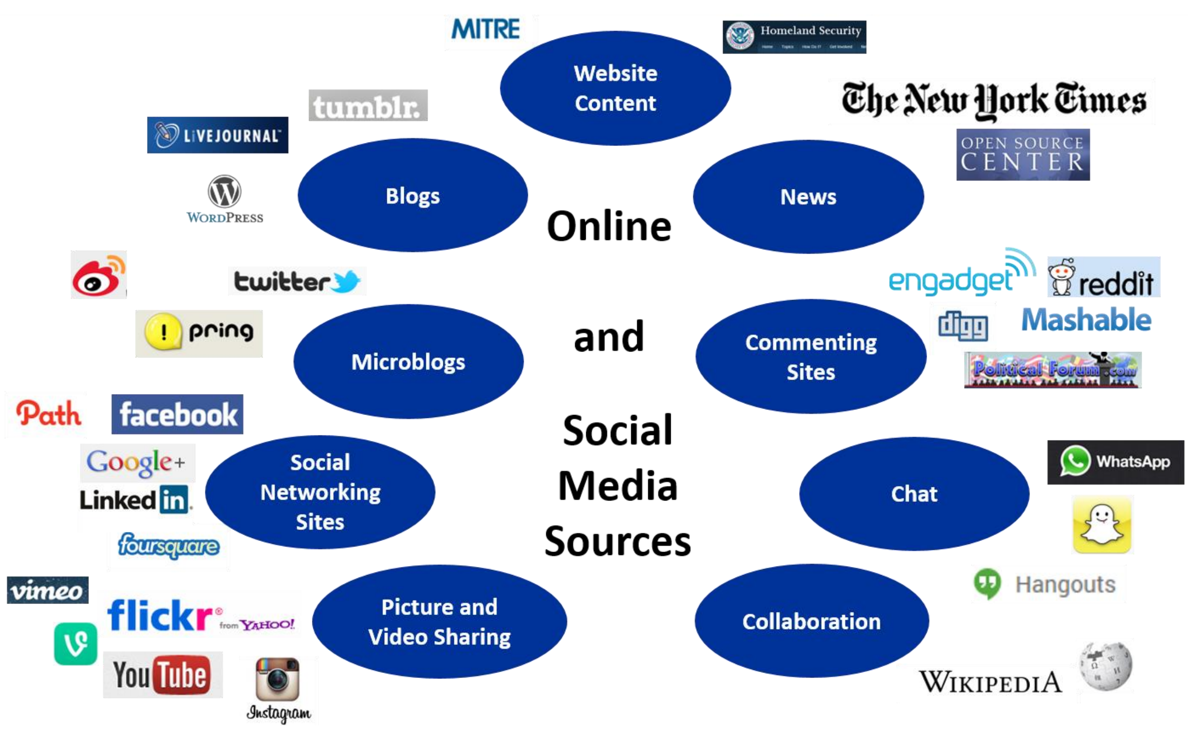

Figure 1. The social media landscape

[1] Federal Emergency Management Agency (2013). 2013 National Preparedness Fact Sheet. http://www.fema.gov/media-library/assets/documents/32695.

[2] Ellison, N. and D. Boyd (2013). "Sociality through Social Network Sites" in The Oxford Handbook of Internet Studies (Ed. William H. Dutton). Oxford: Oxford University.

First responders use tools such as Facebook, Flickr, Instagram, Twitter, and Ushahidi to assist with emergency events including the 2009 California wildfires, 2010 Haiti earthquake, 2011 Japan earthquake and tsunami, 2012 Hurricane Sandy, and 2013 Boston Marathon bombings.[3] Figure 2 shows the growth in use of non-traditional communication sources in emergency response, and highlights the expanding variety of sources used.

During the 2009 California wildfires, observers used MyMaps to share mash-ups of areas still besieged by fire over the course of the emergency.[4] In the 2010 Haiti earthquake, a substantial increase in the use of non-traditional data sources occurred. Relief workers posted photos of the disaster online and the American Red Cross conducted a hugely successful relief fund campaign on Twitter.[5] In fact, within 48 hours of the event, the Red Cross received $8M via text messages.[6] Haiti rescue workers, U.S. Southern Command, and the U.S. Coast Guard, among others, used the social media platform Ushahidi to broadcast logistics information and calls for help, and volunteers created maps for first responders using Ushahidi. Facebook hosted a Haiti Earthquake Relief page that received 43,000 'Likes.'[7]

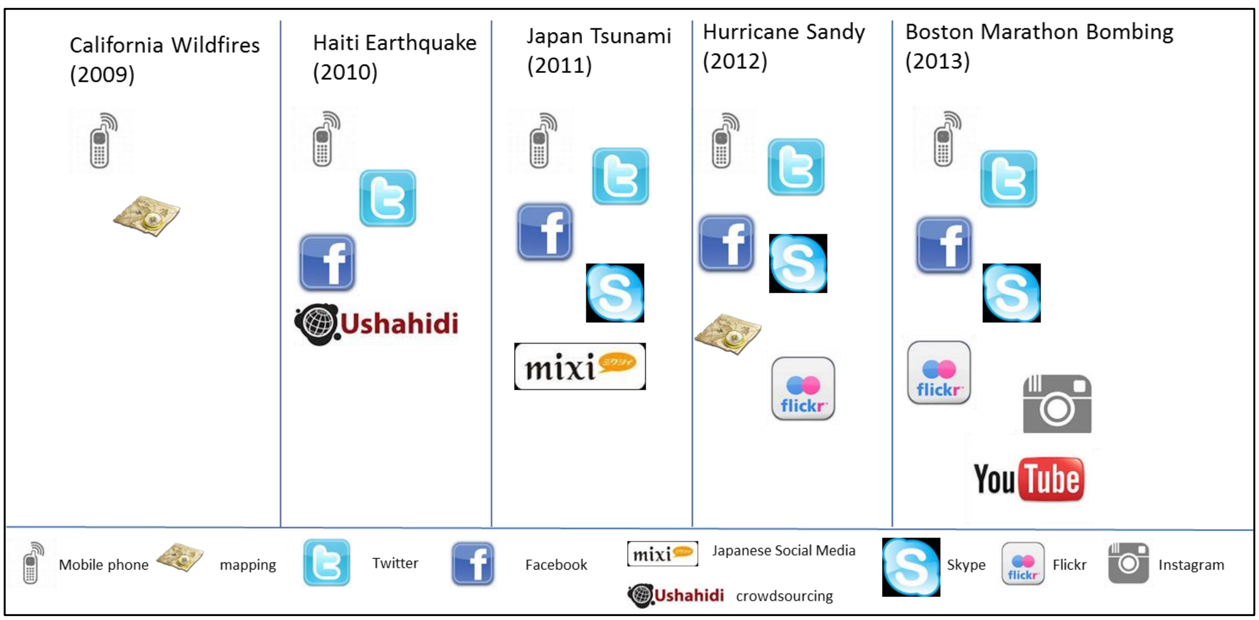

Figure 2. Data sources used in recent emergency disaster response

[3] Kane, G.C. (2013). What can managers learn about social media from the Boston Marathon bombing? MIT Sloan Management Review, (blog) (2013, April 25); United States Department of Homeland Security. Science and Technology Directorate, Virtual Social Media Working Group. (2013). Lessons Learned: Social Media and Hurricane Sandy, June 2013.

[4] Burkett, B. C. (2011, December). Using mobile mapping for wildfire mitigation in Los Angeles County. (thesis). University of Southern California.

[5] Trends in social media: use in natural disasters. (n.d.) My Secure Cyberspace, Carnegie-Mellon University.

[6] Morgan, J. (2010, January 15). Twitter and Facebook users respond to Haiti crisis. BBC News.

[7] "Haiti Earthquake Relief". Facebook.

During the 2011 tsunami in Japan, mobile phone lines jammed and citizens turned to Twitter, Facebook, Skype, and local Japanese social networks to communicate with family and loved ones.[8] In the wake of Hurricane Sandy in 2012, Disaster Tech Lab, a non-profit organization headquartered in Ireland, worked with Crisis Commons to gather data and mapping requests to create the "Hurricane Sandy Communications Map."[9] Finally, in the aftermath of the 2013 Boston Marathon bombings, police asked citizens to refrain from tweeting the locations of law enforcement officers, to use short message service (SMS) to request help, and assist with suspect identification based on photos posted on Facebook.

Table 1 shows a variety of social media tools and capabilities (black X's) juxtaposed with the ways in which agencies specifically used them (red X's) for Hurricane Sandy in 2012. Figure 2 illustrates a shift in the way public safety agencies use social media: government agencies relied upon tools not yet used in 2011 during Sandy to engage multiple stakeholders across several channels, often for several purposes. As users familiarize themselves with capabilities and use them rapidly, more features are likely to be incorporated into emergency mitigation use. As technology and social media platforms continue to evolve, and responder use grows, gaps in capabilities emerge. Table 2 outlines first responder requirements, existing solutions, gaps in capabilities, and recommendations for further research. Next, a deeper look at the data and tools used by New York City's (NYC) Office of Emergency Management (OEM) and the American Red Cross will be discussed, and their efforts to harness online and social media to respond to emergencies.

Tool	Info-Sharing (one-way)		Info-Sharing (two-way)		Situational Awareness		Rumor Control		Reconnection		Decision-Making		Donations		Volunteer Mgmt.	
Twitter	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
Facebook	X	X	X	X	X	X	X	X	X	X		X		X	X	X
SMS	X												X	X		
Photo-Sharing	X	X	X	X	X	X		X			X	X				
Video-Sharing	X	X	X	X	X	X		X			X	X				
Websites	X	X		X			X	X		X				X		X
Mapping			X		X	X		X		X	X	X				X

Table 1. Emergency responder use of social media tools during Hurricane Sandy[10]

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[8] Gao, H. et al. (2011). Harnessing the crowdsourcing power of social media for disaster relief. IEEE Intelligent Systems. 26(3) pp. 10-14.

[9] United States Department of Homeland Security. Science and Technology Directorate, Virtual Social Media Working Group. (2013). Lessons Learned: Social Media and Hurricane Sandy, June 2013., p. 26.

[10] United States Department of Homeland Security. Science and Technology Directorate, Virtual Social Media Working Group. (2013). Lessons Learned: Social Media and Hurricane Sandy, June 2013., p.7.

First Responder Requirements	Existing Solutions	Gaps Identified	Research Recommendations
Robust devices with long-lasting battery power		Need for longer battery life and/or more energy efficient devices	Research needed into longer and cost-effective battery life solutions, alternate power sources, and energy efficient devices
Expanded bandwidth for high-consumption media[11]	Federal Spectrum	Need for greater bandwidth	Increased bandwidth or secure wireless communications that do not require connection to the Internet
Centralized aggregated data for content monitoring (for situational awareness and/or "rumor control")	DataBridge, iRevolution.net	Tools in the commercial space which can do this	
Cost-effective solutions for equipment, software, upgrades, and training in their use	Some emergency response (ER) communities able to partner with corporations or purchase equipment through grants	Uneven distribution of equipment; not everyone who needs a device has one	
Ability to match resources with needs for aid			Identification of funding vehicles; potential for corporate partnerships; determination of which ER communities need which tools
Portable devices	Tablets and smartphones in use by ER communities	Need for more tablets and smartphones, tracking devices	
Knowledge of how to use tools	Professional literature; ad hoc instruction, learning "on the job"	Need for consistent instruction in adoption of new equipment and protocols	
Secure connection to social media	Twitter https://option ; various security and account settings on tools such as Facebook		Secure aggregation of tools in one dashboard No
Increased interoperability for automated and simultaneous data updates across social media network sites, video sharing sites, hosted services, web applications, and mash-up tools		Proprietary tools cannot interoperate	
Coordination across information channels and multi-way information sharing	Commercial tools which allow message scheduling (e.g., HootSuite, NetVibes, Radian6, SocialMention, SocialOomph)	No established best professional practices for effective messaging campaigns	

[11] United States Department of Homeland Security. Science and Technology Directorate, Virtual Social Media Working Group (2012). Next Steps: Social Media for Emergency Response. p.4.

First Responder Requirements	Existing Solutions	Gaps Identified	Research Recommendations
Ability to target specific demographics and geographic points	Multiple tools offer detection of latitude and longitude coordinates and/or geoinferencing to detect tweet origin; Twitter "targeted tweets"	Few ways to target demographic and geographic audiences	Research in big data mining for rapid identification of demographic profile and geographic origin
Social media protocols across user communities, including awareness of them and agreed-upon application of protocols[12]	NYC OEM, Massachusetts Emergency Management Agency (MEMA), and other agencies have Facebook pages and Twitter accounts	No published best practices for emergency organization to optimize use of social media vehicles	
Ability to monitor messaging sentiment (e.g., Twitter, Facebook)	Numerous tools exist including Radian6, Sentimedir, Sysomos, Tartan	No mature sentiment analysis capability	Further research in sentiment analysis
Ability to publish messages simultaneously across platforms	Numerous tools exist including HootSuite, NetVibes, Radian6, SocialMention, SocialOomph	No less expensive options	
Ability to target specific demographics or geographic points with searching or messaging	Geofeedia, HootSuite, Nuvi	Data needs to be tagged with latitude and longitude coordinates	Further research in geoinferencing of data not marked with latitude and longitude coordinates
Weather data mash-ups[13]	FEMA Geoplatform Environmental Systems Research Institute (ESRI), Geofeedia, MyMap, Ushahidi	No format optimization to enable use on many types of devices	
Design of metrics for system evaluation and improvement[14]		Need to establish performance metrics to feed system improvement	

Table 2. First responder requirements and gaps in social analytics

[12] United States Department of Homeland Security. Science and Technology Directorate, Virtual Social Media Working Group. (2013). Lessons Learned: Social Media and Hurricane Sandy, June 2013. p.8.

[13] Frankel, Mark, Manager. Emerging Technologies at New York City Office of Emergency Management, (telephone interview). October 18 2013.

[14] Gao, H. et al. (2011). Harnessing the crowdsourcing power of social media for disaster relief. *IEEE Intelligent Systems*. 26(3) p.14.

1.1. Case Study 1: New York City Office of Emergency Management

The NYC OEM was formed in 1996 to plan and prepare the city for emergencies, to coordinate emergency response and recovery, and to educate the public to better prepare for emergencies. During a major incident, the NYC OEM's Emergency Operations Center (EOC) becomes the information and decision-making hub and the department sends field responders to the scene to facilitate inter-agency communication, resource requests, and compliance with incident command protocol. NYC OEM responds primarily to building collapse/explosions, power outages, extreme temperatures, fire, flooding, coastal storms and hurricanes, disease outbreaks, and biological events.

The NYC OEM operates a 24-hour Watch Command team that monitors emergency activity throughout the city. Watch Command monitors radio, computer, and 911 dispatches from the New York Police Department and Fire Department of New York as well as information feeds from regional EOCs, the Federal Aviation Administration, Mass Transit Authority, the Port Authority, and many other federal, state, and local agencies for incidents that affect the city.

Watch Command uses Notify NYC[15] as a means to communicate localized emergency information quickly to city residents. There are five notifications types: emergency alerts, significant event notifications, public health notifications, public school closing/delay advisories, and unscheduled parking rules suspensions. The program started as a pilot in December 2007 after a series of local incidents including tornadoes, a steam pipe explosion, and crane collapses; it went citywide May 2009. As an opt-in program, those registering provide basic contact and location information, allowing messages to be tailored to their area of interest and delivered by email, phone, or SMS/text. Notify NYC has approximately 195,000 registered users and has sent out thousands of notifications about local emergencies since its inception.

NYC OEM turns to social media to augment traditional situational awareness methods. They report that Twitter is useful for early warning of events and for notifications. For example, NYC OEM used Twitter to verify the evacuation of a terminal at a NYC airport, despite the denials of airport personnel. Twitter also provides early warnings of traffic jams on major thoroughfares such as the Brooklyn Bridge. NYC OEM reports that the ability to do anomaly detection and sentiment analysis using online and social media would also be valuable.

According to NYC OEM, two million NYC social media geocoded tweets exist. Figure 3 depicts charts showing the number of tweets available from NYC during a three-month period from Topsy, a social media analytics tool.

[15] New York City Office of Emergency Management. Notify NYC. https://a858-nycnotify.nyc.gov/notifynyc/.

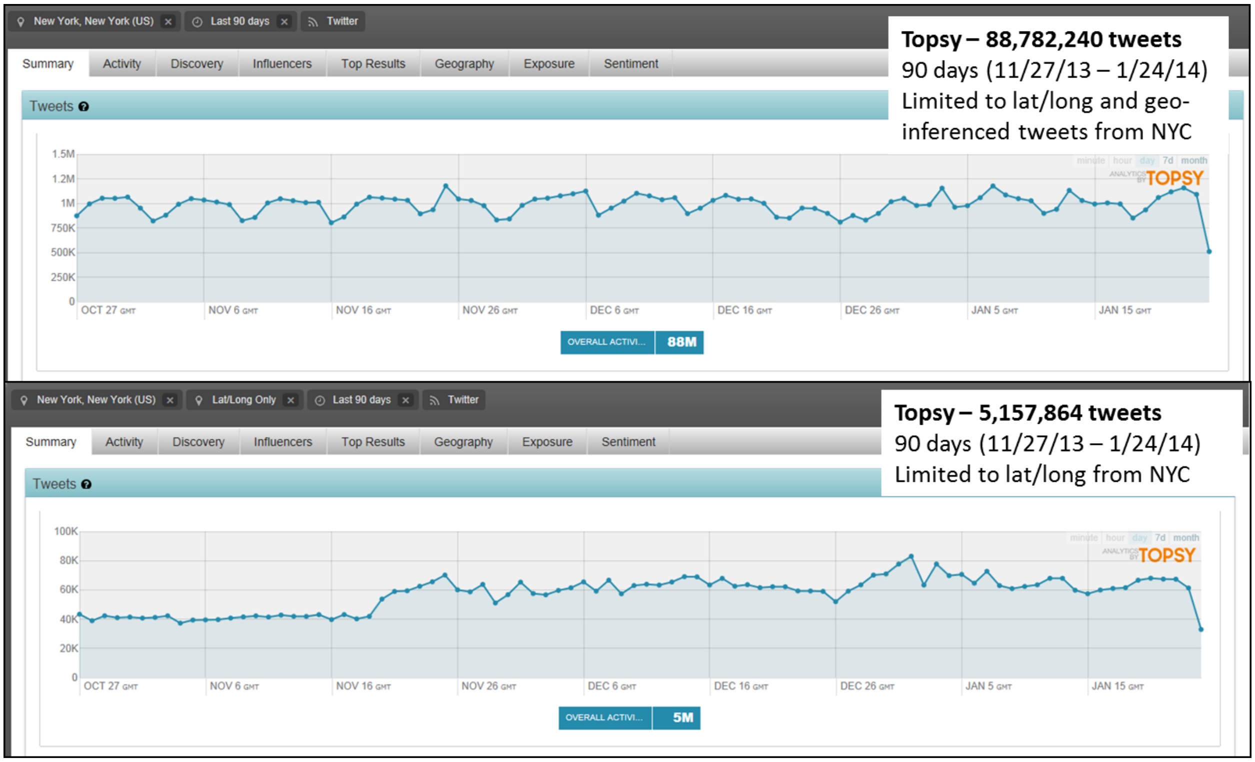

Figure 3. Three months of NYC tweets showing geoinferencing (top) and latitude/longitude (bottom)

HootSuite is currently NYC OEM's social media data provider of choice. (See Section 2.9 for more information on HootSuite.) During major events, such as ice storms and the Macy's Thanksgiving Day Parade, NYC OEM finds HootSuite useful in gathering ground truth information quickly. For example, the department quickly determined the severity of a fire at the Herald Square Macy's department store in the fall of 2013 by accessing photos and video on Instagram and Twitter via the HootSuite platform. The goal is not to respond to all posts, but to aggregate trends and address them.

In building its social media capacity, NYC OEM explored several data providers and tools including the Twitter fire hose, TweetDeck, and Ushahidi. In addition to HootSuite, NYC OEM uses Microsoft tools and accesses Palantir for DataBridge.

NYC OEM found the quantity of information available via the Twitter fire hose to be too unwieldy. Using Gnip as the data provider, the Twitter feed contained a 10 percent pseudorandom sample of all public tweets published each day and was captured in real time via a streaming HTTP connection at a rate of approximately 500 tweets per second.

NYC OEM abandoned TweetDeck in March 2012 after a bug gave some TweetDeck users access to others' accounts.

During Hurricane Irene, NYC OEM used Ushahidi, a crowdsourcing website developed to map incident reports, but found it challenging due to high levels of spam and substantial human-in-the-loop requirements. It also lacked social media guidelines and spatial quality.

Microsoft is part of a technology agreement with NYC to consolidate the city's dozens of individual license agreements into a single agreement and provide more than 100,000 city employees with Internet-based cloud computing services.[16] Microsoft is also piloting a data integration dashboard based on its CityNext platform. This dashboard pulls together data points from news websites, traffic, and transportation conditions, and comingles them with internal data collected about local incidents. The dashboard brings attention to relationships between disparate datasets. By centralizing many sources of data and analyzing them against a set of keywords, for instance, the dashboard visually alerts operators of a potentially developing situation. This platform is also used to automate daily situational awareness reports. The dashboard covers 80 percent of the data sources used to build these daily reports; a process that previously took two hours now only takes 25 minutes.

The Mayor's Office of Data Analytics (MODA), the Department of Information Technology and Telecommunications (DoITT), and NYC Digital work together to collect, analyze, and share NYC data; create a better city supported by data-based decision making; and promote public use of city data. NYC OEM uses data from NYC OpenData to develop products such as the 2013 Hurricane Sandy evacuation zones as well as consumes it as part of its emergency preparedness mission.[17] Agencies routinely collect data on buildings, streets, infrastructure, businesses, and other entities within the city, including permits, licenses, crime-related data, and 311 complaints. MODA centralizes city data, uniting previously disconnected pieces of information from various agencies, and pairs it with New York State, federal, and other open data to create a comprehensive city-wide data platform that serves as a record of city activity and a foundation for NYC OpenData.

NYC OpenData is a data repository of public data generated by various New York City agencies and other city organizations. The NYC Open Data catalog[18] offers access to a repository of more than 1,100 government-produced, machine-readable data sets in 10 categories including business, transportation, education, public safety, housing, and development. The data can be downloaded and exported in eight different formats and used by anyone to conduct research or create applications.

NYC OpenData is hosted by Socrata (socrata.com), a Seattle-based company that provides data discovery services targeting non-technical Internet users who want to view and share government, healthcare, energy, education, or environment data (Figure 4). Socrata hosts hundreds of data sets in a cloud for states, cities, and organizations foreign and domestic (e.g., Baltimore, Maryland, New Orleans, Louisiana, and Somerville, Massachusetts). It issues its products under a proprietary, closed, and exclusive license. In September 2013, Socrata announced a strategic investment and technology development agreement with In-Q-Tel (IQT), an independent strategic investment firm that identifies innovative technology solutions to

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[16] Office of the Mayor of the City of New York. (2010). Mayor Bloomberg and Microsoft CEO Steve Ballmer announce first of its kind partnership to keep New York City at the cutting edge of technological innovation while saving taxpayer dollars.

[17] Office of the Mayor of the City of New York. (2013). Deputy Mayor Holloway and Office of Emergency Management Commissioner Bruno announce final updated hurricane evacuation zones. (press release).

[18] NYC OpenData Catalog. https://nycopendata.socrata.com/dataset/NYC-OpenData-Catalog/tdsx-cvye.

support the missions of the U.S. Intelligence Community. Under the agreement, IQT will make a strategic investment in Socrata and the two entities will work together to further develop Socrata's data platform for internal business analysts in data-rich organizations. Users of Socrata's technologies can transform raw data from multiple sources into more sophisticated and useful resources, such as apps, reports, maps, visualizations, dashboards, and application programming interfaces (APIs).

NYC OEM uses NYC OpenData for planning and certain second-order effects. For example, in the aftermath of a fire, locating critical services (e.g., ambulances, paramedics) can expedite access to them in time-sensitive situations.

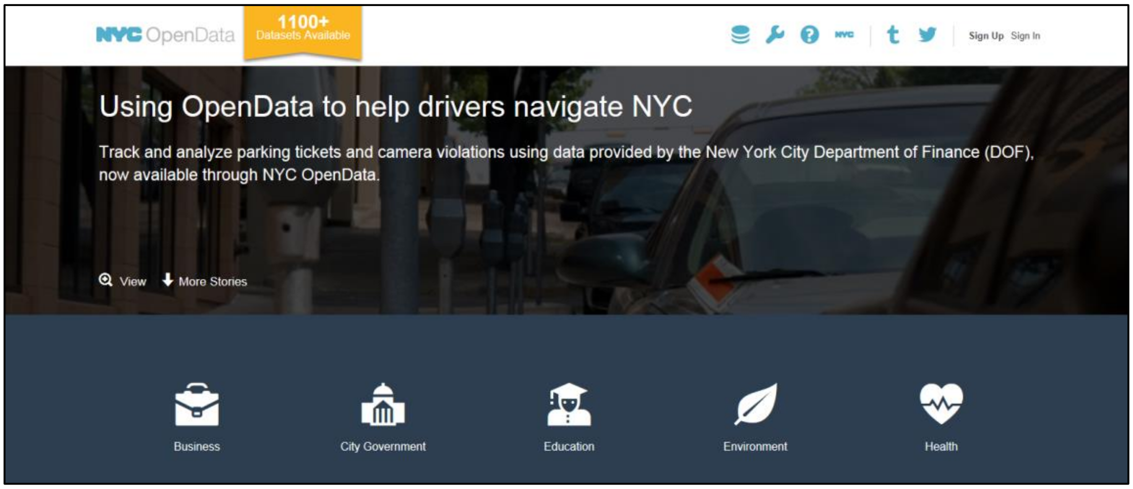

Figure 4. New York Open Data has more than 1,100 data sets in 10 categories

DoITT and MODA work closely together to use DataBridge, an internal computing environment, to reduce safety risk in the city, deliver daily services more efficiently, and enforce laws more effectively.[19] Built from multiple technologies, DataBridge combines a data warehouse with a suite of SAS analytic tools and data fusion software from Palantir. DataBridge unites formerly stovepiped information onto a single platform, allowing for cross-departmental data analysis from 40 different agencies. The DataBridge data ingestion challenge is described by New York City Mayor's Office 911 as a comprehensive operational review of the existing 911 call-taking process,[20] which looked at the possibility of obtaining various data sets to generate mash-ups and to measure and improve end-to-end response time. Analysts can patch in and perform analysis on their own agency's data, or run one agency's data to predict an outcome of another agency's regulatory area. In addition to locating data in one place, MODA uses a geocoding system that allows the team to associate geo-identifiers with addresses and other geographic information. By applying analytics, MODA finds previously unknown patterns and relationships that lead to better decisions and resource allocation.

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[19] NYC OpenData. Featured Datasets. https://nycopendata.socrata.com/data?cat=city government.

[20] Talbot, L. (2013). Lauren Talbot, Mayor's Office of Analytics, DG'13. (video). Presented at DataGotham, New York, New York.

NYC OEM currently engages daily with citizens online, mostly for education purposes. The department uses Twitter, Facebook, YouTube, Instagram, Tumblr, and LinkedIn (business continuity), and would like to add Vine in the near future. Currently, all engagement occurs in English, although NYC OEM recognizes the need to add other languages. When engaging with social media, messages may be posted, pending approval from the appropriate parties.

1.2. Case Study 2: American Red Cross Digital Operations Center

Responding to more than 200 disasters on an average day, the American Red Cross turned to new technologies to augment its traditional disaster response efforts. Since the early 1990s, the American Red Cross has used mapping and Geographical Information Systems (GIS) technology to visualize key spatial trends within communities, such as socio-economic dynamics or areas most affected by frequent flooding (Figure 5). In the aftermath of Hurricane Sandy, the American Red Cross used maps to summarize damage assessment survey results from more than 90,000 respondents.[21] Now the organization uses social media tools to collect and disseminate information, engage with the public, monitor trends, and fundraise. With a goal of responding to all messaging, the American Red Cross incorporates social engagement into all of its activities.

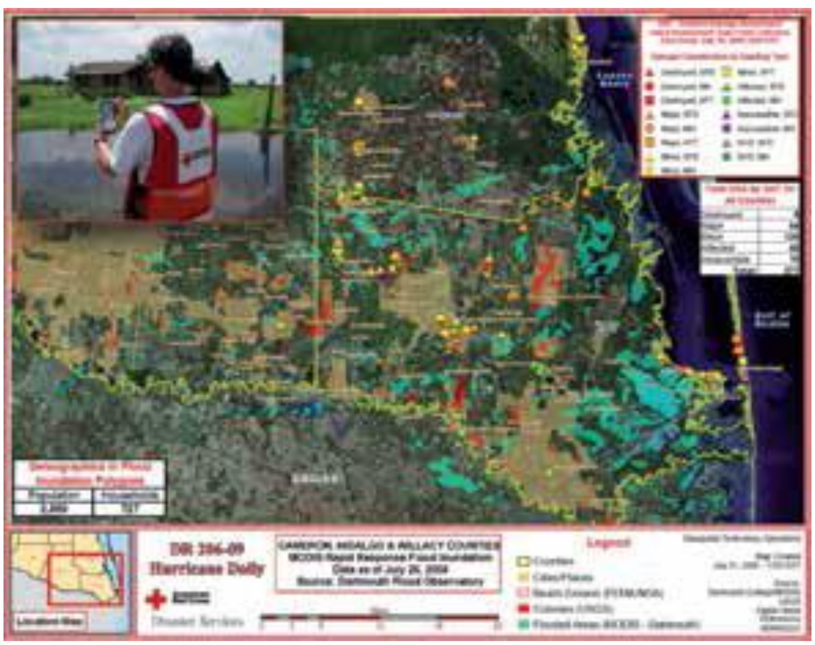

Figure 5. American Red Cross mapping tool

The Red Cross considers the 2010 Haiti earthquake as a turning point for the organization. According to an August 2010 *Washington Post* article:

[21] World Disasters Report: Focus on Technology and the Future of Humanitarian Action. (2013). Geneva, Switzerland: International Federation of Red Cross and Red Crescent Societies. http://www.ifrc.org/PageFiles/134658/WDR%202013%20complete.pdf.

"After the earthquake in Haiti, the American Red Cross began receiving tweets from people trapped under collapsed buildings. With much of the country lacking cellphone service, people sought help however they could. But the Red Cross, like many other disaster-relief organizations and emergency responders, didn't have a good way to handle those pleas. Relief workers went through messages manually, contacting search-and-rescue teams, trying to pinpoint locations."[22]

The Red Cross believes in "the need to trust citizens to report on what is happening right in front of them, and that these reports are every bit as reliable as reports by experts, and a whole lot quicker because people have mobile phones now. Pulling in information from citizens and mapping out the situation visually can be a huge resource for those making decisions about response."[23] The Red Cross uses social media for situational awareness and then corroborates those findings with the situation on the ground. Misinformation contained in social media serves as the biggest obstacle. The Red Cross assesses trust through individual conversations and conversations with multiple people that can be aggregated. Possible research directions include applying social media influence metrics to users in disaster zones, as well as pre-screening local volunteers who could be activated if disaster strikes their regions.

More than 4,000 tweets reference the American Red Cross on an average day; this number increases tenfold when disaster strikes.[24] The Red Cross looks at surges in tweet mentions to gauge engagement on small and large scale disasters. According to a 2010 American Red Cross survey, Americans consider social media, email, and web sites as potential alternatives to dialing 911 in an emergency. In fact, 74 percent of those surveyed expect a response from emergency personnel within one hour of posting a call for help on Facebook or Twitter.[25]

The Red Cross believes in collaboration and partners include humanitarian crisis mapping organizations such as the International Network of Crisis Mappers, CrisisCommons, Digital Humanitarian Network, and Ushahidi. Launched in 2009, the International Network of Crisis Mappers is "the largest and most active international community of experts, practitioners, policymakers, technologists, researchers, journalists, scholars, hackers, and skilled volunteers engaged at the intersection between humanitarian crises, technology, crowdsourcing, and crisis mapping."[26] CrisisCommons, also founded in 2009, connects three groups: crisis response organizations, volunteer technology organizations (e.g., OpenStreetMap), and private sector companies willing to donate resources. In the aftermath of the Haiti earthquake, CrisisCommons volunteers quickly created tools such as a Creole-to-English translator for use on first responder

[22] Kinzie, S. (2010, August 12). As people in distress turn to Twitter, the Red Cross seeks the most efficient ways to respond. The Washington Post. http://www.washingtonpost.com/wp-dyn/content/article/2010/08/11/AR2010081105707.html.

[23] Raftree, L. (2010, January 14). Ushahidi in Haiti: What's needed now. Wait… What? Bridging community development and technology. http://lindaraftree.com/2010/01/14/ushahidi-in-haiti-whats-needed-now/.

[24] World Disasters Report: Focus on Technology and the Future of Humanitarian Action. (2013). Geneva, Switzerland: International Federation of Red Cross and Red Crescent Societies. http://www.ifrc.org/PageFiles/134658/WDR%202013%20complete.pdf

[25] American Red Cross. (2010, August 9). Web users increasingly rely on social media to seek help in a disaster. (press release). http://newsroom.redcross.org/2010/08/09/press-release-web-users-increasingly-rely-on-social-media-to-seek-help-in-a-disaster/.

[26] The International Network of Crisis Mappers. http://crisismappers.net/.

phones and interactive street maps using phone-based location technology.[27] CrisisCommons and the Red Cross began working together during a series of tornadoes in Alabama in 2011.[28] DH Network was started in 2012 "to serve as the official interface between highly skilled volunteer networks and the humanitarian organizations that wish to use this latent surge capacity during disasters."[29] Ushahidi, a crowdsourcing website developed to map incident reports, was used in Haiti to map destruction post-earthquake.

In March 2012, the American Red Cross Digital Operations Center (DigiDOC) was launched and billed as the "first social media center devoted exclusively to humanitarian and disaster relief efforts"[30] sitting within a large humanitarian organization. The DigiDOC supports the American Red Cross by sourcing additional information from affected areas during emergencies to better serve those who need help, to spot trends and better anticipate the public's needs, and to connect people with the resources they need, such as food, water, shelter, or even emotional support.[31] Sponsored by Dell, the DigiDOC uses Salesforce's Radian6 software as a static dashboard to monitor and analyze social media in near real time.

Located in the Red Cross National Disaster Operations Coordination Center in Washington, D.C., the DigiDOC provides access to six customized screens that deliver relevant information and draws analysis from channels such as Twitter, Facebook, YouTube, Flickr, and blogs (Figure 6).[32] Additionally, the team managing the DigiDOC makes use of trained digital volunteers to help them sort through the data and engage with the public. In the future, the Red Cross would like to recruit, train, and manage digital volunteers at the local level. Technological capabilities provided include sentiment analysis, customized timelines, charts, word clouds, and heat maps. The team accesses social media data through the Radian6 dashboard. Currently, the data is separated from traditional data feeds but the Red Cross would like to integrate the two data types (Figure 7). Social data visualizations are updated and made available on a regular basis.

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[27] Kinzie, S. (2010, August 12). As people in distress turn to Twitter, the Red Cross seeks the most efficient ways to respond. The Washington Post. http://www.washingtonpost.com/wp-dyn/content/article/2010/08/11/AR2010081105707.html.

[28] Livingston, G. (2012, March 8). The Red Cross launches crisis data response and listening center. Frogloop. http://www.frogloop.com/care2blog/2012/3/8/the-red-cross-launches-crisis-data-response-and-listening-ce.html#ixzz2rumHpLS4.

[29] World Disasters Report: Focus on Technology and the Future of Humanitarian Action. (2013). Geneva, Switzerland: International Federation of Red Cross and Red Crescent Societies. http://www.ifrc.org/PageFiles/134658/WDR%202013%20complete.pdf.

[30] World Disasters Report: Focus on Technology and the Future of Humanitarian Action. (2013). Geneva, Switzerland: International Federation of Red Cross and Red Crescent Societies. http://www.ifrc.org/PageFiles/134658/WDR%202013%20complete.pdf.

[31] American Red Cross (2012, March 7). The American Red Cross and Dell Launch First-of-its-Kind Social Media Digital Operations Center for Humanitarian Relief. (press release). http://www.redcross.org/news/press-release/The-American-Red-Cross-and-Dell-Launch-First-Of-Its-Kind-Social-Media-Digital-Operations-Center-for-Humanitarian-Relief.

[32] Behind the scenes: The Digital Operations Center of the American Red Cross. (2012, April 17). iRevolution. http://irevolution.net/2012/04/17/red-cross-digital-ops/.

Figure 6. American Red Cross Digital Operations Center

Figure 7. American Red Cross Insights Dashboard

The DigiDOC team manages content creation for national social accounts, disseminates requests for help to digital volunteers, gathers the useful and relevant information for volunteer-constituent interactions, sets shifts for digital volunteers, gathers results of listening shifts, and reports on trends in online conversations and actionable information from social sites. DigiDOC also creates daily updated keyword sets for targeted listening and attempts to map keywords to specific disaster response services. For example, when a Twitter post states "I'm hungry," the Red Cross passes that information on to a decision maker (i.e., a relief worker or the local chapter), analyzes whether there is a trend of posts from the same area all referencing the same need, and engages with the individual poster, possibly directing them to other resources such as a local shelter. The group also looks for words such as *scared* and *stressed* and tasks volunteers trained in virtual mental health with consoling users.

Hurricane Sandy represents the largest disaster the DigiDOC team encountered. Thirty-one volunteers pulled more than 2.5 million posts for review and sent 2,386 responses via Radian6. The team sent 229 posts about needs in affected areas to the Red Cross Mass Care team whose job is to respond to immediate basic needs (food, clothing, shelter) of disaster victims.

Ultimately, 88 of those posts resulted in action on the ground. In addition, the team sent 19 daily DigiDOC briefs to Disaster Services and partners. The team responded to hundreds of additional posts on the American Red Cross Facebook page and message box. In areas with limited organizational reach, the DigiDOC team connected neighbors to each other and directed people to local resources. In its fundraising capacity, the Red Cross conducted a highly successful campaign on Twitter—within 48 hours of the event, the Red Cross received $8M via text messages.[33] Despite success, the Red Cross questions whether too much of its service delivery was driven solely by social media posts. Ideally, it would like to more easily cross-reference social media inputs with data on the situation, environment, and population needs obtained through other channels. The Red Cross continues to struggle with how to use social media appropriately in disaster scenarios.

Together with the DigiDOC, the Red Cross runs the newly revamped Digital Volunteer Program in which volunteers respond online to questions from the public, distribute critical information, and provide comfort and reassurance during emergencies. The program includes approximately 150 trained digital volunteers to date. The volunteers notify DigiDOC staff of online trends and situational information that can inform disaster-response efforts and engage with people affected by disasters, providing them with critical safety information, resources, and comforting messages.[34] At the height of social media influx, response time can take up to two days.

As shown in Figure 8, the American Red Cross provides apps for hurricanes, earthquakes, tornadoes, and wildfires to push information to the public before, during, and after emergencies or disasters. According to the 2013 *World Disasters Report*, "before and during Hurricane Sandy, users of the Hurricane App read preparedness information, tracked the storm's direction, checked American Red Cross shelter locations, and shared early warning messages via social media. Immediately after the storm made landfall, app users could search for open shelters and let loved ones know that they were safe. American Red Cross later added recovery information to the app, including locations of American Red Cross vehicles carrying food and water, locations of government-run disaster recovery centers, and open gas stations."[35]

[33] World Disasters Report: Focus on Technology and the Future of Humanitarian Action. (2013). Geneva, Switzerland: International Federation of Red Cross and Red Crescent Societies. http://www.ifrc.org/PageFiles/134658/WDR%202013%20complete.pdf.

[34] American Red Cross (2012, March 7). The American Red Cross and Dell launch first-of-its-kind social media digital operations center for humanitarian relief. (press release). http://www.redcross.org/news/press-release/The-American-Red-Cross-and-Dell-Launch-First-Of-Its-Kind-Social-Media-Digital-Operations-Center-for-Humanitarian-Relief.

[35] World Disasters Report: Focus on Technology and the Future of Humanitarian Action. (2013). Geneva, Switzerland: International Federation of Red Cross and Red Crescent Societies. http://www.ifrc.org/PageFiles/134658/WDR%202013%20complete.pdf.

Figure 8. American Red Cross Hurricane App

In partnership with the International Federation of Red Cross and Red Crescent Societies (IFRC) and regional National Societies, the American Red Cross piloted the use of mobile phones for cash transfers in East Africa in 2013. The program builds upon experiences after the 2010 Haiti earthquake when the Red Cross used SMS texts and remittance companies to deliver cash grants to thousands of earthquake victims.

The American Red Cross made significant progress using social media and other technology solutions during the three-year period between the Haiti earthquake and Hurricane Sandy. The DigiDOC directly supports the organization's mission by sourcing additional information from affected areas during emergencies to better serve those who need help, to spot trends and better anticipate the public's needs, and to connect people with the resources they need, such as food, water, shelter, or even emotional support. The Red Cross strives to engage its constituents wherever possible whether on social media platforms or via apps on mobile phones.

2. Industry Social Analytic Tools

This section provides an overview of industry online and social media analytic tools and discusses their uses. An effort was made to be comprehensive but this set of capabilities is not exhaustive.

2.1. Babel Street

Babel Street is a privately owned social media monitoring firm based in Reston, Virginia founded in 2009. Users create their own searches in either the basic or advanced search interface. The tool is typically deployed as a web application on the Amazon Web Services cloud although it may be instead deployed on a customer site as a separate instance. Babel reports that most users typically search only present day and do not use historical news or messaging, however, up to four years of the full Twitter fire hose is available. Sources are typically segmented by user accounts and users are matched with a source profile that best suits their needs. Babel Street is not a reseller of Twitter data, but the export of tweets can be managed through license purchase from Twitter and the data piped through Babel. Babel can provide a one percent random Twitter feed (Decahose) and index the data for users, if so desired. Babel Street has APIs which can handle large amounts of data for pulling streams.

Babel Street	**<u>Service Provided</u>** Suite of commercial social media analytic dashboard tools which includes geolocation and sentiment analysis capabilities to display social media in near real time. Tool is advertised as scalable to big data analysis. Licensing is offered at three tiers: the Bering ($1,250/mo for 100K tweets/mo (English only)), no application program interface (API) included; the Atlantic ($2,000/mo for 350K tweets/mo (five languages)), includes API; and the Pacific ($3,050/mo for 1M tweets/mo (+200 languages)), includes API plans

2.2. Crimson Hexagon

Crimson Hexagon's ForSight platform is a social media analytics tool that data mines blogs, Facebook, Instagram, Twitter (back to July 2010), and other social media sites to identify social engagement, key influencers, and trending discussion themes. Access includes 25 concurrent "Buzz Monitors" (open Boolean queries across sources that measure automated sentiment across sources based on location and other parameters) and 25 social account monitors (monitor engagement around an owned channel such as a specific Twitter handle or Facebook page). The tool is powered by a patented human-trained algorithm and scales across the body of social data to identify patterns to measure theme, sentiment, and nuanced categories. Data can be searched by location, source, user, and other parameters. Content in 11 languages is monitored but there is no translation capability within the tool.

Its live stream tool displays social media in near real time in three ways: through the streaming post list, the Live Map, and an hourly volume chart for the previous 24 hours. The geographic origins of posts and the relative influence of the posts' authors register visually on the Live Map, indicating where conversation is occurring. The post list streams posts and tweets gathered by keywords, along with authors' Klout scores. Crimson Hexagon also has a historical data library and adds a billion new posts every two days. Crimson Hexagon is not a reseller of Twitter data and acquires its data from Twitter Gnip. Geographical data collected is based on user-reported location, latitude, and longitude coordinates when provided. Message content is not used to identify location but is used to identify affinity groups and interests to measure affinity group size and volume of trend. In May 2014, Crimson Hexagon partnered with HootSuite Enterprise to provide Live Stream posts directly to HootSuite Enterprise.

Crimson Hexagon	**<u>Service Provided</u>** Boolean searchable social media analysis tool with sentiment analysis and geoanalytic capability. Tool is well reviewed for its Boolean search capabilities, accuracy in sentiment analysis, and trainability of its algorithm to increase reliability of results, visual appeal, and vendor's customer service. Basic Annual Package is $48,600/ year for two build users (may create collection strategies) and up to ten basic users (may perform sub-queries on collected sets) plus one year of historical data. The API is updated as features are added to the platform and may be used to export analyzed data (authors, blog posts, sentiment, trend, and volume). Raw data is not available for download into external tools for further manipulation. Training, support, and unlimited mentions are included. $58,600 package includes Twitter data back to 2008 plus all above API is $10K/year for unlimited calls or pulls from the API.

2.3. DataSift

DataSift collects more than 20 social media sources, including 100 percent of Twitter. Other data sources include Bitly, Facebook, Instagram, NewsCred, WordPress, YouTube, Tumblr, and LinkedIn. It also supports web scraping, and more than 40 analytics including natural language processing (NLP), sentiment, links, demographics-gender, topics, entity, and Klout. DataSift supports 140 languages using Google Translate. Geolocation uses tweets with latitude, longitude, and self- identified fields; users can define a 25-point polygon to specify an area to obtain data.

One unified API is available for historic, real-time data across all data types, and data can be pushed or pulled, raw or normalized JavaScript Object Notation (JSON). Time stamps are in GMT. A free developer trial is available at dsft.ly/dev-trial. In December 2013, DataSift announced the introduction of a new rules engine (VEDO) that features a tagging component for characterizing data. Enterprise level subscriptions start at $5,000 per month plus data costs (e.g., Twitter 10 cents/tweet; Weibo 20 cents/1,000 posts).

DataSift	**<u>Service provided</u>** The platform allows two simultaneous users plus a set of dashboard users who can perform sub-queries on results sets. Enterprise subscriptions from $5,000 to $38,000/month. Opinion Analysis platform costs $38,000/year and concurrently runs 25 different opinion analyses on one year of historical data. Depending on the subscription chosen, additional years of historical data may cost $10,000/year.

2.4. Geofeedia

Geofeedia is a geospatial social media monitoring company founded in 2011.[36] Using location data from geo-enabled smartphones and digital photos with imbedded coordinates, Geofeedia maps tweets, photos, and video posted from mobile devices within seconds. The company claims that the "Geofeedia's data set contains the hidden 70+ percent of data coming from locations compared to traditional tools that rely on certain words to be included in their data sets." [37]

Geofeedia tracks posts from Twitter, Instagram, YouTube, Flickr, and Picasa, placing them on Bing maps down to the city block level. Users can search for a specific address, city, zip code, or place name, and the results can be refined by zooming or scrolling to a specific location or by drawing a boundary around a location. Law enforcement and government entities comprise Geofeedia's main users.

Geofeedia	**<u>Service Provided</u>** Geofeedia tracks posts from Twitter, Instagram, YouTube, Flickr, and Picasa and places them on Bing maps down to the city block level. Offers a variety of social media monitoring packages. Pricing available on request.

2.5. Graphika

Graphika, formerly Morningside Atlas, has all the capabilities of Atlas plus several enhancements. Raw data in Excel format is now visualized in Graphika, allowing for improved exploratory capability for the user. The interface allows the user to drill into key conversations, power scores, and most used terms. Unlike Atlas, Graphika shows each segment of the map, that segment's fraction of the whole, the segment member size and power. A segment can have fewer members but more power, depending on who is in that segment. The user can drill into the overarching segments and look at the same metrics for sub-segments (fraction, member size, power). Graphika also visualizes several new parameters on which data can also be sorted: *Power Score*: a measure of the network density of a segment; *MScore:* a gauge of relative influence of a particular item (e.g., a Twitter account, photo) within a segment; and *Peakedness*: a measure of how quickly a concept jumps to the top of a conversation, how long it stays (displayed as a spiky or smooth graph alongside an account or content item. The user can also explore segments or sub-segments and see a lot of data formerly not available in Atlas. These include: key influencers (and an associated MScore); current conversation leaders; key websites; key content; key tweets, photos, and videos (and peak dates); and latest conversation terms.

[36] Geofeedia.com. http://geofeedia.com/.

[37] Geofeedia FAQ. http://geofeedia.com/resources/faq.

Graphika	**<u>Service Provided</u>** Visualization tools that allows users to drill down into uploaded social media messaging content to identify user connections, key topics, and affinity groups. Pricing available on request

2.6. Hashtagify.me

Hashtagify.me displays hashtags associated with topics of interest when users enter search terms or other hashtags of interest in a "map" depicting their search terms with linkages to the ten most closely related terms present in the same tweets. It uses the one percent of tweets that Twitter distributes for free. Languages of tweets are identified, as are percentages of occurrences of selected hashtags in those languages, and top influencers can be identified.

Hashtagify.me	**<u>Service Provided</u>** Site offers insight into trending hashtags, who is using them, popularity, and relationships to other hashtags in near real time with option for viewing in table format. Several plans for alerting capability; personal ($9.90/mo); business ($69/mo); and enterprise ($299/mo) for varying levels of services (e.g., trend analysis, top influencers/hashtag). All plans have 14-day free trial. Service offered through Hashtag.me partner Cybranding.

2.7 HootSuite

HootSuite is based in Vancouver, Canada and funded by venture capital. Hosted on the cloud, the HootSuite dashboard allows individuals and enterprise teams to manage their social media accounts. HootSuite has a three-tiered pricing model. The free version provides single users with five social profiles, basic reports, basic message scheduling, basic app integrators, and two rich site summary (RSS) feeds. The Pro version provides users with 50 social profiles, one report, advanced message scheduling, basic app integrators, unlimited RSS feeds, security, 100 archived messages, and technical support for two users. At the Enterprise level, up to 500,000 users can access unlimited social profiles and reports, in addition to advanced message scheduling, unlimited app integrators, advanced security, unlimited message archiving, technical support, and geo-targeting. The Pro version starts at $8.99/month. In January 2014, HootSuite acquired uberVU, which enhances HootSuite with sentiment and influence analysis capabilities. In May 2014, HootSuite partnered with Crimson Hexagon on an integration that provides HootSuite customers with posts from the Crimson Hexagon's ForSight platform streamed directly into HootSuite Enterprise version.

HootSuite	**<u>Service Provided</u>** The free version provides single users with five social profiles, basic reports, basic message scheduling, basic app integrators, and two RSS feeds.	**<u>Service Provided</u>** The Pro version provides users with 50 social profiles, one report, advanced message scheduling, basic app integrators, unlimited RSS feeds, security, 100 archived messages, and technical support for two users. Starting at $8.99/month.	**<u>Service Provided</u>** At the Enterprise level, up to 500,000 users can access unlimited social profiles and reports, in addition to advanced message scheduling, unlimited app integrators, advanced security, unlimited message archiving, technical support, and geo-targeting.

2.8 HumanGeo

HumanGeo is a New York, New York-based company founded in 2011. HumanGeo is primarily a services-based company, with a focus on using technology to meet the security and intelligence needs of clients. The company has a history of working with the federal government to map data and provide threat detection services based on social media data. HumanGeo's staff includes former technologists, operators, and analysts with experience working with the U.S. Special Operations Command and Intelligence Agencies, and providing real-time support during missions.

HumanGeo's Media Monitor service focuses on the use of location-based smart systems to zero in on locations from which discussion trends and news are emanating. It also maintains an historical database called the GeoIndex, a collection of more than 100 million geolocated buildings and places of interest worldwide, which helps put information into useful context. Media Monitor provides clients with information and public sentiment on topics of interest through monitoring of major social media data sources including Facebook, Twitter fire hose, Flickr, Reddit, and YouTube. The service also captures data from blogs and global social media sites generated from locations worldwide. Clients have the option of storing data on their own servers or servers operated and maintained by HumanGeo.

Human Geo **Media Monitor**	**<u>Service Provided</u>** Tool provides geolocation of news and discussion trends, maintaining a collection of more than 100M geolocated places of interest worldwide. Provides sentiment on major social media tool messaging from Facebook, Twitter, YouTube and others Pricing available on request

2.9 InTTENSITY

InTTENSITY's flagship social media product is its Social Media Command Center (SMCC), which is a web-based application that looks at 75 million social media sources on an ongoing basis, including the full Twitter fire hose, Facebook, and a variety of blog pages for sentiment detection. The SMCC was piloted in 2013 with the U.S. Department of State for use in sentiment detection of what citizens want and believe. Data is injected into a real-time ingestion and orchestration engine that allows the creation of distinct processing pipelines to filter and perform specific NLP-based enrichment of the social media data of interest. InTTensity does not archive the Twitter fire hose; users may save any tweets starting from their initial subscription.

InTTENSITY	**<u>Service Provided</u>** Suite of Commercial Off-the-Shelf (COTS) and software-as-a-service applications including the SMCC, a web-based application that looks at 75 million social media sources on an ongoing basis (last month only), including the full Twitter fire hose, Facebook, and a variety of blog pages Pricing is available on request

2.10 LM Wisdom

The Web Information Spread Data Operations Module, Lockheed Martin (LM) Wisdom, is a predictive analytics and big data technology tool manufactured by Lockheed Martin that monitors and analyzes open source intelligence data. The tool can ingest RSS feeds, blogs, video content, Twitter data, and other social media (not identified) to create "actionable intelligence for customers." It collects, analyzes, and stores structured, semi-structured, and unstructured data. Using its high performance analytic algorithm, LM Wisdom analyzes content in near real time to capture cultural context, trends, sentiment, and influence. The product website advertises a flexible, user-friendly interface with multidimensional views of data in a variety of graphical and statistical outputs. Multiple languages are covered including Arabic and Farsi. LM Wisdom supports a range of scalable delivery and pricing options. The product can be accessed via secure web connection or installed on customer specified hardware. Operations and analyst support as well as user training are provided, as is assistance in the creation of customer-specific taxonomies.

Lockheed Martin Wisdom	**<u>Service Provided</u>** Predictive analytics and big data technology tool that monitors and analyzes open-source intelligence data in near real time. The tool can ingest RSS feeds, blogs, video content, and Twitter data and other social media. Supports a range of scalable delivery and pricing options. Pricing available on request.

2.11 Marketwired Sysomos

Sysomos offers two products—Media Analysis Platform (MAP), a dashboard that analyzes social media conversations, and Heartbeat, a near real-time monitoring and measurement tool that provides updated snapshots of social media conversations.

MAP is an in-depth research tool, while Heartbeat is a cost-effective tool designed for day-to-day monitoring and measurement requirements. MAP helps users understand which data to monitor through its full search capability. Heartbeat instances are set up for each search strategy. Sysomos provides partners with various API (i.e., data API, charts, trends and sentiment API, and engagement and workflow API).

Sysomos MAP employs Unicode and crawls content in 190 countries and 186 different languages. The tool covers content from 50 million active blogs, 12-13 million forums, 55,000 traditional media sources, and video coverage of YouTube, DailyMotion, Vimeo, and MySpace. It also offers two years of the full Twitter fire hose. Available from Facebook are public status messages posted on user walls, personal profile pages, and discussion forums from top public pages. "Authority" scoring, an indicator of how engaged and influential a source is within a given media channel, is assigned to messaging on a 1-10 scale. User location is provided and is based upon user disclosed information. This means that the author or source must explicitly state their location for MAP to collect location information. Collection of demographic data such as age and gender is based on user disclosed information as well as on various intelligent data extraction techniques (e.g., scanning profiles and user names for gender specific clues).

Marketwired Sysomos	**Service Provided** MAP, a dashboard that analyzes social media conversations including ability to search a two-year data archive. MAP is Sysomos' full environment and billed as an in-depth research tool. ~$2,200 per MAP seat per month	**Service Provided** Heartbeat, a near real-time monitoring and measurement tool that provides updated snapshots of social media conversations. Working off a limited dataset, it is billed as a "cost effective" tool designed for day-to-day monitoring and measurement requirements. ~$1,000 per Heartbeat instance per month

2.12 Meltwater Buzz

Meltwater Buzz is a social media-monitoring tool, primarily supporting companies as they try to understand what is being said about their products and engage with their customer base. Meltwater Buzz's web-based platform uses proprietary crawler software to monitor over 280 million social media sites that include 100 percent of the Twitter Firehose, Facebook, blogs, forums, message boards, wiki pages, and video sites. Ongoing conversations may be tracked for immediate engagement and historical discussions researched for six months prior. Meltwater Buzz is praised for its good customer service. Meltwater is a Norwegian wholly-owned subsidiary of Meltwater Holdings, Inc. a company registered in the Netherlands.

Meltwater Buzz	**<u>Service Provided</u>** Tool provides social media monitoring for corporate brand management and customer engagement using a proprietary crawler. **Pricing information:** One reference to price found cited annual license fee of $10,275.

2.13 NetVibes

NetVibes is a personalized dashboard publishing platform composed of widgets pulled from a widget list open to third party developers. Common uses include brand monitoring, e-reputation management, product marketing, community portals, and personalized workspaces. It is a web-based tool.

The tool workspace is organized into tabs, each tab containing user-defined modules. Pages can be personalized through the use of existing themes or by creating personal themes. Customized tabs, feeds, and modules can be shared individually with others or via the NetVibes Ecosystem. The interface is clean and customizable. Trade press has reviewed its RSS reader favorably (BlinkList, Laptop Magazine, 2013).

The NetVibes blog offers online help, documentation, user guide, tutorials, service upgrade announcements, and maintenance schedules. Founded in 2005, NetVibes is a French company.

NetVibes	**<u>Service Provided</u>** Social media monitoring for brand monitoring, brand sentiment, e-reputation management. Available packages are NetVibes Basic (free), NetVibes VIP ($3.50 per month), NetVibes Individual ($649.00 per month), at NetVibes Team (pricing on request).

2.14 Nuvi

Nuvi offers three near real-time visualizations for social media data: the bubble stream, map tool, and word burst. Nuvi uses the entire Twitter fire hose and accesses the full Twitter historical archive. The tool tracks tweets in 24 languages, locations of tweets, trending topics, the number of tweets per language, and trending negative terms. Public Facebook posts are accessed via “written connectors.” Raw data is available for export from Nuvi to clients’ tools for further analysis. Customers can create their own search strategies; more sophisticated Nuvi users will create strategies for other customers needing assistance. The Nuvi software panel is leased to client desktops for customers to log in, search, and create their own set-ups.

The Nuvi overview dashboard provides statistics—volume, shared mentions, dates of spikes—which can be more deeply examined to find influencers, accounts with most reach (potential audience for a particular topic), and most spread. A topic comparison dashboard shows which topics generate more or less conversation within geographical areas.

Nuvi	**<u>Service Provided</u>** Offers near real-time monitoring and visualization of social media tools. Nuvi offers product trials for 2-3 days and fee-based, 30-day trials. Nuvi offers the most recent 30 days of historical data for free; beyond this timeframe, a surcharge of $10.00 per day from Twitter is applied. Licensing fees vary depending on the volume of data needed by the customer. Nuvi also has partnerships with Gnip and Datasift.

2.15 Recorded Future

Recorded Future's Enterprise Web Intelligence Platform can be used on the web or brought "in house"; it is focused on "predictive analytic tools." Using what the company calls a "temporal analytics engine," Recorded Future provides forecasting and analysis tools to help analysts predict future events by scanning sources on the Internet and visualizing the information to show networks and patterns in the past, present, and future. The tool can be used to identify events slated to occur in the future on a given date; "one month from now" and "two weeks from today." Natural language processing is used to determine events (100) and entities (40). The tools currently have 300,000 API-available sources, including RSS feeds, WordPress, Facebook, and one million tweets daily. Seven languages (Arabic, Chinese, English, Farsi, French, Russian and Spanish) are supported. Geolocation of tweets is not available.

Recorded Future	**<u>Service Provided</u>** User access to Enterprise Web Intelligence Platform, forecasting and analysis tools to help analysts predict future events. Currently works with 300,000 API-available sources. **Pricing information**: ~$125,000/year/5 seats plus data API costs (~$9,000/month); multiple packages available

2.16 SAS

SAS Social Media Analytics (SMA) tool, introduced in 2010, is a multi-module platform for use in monitoring social media coverage of user-designated topics. Covering more than 20,000 social media tools (e.g., blogs, Facebook, Flickr, microblogs, YouTube) users can monitor real-time Twitter traffic and generate key metrics on traffic volume, positive, neutral, and negative sentiment, key influencers, and word clouds. The tool can be used to look at retrospective data (unclear how much historical data are available) and create forecasts. Data can be examined at the summary and individual document levels and may be exported in multiple standard formats. The tool supports multiple (~25) foreign languages. A November 2013 report generated for the

DHS OHA by Data Networks Corporation, “Social Media Natural Language Processing Software and Services Project Assessment Report” concluded that “the SMA system delivered to National Biosurveillance Integration Center (NBIC) by SAS does not meet the needs of the Center and will likely present minimal value if adopted for operational use by NBIC analysts.” The report further stated that “any social media data platform acquired by NBIC in the future should encompass a customized approach to design with NBIC needs in mind, rather than tailoring a non-biosurveillance-related COTS product.” SAS SMA has an iPad app.

SAS **Social Media Analytics**	<u>**Service Provided**</u> Tool offers multiple visualization capabilities for social media sources including sentiment analysis. Ranges from $5,000 – $15,000/month plus a one-time start-up fee

2.17 Salesforce Radian6

Based in California, Salesforce Radian6 is a fee-based, near real time, online, and social media feed monitor that identifies and tracks gender, location, education levels, career, and lifestyle interests of Twitter message posters. Radian6 is the “social listening” component of the three-part Salesforce Marketing Cloud in which users build queries and save them in “topic profiles” to search more than150 million sites and sources for results matching profile search criteria. The tool is advertised as a way for companies to monitor perception and discussion of their brand and reputation.

Five widgets typically analyze the retrieved data. These are “topic analysis” (total number of posts based on a given topic profile), “conversation cloud” (snapshot of conversations in a topic profile), “river of news” (the text of tweets retrieved in a profile), “topic trends” (how topics trend over time), and the “influence bureau” (display of accounts with most vocal influence on a given topic). Filtering options include multiple foreign languages, specific sources (e.g., Twitter, Facebook, MySpace), content types (e.g., images, videos, news, blogs), and keywords that can be entered in simple or advanced modes using Boolean operators (AND, OR, and NOT). Searches initially cover the last 30 days and subsequently add one day at a time over the lifetime of the topic.

A natural language processing (NLP) positive or negative sentiment analysis capability is available through Radian6 Insights, which is a series of add-on analytical tools in multiple languages. Only two of these (Radian6 Insights and Basic Demographics) are free to add; others are fee-based. A social scoring system to measure customer abilities to influence action online and topic longevity is also available. Insights can be chosen and added to the analytics dashboard.

Salesforce Radian6	**<u>Service Provided</u>**
	The "starter package" for an agency includes one topic profile and includes one million mentions, unlimited user licenses across the full platform, an analysis dashboard, engagement console, and summary dashboard for $950/month.
	• Tier 1: Up to 10,000 hits per month (one topic profile (max) and 5 users) $7,800/year
	• Tier 2: Up to 20,000 hits per month (up to 100 topic profiles and 1,000 users) $10,080/year (bundled into contract)
	• Tier 3: Up to 250,000 hits per month (up to 100 topic profiles and 1,000 users) $31,320/year
	    ○ Additional 50,000 hits per month $10,440/year
	    ○ Additional 1,000,000 hits per month $52,200/year
	    ○ Additional Dashboard User (for 10K Tier) $1,200/year
	    ○ Additional year of historical data $1,200 for each year of data

2.18 SocialMention

SocialMention is a social media search platform that culls content from social sites that rely on user-generated content, such as blogs, Facebook, Twitter, LinkedIn, Flickr, YouTube, plus over 80 other sites. Keywords and social media sites can be searched to curate a dashboard showing a variety of information regarding comments on searched terms. Terms are scored on four factors: strength (frequency), sentiment (ratio of positive to negative mentions), passion (likelihood that people mentioning the term will use it more than once), and reach (unique number of users mentioning the term divided by the total number of mentions found).

Social Mention	**<u>Service Provided</u>** Social media platform search platform covering major social media tools (e.g., Facebook, Twitter). Scores results on multiple criteria (e.g., sentiment, frequency of terms). SocialMention is free for up to 100 queries/day. For additional queries, SocialMention charges a fee based on use, beginning at $100/month for up to 25,000 queries.

2.19 SocialOomph

SocialOomph is a tweet and post scheduler that allows free scheduling for up to five Twitter accounts and unlimited Facebook accounts. Sources include Twitter, Facebook (profiles, pages, and groups), LinkedIn (profiles, groups, and company pages), RSS feeds, blogs, Plurk, App.net, and Onlywire.

SocialOomph aggregates, indexes, and makes searchable a variety of information (e.g., social platforms, cataloging programs, files, tasks, email, social media, and locally stored files) on one dashboard. A web-based tool, it supports some drag-and-drop capabilities across different online platforms. Platforms include Facebook, Twitter, LinkedIn, Gmail, Flickr, Picassa, and Hotmail.

SocialOomph offers two versions: free and professional. The free version includes unlimited accounts; tweet scheduling, keyword tracking, and Uniform Resource Identifier(URL) shortening capability. The professional version includes Linkedin and Facebook scheduling, import of RSS feeds, scheduling blog posts, bulk tweet upload, delegation of account management to other users, and advanced search tools. Users can access SocialOomph Twitter Unlimited Free with the option to upgrade to the fee-based account at $35.94 per month. Users can sample a free seven-day trial of the Professional version. It does not offer API for data downloads.

Social Oomph	**<u>Service Provided</u>** Tweet and post scheduler Users can access SocialOomph Twitter Unlimited Free with the option to upgrade to fee-based accounts at $6.97 for Twitter Unlimited and $17.97 biweekly for SocialOomph Professional. A free seven-day trial of the Professional version is available with the option of staying indefinitely with the free version.

2.20 Spiral16

Spiral16 specializes in social media monitoring, sentiment analysis, and business intelligence. It covers all social media outlets that are both publicly available and indexed, including blogs, forums, and associated comments, as well as Facebook and Twitter. Through a partnership with Gnip, Spiral16 provides access to 100 percent of the Twitter fire hose. Geo-location is included as metadata by some data sources and is based on self-reported information only.

Spiral16	**<u>Service Provided</u>** Working with Spiral16 analysts, customers create metrics and frequency of reporting to track their respective brands and topics of interest for dashboard display and custom report generation. Platform access starts at $1,000/month for up to two users

2.21 SproutSocial

SproutSocial is a fee-based social media management tool to gauge the influence of posted messages and identify demographics of followers, aggregating the social feeds on one scrolling screen. Users can generate analytical reports on engagement, shares, and profile users. A web app, IOS, and Android versions are available.

The tool is consistently well reviewed for its analytic capabilities, ease of use, and interface; updates are easy to perform and the dashboard provides easy to use snapshots of all activities. Twitter accounts can be monitored and users' tweets can be scheduled and saved. This tool is not as mature as HootSuite; SproutSocial has been intermittently criticized in trade press for software bugs.

Sprout Social	**<u>Service Provided</u>** Social media management tool used to monitor social media channel traffic (e.g., Facebook, Google+, LinkedIn, Twitter) The pricing model includes a Deluxe version ($59 per user per month), Premium version at ($99 per user per month) and Team version ($500/three users/month).

2.22 TweetDeck

TweetDeck is a free Twitter dashboard application that allows users to manage multiple Twitter accounts from different computers. TweetDeck by Twitter interfaces with the Twitter API for users to send and receive tweets and view profiles. Columns can be defined as home, search, interaction (chat), followers, @ mentions ("addressed to" for single or all accounts), messages (for single or all accounts), activity, users, favorites, trending, lists, and scheduling.

Users can arrange an unlimited number of feeds into customizable columns in the user interface, filter feeds, schedule tweets to be sent, and set alerts when new tweets of interest appear. After defining the column, the user identifies the feeds for the column. URLs can be shortened quickly. Originally developed in 2008, Twitter acquired TweetDeck in May 2011 and launched as TweetDeck by Twitter in December 2011. Trade press has praised the capabilities of the Twitter dashboard for a simple and easy-to-use interface.

TweetDeck	**<u>Service Provided</u>** User logs onto a dashboard to which multiple Twitter accounts can be linked to monitor and schedule posts for brand management. Free

2.23 Twitter Gnip App

Twitter/Gnip is a social media aggregation company providing data from many social media websites via robust streaming APIs. Data sources include Disqus, StockTwits, Foursquare, Tumblr, Twitter, WordPress, Facebook, NewsGator, Vimeo, Flickr, YouTube, IntenseDebate, Instagram, Google+, and Delicious. Gnip supports JSON raw format (quicker, as it allows stripping of formatting) and JSON Activity Stream.

Twitter packages include:

- *Historical PowerTrack* to access the archive of Twitter data back to 2006 (available either in batches or via subscription).
- *Decahose* for a statistically valid sample of at least 10 percent of all Tweets selected at random and streamed in real time.

- *PowerTrack* for complete coverage of user-defined filtered data.

Twitter/Gnip performs near real-time enrichment (e.g., unwinding URLs, language detection, Klout scores, Klout topics, and geolocation of tweets where latitude/longitude data (2 percent) or self-identified location data (30 percent) are available). Gnip testing reports testing 80 percent accuracy in location identification.

Twitter/Gnip has built an internal app on top of its Search API product that provides a sample interface for potential use by Gnip customers who may want to use it to leverage the Search API in their own products. This is a single, one-page search interface with CoffeeScript and Syntactically Awesome Stylesheets (SASS) source map debugging support that allows the user to search, using simple Boolean logic, the last 30 days of Twitter. It includes a free map that shows up to 100 geolocated tweets as well as a scrolling interface that provides the actual tweet contents. This app is a lightweight, inexpensive capability that could be used in the near term by organizations that need to leverage the Twitter API but do not have the expertise or funding to develop or purchase tools.

Twitter Gnip App	**<u>Service Provided</u>** Lightweight, inexpensive user interface that leverages Twitter Search API to display search results on a map and as a scrolling list of tweets. $1,750/month - includes 10,000 API requests per month, includes request for data and counts. Gnip's Profile Geo Enrichment feature may be added at a cost of $300/month. When Search API requests exceed contractual limit, $100/1,000 requests (billed monthly).

3. Internet of Things

The "Internet of things" (IoT) describes complex machine-to-machine (M2M) systems that complete complex tasks based on data collected by many distributed sensors,[38] as illustrated in Figure 9. IoT is envisioned as ubiquitous interconnectedness, creating an "Internet of Everything" (IoE). In an IoE world, some experts say "every ambulance and fire truck, every medical device, even clothing people wear, could talk to the network, sending information back to a database that can then interact with other databases, such as Google Glass."[39]

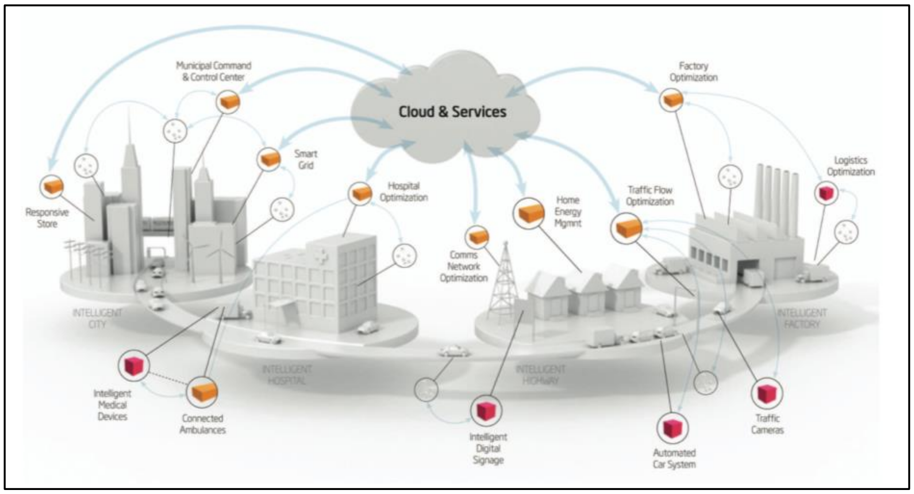

Figure 9. The "Internet of things"[40]

Imagine the following scenario of an individual caught in a future disaster: a victim is wearing shoes embedded with a global positioning system (GPS) chip which regularly sends his vital statistics through the digital cloud to a database (Nike operates such a system now with its Nike+, which knows basic data about the wearer such as weight and heart rate). Emergency personnel finding the injured wearer could automatically send these readings to a hospital. Emergency personnel wearing tagging and tracking devices communicate their locations, allowing command and control to know the status of the rescue, as well as personnel locations as victims are moved to safety. The ambulances and paramedic teams nearest to the disaster scene could be located and dispatched.[41]

The potential IoT components discussed in this section include: 1) tagging systems such as RFID, barcodes, and embedded chips; 2) smart devices such as house sensors and smartphones; 3) digital displays; and 4) 3-D printing.

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[38] ZDNet. (2014). Tapping M2M: the 'Internet of Things'.

[39] Maney,K. (2013, May 9). Everything Changes with the Internet of Everything. Forbes.

[40] Peakin, W. (2012, December 17). Briefing: Ideas. Holyrood Magazine.

[41] Maney,K. (2013, May 9). Everything Changes with the Internet of Everything. Forbes.

3.1. Tagging Systems

An RFID system consists of a tag that includes a microchip with an antenna and an interrogator, or reader, with an antenna. The reader sends out electromagnetic waves and the tag antenna is tuned to receive these waves. A passive RFID tag draws power from a field created by the reader and uses it to power the microchip's circuits. The chip then modulates the waves that the tag sends back to the reader and the reader converts the new waves into digital data. An active tag includes an on-board battery and periodically transmits its ID signal.[42]

Barcodes are machine-readable patterns of varying width parallel lines that provide data about the object to which it is attached. Figure 10 shows a Universal Product Code (UPC) code, a common example of barcode technology. Quick Response Codes, known as QR codes, are two-dimensional barcodes originally developed for the automotive industry to expedite the scanning of components. QR codes, also shown in Figure 10, now most commonly direct the smartphone or mobile device that scans it to a specific URL.

0 36000 29145 2

Figure 10. UPC and QR codes

Barcode technology, used for asset management and access control, is often found as a component of commercial first responder systems.[43] Mercedes-Benz places QR codes in its vehicles to assist first responders in accessing and removing injured occupants. The company notes, "The QR code will be scannable by a standard smartphone or tablet with a relevant app, providing those who scan it a detailed "rescue map" of the [car] model, including such things as where the airbag locations, electrical cables, the battery, cylinders under high pressure, the car's layout, and other information. This will let the rescue workers determine how best to access the vehicle."[44]

RFID systems have been used for logistics management by private industry and the military for many years. In the realm of emergency response, they have been used for identification and tracking of emergency responders working in harm's way, identification and tracking of evacuees, and tracking of remains of disaster victims.[45] RFID can also be used for tracking first responder assets and resources as well as for access control to EOCs and incidents. For many first responder organizations, the RFID tags and readers are cost prohibitive; however, there is high interest in acquiring this technology due to its potential to save lives (i.e. tracking firefighters in a burning warehouse).

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[42] Frequently Asked Questions. (n.d.). RFID Journal.

[43] First Responder Solutions. BarcodesInc.com.

[44] Mercedes Benz to Place QR Code Stickers on Vehicles for First Responders. (2013, May 28). Slashgear.com.

[45] RFID Chips Help Track Katrina Dead. (2005, September 28). NBCNews.com.

Victim Tracking and Tracing Systems (ViTTS), explored by some European nations, consist of a mobile access router that feeds data on victims from hand-held personal digital assistants (PDA), via general packet radio service (GPRS), digital radio, or directly by satellite to a central database. The ViTTs data include a unique identification number (barcode), the victim's name, a digital photograph, a color-coded treatment priority, and a dictated summary of the patient's medical condition to reduce documentation time. The data are compressed and encrypted before being sent to the database. Dispatch personnel can immediately enter voice messages into the system, ensuring that all patient data is available in text format shortly after being collected without additional work by on-site rescue workers. In addition to a color-coded priority card, victims are equipped with GPS transmitters or RFID tags to track their location after transport to treatment facilities. Victim locations are transmitted via GPRS to a central database.[46]

There is hesitancy to use similar systems in the United States due to privacy and security concerns.[47] Emergency response expert Michael Schultz, Senior Emergency Management Consultant at City University of New York, explained in a recent telephone interview that although RFID tagging and tracking account for the location and transport of disaster victims, tagging may be perceived as dehumanizing, and poses a large barrier to entry for such uses of RFID tagging.

Supported by hundreds of vendors, RFID technology offers widespread application, most prevalent in asset and resource identification, tracking, location, and verification. RFID can be found at every link in the supply chain and is used for access, control, baggage handling, instrument calibration, payments, livestock and pet identification, and in medical applications and compliance monitoring. Solutions pertinent to the first responder community are those that facilitate tracking equipment, responders, victims, and casualties, as well as those that provide access management to an incident scene or EOC. Table 4 provides a sampling of products and vendors.[48] Table 5 outlines first responder requirements, existing solutions, gaps in capabilities, and recommendations for further RFID research. Table 6 provides a brief synopsis of 13 U.S. university RFID labs and projects, many of which partner with other public and private organizations (e.g., the Worcester Polytechnic Institute lab was jointly funded by the Department of Justice, DHS, and the FEMA).

[46] Victim Tracking and Tracing System (ViTTS). (n.d.) VonBergh Global Medical Consulting.

[47] United States Department of Homeland Security. Data Privacy and Integrity Committee to the Secretary and the Chief Privacy Officer of the Department of Homeland Security. (2006, December 6). The Use of RFID for Human Identity Verification. Report No. 2006-02.

[48] Featured Vendors. (n.d.). rfidconnect.

Product	Vendor	Function
4G Core VPro[49]	Intel/ Aeroscout	Active, RFID Wi-Fi tag enabling indoor, location-based services
All Hazard Response Network[50]	RadiantRFID	Evacuation and shelter management, disaster management, responder management, corporate building evacuation, campus evacuation, base camp management, etc.
AllGuard, SafeGuard[51]	GuardRFID	Asset tracking, staff location, man-down indication
Ekahua Vision 2.0[52]	Ekahau, Inc	Real-Time Location System using active RFID Wi-Fi
Embedded RFID Readers[53]	ThingMagic	Partnered with numerous RFID vendors; provides customized RFID solutions
Rugged RFID tags[54]	Xtreme RFID	RFID tags for use in extreme environments and harsh conditions

Table 3. Tagging solutions for first responders

First Responder Requirements	Existing Solutions	Gaps Identified	Research Recommendations
Ability to locate and track persons and assets in real-time	GPS, wearable sensors (Google Glass)	Signals are not readily available, cell towers are not ubiquitous, sensors are cost prohibitive	Alternate sources of power, methods of tracking and tagging humans, methods of relaying personal data electronically from rescue sites
Ability to relay data about the assets and do so securely	ViTTs Multiple commercial tools for material tracking	Readily available commercial tools	Needed
Cost-effective solutions for tracking and tagging	Needed	Less expensive tagging and tracking systems	Needed
Ability to reduce stigma associated with "tagging" persons in emergency situations	Needed		Sociological research into how tagging can be viewed as a life-saving practice rather than a dehumanizing one

Table 4. First responder requirements for RFID applications

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50 Swedberg, C. (2013, September 16). Intel's Gen 4 vPro Computer Processors Feature AeroScout. Wi-Fi RTLS Technology. RFID Journal.

50 "All Hazard Response Network." (n.d.). Radiant RFID.

51 Guard RFID. http://guardrfid.com/

52 Ekahau. http://www.ekahau.com/

53 ThingMagic RFID Products

55 Xtreme RFID http://xtremerfid.com/

Institution	Project/Capability	Link
California Institute for Telecommunications and Information Technology	WIISARD-SAGE – Wireless Internet Information System for Medical Response in Disasters and Self-Scaling Architecture for Group and Enterprise Computing	http://www.calit2.net/newsroom/article.php?id=1703
Ohio State University	ElectroScience Laboratory – RFID research goals include developing new reader antennas and item tag antennas, developing propagation models and completing system models, and verifying new designs with real-world measurements	http://electroscience.osu.edu/10070.cfm
Penn State University	RFID Lab – conducts broad-based research on various aspects of RFID development and implementation and promotes RFID awareness and applications showcasing a wide range of RFID applications	http://net1.ist.psu.edu/rfid/mission.html
Rutgers University	RFID Lab – supports technology research, logistical work flow simulations, and retail supply chain compliance testing	http://civet.rutgers.edu/tech-transfer-labs.php
University of Arkansas	RFID Research Center – applied RFID application research primarily supply chain focused	http://rfid.uark.edu
University of Maine	National Center for Geographic Information & Analysis – variety of research projects, some of which use RFID and are applicable to emergency management	http://umaine.edu/ncgia/research-projects/senseme/
University of Massachusetts, Amherst	Center for Advanced RFID Research – Real-time RFID event stream processing for monitoring and anomaly detection, RFID tag localization for object tracking systems, security vulnerabilities of RFID enabled devices, management of RFID data in enterprise supply chain and health care environments, and very large scale integration design for secure RFID hardware	http://rfid.cs.umass.edu
University of South Florida	RFID Center for Applied Research – applications of RFID in transportation, supply chains (cold chain and perishables), and pharmaceuticals	http://ee.eng.usf.edu/RFID/
University of Texas at Arlington	RFID Deployment Lab – deployment and commercialization lab for the study of current and future RFID, Auto-ID and wireless technologies	http://www.uta.edu/ie/labs/rfid.html
University of Pittsburgh	RFID Center of Excellence – studies applicability of RFID technology and commercial cellular networks to an online triage system for handling mass casualty situations	http://www.engineering.pitt.edu/labs/rfid/
University of Wisconsin	RFID lab – iTrace for Blood Centers automatically identifies, reconciles, and tracks blood products	https://www.uwebc.org/uwrfidlab/
Villanova	RFID Lab – capabilities include RFID system evaluation and design, the development of new RFID technologies and RFID antennas, and electromagnetic modeling and analysis. The lab hosts testing facilities for RFID products and supports the evaluation of RFID tags and RFID-assisted tagged localization methods, collision avoidance techniques, and signal propagation characteristics.	http://www1.villanova.edu/villanova/engineering/research/centers/cac/facilities/rfidlab.html
Worcester Polytechnic Institute	Precision Indoor/Outdoor Personnel Location Project – the goal is to protect lives of emergency responders and enhance their ability to accomplish missions through research and development of systems for personnel location and tracking, physiological status monitoring, environmental sensing, and command and control	http://www.wpi.edu/academics/ece/ppl/

Table 5. Research institutions working in RFID applications

Today, first responders predominantly rely on radios to communicate location. A contributing factor in the tragic demise of 19 Arizona firefighters in June 2013 was the loss of radio communications 30 minutes prior to their deaths. The *Yarnell Hill Serious Accident Investigation Report* stated, "…a Very Large Airtanker was on station over the fire waiting to drop retardant as soon as the crew's location was determined."[55] Although RFID is not specifically mentioned, the report recommends, "the State of Arizona request the National Wildfire Coordination Group to review current technology that could increase resource tracking, communications, real-time weather, etc.," including GPS units.[56]

A 2003 University of California San Diego project called the Wireless Internet Information System for Medical Response in Disasters, or WIISARD,[57] is a medical emergency response application with a client-server architecture that features one central server and data repository accessed by large numbers of wireless clients distributed over large areas. The WIISARD system is comprised of five interlocking components including patient wireless devices, a responder wireless device and system, a command center system, disaster databases, and a hospital system.

After a demonstration of WIISARD technology at the WIISARD-SAGE exercise at the "Golden Guardian" emergency preparedness exercise in May 2010, on the California State University's San Marcos campus, participant Mike Lopez, Carlsbad Fire Depart battalion chief and a Special Weapons and Tactics medic, said that he could see, "the benefits of providing an RFID tag to all public safety personnel the moment they are hired."[58] Many other emergency responders who used the technology during the drill said, "Once the kinks are worked out, the technology could provide an unobtrusive way to do their jobs more safely and efficiently."[59] Additionally, employment unions may object to the tracking of personnel.[60]

RFID solutions would provide efficiencies as well as lifesaving and life preserving capabilities to the first responder community. Adoption costs are significant due to tight budgets and competing demands for limited resource dollars, however. Adequate expertise and time is needed to ensure that acquired RFID solutions will not be hampered or disabled by signal interference or harsh conditions. Additional issues include interoperability of RFID tags and readers across multiple jurisdictions, the ease of data sharing across public and private partners, perception that RFID use is dehumanizing for victims, and privacy and security concerns.

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[55] Arizona State Forestry Division. Office of the State Forester. (2013, June 30). Yarnell Hill Fire Serious Accident Investigation Report.

[56] Arizona State Forestry Division. Office of the State Forester. (2013, June 30). Yarnell Hill Fire Serious Accident Investigation Report.

[57] UCSD, VA and Cal-(IT)² Wireless Technology to Enhance Mass Casualty Treatment in Disasters. (2003, October 23). UCSD Health Science News.

[58] Fox, T.M. (2010). WIISARD-SAGE Team Tests Improved Computing, Communication Technologies at Disaster Drill. (2010, July 12). California Institute for Telecommunications and Information Technology. (press release).

[59] Fox, T.M. (2010). WIISARD-SAGE Team Tests Improved Computing, Communication Technologies at Disaster Drill. (2010, July 12). California Institute for Telecommunications and Information Technology. (press release).

[60] Brewin, B. (2011, December 14). Unions Slam VA Plan to Track Employees Electronically. NextGov.com.

3.2. Smart Devices

Law enforcement and first responders use smart consumer devices which leverage social media to manage tasks and provide situational awareness. From the Metropolitan Boston Transit Authority's (MBTA) "See Say"[61] app which allows transit riders to anonymously alert the police via smartphone to unusual activity on subway trains and platforms, to apps that allow police to use their smartphones and cell phones as police radios, such as the Raytheon One Force Mobile Collaboration App, emergency responders leverage smart devices developed by industry for their needs.

In June 2013, the Boston Police acquired 100 iPads to use for wireless virtual private network (VPN) access to police databases, warrant checks, crime scene mapping, crime scene photo transmission, and location of missing persons by searching and following Facebook and Twitter. In 2011, the Redlands, California, police department received a grant to deploy 110 iPhones and 67 iPads to its officers and command staff. Benefits reported include increased portability over cruiser laptops, rapid dissemination of crime scene video, Internet searching, and generation and filing of incident reports on the iPad.

Commercial sources produce many apps targeted for use by the first responder community. These include the 2011 pairing of Apple with Zco Corporation to design "PolicePad" applications for the iPad, Mission Mode's disaster and crisis apps for iPhone and iPad, and several others. Officer.com, a professional site for police officers, offers ideas about using smart devices on the job. The April 2013 issue of *Law and Order Magazine*, a professional publication for law enforcement officers, produced a survey of the best apps available for police use.[62] Table 7 lists tools used by first responders and Table 8 outlines first responder requirements, existing solutions, gaps in capabilities, and recommendations for further research for smart consumer devices.

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[61] Massachusetts Bay Transportation Authority (MBTA). (2012). See Say Smartphone App hhttp://www.mbta.com/about_the_mbta/news_events/?id=24872&month=&year

[62] Marks, K. (2013, April). Emergency Response Mobile Applications. Law and Order: The Magazine for Police Management.

Tool	Functionality	Modality
FiRST Responder	Provides first responders and emergency managers easy access to map-based improvised explosive device standoff distances and hazardous materials (HAZMAT) spill evacuation areas	Mobile app mapping tool
ShotSpotter	Provides a combination of acoustic sensor data, algorithm audio analysis, and GPS to help local government agencies and police forces locate real-time gunfire activity in their cities	Sensor
Google PersonFinder	Although now using a manual data input process, potential exists for automated population of data derived from multiple interconnected systems (e.g., GPS chip-embedded shoes, data stored in medical devices)	Crowd sourced website
Google Fusion Tables	Tables of locations can become maps and updated in real time to track and share important events (e.g., fire outbreaks, violent outbreaks) in one place, identify data patterns, and facilitate collaboration among responders	Mapping and data visualization tool
Google Crisis Map	Crisis Map uses the familiar Google Maps API to put critical disaster-related geographic data in context, and in a map-based viewing frame optimized for usability across a range of browsers and mobile devices. Crisis Map is embedded on a website that is shared and updated with coworkers.	Mapping and data visualization tool
Google Maps Engine Lite	Google Maps Engine provides map-making capabilities for mark-up of crisis information, such as road closures and resources such as emergency medical stations. Map permissions are set to control sharing; data can be imported from spreadsheets. Product hosted on Google servers.	Mapping and data visualization tool
WISER	Wireless Information System for Emergency Responders (WISER) provides a wide range of information on hazardous substances, including substance identification support, physical characteristics, human health information, and containment and suppression advice	Information resource
Mutualink	IP-based multimedia overlay network, designed to leverage the sharing of existing radio, video, telephone, and IP-sensory equipment including disparate systems, as well as next-generation communication technology; in use by DHS	Mobile communications infrastructure
CityConnect	Connect and interact with citizens through mobile devices; in use in Davenport Iowa. Mobile app allows user to connect with police via Facebook, YouTube, Twitter, and the department's website. Can be used to report problems and submit tips to help solve crimes; connects with app users via a blog and allows them to sign up for emergency alerts targeted to the area in which they live or work.	Social networking
Virtual Radio App	Allows PCs, tablets, and smartphones to be used as virtual radios; users communicate over the data network when they are out of range of land mobile radio coverage or when a redundant form of voice communication is needed	Radio communication
One Force	A suite of collaboration tools for groups of users on smartphones and other mobile devices; includes voice communications, maps, drawing tools, real-time GPS tracking, image sharing, and streaming video	Mobile collaborative
PremierOne (Motorola)	Accesses and shares information across multiple applications and platforms, such as real-time information from computer aided dispatch, records management systems and local, state and federal databases	
NowForce	Transforms mobile devices into "life-saving networks" through use of GIS, and provides significant benefits to first responders in developing nations	Geo-mapping
Zephyr Physiological Status Monitoring Responder	Visibility into the physical status of personnel enabling monitoring of multiple individuals and teams simultaneously for fire fighter teams, HAZMAT, Weapons of Mass Destruction Civil Support Teams or any teams that deploy into potentially hazardous, challenging environments	
Bounce Imaging	Low cost imaging device designed to be thrown into dangerous situations, such as a burning building	
TRX System	Situational awareness; used successfully by firefighters in a controlled training setting; delivers accurate 2-D and 3-D feature maps, enabling location where GPS is unavailable	TRX System

Table 6. Industry solutions targeted at law enforcement and emergency responders

First Responder Requirements	Existing Solutions	Gaps Identified	Research Recommendations
Adequate bandwidth for rapid transmission bandwidth-intensive formats such as video	Cell phone service; mobile cell towers	Slow transmission speeds depending on location	Greater bandwidth and faster data speeds
Secure data access and transmission	Police department communications are secure	Secure mobile VPN to Internet	Easy to use secure VPN
Interfaces able to access centralized data sources and aggregate social media data	Multiple social media aggregation tools exist (see Table 2)	Disparate sources in multiple locations that cannot all be accessed as fast as needed- particularly proprietary data	Data integration of multiple formats at varying levels of secure access
Interfaces which permit simultaneous updating across online tools	Several commercial social media aggregation tools have this capability (see Table 2)	Low-cost solutions	Lower cost computing components and technology to control cost of tools

Table 7. First responder requirements for smart consumer devices

Smart sensors in combination with mapping have long been used in traffic monitoring and congestion prediction. Sensors are now being used to monitor environmental variables such as air quality, sound pollution, seismic movement, and water quality and motion. In the urban planning world, sensors monitor vehicular as well as pedestrian traffic.[63]

Smartphone sensor capabilities vary by manufacturer and device version. In a rapidly evolving and competitive industry, it is challenging to maintain a current list of available sensor features by manufacturers. A 2012 article in *Pervasive Computing* offers a relatively timely summary of sensors: "Today's top-end smartphones come with 1.4-GHz quad-core processors and a growing set of inexpensive yet powerful embedded sensors. These smartphones include an accelerometer, a digital compass, a gyroscope, a GPS [receiver], quad microphones, dual cameras, near-field communication, a barometer, and light, proximity, and temperature sensors."[64] For example, Apple lists the following sensors in its iPhone 5 specifications: three-axis gyro, accelerometer, proximity sensor, ambient light sensor, and fingerprint identity sensor.[65]

The Samsung Galaxy S4 smartphone, released in 2013, includes a barometer, thermometer, and hygrometer (humidity measurement). SingularityHUB technical writer Jason Dorrier likes the implication for climate study, as these are three key weather station metrics. "Using millions of smartphone data points," Dorrier noted, "developers could knock out apps rendering detailed heat, humidity, and pressure maps and bundle them into weather apps. The data would be available at any given point in time…and available over time… Climate studies might draw on smartphone data to inform their studies and reports."[66]

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[63] Ling, P. (2011). Traffic Monitoring System uses Bluetooth Sensors Over ZigBee. EETimes. http://www.eetimes.com/document.asp?doc_id=1260503

[64] Campbell, A. and T. Choudhury. (July-September 2012). From Smart to Cognitive Phones. Pervasive Computing.

[65] iPhone 5S, Technical Specifications, Sensors.

[66] Dorrier, J. (2013, April 1). Sensors in Smartphones: Galaxy S4 Adds Pressure, Temperature, and Humidity Sensors. SingularityHUB.

Many smartphones are equipped with sensors that can gather information about human behavior, as identified in Table 9. A recent report from the National Research Council summarizes examples of gathering data at a global scale based on information gleaned from smartphone sensors. The report states, “The convergence of sensing, communication, and computational power on mobile devices such as cellular phones creates an unprecedented opportunity for crowdsourcing data.”[67] Smartphones now integrate sensor suites with GPS data, accelerometers, magnetometers, light sensors, and cameras, and can process and transmit geolocalized data.

[67] National Research Council. Division on Engineering and Physical Sciences, Board on Mathematical Sciences and Their Applications, Committee on the Analysis of Massive Data; Committee on Applied and Theoretical Statistics; Board on Mathematical Sciences and Their Applications. Frontiers in Massive Data Analysis. p. 91.

Sensor (tool)	Type	Functionality	Modality
Accelerometer	Hardware	Measures the acceleration force in meters per second squared (m/s^2) that is applied to a device on all three physical axes (x, y, and z), including the force of gravity	Motion detection (e.g., shake, tilt)
Ambient Temperature	Hardware	Measures the ambient room temperature in degrees Celsius	Monitoring air temperatures
Gravity	Software or Hardware	Measures the force of gravity in m/s^2 that is applied to a device on all three physical axes (x, y, and z)	Motion detection (e.g., shake, tilt)
Gyroscope	Hardware	Measures a device's rate of rotation in rad/s around each of the three physical axes (x, y, and z)	Rotation detection (spin, turn, etc.)
Light	Hardware	Measures the ambient light level (illumination) in lx (lux or standard unit of illuminance)	Controlling screen brightness
Linear Acceleration	Software or Hardware	Measures the acceleration force in m/s^2 that is applied to a device on all three physical axes (x, y, and z), excluding the force of gravity	Monitoring acceleration along a single axis
Magnetic Field	Hardware	Measures the ambient geomagnetic field for all three physical axes (x, y, and z) measured in microteslas (μT).	Creating a compass
Orientation	Software	Measures degrees of rotation that a device makes around all three physical axes (x, y, and z). As of API level 3, one can obtain the inclination matrix and rotation matrix for a device by using the gravity sensor and the geomagnetic field sensor in conjunction with the getRotationMatrix method.	Determining device position
Pressure	Hardware	Measures the ambient air pressure in hectopascals (hPa) or millibars (mbar)	Monitoring air pressure changes
Proximity	Hardware	Measures the proximity of an object in centimeters relative to the view screen of a device. This sensor is typically used to determine whether a handset is being held up to a person's ear.	Phone position during a call
Relative Humidity	Hardware	Measures the relative ambient humidity in percent	Monitoring dew point, absolute, and relative humidity
Rotation Vector	Software or Hardware	Measures the orientation of a device by providing the three elements of the device's rotation vector	Motion detection and rotation detection
Temperature	Hardware	Measures the temperature of the device in degrees Celsius. This sensor implementation varies across devices and this sensor was replaced with the TYPE_AMBIENT_TEMPERATURE sensor in API Level 14.	Monitoring temperatures

Table 8. Sensor types supported by the Android platform[68]

[68] Portions of this page are reproduced from work created and shared by the Android Open Source Project and used according to terms described in the Creative Commons 2.5 Attribution License, Table: Sensor types supported by the Android Platform. http://developer.android.com/guide/topics/sensors/sensors_overview.html. And Good habits for sensors http://www.slideshare.net/datta_jini/android-sensors-18449038.

In Marin County, California, paramedics and residents were involved in a June 2012 to June 2013 year-long pilot program with Lifesquare, a Silicon Valley healthcare IT start-up. Lifesquare asked participants "to input personal information about their medications into its website and then place corresponding QR code stickers where emergency responders can scan them with an iPhone. The secure link from the sticker will then provide paramedics and firefighters with information they need during a medical response call."[69]

Smart device sensor innovations include Neuralphone, CenceME, and SoundSense. Neuralphone is a brain computer interface that harnesses a user's electroencephalographic (EEG) signals to locate contacts in a smartphone. CenceMe is a personal sensing system that enables members of social networks to share their sensing presence with their friends in a secure manner. Sensing presence captures a user's status in terms of activity (e.g., sitting, walking, meeting friends), disposition (e.g., happy, sad, doing OK), habits (e.g., at the gym, coffee shop today, at work) and surroundings (e.g., noisy, hot, bright, high ozone). SoundSense is a device that harnesses mobile phone microphones.[70]

Smart device applications in the non-emergency response sector are commonly available on the commercial market through iTunes and elsewhere, and have been developed for temperature, moisture levels, water pressure, leak/flood detection, air quality, lighting, motion detection and control, multimedia control, and whole house infrared for home owners. Well-known examples are the Nest "Learning Thermostat"[71] system and the Phillips Hue[72] light control system. Other products include Lockitron, a commercial residential keyless entry system;[73] Wigwag, a wireless graphical interface control and light level monitoring system;[74] EchoWater, a leak detection system;[75] and FrontPoint, a door and window opening and closing detector.[76]

Released to the consumer market in spring 2014, Google Glass[77] is a wearable computer with an optical head-mounted display which uses voice commands to search the Internet, take and share photographs, and interact virtually in real-time. Some government agencies are fast-tracking Google Glass pilot programs. The Morris, New Jersey Department of Law and Public Safety will experiment with the device upon its release. Director Scott Di Giralomo noted in a recent press article that he hopes Google Glass will work well with a service called Mutualink that allows first responders from different agencies to share audio and video communications.

[69] Davis, K. (2012, May 31). Emergency Workers Scan QR Codes to Access Health Information." Macworld. & ITWorld (video). http://www.itworld.com/government/279282/emergency-workers-scan-qr-codes-quickly-access-health-information.

[70] SoundSense. MetroSense: Projects.(video).

[71] Nest Learning Thermostat. https://nest.com/thermostat/life-with-nest-thermostat/.

[72] Hue Personal Wireless Lighting. http://www.usa.philips.com/e/hue/hue.html.

[73] Lockitron. https://lockitron.com/preorder .

[74] Wigwag. http://www.wigwag.com/.

[75] EchoWater. http://www.belkinbusiness.com/echo-water-0.

[76] FrontPoint. http://www.frontpointsecurity.com/equipment/security-and-fire/door-window-sensor.

[77] Google Glass. https://www.google.com/glass/start/what-it-does.

Recent research (Table 10) has been conducted in the areas of energy expenditure minimization by smart devices,[78] and defense against mobile malware for smart device security.[79] Networking research includes the use of mesh sensor networking of consumer mobile devices to create "smart cities." Smart cities would monitor and access multiple infrastructural services (transportation, sanitation),[80] use mesh sensor networking when cell service and an Internet backbone are not available, and synchronize sensor nodes to ensure that shared sensor data is not lost and that interaction among devices is seamless.[81]

Issues such as software vulnerabilities, device cost, battery life, and organizational protocol on use of devices are of concern to users in the disaster response sector. In some instances, devices must be particularly rugged to withstand the working conditions of the responders and to handle the network communications, or substitute for a network connection or cell tower when none is in reach. Training for device and app use and personalization may be necessary. Privacy issues must be considered when collecting and using sensor data.

Public to public communication can be challenging as law enforcement strives to control rumors disseminated on social networks or incorrectly communicated information in the press. Confidence in the source of information is also important to ensure that citizens will follow first responder directions given in an emergency situation. Sifting through data on social media to find the most useful pieces of information to inform triage or next steps, particularly in light of the vast amount of incorrect data posted to media sites, is also problematic for responders monitoring social media for situational awareness.

Technological solutions are required for rapid analysis of social media data to identify images, for rapid categorization of social media for analytic purposes, and for rapid identification of sentiment and sentiment targets for access and use on smart consumer devices. Emergency response agencies must have the funding to equip personnel with devices and to upgrade these to meet evolving technological requirements. Planning must be done to ensure interagency device compatibility and information assurance solutions protect communications and data storage.

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[78] Datta, S.K. et al. (2013). Minimizing Energy Expenditure in Smart Devices. 2013 Conference on Information and Communication Technologies.

[79] Arabo, A. and B. Prangonno. (2013). Mobile Malware and Smart Device Security: Trends, Challenges, and Solutions. 19th International Conference on Control Systems and Computer Science (CSCS).

[80] Balakrishna, C. (2013). Enabling Technologies for Smart City Services and Applications. 2012 Sixth International Conference on Next Generation Mobile Applications, Services and Technologies.

[81] Khederi, N. et al. (2013, April). Synchronization in Wireless Sensors Networks Using Balanced Clusters. WMNC'2013. pp. 1-4.

Institution	Project/Capability	Link
Institute for Security, Technology, and Society, Dartmouth University	Neuralphone – a brain computer interface that harnesses a user's EEG signals to locate contacts in a smartphone	http://metrosense.cs.dartmouth.edu/projects.html
The Institute for Security, Technology, and Society, Dartmouth University	CenceMe personal sensing system – enables members of social networks to share their sensing presence with their buddies in a secure manner	http://metrosense.cs.dartmouth.edu/projects.html
The Institute for Security, Technology, and Society, Dartmouth University	SoundSense – harnesses mobile phone microphones[82]	http://metrosense.cs.dartmouth.edu/projects.html
The Ohio State University	E-Small Talker[83]; E-Shadow – senses information published by Bluetooth to help potential friends find each other; enables rich local social interactions with local profiles and mobile phone based local social networking tools[84]	http://bit.ly/1eaB3uQ http://researchnews.osu.edu/archive/eshadow.htm
Illinois Institute of Technology	SmartLoc – use smartphone's inertial sensors to determine its position whenever the GPS is offline[85]	http://www.cs.iit.edu/~winet/projects/smart-loc.html
Wireless Sensor Data Mining Lab (WISDM), Fordham University	Activity recognition app capable of identifying the physical activity of the user carrying the device (e.g., walking, jogging, standing)	https://www.actitracker.com/
WISDM, Fordham University	Mobile health monitoring – could be used to improve the user's health by measuring how much or little physical activity they engaged in each day	http://www.cis.fordham.edu/wisdm/
Massachusetts Institute of Technology (MIT)	SignalGuru – collects traffic signal information via camera to help drivers learn when slowing down could help them avoid waiting at lights. Reducing the need to idle and accelerate from a standstill saves gas.	http://bit.ly/1a41t0c
Institute for Software Integrated Systems, Vanderbilt University	WreckWatch – Accident detection system – smartphone-based wireless mobile sensor networks as an accident detection system, utilizing mobile context information and polling onboard sensors to detect large accelerations	http://dl.acm.org/citation.cfm?id=1997797
University of Florida Gainesville	Smart Home – component system the mPCA smartphone interacts with sensors in a smart space to assist individuals with Alzheimer's Disease in daily activities by means of reminders, orientation, context-sensitive teaching, and monitoring	http://www.icta.ufl.edu/gt.htm

Table 9. Research institutions working in smartphone sensors

[82] SoundSense. MetroSense: Projects. (video).

[83] Yang, Z. (2010) Opportunistic Computing in Wireless Networks: Dissertation. Ohio State University.

[84] Smartphone App Helps You Find Friends in a Crowd (n.d.) The Ohio State University: research.

[85] C. Bo.et al (2013). SmartLoc: Push the Limit of the Inertial Sensor Based Metropolitan Localization Using Smartphone.

3.3. Digital Signs

Digital signs are an electronic medium that displays television programming, menus, advertising, and other messages. They are found in both public and private environments including retail stores, hotels, restaurants, and corporate buildings. Digital signs use liquid-crystal display, light-emitting diode, plasma display, or project images to display content. Digital sign displays are most commonly controlled by personal computers or servers through the use of either proprietary or open source software (e.g., OpenSplash),[86] and they can be controlled wirelessly.

In terms of communication standards, Point of Purchase Advertising International (POPAI), the global association for marketing at retail, released several digital sign standards to promote interoperability between different providers. These standards documents seek to establish a foundation of performance and behavior that all digital sign systems can follow. The current standards published by POPAI include: Screen-Media Formats, POPAI Digital Sign Device RS-232 Standards, and POPAI Digital Sign Playlog Standards V 1.1.

Lack of interoperability serves as a challenge to the spread and optimal use of digital signage. According to a November 2011 International Telecommunications Union report, "the fact that most digital signage solutions are proprietary systems impedes the integration of various applications across different networks or vendors. As long as products from different vendors do not interoperate, it will remain challenging and costly to build and expand large-scale digital signage networks."[87] The World Wide Web Consortium (W3C) created and maintains one standard, SMIL which stands for Synchronized, as in scheduling; Multimedia, as in video, audio, images and text; Integration, for multi-zone screen layout; and Language, an XML-based text file format. The standard is increasingly supported by digital signage solution providers.[88]

College campuses (e.g., Boston University, the California State University System, Duke University, and University of Illinois) deliver real-time electronic communications and applications to students, faculty, staff, and visitors in campus public spaces. Although the displays are used to promote events, news, weather, and/or parking lot opening/closures, they also serve as an integral part of emergency management and crisis response plans.[89]

MEMA currently uses Clear Channel Outdoor billboards in the metropolitan Boston area to provide critical safety messages about weather emergencies,[90] Amber alerts, and, in April 2013, to warn citizens to stay away from Copley Square during the Marathon Bombing investigation. During that event, digital signs along Interstate 93 advised drivers to keep away from downtown Boston where two bombs detonated at the end of the Boston Marathon race course. Currently, multiple digital sign vendors[91] sell media server equipment, software, and services. Table 11 outlines first responder requirements, existing solutions, gaps in capabilities, and

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[86] OpenSplash (open source media player)

[87] Dupin, F. and M. Adolph. (2011). Digital Signage in All the Right Places. International Telecommunications Union.

[88] Synchronized Multimedia Integration Language (SMIL 3.0).

[89] Universities Embrace Digital Signage at an Accelerated Pace. (June 2011). Platt Retail Institute.

[90] Dick, M. (2013, February 8). Digital Signs on I-93 Keep Drivers up to Date During Storm. Boston.com.

[91] Cotterhill, A.J. (2013 December 2). Top10 Digital Signage Vendors 2013. DailyDOOH.

recommendations for further digital sign research. Table 12 provides a brief synopsis of universities researching digital signs.

First Responder Requirements	Existing Solutions	Gaps Identified	Research Recommendations
Access to community digital signs (e.g., city, university, private)	Clear Channel Outdoor, Broadsign, Real Digital Media, SignageLive	Interoperability among commercial platforms	Interoperability standards
Capability to monitor changing environment and timely access to digital signage and knowledgeable staff			
Tools built to agreed-upon standards so digital signs can communicate	POPAI, SMIL standards		Tools constructed with agreed upon technical standards

Table 10. Research targeted at law enforcement and emergency responders

Institution	Project/Capability	Link/further Information
Texas A&M University	Impact of public digital signage on traffic safety	http://www.thesignagefoundation.org/Portals/0/FTISResearch.pdf
FTW Telecommunications Research Center, Vienna, Austria	Smartphone interaction and public displays	http://www.igi-global.com/article/touchpad-smart-lens/77620
Media Research Lab, New York University	Autostereoscopy (seeing 3-D images without special eye ware) – applications in medical imaging, project displays, cathode ray tube based systems	http://www.mrl.nyu.edu/projects/autostereo/
Computer Laboratory, University of Cambridge, United Kingdom	Multi-view autostereoscopic 3-D displays	http://bit.ly/1fhpb6U
Lancaster University, United Kingdom	Holoscopic 3-D image rendering	http://www.research.lancs.ac.uk/portal/en/publications/holoscopic-3d-image-rendering-for-autostereoscopic-multiview-3d-display(d90abca2-a407-4764-b9b9-b87ec94ba94c).html
Tokyo University of Agriculture and Technology, Japan	Olfactory digital display	http://www.computer.org/csdl/trans/tg/2013/04/ttg2013040606-abs.html
Massachusetts Institute of Technology	Transparent display projecting words and images on a flat glass surface	http://web.mit.edu/newsoffice/2014/seeing-things-a-new-transparent-display-system-could-provide-heads-up-data-0121.html
Electronics and Telecommunications Research Institutes, Daeieon, Republic of Korea	Emergency alerting services on digital displays for disaster management	http://ieeexplore.ieee.org/xpls/icp.jsp?arnumber=6488275

Table 11. Research institutions working in digital signs

3.4. 3-D Printing

Also called additive manufacturing, 3-D printing represents a collection of technologies, some of which have been around since the 1980s. This type of printing offers has a strong track record of making of prototypes and customized parts as well as limited production runs. Implants represent the most common medical application of 3-D printing. Priced at tens of thousands of dollars, commercial 3-D printers can manufacture multi-material objects from a variety of source materials including plastics, rubber, glass, metal, sand, and even living cells. Consumer printers cost a little more than $1,000 and are limited to working with plastics.[92]

Advocates in the first responder community point out that shipping raw materials and 3-D printers instead of medical supplies cuts shipping costs and waste. Additionally, 3-D printing can be used to make customized medical equipment such as splints, crutches, and casts. Furthermore, some 3-D printers can run on solar power. 3-D printing might not scale in disaster zones, however. It takes hours to days to produce each item and items built are currently limited by the size of the machines themselves.

Although not in current use by the American Red Cross or international aid organizations, advocates remain optimistic on how 3-D printing can contribute to the first responder community. According to Thomas Campbell, a Virginia Polytechnic Institute and State University professor and senior fellow at the Atlantic Council, “there's great potential in the developing world for relief efforts. If you have a medical device 3-D printer on the ground and you suddenly have a hurricane or tsunami whip through, instead of having to ship everything there, you may just have a fab lab of some sort and produce the crutches, splints, and whatever else you need there on the ground.”[93] Steve Haines, mobilization director for global campaigns at Save the Children International agrees, “3-D printing could make a huge difference to emergency responses, saving a fortune by printing things like tools, basic items and equipment on the ground from recycled materials, rather than flying them in from other countries.”[94]

Table 13 outlines first responder requirements, existing solutions, gaps in capabilities, and recommendations for further 3-D printing research. Table 14 provides a brief synopsis of universities conducting 3-D printing research.

First Responder Requirements	Existing Solutions	Gaps Identified	Research Recommendations
Scalable and affordable 3-D printing solutions (equipment, software)	Needed	Printing is not scalable to large volume; cost is currently prohibitive	
Ability to post simultaneously across multiple non-compatible platforms	Needed	Commercial platforms current use multiple formats	
Effective messaging campaigns			

Table 12. 3-D printing gaps

[92] Greengard, S. (2013). All the Items Fit to Print. Communications of the ACM, 56(7), pp. 17-19.

[93] Koebler, J. (2013, October). Is 3-D Printing the Future of Disaster Relief? Motherboard.

[94] Byrne, I. (2012, November 15). 3-D Printing: Can it Help People in Disasters? Thomson Reuters Foundation.

Institution	Project/Capability	Link/Further Information
ETH Zurich	Solving balance issues in 3-D standing models	http://dl.acm.org/citation.cfm?id=2461912.2461957
Stanford University	3-D organ modeling to aid in surgery to allow doctors to test different surgical strategies in advance	http://bit.ly/1jOCQYQ
Cornell University	3-D speaker including plastic housing, fully functional conductive coil, and magnet spun from two specially designed printers. Magnet made from high viscosity blend of strontium ferrite.	http://www.digitaltrends.com/home-theater/cornell-researchers/
Lancaster University, UK	Impact of 3-D printing on transportation up to 2030: will transportation of goods be drastically reduced as companies and citizens "print out" all the objects they require	http://bit.ly/1fqFNvj
University of Edinburgh	Intellectual property implications and patent infringement	http://www2.law.ed.ac.uk/ahrc/script-ed/vol7-1/bradshaw.asp
Airbus, General Electric Aviation	3-D printing implications for the aviation industry	http://www.airbus.com/innovation/future-by-airbus/concept-planes/the-airbus-concept-cabin/future-technologies/
Lawrence Livermore National Laboratory (LLNL)	3-D printing materials research	https://www.llnl.gov/news/aroundthelab/2013/Mar/ATL-032513_forum.html
MIT	Development of OpenFab programmable architecture to streamline the production of complex structures with varying material properties	http://www.csail.mit.edu/node/2060

Table 13. Research institutions working in 3-D printing

4. Overview of Big Data Approaches

Big data analysis and supporting tools are increasingly front and center in government and industry where information about trends, anomalies, and future events is sought. Big data is characterized by its "5 Vs": *volume*, *velocity*, *variety*, *veracity*, and *value*. Problems that could benefit from big data analytical approaches include:

- Analyzing data about cyberattacks and vulnerabilities to understand attacks, adversary objectives, and ways to improve defenses;
- Performing social network analysis using integrated entity data from structured databases and extracted from text sources;
- Performing analysis of historical sensor data and derived tracks to understand patterns of activity;
- Identifying fraud by correlating published financial data, reports to government agencies, and other sources;
- Estimating the diffusion of messages in a region using data about social groups, online communications, and media;
- Understanding disease outbreaks and other complex events more thoroughly by using data-driven hybrid modeling of emergency response; and
- Identifying pathogen mutations and predicting drug effects using next-generation DNA sequencing data.

The big data analytics approach must support the data and analytics needed for the problem, be cost effective (e.g., commodity hardware), be able to use new types of data and analytics quickly, be scalable to accommodate more data and analytics, and work on all data, not just aggregate or subsets of the data.

Relational databases were invented to keep bank account balances. In that application, a deposit could occur at the exact same time as a withdrawal. Database transactions for these kinds of applications were designed to make four guarantees, known as the ACID properties of transactions:

3. **A**tomicity – transaction either happens completely or not at all, never partially
4. **C**onsistency – different applications see the same state if they ask at the same time
5. **I**solation – even though multiple concurrent transactions may occur on the same data, the database makes it look as if there is only one transaction on each piece of data at a time
6. **D**urability – changes made by a transaction are made persistently and not lost

Analytic databases do not need the full set of ACID properties, however; there is almost never the need to update an object "in place." For example, a new set of data about a real-world entity can be treated as a new object or a new version of an object, creating a historic record of all data received by the system. In other words, analytic databases "Write Once, Read Many". Users write the data when they receive it, then read it every time they want to use it in analysis. Users never update it. At some point users may delete it in bulk, e.g., expire all the data more than *x* years old, but in general, individual records do not need to be deleted.

The consistency, availability and partial tolerance, or Brewer's theorem, states that if a database does not need full ACID transactions (especially Consistency), it can be made more available and more partitionable (if the cluster of servers experiences a network failure and is temporarily partitioned into two clusters). For example, not only sequel query language (NoSQL) databases do not implement ACID transactions, they support atomicity, and durability, along with high availability and some partitionability.

Table 14 shows a comparison of the pros and cons of big data analytics, including 1) Relational databases, 2) MPP databases, 3) NoSQL databases, and 4) Analytic Cloud Computing. These approaches are then discussed in further detail.

Analysis Approach	Pros	Cons
Relational databases	Huge experience base of SQL developers; Row-level security (in some products); Accredited; Most enterprise data models designed for relational database management systems RDBMS; Extensibility to XML and object models	Expertise required to tune for big data or analytics; Expensive for big data; Not scalable; Not agile – lots of indexes and careful query tuning required for big data analytics
MPP databases	Huge experience base of SQL developers; Row-level security (in some products); Most enterprise data models designed for RDBMS; Extensibility to XML and object models	Some expertise required to tune for big data or analytics; Expensive for big data; Limited open source options
Document-oriented NoSQL	Scalability; Ease of setting up an instance; Ability to work with document data; either low cost or open source	Document-orientation not right for all needs

Analysis Approach	Pros	Cons
databases		
Analytic Cloud Computing and Key-Value NoSQL Databases	Scalability; either low cost or open source; Agility to use new types of data and create new analytics much quicker (than traditional RDBMS); Fine-grained security	Rapidly-evolving; Varying maturity; Lack of staff with skills in government programs; Latency to initiate an analytic job (if user lacks the right key to retrieve just a small subset of the data)

Table 14. Comparison of big data analytical approaches

4.1. Relational Databases

Perhaps the most familiar and mature approach is to use a data warehouse implemented as tables in a relational database management system. The database system stores the data on persistent media (typically disks), and may be compressed to reduce the time required to write and later read the data. Data can be stored by row or by column. Column-oriented storage offers advantages for analytic queries that retrieve only a small subset of the columns in a table, and can improve compression since like types of data are stored together. The database designer typically determines which columns will be used to uniquely identify a row, and may be able to choose row- or column-oriented storage, but the system decides how to store and retrieve data efficiently.

Within data warehouses, incoming data is transformed into the data model of the warehouse via an extract, transform, and load (ETL) process. The ETL process can be used to cleanse data, addressing data quality issues that might prohibit successful analysis. ETL can also be used to tag data with source and other metadata. Often, detailed data records in the warehouse are aggregated or summarized into additional databases called data marts. Data marts are typically used for analysis. The separation of derived data (in a data mart) from data provided by firms (in the warehouse) is not required; both tables can be stored in the same database and updated when additional data is ingested.

Relational databases can be queried using SQL. SQL queries specify searches and limited computations on the data. SQL queries also specify what data is to be used in the search or computation, but do not dictate how that data should be found within the database. The database system parses each submitted query and develops an efficient plan for performing the computation, based on the query, statistics on the data to be queried, and presence of any additional means that can be used to speed up execution of the query. These additional means include indexes, which store additional information about values in one or more columns in the database. They also include the ability to declare that a table be kept in sorted order, or logically partitioned, according to the valued of selected columns. Developers typically must carefully design their queries to have sufficient performance to support analysis.

When text or other unstructured data are included, they typically are processed and analyzed separately. Structured information may be extracted from text sources and loaded into the warehouse. Currently, most parts of the ETL process are supported by commercial technologies, though ingesting data into a relational data warehouse can still take months of work before analysis can begin. Figure 11 shows the relational database approach.

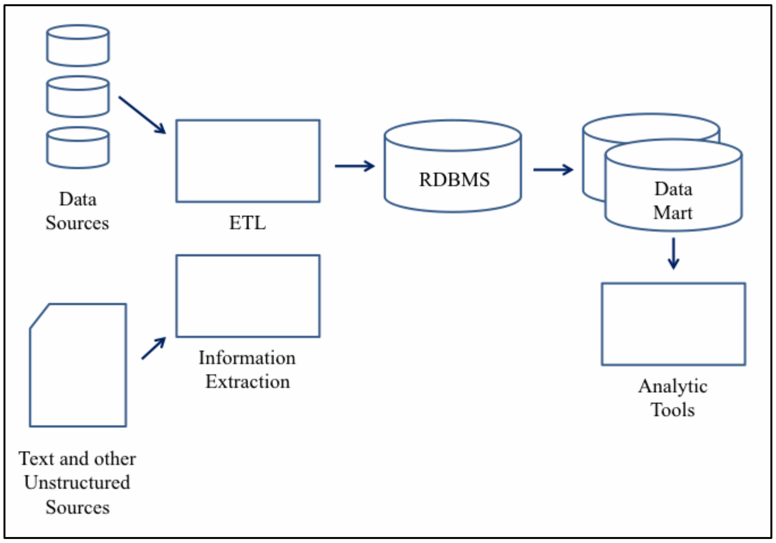

Figure 11. Relational database approach

4.2. Massively Parallel Processing (MPP) Databases

In the relational database approach, it can be difficult and expensive to scale with growing data sizes and to run ever more complex queries against new or continuously arriving data. One response to these needs is a growing trend toward MPP databases. Within an MPP database, data is sharded, or distributed across a cluster of servers, each with storage and computational capability. MPP databases offer many of the properties described above for relational databases, with several key differences:

- As data size grows, the MPP database can be scaled out by adding servers, with more predictable improvement in performance of queries.
- Rather than using indexes and carefully designed queries to achieve performance, MPP databases use parallelism. This avoids the need for most indexes, which require additional storage and must be updated when new data is ingested, and simplifies the process of incorporating a new data source.
- The database designer must choose a function to spread data across the cluster. The function must be chosen such that all servers in the cluster can work in parallel on the tasks of loading new data into the database and perform as-needed computation for queries.
- Often data can be loaded into the MPP database in parallel. In addition, data can be transformed and cleansed after it is loaded (ELT) or both before and after loaded (ETLT), taking advantage of the parallelism and consistency checking provided by the database while possibly creating additional copies.
- Data marts may not be needed; analytics can often be done, in parallel, directly on the warehouse. In addition, some commercial analytic tools can perform computation in an MPP database rather than operating on a separate copy of the data.

Figure 12 shows the MPP database approach.

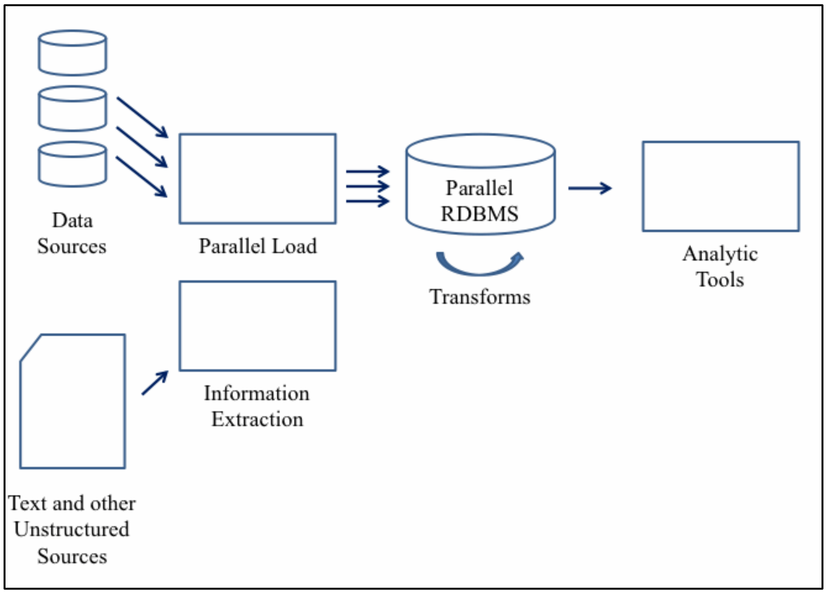

Figure 12. MPP database approach

4.3. NoSQL Databases

Another growing trend in analytic databases is to relax some guarantees made by traditional databases to support consistent management of data, despite concurrent access by multiple users. These guarantees are essential for transactional applications, such as maintaining bank account balances while tracking deposits and withdrawals, but are much less relevant for analytic systems that constantly receive data, and rarely or never modify an existing data record. The resulting NoSQL database technologies even drop native support for SQL queries, supporting only record lookup by key or by range of keys. Here, a key is a set of columns that collectively can be used to uniquely identify every possible record in a database table. For many NoSQL databases, add-on technologies support a subset of SQL. This makes it possible for an analytic system to take advantage of improved analytic capability resulting from relaxation of some transaction guarantees, while retaining some benefits of using a high-level query language that allows the database to make performance optimizations under the covers.

NoSQL databases support a wide variety of data models, including semantic web triples, graphs and networks, and semi-structured documents.

Semantic web triples are of the form subject-relationship-object—a financial firm (subject) might offer (relationship) a given financial instrument (object). Semantic databases support automated logical reasoning in which data is derived that is not present in the database but is implied by data in the database. For example, consider a semantic database that encodes information about relationships between firms. If the database has information that firm A owns firm B, and that firm B has a controlling interest in firm C, then with reasoning, the database can infer that firm A can control actions by firm C. Recently, semantic databases have been demonstrated with up to 1 billion triples (for examples see published claims by Franz's AllegroGraph and the Billion Triple Challenge). Conducting reasoning on semantic databases of this size remains a research challenge, however. These stores are being explored to support graph analytics, such as social network analysis, since the intrinsic data model naturally supports vertices (subjects and objects) and edges (relationships).

One variety of NoSQL databases, where the data model is the key-value model, differs from the relational model in several important ways:

- Instead of a pre-declared schema, new columns can be added at any time, allowing new types of data to be added to the analytic system in a flexible manner. These are often grouped in column families, allowing efficient storage and analytics.
- All records feature a timestamp and version. Instead of updating a record in place, a new version is created. Analytics use only the most current version for a given key, by default, or can access prior versions.
- Similar to MPP databases, the data is often sharded across a cluster of servers to allow analytics and data loading to work in parallel. Indexes typically are not supported, as opposed to less frequently used in MPP databases. A database can be scaled out as needed.
- Tables are stored in sorted order, by key. This supports fast retrieval of a record by key, or a range of keys. SQL is typically only supported by add-on tools.

Figure 13 shows the NoSQL database approach.

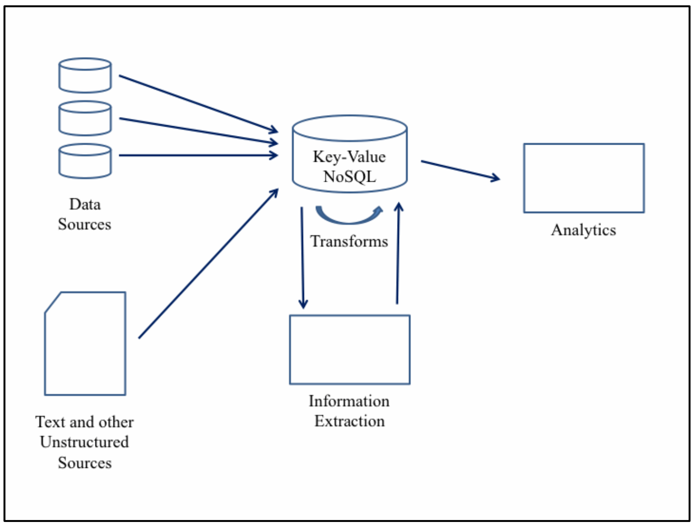

Figure 13. NoSQL database approach

One reason for the popularity of the NoSQL database approach for analytics is that it does not require ETL as a precursor step to making data available for analytics; new data types can be added at any time so data need not be transformed to a common data model. This allows analytics to be conducted on a new type of data very quickly, with the risk that the new data may not be cleansed, integrated, or even understood sufficiently to support sound analysis. Transformations can be conducted in a NoSQL system, either before or after data is loaded into the database.

Currently, most users of NoSQL databases use open source software, though this may reflect the early state of evolution of the NoSQL industry. Users of this technology currently build custom analytics using approaches, such as key-value lookup, MapReduce, and perhaps SQL. If desired, derived data can be loaded into data marts—relational databases that support SQL and commercial analytic tools.

Many NoSQL databases lack mature security and access control capabilities. A notable exception is the Accumulo database, a government-developed, key-value NoSQL database that was released into the open source community in 2011.[95] Modeled after Google's BigTable, Accumulo is comparable to HBase and other key-value NoSQL databases. Accumulo supports an information security approach where each data record (or potentially, cell) is labeled with visibility attributes that govern access to the data. The visibility attributes are then used in combination with user certificates and enterprise attributes (e.g., roles of each user) to manage access to the data at the desired granularity.

4.4. Analytic Cloud Computing

Analytic Cloud Computing must be scalable (near linear scale out), agile (easy to add new types of data and new analytics), affordable (many open source options using commodity hardware with built-in fault tolerance exist), able to work on all data, offer row- or cell-level security, and provide access to support. Challenges include a limited number of supporting vendors and limited experience base, latency in initiating a new job, and ensuring the solution is a good one to the problem at hand.

Some analytics efforts have abandoned databases all together, often in attempts to analyze massive amounts of data in a cost-effective manner. In the most basic form of Analytic Cloud Computing, data is stored in a distributed file system in a cluster of servers, and a parallel program is used to perform data analytics. Parallel programs offer the advantage that portions of the computation occur at the same time, allowing the computation to be sped up by adding more servers to the cluster. Hadoop is an open source implementation of this approach, namely, storage and large scale processing of data sets on clusters of commodity hardware. Built by Yahoo!, Hadoop is now managed by Apache Software Foundation. It features two components: Hadoop Distributed File System (HDFS) and MapReduce engine. MapReduce is a programming model for processing large data sets with a parallel, distributed algorithm on a cluster. Developed at Google, "Map" and "Reduce" combine two capabilities from existing functional computer languages.

Hadoop includes two key components:

- The HDFS, which gives the view of a single file system, implemented over a cluster of servers, each with its own storage. HDFS automatically replicates data, storing extra copies on different servers in the cluster for fault tolerance. HDFS is designed to manage very large files, using large block size (i.e., the minimum amount of data read from or written to the file) to give better performance for analytics that work with large amounts of data.
- MapReduce is a simple parallel programming language for analytics. Hadoop manages the execution of a MapReduce program in parallel, across the cluster. In the first phase of

[95] Accumulo Open Source Software Proposal. http://wiki.apache.org/incubator/AccumuloProposal.

a MapReduce program, a Map function is applied to each object in a set, producing an intermediate result set. The intermediate results are gathered from the servers that computed the Map, and written to servers that will be used in the second phase. Then, the corresponding Reduce function is used to aggregate final results from the intermediate results. An advantage of MapReduce is that it can run on inexpensive clusters of commodity hardware.

Hadoop manages the sharding of data in the cluster. An analytic program may contain many MapReduce steps, each of which includes a Map phase followed by a Reduce phase. Each MapReduce step is executed by a number of Map and Reduce processes, each taking as input the output of the prior step, and each working with a subset of the data involved in the computation. These processes can work in parallel without inter-process communication, which greatly simplifies the task of writing a correct parallel program. Hadoop manages the startup, execution, and completion of these processes, and deals with faults that occur by starting new Map or Reduce processes, perhaps using replicated copies of the data. In essence, Hadoop supports parallel analytics that work over massive data in a way that is tolerant of faults that occur during long-running programs.

Hadoop and MapReduce are often used in combination with key-value NoSQL databases. In fact, many key-value NoSQL databases use HDFS for file management. The resulting analytic system supports MapReduce parallel programs running on underlying files or key-value tables. These systems can use key-value tables to pre-compute complex analytics. For example, one might use a MapReduce program to compute the number of instances within a period that a security price rose more than 10 percent then later fell by at least 10 percent in the same day. The NoSQL database can then be used to store the results using the symbol of the security and the day when the rise and fall occurred as the key. Relational databases have a similar capability: a new table (called a view) can be derived from source tables using an SQL query. If the view table is materialized (i.e., stored on disk), it can be accessed quickly by other queries, at the cost of additional storage and the need to update the view table when the data in the source tables changes.

MapReduce can be used to transform and cleanse data after it is loaded (Extract Load Transform ELT) or both before and after loaded (Extract Transform Load Transform - ETLT) MapReduce can also be used to derive data for use by analytic tools or other types of databases. Analytic cloud systems often store text and other unstructured sources in Hadoop files and operate on them using MapReduce. Many relational databases include extensions for storing text and other types of unstructured data, but these are less commonly used for analytics on large amounts of data. Figure 14 shows a variant of the analytic cloud approach.

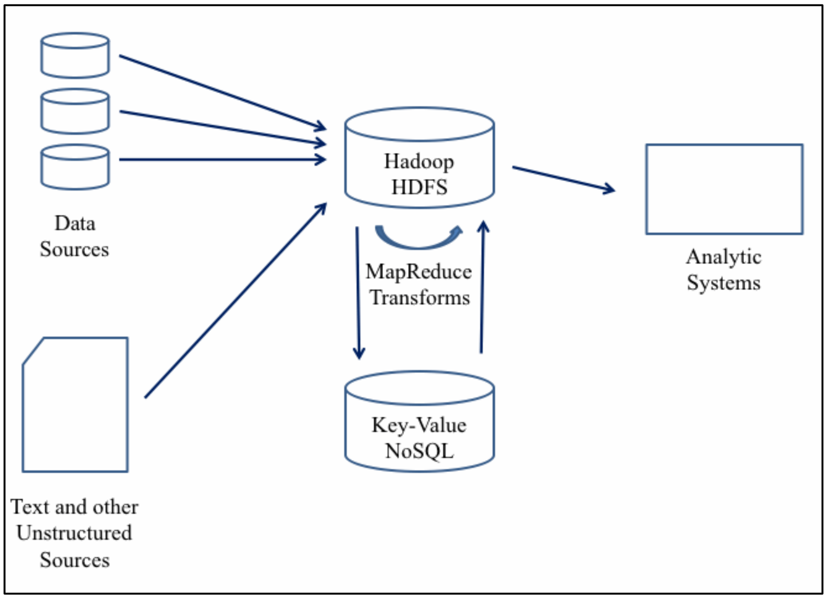

Figure 14. Analytic cloud approach

5. Summary and Detailed Recommendations

NYC OEM and the American Red Cross worked with Microsoft and Dell, respectively, to craft technology-driven solutions for emergency management and disaster response.

To fulfill its emergency management mission, the NYC OEM found innovative ways to use technology to oversee and manage first response from the EOC Watch Command. Technology initiatives include:

- Keeping citizens informed on major events in the city via NYC Notify;
- Monitoring the social media scene during events and crises, and engaging at the aggregate level via HootSuite;
- Using NYC OpenData for data discovery, and DataBridge to improve services; and
- Engaging with New Yorkers daily and directly using online social media platforms (e.g., Twitter, Facebook) for educational purposes.

NYC OEM continues to strive to develop and improve near real-time solutions to help them make better, trusted decisions for the citizens of New York. One example is the Microsoft CityNext platform—the dashboard covers 80 percent of the data sources used by the EOC Watch Command. Reports that previously took two hours to create, now take 25 minutes.

Responding to more than 200 disasters on an average day, the American Red Cross made significant progress in using social media and other technology solutions in the almost three-year period between the Haiti earthquake and Hurricane Sandy. The DigiDOC, the Red Cross' social media center, directly supports the organization's mission by using Radian6 to:

- Source additional information from affected areas during emergencies to better serve those in need of help;
- Spot trends and better anticipate the public's needs; and
- Connect people with the resources they need, such as food, water, shelter, or even emotional support.

The American Red Cross strives to engage its constituents wherever possible, including face-to-face contact, social media platforms, or via apps on mobile phones.

Traditional data sources in use by the first responder community (e.g., police reports and forensic evidence) are not covered in this report. The big data sources in use and for potential use by first responders that this report does examine include:

- **News and blogs** which can be used to monitor public perception of events, identify communities in need of assistance, and counter rumors or incorrect reporting during ongoing crises (e.g., Boston Marathon bombing, Hurricane Sandy). Mobile access to aggregated news sources and tools to detect sentiment in the reporting are required to do this. Multiple commercial news aggregators, as described throughout this document, are available. Cost can be a factor in their acquisition for an enterprise, however, and sentiment analysis, which aids in filtering content, remains a research challenge.
- **Social media**, a communication platform where participants may interact with streams of user-generated content and create and maintain individual identifiable profiles of their own creation, has proven useful in recent emergencies, such as the Boston Marathon

bombing and Hurricane Sandy. Law enforcement and government officials monitored Twitter and Facebook content, and used the platforms to broadcast messages to the public and receive calls for help. Multiple platforms are available, such as Twitter, Facebook, Flickr, and Ushahidi. A challenge in using social media is the rapid determination of the veracity of citizen reporting, access to portable devices in the field, and the ever-increasing need for bandwidth.

- **Tagging** and tracking of material in emergency scenarios has been in use for many years, and multiple commercial tools exist for doing so. The first responder community can use RFID technologies for managing assets, identifying resources, and tracking both emergency responders and citizens (evacuees, disaster victims, and fatalities). First responders require tagging solutions for use in near real-time tagging of assets and personnel. Cost is prohibitive and there is some resistance to tagging of persons as "dehumanizing." Currently, many commercial tools exist for tagging and tracking assets in harsh environments. Barcodes and QR codes are discussed briefly in the context of their role as building blocks to the IoT, which may someday allow millions of objects to be detected and controlled.
- **Smart consumer devices** that leverage social media are in use by law enforcement and first responders to manage tasks and provide situational awareness through access to social media platforms. Many police departments (e.g., Redlands, Calif., and Boston, Mass.) have acquired tablets and PDAs for officers. Increasingly sophisticated devices now integrate sensor suites with GPS data, accelerometers, magnetometers, light sensors, and cameras, and are capable of processing and transmitting geolocalized data. First responders need affordable, rugged devices that withstand harsh conditions and offer long battery life. At times, first responders need access to communications in locations where cell towers are absent or disabled. Many commercial tools are available specifically for use by law enforcement officers, such as tools that aid in the location of missing persons, determine the point of origin of a gunshot, provide redundant voice command systems, and use 2-D and 3-D feature maps.

Recommendation: It would be valuable if the DHS Science and Technology Directorate (S&T) provided researchers access to various big data sets and industry tools, and required engagement with users through exercises and partnerships as part of the grant process. This would allow researchers to work with data at scale, understand what industry solutions exist, fill industry gaps, and test their research in relevant environments—all while engaging with first responders.

As an example, InnovAccer appears to be addressing researcher data and standard analytic needs as described below.

> *InnovAccer (Innovation Accelerated) is based in New Delhi and provides custom big data, text mining, and predictive analytics solutions for: Harvard, The Wharton School, Stanford University, MIT, HEC Paris, Columbia University, London Business School, IESE Business School, NYU, Duke University, INSEAD, ESADE, University of California, Berkeley, University of Cambridge, IE Business School, University of Oxford, and University of Chicago. Advanced analytics include:*
>
> - Machine Learning: Random Forest, Decision Trees, Naive Bayes, Support Vector Machines, Multilayer Perceptron, Neural Networks, k-NN/k-means/Nearest; Neighbor/Minimum Distance Clustering;
> - Regression Techniques: Multivariate adaptive regression, Classification and Regression Trees, Logistic Regressions, Discrete Choice; and
> - Forecasting Models: Autoregressive Moving Average (ARMA); Auto Regressive Integrated Moving Average (ARIMA); Auto Regressive Integrated Moving Average with Exogeneous Input (ARIMAX); *Integrated Generalized Autoregressive Conditional Heteroskedasticity (*iGARCH).[96]

Such a service would allow new research and development (R&D) efforts to obtain data and standardized processing quickly, from which they could innovate. Requiring each group to obtain data and standardized processing is time consuming and repetitive.

Data can also be purchased through providers such as DataSift or Gnip. Industry dashboards, such as Marketwired's Sysomos and Salesforce's Radian6, also provide means to come up to speed quickly and obtain data. HootSuite provides a valuable dashboard, albeit one using platform-based APIs and few analytics. Using these services would require negotiation of data and dashboard licensing agreements, but this should be manageable for a research portfolio with limited users. The American Red Cross established a similar relationship for their social media volunteers (i.e., Hurricane Sandy had 31volunteers).

Using industry solutions would largely address the following gaps identified in the DHS and National Geospatial Agency (NGA) workshop report:[97]

- Use social media to facilitate disaster response and enable post-disaster recovery;
- Identify actionable data from the massive volume of data;
- Make sense of data;
- Understand the audience;
- Engage with the public;

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[96] Innovaccer.com http://www.innovaccer.com/

[97] DHS, S&T, NGA. (2013, July 22-23). Identification of Key Knowledge Gaps in Social Media Use During Disasters. Workshop Report. http://www.hsuniversityprograms.org/default/assets/File/DHS-NGA%20Social%20Media%20Workshop-Jul2013-Final%20Report.pdf

- Evaluate messaging and audience reaction; and
- Share information.

Aggregation dashboards can be relatively inexpensive due to advancements in tools for marketing and engagement. Fully featured tools that allow search and advanced analytics are available — specifically, Marketwired's Sysomos and Salesforce's Radian6.

The Joint Interagency Field Experimentation (JIFX) Program provides the opportunity to engage with end-users in an exercise environment. Requiring R&D efforts to apply to JIFX, for example, would define for a clear user-focused requirement. As described below, JIFX interests are driven by on-the-ground needs, which would ensure that R&D fills pressing first responder gaps.

> *The JIFX Program was started in 2012 under the sponsorship of the Office of the Secretary of Defense and DHS. JIFX events are held quarterly, normally at the Naval Postgraduate School (NPS) facilities at the California National Guard's Camp Roberts. NPS conducts biannual Research and Experimentation for Local and International Emergency and First Responders (RELIEF) experimentation events in cooperation with the humanitarian assistance and disaster response (HA/DR) community at Camp Roberts.[98] JIFX seeks to provide a field experimentation resource for the Unified Combatant Commands and other federal agencies. In addition, state, local, and international emergency management, disaster response, and humanitarian assistance organizations participate in JIFX, helping to create an innovative and cooperative learning environment.*
>
> *Planned event descriptions express specific interest in the use of social media for situational awareness: "Seeking social media technologies that conduct aggregation and search with the ability to search based on geographic location, keyword, or a set of scenario-specific parameters, using NLP and inferred context; identify and establish baseline monitoring and detect events and applicable trends, based on user-generated thresholds and mission-specific operational requirements" and "...provides authentication and filtering to integrate crowdsourcing efforts and to provide a means for manual verification and/or comparison of crowdsourcing results; simple Graphical User Interface to enable user-generated filtering parameters; and to filter and remove personally identifiable information. Of interest are also technologies that perform analysis with the ability to integrate the results with pre-existing data sets and sensor data, to establish meaningful relationships."*

Recommendation: It would be valuable if DHS S&T engaged in standards development for first responder-related big data by requiring R&D efforts to be cognizant of standards efforts, and to join relevant groups. This would allow researchers to prototype capabilities that would help with standards development and could more easily be transitioned for use. The W3C is one group focused on social media standards.

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[98] JIFX (Joint Interagency Field Experimentation Program) Background. http://my.nps.edu/web/fx/what-is-jifx-..

As researchers, industry, and governments seek to harness the benefits of big data, and study human behaviors captured through ever-evolving web-based social media platforms, a need for consistent technology standards has emerged. One group that has emerged to develop web standards is the W3C, self-described as "an international community where member organizations, a full-time staff, and the public work together to develop Web standards. Led by Web inventor Tim Berners-Lee and Chief Executive Officer Jeffrey Jaffe, W3C's mission is to lead the Web to its full potential."[99]

W3C provides recommendations for standards in different areas, such as application development, graphics, audio and video, and internationalization. The W3C website provides recommendations and status on the development of standards in the different areas. For web applications, W3C recommends HTML5. "W3C standards define an Open Web Platform for application development that has the unprecedented potential to enable developers to build rich interactive experiences, powered by vast data stores that are available on any device. Although the boundaries of the platform continue to evolve, industry leaders speak nearly in unison about how HTML5 will be the cornerstone for this platform. But the full strength of the platform relies on many more technologies that W3C and its partners are creating, including cascading style sheets, scalable vector graphics, web open font format, the Semantic Web stack, XML, and a variety of application programming interfaces (API)."[100]

In its discussion on internationalization, W3C discusses the complexity of designing technology that supports text from any writing system in the world. "This is why W3C technologies are built on the universal character set, Unicode…There are other factors to consider, however, when using characters. For example, Unicode based encodings allow the exact same text to be stored using slightly different combinations of characters. For efficiency and accuracy in comparing, sorting, and parsing text, the different sequences need to be recognized as 'canonically equivalent.' You need to consider how to manage this when developing applications or specifications that perform or rely on such tasks."[101]

Recommendation: It would be valuable if DHS S&T prototyped local to national first responder-related big data systems for daily and crisis use cases. As illustrated in Figure 15, during daily operations, the local level would use big data analytic tools and push very limited information to the regional and national level; however, during a crisis, the flow of information would increase to support more responding agencies. HootSuite, Marketwired's Sysomos, and Salesforce's Radian6 offer such capabilities today and are described above. Although currently not in use to support a local to national capability, NYC OEM's and the American Red Cross' use of HootSuite and Radian6, respectively, are important examples. End-to-end solutions are

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[99] About W3C http://www.w3.org/Consortium/.

[100] Standards. http://www.w3.org/standards/.

[101] Internationalization Activity. http://www.w3.org/International/.

required to manage big data so that it can be rapidly provided to first responders at all levels in near real-time to support decisions, especially during a crisis.

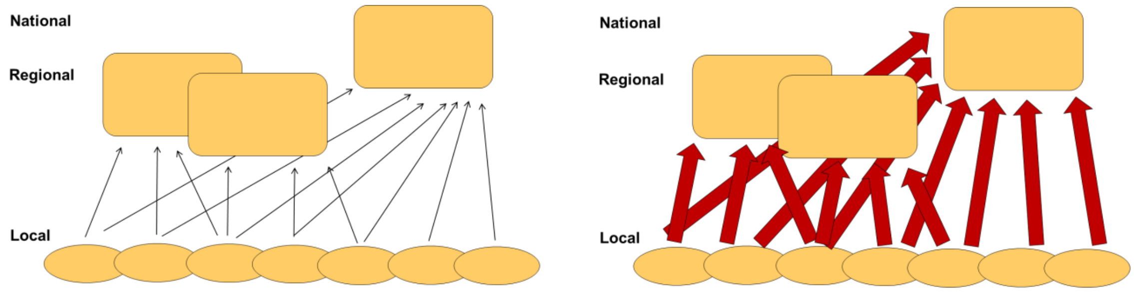

Figure 15. Local to national information sharing: daily (left) and crisis (right) conditions

Prototyping tools that address local to national response to disasters would greatly help identify industry solutions and research gaps for the DHS mission. The list below was compiled based on developing a prototype for another mission. Examples of current gaps in industry tools include:

- Multisource sentiment analysis including aliasing, opinion holder, and sentiment target in multiple languages;
- Twitter, language-agnostic demographic analysis, **especially location**, deceptive, native language;
- Multisource, narrative analysis in multiple languages;
- Multisource, language-agnostic meme detection;
- Multisource, language-agnostic social network analysis;
- Multisource, tunable methodologies for alerting operators (e.g., phase change, **event detection**);
- Integration of sociocultural analytic results in near real-time with the ability to explore the data;
- Course of action analyses.

The DHS and NGA workshop report[102] also highlighted event detection and geotagging as well as a novel gap message targeting. The industry tools allow one to do this, but research focusing on message targeting for DHS missions would be valuable: "How are the messages received or acted upon by the public? What are the most effective messages to motivate people to act? How can message effectiveness be measured?"

A drilldown for sentiment analysis follows:

> *Day et al. (2012)[103] emphasize that "media analysis has until recently been a highly manual process wherein analysts cull news articles and provide a digest on topics of*

[102] DHS, S&T, NGA. (2013, July 22-23). Identification of Key Knowledge Gaps in Social Media Use During Disasters. Workshop Report. http://www.hsuniversityprograms.org/default/assets/File/DHS-NGA%20Social%20Media%20Workshop-Jul2013-Final%20Report.pdf.

[103] Day, D., et al. (2012). Multi-Channel Sentiment Analysis. International Cross-Cultural Decision Making, Focus 2012, San Francisco, CA. 23-25 July. MITRE Public Release #12-1965.

interest to leadership. This approach is limited by the amount of material that can be reviewed by the human resources available, and as a result tends to be used in a reactive context. It is difficult to compare results across time and geography." Another area of analytics is automated sentiment analysis, reviewed in 2008 by Pang and Lee.[104]

Sentiment expressed in news, blogs, tweets etc., may well be of interest to command and control (e.g., how angry or frightened were some New Yorkers over the dangling crane during Hurricane Sandy?) and can be detected through reading of text, but volume prohibits that. Sentiment detection is needed for rapid sorting of content by sentiment. The main difficulty in the field of sentiment analysis is identifying the target of the sentiment. In addition, the sentiment models must be trained.

Although sentiment analysis technology has matured over the past several years, it is only about 80 percent accurate when trained on target data sets. It is a tool which assists a user in getting through large volumes of data quickly to pinpoint useful information to address (finding the "needles in the haystack"). In addition, first responder or command and control personnel cannot typically afford the time to study dashboards of news and blog analytics prior to making decisions. They will need a means to view output from discrete categories of material that they have previously vetted for utility, probably on a handheld device, and determine its relevance to the situation at hand. They will need training in use of tools.

The value of understanding the sentiment of a population and monitoring media coverage of a crisis as it unfolds has been shown. During the Boston Marathon bombings, police monitored news sources, corrected erroneous information via their own tweets and press conferences, and asked that press and citizen journalists not further share information the fugitives could use to aid in their escape.

In the World Disasters Report shown in Table 15, technological innovations were cited that could be used by first responders.[105] First responder-related big data for indications and warnings, social media outreach, advanced analytics, and tracking systems are also recommended.

Examples of technological innovation for use in humanitarian actions		
Humanitarian action phase	**Selected action**	**Selected technological innovations**
Mitigation	Early warning	Big data analytics for early warning, including social media, satellite imagery, etc.
		Advances in computing
		Text messages and social media warning systems
		Open data, access through social media
Preparedness	Planning and training	Resource databases and social networks
		Online distance learning and discussion platforms, mail lists

[104] Pang, B. and L. Lee. (2008). Opinion Mining and Sentiment Analysis. Foundations and Trends in Information Retrieval, 2(1-2):1–135.

[105] World Disasters Report: Focus on Technology and the Future of Humanitarian Action. (2013). Geneva, Switzerland: International Federation of Red Cross and Red Crescent Societies. http://www.ifrc.org/PageFiles/134658/WDR%202013%20complete.pdf.

Examples of technological innovation for use in humanitarian actions		
Humanitarian action phase	**Selected action**	**Selected technological innovations**
		Mobile platforms
		Social media campaigns
Response and recovery	Situational awareness and needs analysis	Big data analytics
		Information sharing platform
		Mobile and digital data collection
		Satellite imagery, aerial photography, unmanned aerial vehicles
		Crowdsourcing information
		Micro-tasking
		Secure data transmission and encryption
		Long range data transmission
	Resource management and accountability	Resource mobilization through social media
		Mobile cash transfers
		Commodity and resource tracking through mobile phones
		SMS-based feedback from affected people receiving aid
		Resource management platforms
		Matching needs and volunteers through social media
	Search and rescue	Reunification through social media
		Search and identification through 'digital signature' (e.g., mobile phone SIM card

Table 15. World Disasters Report technological innovations for first responders

Recommendation: It would be valuable if DHS S&T funded research on the Social Internet of Things, which is relevant to healthcare, energy, and transportation. DHS-related missions in this space fall under PPD-21, which advances a national policy to strengthen and maintain 16 secure, functioning, and resilient critical infrastructure sectors. These sectors include emergency services, transportation, health care, and the public health sector. Falling within these domains are traffic control, monitoring and controlling the spread of infectious disease, and disaster response. Social Internet of Things can help determine the crisis impact area spatially, and address victim needs, resource and victim tracking, public sentiment, and communication with the public.

Figure 16 shows that the Internet of Things is enabled by Internet search engines (e.g., Yahoo!, Google, and YouTube), Internet commerce (e.g., eBay, Amazon, and iTunes), and social networks (e.g., Facebook, Twitter, and Pinterest). Ninja Blocks, ADT Pulse, and Amazon Prime are services that facilitate the connection of things to the Internet. Ninja Blocks is a $200, open-source home automation tool that allows you to connect a variety of sensors to the Internet. Each Ninja Blocks box contains an accelerometer, thermometer, and ports for up to five sensors. ADT Pulse is a home automation system designed to be used in connection with an ADT monthly subscription. The ADT Pulse Wireless Platform is a small white box that acts as a receiver for other ADT smart home products, such as cameras, door locks, and lights. The device can collect data from other smart objects in a user's home and, if the user is a member of ADT, contacts the security company should any unusual readings appear. Amazon Prime is a $79-per-year, second-day delivery program from Amazon. In addition to free shipping, Amazon Prime provides free access to Amazon Instant Video, as well as the ability to borrow a subset of Kindle books.

Figure 16. Internet of Things

The Social Internet of Things takes inputs from social media, mobile devices, and sensors, and with the help of human understanding, outputs actions in the form of communications (e.g., press conferences, press releases, and social media releases), digital signs, and 3-D printing as shown in Figure 17.

- **Digital signs** have become commonplace on college campuses to deliver real-time electronic communications and applications to students, faculty, staff, and visitors in campus public spaces. Although the displays are often used to promote events, news, weather, and parking lot opening or closures, they serve an integral part of emergency management and crisis response plans. The MEMA currently uses Clear Channel Outdoor billboards in the metropolitan Boston areas to provide critical safety messages about weather emergencies, Amber alerts, and, in April 2013, to warn citizens to stay away from Copley Square during the Marathon Bombing investigation. Digital signs can be used as a control point for mass communication, leveraging information collected through social media monitoring and smart device sensing.
- **3-D printing** offers a strong track record of manufacturing prototypes and customized parts, as well as limited production runs. Advocates in the first responder community point out that shipping raw materials and 3-D printers instead of medical supplies reduces both shipping costs and waste, and that 3-D printing can be used to make customized medical equipment such as splints, crutches, and casts as needed onsite. Further research in scalable mass production and affordable equipment is required.

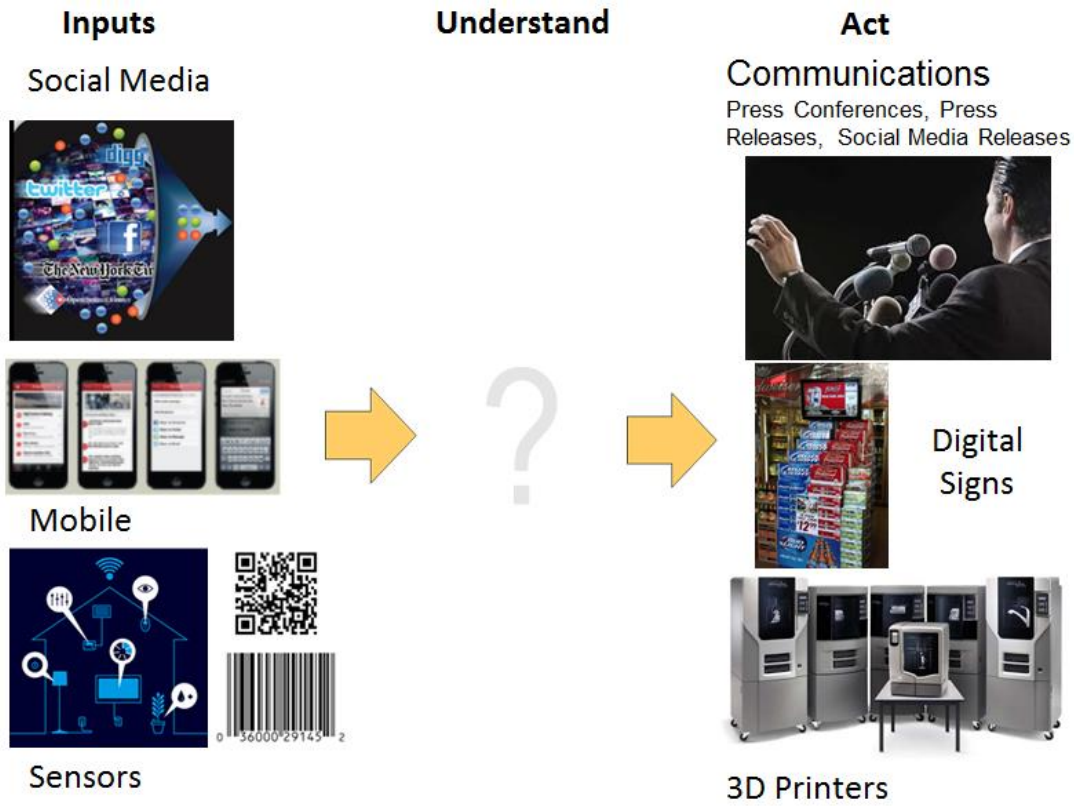

Figure 17. Social Internet of Things with inputs (left), user understanding (middle), and action (right)[106]

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[106] World Disasters Report: Focus on Technology and the Future of Humanitarian Action. (2013). Geneva, Switzerland: International Federation of Red Cross and Red Crescent Societies. http://www.ifrc.org/PageFiles/134658/WDR%202013%20complete.pdf.; Home Tweet Home: A House with its Own Voice on Twitter." MIT Technology Review; Message development. (n.d.) Kyle P. Adams & Associates; Aerva Powers Network of 2,000 Retail-Based Screens for World's Largest Beer Company. (n.d.) Aerva; What is 3D Printing? (n.d.) About3DPrinters.com. http://about3dprinters.com/

Of utmost importance is the notion that if the first responder community is to use big data in the management of crisis scenarios, both at the command and control level and "on the ground," it needs technological solutions that make sense of the vast amounts of data collected by sensors from disparate sources. As the Social Internet of Things expands, and more data is available through social media, automated means of verifying accuracy and veracity of data, sorting and labeling it for storage and recall, data manipulation, determination of sentiment expressed in messaging, and social network analysis will be needed.

The big data analytics approaches reviewed include: 1) Relational databases, 2) MPP databases, 3) NoSQL Databases, 4) Semantic Databases, and 5) Analytic Cloud Computing. Analytic Cloud Computing meets many of the criteria needed to bring these data sources together. It is scalable (nearly linear), agile (easy to add new types of data and new analytics), affordable (many open source options using commodity hardware with built-in fault tolerance exist), able to work on all data, offer row or cell level security, and provide access to support. The challenges include a limited number of supporting vendors and limited experience base, latency in initiating a new job, and ensuring that the solution is a good one to the problem at hand.

6. Acronyms

Acronym Term	Acronym Definition
ACID	Atomicity; Consistency; Isolation; Durability
API	Application Programming Interface
ARIMA	Autoregressive Integrated Moving Average
ARIMAX	Autoregressive Integrated Moving Average with Explanatory Variable
ARMA	Autoregressive Moving Average
CAD	Computer Aided Dispatch
CAP	Consistency; Availability; Partitions
CEO	Chief Executive Officer
CFI	Cluster Focus Index
CI	Competitive Intelligence
COCOM	Combatant Command
CSS	Cascading Style Sheets
CSV	Comma-Separated Values
D2M	Data-to-Model
DHS	Department of Homeland Security
DigiDOC	Digital Operations Center
DNA	Deoxyribonucleic Acid
DOD	Department of Defense
DoITT	Department of Information Technology and Telecommunications
DOJ	Department of Justice
EEG	Electroencephalogram
ELT	Extract, Load, and Transform
EOC	Emergency Operations Center
ER	Emergency Response
ESADE	Escuela Superior de Administración y Dirección de Empresas
ETL	Extract, Transform, and Load
ETLT	Extract, Transform, Load, and Transform
ETRI	Electronics and Telecommunications Research Institutes
FEMA	Federal Emergency Management Agency
FFRDC	Federally Funded Research and Development Center

Acronym Term	Acronym Definition
FIFA	International Federation of Association Football
FTW	Telecommunications Research Center Vienna
GIS	Geographic Information System
GPRS	General Packet Radio Service
GPS	Global Positioning System
GUI	Graphical User Interface
HA/DR	Humanitarian Assistance and Disaster Response
HAZMAT	Hazardous Materials
HDFS	Hadoop Distributed File System
HEC Paris	Hautes études commerciales de Paris
HS SEDI	Homeland Security Systems Engineering and Development Institute (or SEDI)
HTML5	HyperText Markup Language 5
HTTP	HyperText Transfer Protocol
IE Business School	Instituto de Empresa Business School
IED	Improvised Explosive Device
IFRC	International Federation of Red Cross and Red Crescent Societies
iGARCH	Integrated Generalized Autoregressive Conditional Heteroskedasticity
INSEAD	Institut Européen d'Administration des Affaires"
IoE	Internet of Everything
IoT	Internet of Things
IQT	In-Q-Tel
IR	Infrared
ITI	Insider Threat Identification
JIFX	Joint Interagency Field Experimentation Program
JSON	JavaScript Object Notation
KML	Keyhole Markup Language
LBS	Location Based Services
LCD	Liquid-Crystal Display
LED	Light-Emitting Diode
LLNL	Lawrence Livermore National Laboratory
LMR	Land Mobile Radio

Acronym Term	Acronym Definition
M2M	Machine-to-Machine
MAP	Media Analysis Platform
MBTA	Metropolitan Boston Transit Authority
MEMA	Massachusetts Emergency Management Agency
MIT	Massachusetts Institute of Technology
MODA	Mayor’s Office of Data Analysis
MPP	Massively Parallel Processing
MSA	Modern Standard Arabic
NGA	National Geospatial Intelligence Agency
NLP	Natural Language Processing
NoSQL	Not Only SQL (Structured Query Language)
NPS	Naval Postgraduate School
NWCG	National Wildlife Coordination Group
NYC OEM	NYC Office of Emergency Management
NYU	New York University
PDA	Personal Digital Assistant
PDF	Portable Document Format
POPAI	Global Association for Marketing at Retail
PPD	Presidential Policy Directive
QR Code	Quick Response Code
R&D	Research & Development
RDBMS	Relational Database Management System
RFID	Radio Frequency Identification
ROI	Return on Investment
RSS	Rich Site Summary
RTLS	Real-Time Location System
S&T	Science and Technology Directorate
SEDI	Systems Engineering and Development Institute (or HS SEDI)
SMCC	Social Media Command Center
SMIL	Synchronized Multimedia Integration Language
SMS	Short Message Service

Acronym Term	Acronym Definition
SQL	Structured Query Language
SVG	Scalable Vector Graphics
UPC	Universal Product Code
URL	Uniform Resource Locator
ViTTs	Victim Tracking and Tracing System
VLSI	Very-Large-Scale Integration
VPN	Virtual Private Network
W3C	World Wide Web Consortium
WIISARD	Wireless Internet Information System for Medical Response in Disasters
WIISARD-SAGE	Wireless Internet Information System for Medical Response in Disasters and Self-Scaling Architecture for Group and Enterprise Computing
WISDM	Wireless Sensor Data Mining Lab
WISDOM	Web Information Spread Data Operations Module
WISER	Wireless Information System for Emergency Responders
WMD	Weapons of Mass Destruction
WOFF	Web Open Font Format
WORM	Write Once Read Many
WPI	Worcester Polytechnic Institute
XML	Extensible Markup Language

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